

Georges Dionne *Editor*

Handbook of Insurance

Second Edition

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Handbook of Insurance

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Georges Dionne
HEC Montréal, Québec, Canada

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*To:
My family,
for their continuous support*

*Claire Boisvert
for her excellent collaboration*

*My students
for their hunger for learning*

Preface

What a pleasure it is to discover the second edition of the Handbook of Insurance, edited by Georges Dionne, 12 years after the first! Almost all original basic texts are there, for the most part updated to incorporate the scientific foundations of insurance, and have been re-explored through 15 new contributions of great relevance. The field of insurance economics is indeed expanding every year, and it is fascinating to see the depth and breadth of this growth. Old problems are revisited, reformulated, and remodeled, bringing new conclusions and solutions. And through a process of germination, these fruitful developments generate a new stream of highly interesting research.

Many key concepts at the core of risk, uncertainty, and insurance economics have been further refined, reassessed, and reanalyzed over the past 12 years—for example moral hazard, adverse selection, the symmetry and asymmetry of information, and risk aversion. Traditional issues have been re-explored, such as underwriting cycles, the performance of insurance companies, risk management, distribution networks, regulation, recourse to reinsurance, coexistence between private and public insurance, health insurance, and fraud. New issues have emerged or have grown in importance, including systemic risk, longevity risk, long-term care, interactions and dependencies between variables, the corporate governance of insurance companies, capital allocation within insurance companies, and alternative risk transfer devices such as industry loss warranty (ILW), sidecars, cat bonds, swaps, and securitization.

What is striking when reading these various contributions is the recurring issue of optimization. How do you design an optimal insurance contract to minimize moral hazard, whether *ex ante* or *ex post*, and reduce or eliminate adverse selection? What is the optimal demand for insurance from a corporation and for reinsurance from an insurance company? How do you draft an optimal regulation, allowing market forces to operate and competition to function, while minimizing costly failures? How do you optimize capital allocation within a company between the various branches, lines of business, and markets? How do you optimize a portfolio of risks by minimizing dependencies? How do you optimize the amount of capital for a given insurance company, while maximizing the rate of return, yet respecting the solvency level corresponding to the chosen risk appetite?

These 37 new contributions and updates provide answers—sometimes straightforward, sometimes more complex—to all of these questions, and provide highly useful tools for a greater understanding of the markets and institutions transferring and sharing risks. This handbook contains a wealth of ideas, insights, models, data and empirical tests, providing food for thought for academics, policy makers, and last but not least, managers of insurance and reinsurance companies. I am convinced that careful reading of this handbook will help researchers to detect new fields and hypotheses to explore, policy makers to draw up regulations based on solid grounds, and managers of insurance companies to innovate, redesign contract policies, improve the use of capital, reorient distribution networks, protect against fraud, and so on. In an ever-expanding risk universe, increased sophistication is the only way to

push back the frontiers of insurability and therefore maintain, or even improve, the level of protection offered to individuals and corporations throughout the world.

May I take the opportunity of this preface to congratulate Georges Dionne for his outstanding contribution to the science of risk and uncertainty. His capacity to develop theories and models, while validating them through empirical work, and to deal with the real issues at the core of insurance industry practice, is unique. May I also thank each of the authors of this new handbook, for providing contributions of such high quality.

I have a simple wish that this handbook be diffused to as wide an audience as possible, both in academic and professional spheres. It will help to improve understanding in terms of the demand and supply of insurance and reinsurance and to promote market solutions for more efficient risk trading. The development of insurance—both for P&C and Life lines—is undoubtedly of benefit to the welfare of society as a whole.

Chairman and CEO of SCOR

Denis Kessler

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Introduction

It was the article “Uncertainty and the Welfare Economics of Medical Care” by Kenneth Arrow (*American Economic Review*, 1963) that first drew my research attention to risk, uncertainty, insurance, and information problems. This article proposed the first theorem showing that full insurance above a deductible is optimal when the premium contains a fixed-percentage loading, provided there are no information problems. It also suggests economic definitions of moral hazard and adverse selection. It generated many doctoral dissertations, my own included.

During the 1970s, researchers proposed theorems regarding optimal insurance coverage, security design, moral hazard, adverse selection, and equilibrium concepts for markets with imperfect information. The 1980s were characterized by several theoretical developments such as the consideration of more than one contracting period; commitment; many contracting agents; multiple risks; non-expected utility; and several information problems simultaneously. Other economic and financial issues such as underwriting cycles, financial pricing of insurance, insurance distribution, liability insurance crisis, and retention capacity were addressed by academics and practitioners during that period. Hierarchical relationships in firms and organizations and organizational forms were also studied, along with the measurement of efficiency and the pricing and design of insurance contracts in the presence of many risks.

The empirical study of information problems became a real issue in the 1990s and advanced rapidly in the 2000s. These years were also marked by the development of financial derivative products and large losses due to catastrophic events. Alternatives to insurance and reinsurance coverage for these losses are currently emerging in financial markets. Also, during this period, new forms of risk financing and risk engineering were proposed by the financial markets to cover the growing exposure to catastrophic risk as well as the rising loss exposure from legal liability and other dependent and significant risk exposures. New sources of risk capital were developed, including loss warranties, sidecars, and risk-linked securities, such as catastrophe bonds, options, and swaps. Alternative securitization designs were proposed to expand the market for insurance-linked securities. Risk engineering and modeling techniques were developed to improve solvency measurement and risk management.

New theoretical developments were also published to better understand decision making under risk and uncertainty. Today, higher-order risk attitudes play a central role in understanding how decisions are made by consumers and managers. Portfolio and insurance models that integrate background risk have been put forth to solve different puzzles, partially explained by inadequate standard models for complex risky situations. Longevity risk, long-term care insurance, and corporate governance are now challenging researchers and managers in the insurance industry. Finally, the 2000s have seen the rapid growth of liquidity and operational risks and the second major financial crisis of modern society marked not only by systemic risk in financial markets but also by speculation and lack of transparency in different markets, including the insurance industry.

The aim of this new version of the *Handbook of Insurance* is to update this reference work on risk and insurance for professors, researchers, graduate students, regulators, consultants, and practitioners. It proposes an overview of current research with references to the main contributions in different fields. Fifteen new chapters were added. Many of them cover new research subjects developed since 2000 such as higher-order risk attitude (Chap. 2), statistical dependence (Chap. 6), precaution (Chap. 8), securitization (Chap. 20), corporate governance (Chap. 26), systemic risk (Chap. 27), modern capital allocation (Chap. 29), new insurance market regulation (Chap. 31), longevity risk (Chap. 34), long-term care insurance (Chap. 35), and new life insurance financial products (Chap. 36).

The new version contains 37 chapters written by 59 contributors, who have produced significant research in their respective domains of expertise. Almost all chapters of the 2000 version were rewritten either by the original authors or by new authors: Six are not included in this new edition. This handbook can be considered as a complement to the previous books published by the S.S. Huebner Foundation of Insurance Education in 1992 (*Foundations of Insurance Economics—Readings in Economics and Finance*, G. Dionne and S. Harrington; *Contributions to Insurance Economics*, G. Dionne) and to the two more recent books of readings edited by G. Niehaus, *Insurance and Risk Management* (vol. I: *Economics of Insurance Markets*; vol II: *Corporate Risk Management*).

Each chapter begins with an abstract and can be read independently of the others. They were (with very few exceptions) reviewed by at least two anonymous referees. Below, the contents of this new edition are outlined.

History and Risk and Insurance Theory Without Information Problems

The first chapter is concerned with the history of research in insurance economics. H. Loubergé relates the evolution of insurance research since 1973. One important message from this contribution is that the significant developments of insurance economics during the last 40 years are exemplified by those in the economics of risk and uncertainty and in financial theory. Insurance economics now plays a central role in modern economics by proposing examples and new ideas for understanding the general economy, which is significantly exposed to various risks and uncertainties.

We next turn to the foundations of insurance theory in the absence of information problems. L. Eeckhoudt and H. Schlesinger propose an overview of higher-order risk attitudes, which play a central role in expected utility theory for examining decisions under risk and uncertainty. It is now well understood that risk aversion is not sufficient to explain many behaviors. The authors show how higher-order risk attitudes are consistent with preferences over moments of a statistical distribution even if higher-order attitudes are much more general than preferences over statistical moments.

M. Machina's chapter investigates whether some classical results of insurance theory remain robust despite departures from the expected utility hypothesis. His analysis covers insurance demand; deductible and coinsurance choices; optimal insurance contracts; bilateral and multilateral Pareto-efficient risk-sharing agreements; self-insurance vs. self-protection; and insurance decisions with ambiguity. The general answer to the above question is positive, although some restrictions are necessary given that the non-expected utility model is broader than the classical, linear expected utility model.

C. Gollier concentrates on the derivation of optimal insurance designs when insurers and policyholders have symmetric information about the distribution of potential damages. His chapter shows that the standard optimal result of full insurance coverage above a straight deductible can be obtained without the linear expected utility model. However, the hypothesis of linear expected utility still generates additional results when transaction costs are nonlinear.

The way in which changes in risk affect optimal-decision variables is a difficult and elusive research topic. The major problem is that risk aversion is not sufficient to predict that a decision maker will

reduce his optimal risky position (or increase his insurance coverage) when an exogenous increase in risk is made in the decision maker's environment. Usually, strong assumptions are needed regarding the variation of different measures of risk aversion or regarding distribution functions, to obtain intuitive comparative static results. C. Gollier and L. Eeckhoudt increase the level of difficulty by adding a background risk to the controllable risk. They propose restrictions on first- and second-order stochastic dominance to obtain unambiguous comparative statics results. They also consider restrictions on preferences. Their applications cover the standard portfolio problem and the demand for coinsurance.

P. Embrechts and M. Hofert propose a general overview on modeling risk in finance and insurance. Specifically, they cover interactions and dependencies between different risks. Well-known concepts to model risk are presented, and their advantages and weaknesses are analyzed. Their general approach is particularly useful for analyzing the total risk of complex portfolios containing many dependent risks such as those of insurers and reinsurers and for computing their optimal and regulated capital.

H. Schlesinger has contributed to many articles on market insurance demand. He first presents the classical results related to changes in optimal coinsurance and deductible insurance with respect to initial wealth, loading (price), and attitudes towards risks. The single-risk models are extended to account for multiple risks such as solvency and background risks. It is interesting to observe how many results in the single-risk models extend to the multiple-risk environments.

Prevention and precaution are risk management activities that are still very difficult to understand even in the context of symmetric information. Prevention is associated with self-protection and self-insurance activities introduced in the literature 40 years ago. The effect of risk preferences on optimal self-protection is still puzzling. The concept of precaution is more recent in the economics literature. It is a risk management activity for risky situations that are imperfectly known by decision makers, such as a new pandemic. C. Courbage, B. Rey and N. Treich show how this concept is strongly linked to the effect of the arrival of information over time and to situations where probability distributions are ambiguous.

Asymmetric Information

The book then moves on to asymmetric information problems, which have often been introduced into economics and finance literatures through examples of insurance allocation problems. Two sections of the book are devoted to this subject. The first reviews the main theoretical results related to *ex ante* and *ex post* moral hazard (insurance fraud), adverse selection, liability insurance, and risk classification. The second studies the empirical significance of these resource allocation problems.

R. Winter extends his 2000 survey by presenting the development of optimal insurance under moral hazard since the beginning of the 1970s. *Ex ante* and *ex post* moral hazard is analyzed. He shows how the insurance context manages to introduce general results in the hidden-action principal-agent problem. Particular attention is paid to the endogenous forms of the insurance contracts and to the factors that influence the design of such contracts. For example, when noncontractible effort affects the frequency but not the severity of accidents, a deductible is optimal whereas when effort affects only the severity, coinsurance above a deductible is optimal. The author also discusses the implications of repeated contracts on the design of optimal insurance policies.

The chapter by G. Dionne, N. Fombaron, and N. Doherty proposes a detailed analysis of adverse selection in insurance markets. Many new subjects are added to the classical one-period models of Stiglitz (Monopoly) and Rothschild and Stiglitz (Competition). Much more attention is paid to the recent developments of multi-period contracting with emphasis on commitment issues and renegotiation between contracting parties. A section is devoted to the endogenous choice of types before contracting, and another one treats moral hazard and adverse selection simultaneously.

Finally, the last section covers various new subjects related to adverse selection: risk categorization and residual adverse selection; multidimensional adverse selection; asymmetric information on risk aversion; symmetric imperfect information; double-side adverse selection; principals better informed than agents; *uberrima fides* and participating contracts.

The risk classification literature was strongly influenced by K. Crocker and A. Snow. Risk classification may not only increase efficiency when certain conditions are met, but it may also introduce adverse equity in some risk classes. The authors revise the theory of risk classification in insurance markets and discuss its implications for efficiency and equity in detail. They show that the economic efficiency of categorical discrimination depends on the informational structure of the environment. They also discuss the empirical literature on risk classification.

J. Ambrose, A. Carroll, and L. Regan study the basic relationships between liability system, liability insurance, and incentives for loss control. They extend the survey of S. Harrington and P. Danzon published in the 2000 version of the handbook. They cover many aspects of liability insurance and its application in the USA: the role of liability rules in providing incentives for loss control; the demand for liability insurance; the effect of correlated risks on liability insurance markets; the design of liability insurance contracts; and the efficiency of the US tort liability/liability insurance system. They also discuss directors' and officers' liability and the general liability insurance crises documented by many studies, including medical malpractice.

Insurance fraud is now a significant resource-allocation problem in many countries. It seems that traditional insurance contracts cannot control this problem efficiently. In fact, there is a commitment issue by the insurance industry because audit costs of claims may become quite substantial. P. Picard surveys the recent development of two types of models: costly state verification and costly state falsification. In the second type, the insured may use resources to modify the claims, whereas in the first he simply lies. In this case, the insurer can use deterministic or random claim auditing that can be conditioned on fraud signals perceived by insurers. Other subjects include adverse selection; credibility constraints on anti-fraud policies; and collusion between policyholders and insurers' agents or service providers when an accident occurs.

The empirical measure of information problems is a more recent research topic in the economics and financial literatures. Many issues are considered in the two chapters written by P.A. Chiappori and B. Salanié and by G. Dionne. P.A. Chiappori and B. Salanié put the emphasis on empirical models that test for or evaluate the scope of asymmetric information in the insurance relationship, whereas G. Dionne discusses insurance and other markets such as labor, used cars, slaves, and mergers and acquisitions. P.A. Chiappori and B. Salanié focus on the methodological aspect of measuring asymmetric information, while Dionne also reports empirical results. P.A. Chiappori and B. Salanié suggest that empirical estimation of theoretical models requires precise information on the contract: information on performance and transfers available to both parties. They underscore the testable consequences that can be derived from very general models of exclusive contracting. Both surveys cover how we can separate moral hazard from adverse selection and asymmetric learning and the recent tests available using dynamic data. G. Dionne concludes that observed efficient mechanisms seem to reduce the theoretical distortions due to information problems and even eliminate some residual information problems. However, this conclusion is stronger for adverse selection. One explanation is that adverse selection is related to exogenous characteristics, while moral hazard is due to endogenous actions that may change at any time. Finally, he shows how some insurance contract characteristics may induce insurance fraud!

R. Butler, H. Gardner, and N. Kleinman review the major contributions on workers' compensation, focusing on empirical measurement of the incentive responses of different indemnity benefits and medical reimbursements. They show how workers' compensation is more complex than other forms of social insurance having a system of diverse state-based laws funded through private, public, and self-insuring entities. Workers' compensation also overlaps with health insurance, unemployment insurance, and other benefits. They conclude by suggesting that more research is needed on the link

between workplace productivity and program characteristics based on worker-centric rather than on program-centric orientation.

The last chapter on the empirical measurement of information problems presents statistical models of experience rating in nonlife insurance. J. Pinquet discusses identification issues on the nature of the dynamics of nonlife insurance data. He shows how longitudinal data can be predicted via a heterogeneous model. Empirical results are presented. He offers consistent estimations for numbers and costs of claim distributions. Examples of predictions are given for count-data models with constant and time-varying random effects, for one and several equations and for cost-number models of events.

Risk Management and Insurance Pricing

The role of corporate insurance demand has not received the same attention as consumer insurance demand in the literature, although we observe that insurance contracts are regularly purchased by corporations and are fairly important in the management of corporate risk. In fact, insurance is simply another risk management tool, much like corporate hedging. The model developed by R. MacMinn and J. Garven focuses on the efficiency gains of corporate insurance to solve underinvestment and risk-shifting problems. Other determinants of the demand for corporate insurance are also reviewed: distress costs, agency costs, and tax costs. Finally, the authors analyze the role of management compensation on corporate insurance decisions and discuss the empirical implications of the theory, tests done and those still needed.

The chapter by H. Kunreuther and E. Michel-Kerjan examines the role of insurance in managing catastrophic risks from natural disasters, by linking insurance to cost-effective risk mitigation measures. This chapter outlines the roles that private markets and municipalities can play in encouraging the adoption of cost-effective risk mitigation measures. It discusses ways to reduce future losses by focusing on protection activities by homeowners and other decision makers. They develop proposals for risk management strategies that involve private–public partnerships.

The development of innovative risk-financing techniques in the insurance industry is one of the most significant advances since 2000. Risk-financing is another part of risk management. Recent innovations in the hybrid insurance and financial instruments have increased insurers' access to financial markets. D. Cummins and P. Barriue propose an extensive overview of hybrid and pure financial market instruments, not only emphasizing CAT bonds but also presenting futures, options, industry loss warranties, and sidecars. They cover life insurance securitization to increase capital and hedge mortality and longevity risks.

The transfer of risks by insurers to reinsurers remains an important risk management activity in the insurance industry. C. Bernard describes the reinsurance market and analyzes the demand for reinsurance. She covers the design of reinsurance contracts from Arrow's contribution to more recent models with background risk, counterparty risk, regulatory constraints, and various risk measures. Moral hazard and securitization are also studied. Finally, the pricing of reinsurance contracts is analyzed.

The next topic is insurance contract pricing, treated in two complementary chapters: the first discusses financial-pricing models, while the second introduces underwriting cycles in the design of insurance pricing. D. Bauer, R. Phillips, and G. Zanjani propose a comprehensive survey of financial pricing for property–liability insurance and discuss extensions to existing models. The financial pricing of insurance products refers to asset pricing theory, actuarial science, and mathematical finance. The authors present different pricing approaches in a common framework highlighting differences and commonalities. These approaches yield values of insurance assets and liabilities in the setting of a securities market.

After reviewing evidence that market insurance prices follow a second-order autoregressive process in US property-casualty insurance market during the 1955–2009 period, S. Harrington, G. Niehaus, and T. Yu present different theories that try to explain the cyclical behavior of insurance prices and profits. They then provide evidence of whether underwriting results are stationary or cointegrated with macroeconomic factors. They also review theoretical and empirical work on the effects of shocks to capital on insurance supply and the research on the extent and causes of price reduction during soft markets.

Industrial Organization of Insurance Markets

The section on the industrial organization of insurance markets starts off with the two researchers who have influenced this area of research the most, D. Mayers and C. Smith. They first stress the association between the choice of organizational structure and the firm's contracting costs. They then analyze the incentives of individuals involved in the three major functions of insurance firms: the manager function, the owner function, and the customer function. They also examine evidence on corporate-policy choices by the alternative organizational forms: executive compensation policy; board composition; choice of distribution systems; reinsurance decisions; and the use of participating policies. The relative efficiency of different organizational forms is reviewed, and the product-specialization hypothesis in the insurance industry is examined.

Insurance distribution systems are analyzed by J. Hilliard, L. Regan, and S. Tennyson. They first highlight the theoretical arguments for the presence of various distribution systems. They also discuss public policy and regulation associated with insurance distribution. Their chapter focuses on three major economic issues: (1) insurers' choice of distributive system(s); (2) the nature of insurer–agent relationships; and (3) the regulation of insurance distribution activities. Both US and international markets are considered.

N. Boubakri offers a survey of the literature on the nature of corporate governance in the insurance industry. This new subject was covered extensively in a special issue of the *Journal of Risk and Insurance* in 2011. Here the focus is on several corporate governance mechanisms such as the Board of Directors, CEO compensation, and ownership structure. The impact of such mechanisms on insurers' performance and risk taking is also discussed. Several avenues of future research are identified.

The analysis of systemic risk is another new subject in the financial literature. D. Cummins and M. Weiss examine the privacy factors that identify whether institutions are systemically risky and the contributing factors that amplify vulnerability to systemic events. Their first conclusion is that the core activities of US insurers are not affected by systemic risk. However, both life and property–liability insurers are vulnerable to reinsurance crises. Noncore activities such as financial activities, including derivative trading, may cause systemic risk. Regulators need better mechanisms for insurance group provision.

Measuring the efficiency and productivity of financial firms is very difficult, because the definitions of output are multidimensional. D. Cummins and M. Weiss, who have significantly contributed to this research, review the modern frontier efficiency and productivity developed to analyze the performance of insurance firms. They focus on the two most prominent methodologies: stochastic frontier analysis using econometrics and nonparametric frontier analysis using mathematical programming. Methodologies and estimation techniques are covered in detail. Seventy-four insurance efficiency studies are identified by the authors from 1983 to 2011, and 37 papers published in upper tier journals from 2000 to 2011 are reviewed. There seems to be growing consensus among researchers on the definitions of inputs, outputs, and prices in the insurance sector.

Capital allocation concerns an assignment of the capital of a financial institution to the various sources of risk within the firm. Its necessity and feasibility are still discussed in the academic literature.

D. Bauer and G. Zanjani show how incomplete markets and frictional costs create conditions sufficient for capital allocation to play a role as either an input to or a by-product of the pricing process. They also review the various approaches to capital allocation, with particular attention paid to the theoretical foundations of the Euler approach to capital allocation. Finally, the chapter illustrates the application of the Euler method in life insurance.

E. Baranoff, T. Sager, and B. Shi's chapter summarizes the theory and empirical analysis of capital structure for life insurers and health insurers. The capital structure question is carefully adapted from the debt vs. equity theories used for nonfinancial firms to the risk vs. capital theories in insurance. The predictions of agency theory, transaction-cost economics, pecking order, debt-equity trade-off, bankruptcy cost, risk-subsidy, and other theories are developed and summarized in the "finite risk" and "excessive risk" hypotheses. They show that insurers have operated under the finite risk paradigm over the last two decades, even during the last financial crisis.

Insurance regulation has long been a subject of considerable interest to academics, policymakers, and other stakeholders in the insurance industry. R. Klein identifies three topics of particular importance that have significant implications for the regulation of insurance companies and markets: 1) catastrophe risk, 2) imperfect competition, and 3) systemic risk. The author provides an overview of insurance regulation and discusses key issues in this area. Over the last decade, catastrophe risk has increased significantly, and systemic risk in financial markets has had implications on insurance regulation.

Developing and emerging countries have considered financial stability as an essential element of their economic and political independence. However, reliance on foreign insurance and reinsurance has remained an important policy issue. J.F. Outreville presents two important features of insurance markets in developing and emerging economies. The first issue is the relationship between insurance development and economic development which has been assessed in many empirical studies. The second issue is to present some empirical tests of the relationship between the market structure and the retention capacity for some of these countries.

Health and Long-Term Care Insurance, Longevity Risk, Life Insurance, and Social Insurance

Health insurance in the USA continues to be a complex mix of private and public programs. The advent of health-care reform legislation, specifically the Patient Protection and Accountable Care Act (PPACA), introduces new challenges and research opportunities. M. Morrissey provides a historical overview of the US system and a summary of the key features of the PPACA that affect health insurance. Attention is then directed to the key issues in health insurance and an update on the research undertaken in the last decade. Key topics include adverse selection and moral hazard where the new research examines multidimensional selection, forward-looking behavior, prescription drug coverage, and utilization management as a mechanism to control moral hazard. The author also presents new research on important aspects of employer-sponsored health insurance, for instance premium sensitivity, compensating wage differentials, and the tax treatment of employer-sponsored coverage. Recent research has also examined the role of the employer as agent for its workers. Finally, the author examines the effects of risk adjustment in the Medicare Advantage program and the effects in the Medicare prescription drug program.

Longevity risk is analyzed by G. Coughlan, D. Blake, R. MacMinn, A. Cairns, and K. Dowd. This risk of unanticipated increases in life expectancy has only recently been recognized as a significant risk that has raised the costs of providing pensions and annuities. The authors discuss historical trends in the evolution of life expectancy and analyze the hedging solutions that have been developed to

manage longevity risk. One set of solutions has come directly from the insurance industry: pension buyouts, buy-ins, and bulk annuity transfers. Another complementary set of solutions has come from the capital markets: longevity swaps and q-forwards. The authors then review the evolution of the market for longevity risk transfer. An important theme in the development of the longevity market has been the innovation originating from the combined involvement of insurance, banking, and private equity participants.

T. Davidoff covers long-term care insurance. He discusses the considerable variation in limitations to “activities of daily living” and associated expenditures on long-term care. He then treats the question of why the market for private insurance against this large risk is small in the USA. Donated care from family, otherwise illiquid home equity, and the shortened life and diminished demand for other consumption associated with receiving care may all undermine demand for long-term care insurance. Information problems also affect the supply of public and private long-term care insurance.

N. Gatzert and H. Schmeiser provide an overview of new life insurance financial products. First, they identify the key developments and drivers for the life insurance industry. They then present different forms of traditional and innovative life insurance financial products and their main characteristics. They also review the basic aspects of the modeling, valuation, and risk management of unit-linked life insurance contracts with two forms of investment guarantees (interest rate and lookback guarantees). Variable annuities are discussed, with an emphasis on challenges for insurers concerning pricing and risk management of the various embedded options. Finally, they look from the customer’s perspective regarding life insurance financial products.

The book ends with the division of labor between private and social insurance. P. Zweifel starts from the observation that the division of labor between private insurance (PI) and social insurance (SI) has changed substantially in the past decades, to the advantage of the latter. The efficiency view of SI explains the existence of SI along with the market failures of PI, namely moral hazard and adverse selection. A benevolent government is introduced that seeks to determine the optimal division of labor between PI and SI. The discussion thus supports the public choice view, which emphasizes the interests of risk-averse voters even with below-average wealth in redistribution through SI. This view predicts a crowding out of PI by SI even in markets without adverse selection. Normative issues are also discussed.

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Chapter 1

Developments in Risk and Insurance Economics: The Past 40 Years

Henri Loubergé

Abstract The chapter reviews the evolution in insurance economics over the past 40 years, by first recalling the situation in 1973, then presenting the developments and new approaches which flourished since then. The chapter argues that these developments were only possible because steady advances were made in the economics of risk and uncertainty and in financial theory. Insurance economics has grown in importance to become a central theme in modern economics, providing not only practical examples to illustrate new theories, but also inspiring new ideas of relevance for the general economy.

Keywords Insurance economics • Insurance pricing • Economics of risk and uncertainty • Financial economics • Risk management • Asymmetric information

1.1 Introduction

In the early 1970s, some 40 years ago, the economics of risk and insurance was still embryonic. Indeed, when the International Association for the Study of Insurance Economics (known as the “Geneva Association”) was founded in 1973, one of the main goals of its promoters was to foster the development of risk and insurance education in economics curricula. In particular, there existed then a clear need to develop an understanding for risk and insurance issues among the future partners of the insurance industry. It seemed also necessary to attract the attention of economists to risk and insurance as a stimulating and promising research field.

At that time, some attempts to link insurance to general economic theory had already been made, but they were still scarce. The books written by [Pfeffer \(1956\)](#), [Mahr \(1964\)](#), [Greene \(1971\)](#), and [Carter \(1972\)](#), or the one edited by [Hammond \(1968\)](#), tried to bridge the gap. (Corporate) risk management started, at least in the USA, to be considered seriously as a branch of study—see [Mehr and Hedges \(1963\)](#) and [Greene \(1973\)](#) for early references. The main obstacle was obvious: traditional economic theory was based on the assumption of perfect knowledge—with some ad hoc departures from this assumption, as in the theory of imperfect competition or in Keynesian macroeconomics. In order to witness an integration of risk and insurance issues into general economics, the theory of risk had to develop and to gain a position at the heart of economic theory. The foundations were already at hand: the [von Neumann and Morgenstern \(1947\)](#) and [Savage \(1954\)](#) theory of behavior under uncertainty, the [Friedman and Savage \(1948\)](#) application to risk attitudes, Pratt’s (1964) analysis of

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risk aversion, [Rothschild and Stiglitz \(1970\)](#) characterization of increases in risk, and the [Arrow \(1953\)](#) and [Debreu \(1959\)](#) model of general equilibrium under uncertainty. These approaches had already started to bring about a first revolution in the study of finance, with the [Markowitz \(1959\)](#) model of portfolio selection and the [Sharpe \(1964\)](#), [Lintner \(1965\)](#), and [Mossin \(1966\)](#) model of equilibrium capital asset pricing (the CAPM). With the benefit of hindsight, we know now that they did provide the starting point for the accomplishment of one of the Geneva Association's long-term objective: the integration of risk and insurance research into the mainstream of economic theory.

The purpose of this chapter is to remind the reader of the situation of insurance economics in 1973 (Sect. 1.2), and to summarize its main development since then in the three main areas of investigations that could be defined at that time: Optimal insurance and protection (Sect. 1.3); market equilibrium under asymmetric information (Sect. 1.4); and insurance market structure (Sect. 1.5). Section 1.6 introduces a personal bias toward financial economics by focussing on the new approaches which resulted from the growing integration of insurance and finance. Section 1.7 concludes. Due to limitations in space and time, two important related topics were omitted from this survey: health economics and social security. In addition, life insurance is only partially covered in Sect. 1.6. The discussion is mainly concentrated on risk and insurance economics issues as they relate to property–liability insurance.¹

1.2 Insurance Economics in 1973

In 1973, the economic theory of insurance had already begun to develop on the basis of five seminal articles: [Borch \(1962\)](#), [Arrow \(1963a\)](#), [Mossin \(1968\)](#), [Ehrlich and Becker \(1972\)](#), and [Joskow \(1973\)](#).² All these articles were based on the expected utility paradigm. Following these articles, and more particularly the first two of them, a bunch of important articles were published. They were a signal that the elaboration of an economic theory of risk and insurance was under way.

1.2.1 *Borch (1962)*

In his 1962 *Econometrica* article “Equilibrium in Reinsurance Markets,” Karl Borch showed how Arrow's ([Arrow \(1953\)](#)) model of general equilibrium under uncertainty could be applied to the problem of risk-sharing among reinsurers. But generations of economists later learned that this insurance application had far-reaching implications for the general economy.³ In 1953, Arrow had shown that financial markets provide an efficient tool to reach a Pareto-optimal allocation of risks in the economy. Nine years later, Borch's theorem⁴ was showing how the mechanism could be organized in practice.

¹Note that all chapters appearing in the 2000 version of this *Handbook* are excluded from the reference list, on the expectations that the present version includes revised version of these surveys.

²Note that two of these six authors, Kenneth Arrow and Gary Becker, received later the highest distinction for economic research—the Nobel Prize in economics.

³See [Gollier \(1992\)](#) for a review of the economic theory of risk exchanges, [Drèze \(1979\)](#) for an application to human capital, and [Drèze \(1990\)](#) for an application to securities and labor markets.

⁴Actually, Borch's theorem was already present in [Borch \(1960\)](#), but the latter article was primarily written for actuaries, whereas the 1962 *Econometrica* article was addressed to economists.

The main argument is the following. In a population of risk-averse individuals, only social risks matter. Individual risks do not really matter, because they can be diversified away using insurance markets (the reinsurance pool of Borch's contribution). But social risks—those affecting the economy at large—cannot be diversified: they have to be shared among individuals. Borch's theorem on Pareto-optimal risk exchanges implies that the sharing rule is based on individual risk-tolerances (Wilson 1968). Each individual (reinsurer) gets a share in the social risk (the reinsurance pool) in proportion to its absolute risk-tolerance, the inverse of absolute risk-aversion. If all individual utility functions belong to a certain class (later known as the HARA⁵ class, and including the most widely used utility functions), the sharing rule is linear. The above-mentioned CAPM, for long the dominant paradigm in finance theory, represents a special case of this general result.

In my view, Borch's contribution provides the corner stone of insurance economics. It may be conveniently used to show how the insurance mechanism of risk-pooling is part of a more global financial mechanism of risk-allocation, and how a distinction may nevertheless be made between insurance institutions and other financial institutions.⁶ For this reason, it may be used to clarify ideas on a hotly debated issue: the links between finance and insurance (see Sect. 1.6 below).

In the years until 1973, Borch's seminal contribution found its main insurance economics extensions in the contributions by Arrow (1970) and Kihlstrom and Pauly (1971).⁷ Arrow (1970) explicitly defined insurance contracts as conditional claims—an exchange of money now against conditional money in the future. Kihlstrom and Pauly (1971) introduced information costs in the risk-sharing model: they argued that economies of scale in the treatment of information explain why insurance companies exist. In 1974, Marshall extended further this analysis by introducing a distinction between two modes of insurance operations: reserves and mutualization (Marshall 1974). Under the reserve mode, aggregate risk is transferred to external risk-bearers (investors). With mutualization, external transfer does not apply, or cannot apply: aggregate losses are shared among insureds.

1.2.2 Arrow (1963a)

The article published in 1963 by Kenneth Arrow in *The American Economic Review* under the title “Uncertainty and the Welfare Economics of Medical Care” represents the second point of departure for risk and insurance economics. This work may be credited with at least three contributions. First, the article provided, for the first time, what has become now the most famous result in the theory of insurance demand: if the insurance premium is loaded, using a fixed-percentage loading above the actuarial value of the policy, then it is optimal for an expected utility maximizing insured to remain partially at risk, i.e., to purchase incomplete insurance coverage. More specifically, Arrow proved that full insurance coverage above a deductible is optimal in this case. Second, Arrow also proved that when the insured and insurer are both risk-averse expected utility maximizers, Borch's theorem applies: the Pareto-optimal contract involves both a deductible and coinsurance of the risk above the deductible—a result later extended by Moffet (1979) and Raviv (1979), and more recently generalized by Gollier and Schlesinger (1996) and by Schlesinger (1997) under the less restrictive assumption

⁵HARA = Hyperbolic Absolute Risk Aversion. As noted by Drèze (1990), the linearity of the sharing rule follows from the linearity of the absolute risk tolerance implied by hyperbolic absolute risk aversion.

⁶The question whether or not “institutions” are needed to allocate risks in the economy was tackled later in the finance literature.

⁷The applications of Borch's theorem in the actuarial literature are reviewed by Lemaire (1990).

of risk aversion.⁸ Third, the article was also seminal in the sense that it introduced asymmetric information into the picture. Arrow noted that transaction costs and risk aversion on the insurer's side were explanations for incomplete risk-transfer, but he also realized that moral hazard and adverse selection represented major obstacles for a smooth running of the insurance mechanism. By attracting the attention of economists to these problems, he paved the way to more focused work by [Pauly \(1968\)](#) and [Spence and Zeckhauser \(1971\)](#)—on moral hazard—and by [Akerlof \(1970\)](#)—on adverse selection.

1.2.3 *Mossin (1968)*

The article by Jan Mossin, “Aspects of Rational Insurance Purchasing,” published in 1968 in *The Journal of Political Economy*, is generally considered as the seminal article on the theory of insurance demand—although some of Mossin's results were also implicit in [Arrow \(1963a\)](#) and explicit in another article on insurance demand published the same year, but earlier, in the same journal ([Smith 1968](#)).⁹ Mossin's article is mainly famous to have shown: (1) that partial insurance coverage is optimal for a risk-averse expected utility maximizer when the insurance premium is such that a positive proportional loading applies to the actuarial value of the policy¹⁰; and (2) that insurance is an inferior good if the individual has decreasing absolute risk aversion (DARA). It was later pointed out (see below) that these strong results are respectively based on the implicit assumptions that the individual faces only one risk, and that the amount at risk is fixed (unrelated to wealth or income).

1.2.4 *Ehrlich and Becker (1972)*

In the modern theory of risk management, insurance is only seen as one of the tools available to manage risk. The whole set of tools may be decomposed into subsets according to the different steps of the risk management process. Insurance belongs to the set of risk-transfer tools and represents a very powerful financial mechanism to transfer risk to the market. Another subset corresponds to risk-prevention. Broadly, risk-prevention mechanisms may be classified under two headings: mechanisms intended to modify the probability of an event; and mechanisms intended to mitigate the consequences of an event. [Ehrlich and Becker \(1972\)](#) were the first to propose a rigorous economic analysis of risk prevention. They coined the terms *self-protection* and *self-insurance* to designate the two kinds of mechanisms and studied their relationship to “market insurance.” For this reason, their article may be seen as the first theoretical article on risk management. Briefly, the article provides three main results:

1. In the absence of market insurance, a risk averse expected utility maximizer will engage into self-protection and self-insurance activities, but the optimal “investment” in these activities depends on their cost. As usual, marginal benefit (in terms of higher expected utility) has to be weighted against the marginal disutility brought about by additional costs, so that complete elimination of the risk is not optimal in general.

⁸More precisely, [Schlesinger \(1997\)](#) considers one version of Arrow's theorem: the case where the insurer is risk neutral and the insured is risk averse (risk aversion being defined by Schlesinger as preferences consistent with second-degree stochastic dominance). In this case a straight deductible policy is optimal whenever the insurer's costs are proportional to the indemnity payment.

⁹Optimal insurance coverage using a deductible was also analyzed by [Pashigian et al. \(1966\)](#) and by [Gould \(1969\)](#).

¹⁰Incomplete insurance may be obtained using a deductible or coinsurance (or both).

2. Self-insurance and market insurance are substitutes: an increase in the degree of protection provided by the insurer induces a rational individual to reduce his investment into activities (or behavior) aimed at reducing the consequences of the insured event. Of course, this result is also of importance for the theory of moral hazard (see Sect. 1.4), but Ehrlich and Becker did not assume asymmetric information.
3. Self-protection and market insurance may be complement or substitutes, depending on the sensitivity of the insurance premium to the effects of self protection. Thus, the insurer can give to the insured an incentive to engage into self-protection activities (which reduce the likelihood of a loss) by introducing a link between the premium rate and the observation of such activities. This result is also of importance for the theory of moral hazard, and more generally for agency theory (the theory of relationships between an agent and a principal).

1.2.5 *Joskow (1973)*

The article published by Paul Joskow in the *Bell Journal of Economics and Management Science* under the title “Cartels, Competition and Regulation in the Property-Liability Insurance Industry” represents the first successful attempt to submit the insurance sector to an economic evaluation. The article assesses competition by analyzing market concentration and barriers to entry, it measures returns to scale, and discusses insurance distribution systems and rate regulation. By providing empirical results on these issues, it has provided a reference point for subsequent research on the sector. Briefly, Joskow found that the insurance industry was approximately competitive, that constant returns to scale could not be excluded, and that the direct writer system was more efficient than the independent agency system.

The five seminal contributions presented above prepared the ground for numerous developments. These may be grouped under three main headings: the demand for insurance and protection, economic equilibrium under asymmetric information, and insurance market structure. They are addressed in Sects. 1.3 to 1.5. It is striking to realize that many of these developments are not developments in insurance economics per se. They occurred within the wider domain of general economics, insurance providing in some cases an illustration of general results, and in other cases a stimulation to search for general results.¹¹

1.3 Developments: Optimal Insurance and Protection

1.3.1 *The Demand for Insurance*

The observation of economic life shows that individuals generally do not insist to get partial coverage when they subscribe an insurance policy. As the insurance premiums are generally loaded (at least to cover insurance costs), this is however the behavior which would be expected from them, according to Mossin’s (1968) results. Moreover, insurance does not seem to be empirically an inferior good. If it was, insurance companies would be flourishing in the poorer nations and would be classified among the declining industries in the richer nations of the world. Moreover, recent empirical research

¹¹The survey of developments presented in the next three sections draws on the excellent survey of insurance economics originally proposed by [Dionne and Harrington \(1992\)](#).

on individual demand for insurance suggests that “higher income is (...) positively associated with insurance purchases of all kinds” (Cohen and Siegelman 2010, p. 69). This is, again, in contradiction with Mossin’s analysis (given that absolute risk aversion is, indeed, empirically decreasing). One of the seminal articles at the roots of insurance economics has thus led to two paradoxes, and it is interesting to observe how theory was reconciled with factual observation.¹²

The second paradox (insurance is an inferior good) did not stimulate much research effort. Some scholars tried to dig into the idea by exploring the conditions under which insurance would be not only an inferior good, but also a Giffen good: see Hoy and Robson (1981) and Briys et al. (1989). But the interest remained limited. There are probably two reasons for that. First, following Arrow (1970), it was quickly recognized among economists that insurance is a financial claim. Thus it does not seem really appropriate to apply to insurance concepts which were derived to categorize consumption goods. Second, it has probably been noticed by most scholars that the condition under which Mossin’s result obtains is not generally met in practice. Mossin assumes that the individual’s wealth increases, but that the risky component of wealth remains unchanged. In reality, changes in wealth generally imply changes in the portion of wealth exposed to a risk of loss, and this is sufficient to resolve the paradox (see Chesney and Loubergé 1986).

The first paradox (partial coverage is optimal) has stimulated much more research effort. It has first been noticed that the result is not robust to changes in the pricing assumptions: for example, full insurance is optimal if the loading is a lump sum.¹³ Some researchers pointed out that the result was either reinforced, or did not hold, if the behavioral assumptions were modified: see Razin (1976) and Briys and Loubergé (1985), or the nonexpected utility developments mentioned below. But the most interesting breakthrough came from enlarging the scope of the analysis. This was made in the early 1980s by deriving the logical conclusion from the observation that insurance is a financial claim. It had been recognized for long (Markowitz 1959) that the demand for financial assets should take place in a portfolio context, taking into consideration imperfect correlations across random asset returns. The same kind of reasoning was applied to insurance by Mayers and Smith (1983), Doherty and Schlesinger (1983a, 1983b), Turnbull (1983), and Doherty (1984). In this portfolio approach, which was soon accepted as an important improvement, the demand for insurance coverage on one risk should not be analyzed in isolation from the other risks faced by the decision-maker: insurance demand is not separable, even when the risks are independent (Eeckhoudt and Kimball 1992). When considering the insurance demand for one risk, one has to take into account the other risks, their stochastic dependence with the first risk, whether they are insurable or not, and under what conditions, whether some insurance is compulsory or subsidized, whether a riskless asset is traded, etc.: see, e.g., Schlesinger and Doherty (1985), von Schulenburg (1986), Kahane and Kroll (1985), Briys (1988), and Gollier and Scarmure (1994).¹⁴ Thus, assuming that correlation is a sufficient measure of dependence,¹⁵ it may be optimal to partially insure a risk which is negatively correlated with an other

¹²Other strange results were observed later on, for example an increased loss probability has an ambiguous impact on insurance purchasing if the insured has DARA preferences and the insurer adjusts the premium to take the increased loss probability into account (Jang and Hadar 1995).

¹³It is obvious that the paradox may be resolved if one introduces differential information. If the insured overestimates the probability (or the amount) of loss, full insurance may be optimal, even when the premium is loaded with a fixed proportional factor.

¹⁴On a related theme, see also Doherty and Schlesinger (1990) for the case where the insurance contract itself is risky, due to a nonzero probability of insurer default. The article shows that full insurance is not optimal under fair insurance pricing, and that the usual comparative statics result from the single risk model do not carry over to the model with default risk. Their work was extended by Cummins and Mahul (2003) to the case where the insurer and policyholder have divergent beliefs about the insurer default risk.

¹⁵In a recent article, Hong et al. (2011) argue that correlation is not an adequate measure of stochastic dependence when expected utility is used. Turning to more general notions of positive and negative dependence, and focussing on

risk, even if the premium is actuarial. Conversely, it may be optimal to fully insure a risk in spite of unfair pricing, if this risk is positively correlated with an other uninsurable risk. In a portfolio context, incomplete markets for insurance provide a rationale for full insurance of the insurable risks. Mossin's paradox can thus be resolved by changing the perspective, instead of changing the analytical model (the expected utility model).¹⁶

Eeckhoudt and Kimball (1992) introduced the concept of prudence into the analysis of optimal insurance purchasing under background risk and pointed out that the demand for insurance for one risk was not independent of the background risk, even when the two risks are independent. Building on these premises, several contributions checked the conditions under which optimal insurance demand under background risk has desirable comparative statics properties, such as an increase in optimal insurance coverage when the insured or uninsured risks increase, or whether a deductible policy remains optimal under background risk: see Meyer (1992), Dionne and Gollier (1992), Eeckhoudt et al. (1991, 1996), Gollier and Schlesinger (1995), Gollier (1995), Gollier and Pratt (1996), Gollier and Schlee (1997), Tibiletti (1995), Guiso and Jappelli (1998), Meyer and Meyer (1998a), and Mahul (2000).

More recently, the insurance model with background risk has been extended to the case where the uninsurable risk is nonpecuniary. This is the case, for example, if the background risk represents a state of health. The problem may be analyzed using state-dependent utility functions or introducing a second argument in the decision maker's utility function, besides wealth. Using the second approach, Rey (2003) has demonstrated that the impact of the nonfinancial risk on insurance demand depends not only on the relationship between the two risks but also on the impact of the background risk on the marginal utility of wealth. For example, if the marginal utility of wealth increases under occurrence of a nonfinancial loss (some degree of disability, for example)¹⁷ and if the two risks are positively correlated, then insurance demand will be increased. Full insurance becomes possible, even with a loaded premium. But full insurance with a loaded premium may also obtain if the two risks are negatively correlated and the marginal utility of wealth is lower under occurrence of a nonfinancial loss.¹⁸ The range of possibilities for contradicting Mossin's first proposition (in Sect. 1.2.3 above) becomes wider.

1.3.2 Insurance, Consumption, and Saving

Research integrating joint optimal decisions on consumption, saving, and insurance represents a different research program, which was addressed by Moffet (1977) and Dionne and Eeckhoudt (1984). The latter authors have shown that investing in the riskless asset is a substitute to insurance purchasing. This work was generalized by Briys (1988) using a continuous-time model. More recently, Gollier (2003) has considered the impact of time diversification on optimal insurance demand in a dynamic framework, under the assumption of no serial correlation in risks. He shows that mainly

coinsurance, they show that the individual will purchase less than full (more than full) insurance if and only if the insurable risk is positively (negatively) expectation dependent with random initial wealth.

¹⁶These theoretical advances closely followed similar advances in the theory of risk premiums under multiple sources of risk: Kihlstrom et al. (1981), Ross (1981), and Doherty et al. (1987). This literature on optimal insurance in presence of a background risk has also close links to the literature on the demand for a risky asset which was pioneered by Arrow (1963b) in a single risk setting and developed later to consider the impact of background risks: see, e.g., Tsetlin and Winkler (2005) and Li (2011) for recent contributions.

¹⁷This case corresponds to a negative cross-derivative of the two-attribute utility function ($u_{12} \leq 0$). Eeckhoudt et al. (2007) show that this is equivalent to "correlation aversion," the aversion to losses affecting simultaneously the two attributes of utility (health and wealth for example).

¹⁸Following Eeckhoudt et al. (2007), the individual is then "correlation loving." For him, in this case, purchasing more insurance against a loss in wealth helps to mitigate the adverse impact of a negative correlation between the two risks.

liquidity constrained individuals will insure largely. Wealthy individuals will take advantage of time diversification to accumulate buffer stock wealth and avoid the costs due to loaded insurance prices.

A related avenue of research concerns the joint determination of insurable asset purchases and optimal insurance coverage: see Meyer and Ormiston (1995), Eeckhoudt et al. (1997), Meyer and Meyer (2004), and Loubergé and Watt (2008) for recent work along this line.¹⁹ In the first of these articles, the individual is endowed with riskless wealth and with a risky insurable asset, but insurance can only be paid for by selling a part of the risky asset. Hence, the model differs from Mossin (1968) where insurance is paid out of riskless wealth. However, because an increase in wealth impacts only riskless wealth, insurance remains an inferior asset under DARA. Eeckhoudt et al. (1997) generalize the previous work by considering an individual who allocates some nonrandom wealth to the purchase of a safe asset, a risky asset, and an insurance contract to cover the risky asset. The optimal demands for the risky asset and for insurance coverage are determined jointly and paid out of risk-free wealth. As the insurance indemnity is not linear,²⁰ it may be optimal to keep some wealth in the risk-free asset. As expected, it turns out that insurance and holding the riskless asset are substitutes. However, the generality of the model does not allow the authors to derive clear comparative statics results. In particular, “increases in initial wealth can lead to increases or decreases in the insurance level and to increases or decreases in the holding of the risky asset, (...) even when the decision maker is decreasingly risk averse” (p. 26). Thus Mossin’s second paradox is not confirmed: insurance is not necessarily inferior under DARA. Further, Meyer and Meyer (2004) considered the case where the individual is endowed with a composite portfolio of risky and riskless assets in fixed proportions. The risky asset may be insured without changing the proportions of the two assets held. Under these peculiar circumstances, insurance turns out to be normal whenever *relative* risk aversion is nondecreasing. In addition, the authors prove that insurance is ordinary (not Giffen) if relative risk aversion is less than or equal to 1, a condition already derived in previous work based on the standard model (Hoy and Robson 1981). The same restrictive condition is also pivotal—as in Meyer and Ormiston (1995) and in Eeckhoudt et al. (1997)—to determine whether insurance demand will increase or not in reaction to an increase in the size of the loss. More recently, Loubergé and Watt (2008) addressed the same issues by focussing on the case where the riskless asset is dominated and all available wealth is invested in a risky and insurable asset (an investment opportunity), partly to purchase the asset, partly to finance insurance purchasing. In their setting, coinsurance is allowed, partial insurance is optimal when the premium is loaded and may be optimal when insurance is fair. The fraction of the investment subject to a loss is a very important parameter in the model, along with risk aversion. If the fraction is low enough, no insurance is optimal. With a larger fraction, and positive insurance, insurance is normal if *relative* risk aversion is nondecreasing. But even with decreasing relative risk aversion, insurance is still normal if the proportion of the investment subject to a loss is higher than the rate at which relative risk aversion decreases.²¹ Insurance demand increases unambiguously if the percentage loss increases. But, when the loss probability increases and the insurer simultaneously adjusts the premium rate to take this change into account, the results are less clear-cut: it turns out that the demand for insurance increases if the relative risk aversion is constant and less than or equal to 1, but may also increase for values of constant relative risk aversion larger than 1 depending on the relationship between this value and the value of the percentage loss to which

¹⁹The following developments on this topic borrow from the literature review in Loubergé and Watt (2008).

²⁰Coinsurance must be excluded to avoid corner solutions of either no holding of the riskless asset or zero demand for insurance. Meyer and Meyer (1998b) address the specific case of deductible insurance.

²¹In this case, with increasing wealth, the rate of increase of the possible loss amount is higher than the rate of decrease of relative risk aversion.

the asset is exposed.²² Obviously, changes in risk aversion complicate the analysis when purchasing of an insurable risky asset and insurance are considered simultaneously, instead of separately.

1.3.3 *Self-protection and Self-insurance*

Research on risk prevention (self-protection and self-insurance activities, in the Ehrlich and Becker 1972, sense) has developed more slowly during the 1980s, but has received increased attention recently. The earlier important contributions came with Boyer and Dionne (1989b) who noted that self-insurance leads to stronger changes in risk than self-protection (see also Chang and Ehrlich 1985), and with Dionne and Eeckhoudt (1985) who showed that increased risk aversion leads to more self-insurance, but obtained the surprising result that an increase in risk aversion does not necessarily result in higher self-protection, everything else constant.²³ Briys and Schlesinger (1990) proved later that these results are quite robust to a change in the model setting, e.g., introducing state-dependent utility functions or a random initial wealth. As noted by them and by Sweeney and Beard (1992), this is due to the fact that, in contrast to insurance, “expenditures on self-protection do not merely trade income in one state of the world for income in another. . . Self-protection reduces income in all states.” The expected utility impact of this lost income in all states must be weighted against the utility impact of a lower loss probability. More precisely, self-protection does not reduce risk in the Rothschild and Stiglitz (1970) sense. As shown by Briys and Schlesinger (1990), “an increase in the level of self-protection causes both a mean-preserving spread *and* a mean-preserving contraction in the wealth distribution, with the spread occurring at lower wealth levels and the contraction at higher wealth levels” (p. 465). For this reason a more risk-averse individual does not necessarily invest more in self-protection. Eeckhoudt and Gollier (2005) showed that introducing prudence into the picture does not lead to a more intuitive result.²⁴ More prudence (in the Kimball (1990), sense) does not lead to more self-protection. In particular, if the optimal self-protection expenditure of a risk neutral agent is such that her probability of loss is $p_n \geq 1/2$, a risk averse and prudent agent spends less on self-protection than the risk-neutral agent (see also Dachraoui et al. 2004; Dionne and Li 2011, for comparable results). The reason is that prevention has a current monetary cost (it is defined as an expenditure) and a more prudent individual wants to increase saving to hedge against future contingencies.

Dionne and Eeckhoudt (1988) also investigated the effects of increasing risk on optimal investment in self-protection activities, while wealth effects on self-insurance and self-protection were analyzed by Sweeney and Beard (1992) and by Lee (2005) in a two-state model. For a given loss, self-insurance turns out to be inferior under DARA, whereas the effect of wealth on self-protection expenses is ambiguous.²⁵ Lee (2010) extended the self-insurance model to a multiple-state setting and showed that results from the two-state model do not carry over to a multiple-state model. Self-insurance may be normal under DARA if several loss states are possible.

²²Using Mossin’s (1968) approach, Jang and Hadar (1995) obtain that the effect of an increase in the probability of loss is in this case indeterminate if the utility function displays DARA, and that the demand for insurance decreases with CARA or IARA utility.

²³Jullien et al. (1999) showed later that “self-protection increases with risk aversion if and only if the initial probability of loss is low enough.”

²⁴See also Courbage and Rey (2006) for an extension of this result to the case of two-argument utility functions, wealth, and health.

²⁵The effect of wealth on self-protection expenses is null under CARA and it depends on the level of the loss probability under DARA and IARA.

But in contrast with most other domains of risk and insurance economics, the analysis of prevention was not replaced, until recently, in a broader multiple risks context. Steps in that direction had been made by [Briys and Schlesinger \(1990\)](#), see above) and by [Briys et al. \(1991\)](#) with their analysis of “risky risk management.” More recently, [Dachraoui et al. \(2004\)](#) noted that their analysis of self-protection for a “mixed risk averse” agent *à la Caballé and Pomansky (1996)* applies as well when the agent faces a background risk. An important additional step on this issue was made by [Lee \(2012\)](#) in his analysis of self-protection under background risk. He considers two kinds of self-protection: self-protection effort and monetary investment in self-protection devices. He obtains that an individual facing a background risk will exert more self-protection effort than the same individual without background risk. Concerning monetary investment in self-protection, he is also able to show that the presence of a background risk will increase self-protection, if the self-protection expenditure is paid out of income not out of wealth, and if wealth and consumption are complements.²⁶ Recently also, [Courbage and Rey \(2012\)](#) investigated the impact of background risks on optimal self-protection expenditures in a two-period model. They show that a prudent individual does not necessarily exert more effort in presence of a background risk. In a two-period model, the results differ depending on whether the background risk is introduced in the first or the second period, and depending on whether the background risk arises in the loss or no-loss state of nature.

1.3.4 *The Demand for Liability Insurance*

Liability risk raises particular issues that were addressed in a specific branch of the insurance economics literature, at the interface between law and economics. An economic agent (*the injurer*) may be made liable for the monetary and non-monetary losses he or she imposes on another agent (*the victim*). The losses are random but are in general influenced by the decisions of the injurer regarding his/her level of potentially harmful activity and his/her level of care. The injurer can contract liability insurance to cover the risk of being sued by the victim(s). The availability of insurance is not without influence on the injurer’s decisions regarding the levels of activity and care, as has been known since [Ehrlich and Becker \(1972\)](#). But the specificity of liability insurance arises from the possibility that the losses imposed on the victim(s) exceed the injurer’s wealth. In this case, the injurer is “judgment proof”: he or she cannot be forced to bear the full monetary consequences of the losses resulting from his or her activity. This has an influence on the injurer’s optimal level of care and insurance demand.

The impact of the “judgment proof problem” on the demand for liability insurance was first analyzed by [Sinn \(1982\)](#). He remarked that when injurers are socially guaranteed a minimum “subsistence” level of wealth, a kink appears in their utility function. Such a kink breaks the overall concavity of the function, with the result that a risk averse injurer may rationally choose not to purchase any liability insurance, even if the insurance premium is actuarially fair. Whether insurance will be purchased or not depends on the injurer’s initial wealth, on the socially guaranteed minimum subsistence level and on the size of the loss, among other usual influences such as risk aversion and insurance price. If insurance is purchased, it will be full insurance if the premium is actuarially fair (no proportional loading applies) and partial insurance if the premium entails a proportional loading—as expected from [Mossin’s \(1968\)](#) results. However, a noteworthy implication of the analysis is that insurance demand for liability insurance is an increasing function of the injurer’s initial wealth, even

²⁶Note that all this literature on self-insurance and self-protection has been driving away from the study of the links between insurance demand and prevention. In addition, except for the recent article by [Lee \(2012\)](#), it has focussed on the case where prevention implies a monetary cost (prevention expenditures), instead of the case where prevention implies an “effort” producing a direct loss in utility—presumably because the analysis of the latter case is more straightforward.

if the injurer's preferences are DARA and the possible loss is fixed, a result opposite to the one obtained by Mossin in the property insurance case.

Huberman et al. (1983) emphasized that the reluctance of injurers to purchase liability insurance derives from the fact that the insurance premium takes into account a range of (high) losses to which injurers are not exposed if such losses exceed the value of their assets (or the difference between their assets and the socially guaranteed minimum subsistence level). Using the example of a 3-state model and assuming actuarially fair insurance pricing, they show that when a possible large loss exceeds the injurer's assets it is preferable for the injurer to set a limit on the insurance indemnity and remain partially covered, even for losses that do not imply bankruptcy. The risk-spreading function of insurance is hampered.

Liability insurance and the judgment proof problem were comprehensively analyzed by Shavell (1986) in a model where the potential injurer decides simultaneously on insurance purchasing and on the optimal level of care under two possible legal frameworks: strict liability and the negligence rule.²⁷ Under strict liability, the results depend on whether the insurer can observe the insured's level of care or not. With perfect information, the insurer can adjust the premium to the level of care. In this case, if the injurer's initial wealth exceeds some threshold, full insurance and an efficient level of care are both optimal. As care is observable and impacts the insurance premium, the insured gains from adopting the efficient level of care, whereas in the absence of insurance, a lower level of care would have been optimally chosen, due to the judgment proof problem. If the injurer's initial wealth is below the threshold, no insurance is purchased and the level of care is zero or reduced below the efficient level.

These results make a strong case for imposing compulsory liability insurance, but they are conditioned on the perfect observability assumption. If care exercised by the injurer is not observable by the insurer, either no insurance is chosen (in a wider range of injurer's wealth), or insurance is partial, with a sub-efficient level of care. In this situation, the case for compulsory liability insurance is not made. A tension arises between risk-spreading and appropriate incentives to avoid losses.

When the negligence rule holds, care is assumed to be observable. In this case, it is optimal for the injurer not to purchase any insurance and to exercise the optimal no-insurance level of care when the judgment proof problem arises: either no care at all if initial wealth is below a first threshold; an increasing level of care if initial wealth is beyond this threshold but below a second threshold; and the efficient level of care if initial wealth is beyond the second threshold. The reason is that it is useless to purchase insurance if the injurer applies the appropriate level of care. Not applying this level and purchasing coverage for the risk of being liable would be more costly.²⁸ Of course, the result under the negligence rule hinges on the belief that the injurer will not be judged liable for the loss imposed on the victim(s) if the efficient level of care was chosen. Judicial uncertainty is ruled out (see Shavell 2000, for more on this issue). More generally, the results presented above rely on the assumption that the legal tort liability/liability insurance system is efficient, which has been hotly debated, particularly in the wake of the US liability insurance crisis of the mid-1980s (see Danzon and Harrington 1992, for an early survey of liability insurance issues).

²⁷Under the negligence rule, an injurer cannot be made liable for the losses imposed on a victim if the injurer has applied the appropriate level of care. In theoretical work, the appropriate level of care is the socially efficient level of care optimally chosen by a risk averse potential injurer if the judgment proof problem does not arise. This level balances the marginal benefits and marginal cost of care.

²⁸In addition, the injurer would run the risk of being denied indemnification by the insurer if it turned out *ex post* that the level of care was inappropriate.

1.3.5 *Other Contributions*

Other work in the theory of optimal insurance concerns:

1. The specific issues raised by the corporate demand for insurance: these issues will be considered in Sect. 1.6 below.
2. The focus on anomalies observed in actual insurance purchasing behavior (Kunreuther and Pauly 2005).
3. The extension of the expected utility model to take into account state-dependent utility functions. One can thus introduce into the analysis important observations from reality. For example, the observation that the indemnity paid by the insurer cannot provide complete compensation for a non monetary loss, such as the loss of a child, or the observation that the marginal utility of wealth is different under good health and under disability: see Arrow (1974), Cook and Graham (1977), and Schlesinger (1984) for important contributions along this line. This line of research is however related to, and generalized by, the recent literature on insurance purchasing under multi-attribute utility functions (see above: Rey 2003).
4. The replacement of the expected utility model with recent generalizations, grouped under the heading “nonexpected utility analysis.” This research program has already produced several interesting results. Using the distinction between risk aversion of order 1 and risk aversion of order 2,²⁹ Segal and Spivak (1990) have shown that Mossin’s (1968) result on the optimality of partial coverage under a loaded insurance premium does not hold necessarily if risk aversion is of order 1 (see also Schlesinger 1997). Now, risk aversion of order 1 may occur under the expected utility model (if the utility is not differentiable at the endowment point), or under some generalizations of this model, such as Yaari (1987) dual theory, or Quiggin (1982) rank-dependent expected utility theory. In particular, using Yaari’s model, Doherty and Eeckhoudt (1995) have shown that only full insurance or no insurance (corner solutions) are optimal with proportional insurance, when the premium is loaded.³⁰ Karni (1992) has shown that Arrow’s (1963a) result on the optimality of a deductible policy is robust to a change in behavioral assumptions if the modified model satisfy some differentiability conditions, which are met by Yaari (1987) and Quiggin (1982) models. Indeed, Schlesinger (1997) has shown that this result is very robust to a change of model. Konrad and Skaperdas (1993) applied Ehrlich and Becker (1972) analysis of self-insurance and self-protection to the rank-dependent expected utility model. Schlee (1995) confronted the comparative statics of deductible insurance in the two classes of model. So far, the most comprehensive attempt to submit classical results in insurance economics to a robustness test by shifting from expected utility to nonexpected utility can be found in Machina (1995). He uses his generalized expected utility analysis (Machina 1982) and concludes that most of the results are quite robust to dropping the expected utility hypothesis. However, the generality of his conclusion is challenged by Karni (1995) since Segal and Spivak (1990) have shown that Machina’s generalized expected utility theory is characterized by risk aversion of order 2.

The demand for insurance under background risk in a nonexpected utility setting was analyzed by Doherty and Garven (1995) using Yaari (1987) dual choice theory. They show that an interior solution (partial insurance) *may* be obtained under proportional coverage and a loaded insurance premium if an independent background risk is present (full insurance remains optimal if the premium is fair). Dropping the independence assumption, they note that the likelihood to get a corner solution increases.

²⁹The orders of risk aversion, as defined by Segal and Spivak (1990), rest on the behavior of the risk premium in the limit, as the risk tends toward zero.

³⁰This result is reminiscent of the same result obtained under Hurwicz’s model of choice under risk: see Briys and Loubergé (1985).

But, qualitatively, the effects of introducing positively or negatively correlated background risks are the same as under expected utility. More generally, [Schlesinger \(1997\)](#) has shown that introducing an independent background risk in a decision model with risk aversion does not change the predictions obtained under a single source of risk: full insurance is optimal under a fair premium; partial or full insurance may be optimal under a loaded premium; and a deductible policy remains optimal.

1.4 Developments: Markets Under Asymmetric Information

The [Arrow \(1953\)](#) model shows that a market economy leads to a general and efficient³¹ economic equilibrium—even under uncertainty—if the financial market is complete, i.e., provided the traded securities and insurance contracts make possible to cover optimally any future contingency. This is an important result since it extends to the case of uncertainty the classical result on the viability and efficiency of a free market economy.

However, as Arrow himself noted in his 1963 article (see above), optimal coverage is not always available in insurance markets due to various reasons. Among these reasons, asymmetric information has received much attention in the economic literature and has been generally discussed under two main headings: moral hazard and adverse selection. Moral hazard exists when (1) the contract outcome is partly under the influence of the insured, and (2) the insurer is unable to observe, without costs, to which extent the reported losses are attributable to the insured's behavior. Adverse selection occurs when (1) the prospective insureds are heterogeneous, and (2) the risk class to which they belong cannot be determined a priori by the insurer (at least not without costs), so that every insured is charged the same premium rate.³² Clearly, asymmetric information is a source of incompleteness in insurance markets: e.g., a student cannot be insured against the risk of failing at an exam; a healthy old person may not find medical insurance coverage at an acceptable premium, etc. For this reason, a free market economy may not be efficient, and this may justify government intervention.

1.4.1 Moral Hazard

Economists make a distinction between two kinds of moral hazard, depending on the timing of the insured's action. If the latter occurs before the realization of the insured event, one has *ex ante* moral hazard, while *ex post* moral hazard exists when the insured's action is taken after the insured event.³³

Ex ante moral hazard was studied by [Pauly \(1974\)](#), [Marshall \(1976\)](#), [Holmstrom \(1979\)](#), and [Shavell \(1979\)](#), among others. They showed that insurance reduces the incentive to take care when

³¹An economic equilibrium is efficient if it is Pareto optimal: it is impossible to organize a reallocation of resources which would increase the satisfaction of one individual without hurting at least one other individual. The first theorem of welfare economics states that any competitive equilibrium is Pareto optimal, and the second theorem states that a particular Pareto optimum may be reached by combining lump sum transfers among agents with a competitive economic system. In an efficient equilibrium, market prices reflect social opportunity costs.

³²In an interesting article on the history of the term "moral hazard" [Rowell and Connelly \(2012\)](#) note that the concepts of moral hazard and adverse selection have often been confused in the insurance literature. They also remark that this literature tends to attribute a pejorative meaning to "moral hazard," often associated with fraud, in contrast to the economic literature which focuses on incentives and maintains that "moral hazard has in fact little to do with morality" ([Pauly 1968](#)).

³³*Ex post* moral hazard is particularly important in medical insurance, where claimed expenses are dependent on decisions made by the patient and the physician once illness has occurred.

the insurer is unable to monitor the insured's action. [Dionne \(1982\)](#) pointed out that moral hazard is also present when the insured event results in non-monetary losses, for example the loss of an irreplaceable commodity. Quite generally, partial provision of insurance is optimal under moral hazard. More specifically it was demonstrated that uniform pricing is not optimal when the insured's behavior affects the probability of a loss. The equilibrium premium *rate* is an increasing function of the amount of coverage purchased (nonlinear pricing): see [Pauly \(1974\)](#). In addition, under moral hazard in loss reduction, the optimal contract is conceived such as to make the degree of coverage a nonincreasing function of the amount of losses, large losses signaling careless behavior by the insured. Small losses are fully covered, but losses exceeding a limit are partially covered ([Winter 1992](#), proposition 4). [Shavell \(1982, 1986\)](#) extended the study of moral hazard to the case of liability insurance. He showed that making liability insurance compulsory results in less than optimal care.³⁴

The existence of long-term (multi-period) contracts does not necessarily mitigate the effect of moral hazard. Under the infinite period case, [Rubinstein and Yaari \(1983\)](#) proved that the insurer can eliminate the moral hazard problem by choosing an appropriate experience rating scheme that provides an incentive to take care. But the result does not, in general, carry over to the finite period case ([Winter 1992](#)). In addition, the possibility for the insured to switch to an other insurer makes a penalty scheme difficult to enforce in truly competitive insurance markets, where insurers do not share information on prospective insureds.³⁵

Ex post moral hazard was first pointed out by [Spence and Zeckhauser \(1971\)](#), and studied later by [Townsend \(1979\)](#) and [Dionne \(1984\)](#). In this case, the nature of the accident is not observable by the insurer, who has to rely on the insured's report or engage in costly verification.³⁶ [Mookherjee and Png \(1989\)](#) showed that random auditing represents the appropriate response by the insurer in this situation. Their work was extended by [Fagart and Picard \(1999\)](#) who investigated the characteristics of optimal insurance under random auditing. Using a deterministic auditing policy, [Bond and Crocker \(1997\)](#) obtained that the optimal insurance contract includes generous payment of easily monitored losses and undercompensation for claims exhibiting higher verification costs.

The consequences of moral hazard for the efficiency of a market economy were studied by [Helpman and Laffont \(1975\)](#), [Stiglitz \(1983\)](#), [Arnott and Stiglitz \(1990\)](#), and [Arnott \(1992\)](#), among others. They showed that a competitive equilibrium may not exist under moral hazard, and that the failure to get complete insurance coverage results at best in sub-efficient equilibrium. This is due to the fact that "moral hazard involves a trade-off between the goal of efficient risk bearing, which is met by allocating the risk to the insurer, and the goal of efficient incentives, which requires leaving the consequences of decisions about care with the decision maker." ([Winter 1992](#), p. 63). However, government intervention does not necessarily improve welfare in this case. This depends on government information, compared with the information at the disposal of private insurers. Arguments may be put forward in favor of a taxation and subsidization policy providing incentives to avoid and reduce losses, but public provision of insurance does not solve the moral hazard problem ([Arnott and Stiglitz 1990](#)).

Moral hazard has become a popular theme in economics, not only because its presence in insurance markets results in less than optimal functioning of any economic system, but also because it is a widespread phenomenon. As [Winter \(1992\)](#) notes, moral hazard can be defined broadly as a conflict

³⁴Note that moral hazard is also present in the insurer–reinsurer relationship (see [Jean-Baptiste and Santomero 2000](#)). The success of index products in insurance securitization is partly due to the fact that they remove the moral hazard from the relationship between insurers and providers of reinsurance coverage ([Doherty and Richter 2002](#)).

³⁵The situation is of course different in monopolistic insurance markets (see [Boyer and Dionne 1989a](#)) or in markets where retrospective rating is mandatory.

³⁶At some point, the moral hazard problem becomes a fraud problem—see [Picard \(1996\)](#), [Crocker and Morgan \(1998\)](#), the special issue on fraud in *The Journal of Risk and Insurance*, September 2002 ([Derrig 2002](#)), and more recently [Dionne et al. \(2009\)](#).

of interests between an individual (behaving rationally) in an organization, and the collective interest of the organization. Insurance markets provide the best illustration for the effect of moral hazard, but the latter is also observed in labor relationships, in finance contracts, and quite generally in all circumstances where the final wealth of a *principal* is both uncertain and partially dependent upon the behavior of an *agent* whose actions are imperfectly observable: for example, in a corporation, the wealth of the firm's owners (stockholders) is partly dependent upon the actions of the manager; in judicial procedure, the final outcome is partly dependent upon the efforts of the lawyers; in a team, the success of the team is partly dependent on the individual effort of the members, etc. All these situations were studied in the economic and financial literature under the headings of *principal-agent relationships* or *agency theory*, with close connections to the literature on moral hazard in insurance: in both cases, the objective is to define the optimal "incentive contract" to mitigate the effect of asymmetric information, and to study the consequences of different arrangements on deviations from efficiency: see [Ross \(1973\)](#), [Radner \(1981\)](#), [Lambert \(1983\)](#), and [Grossman and Hart \(1983\)](#) for canonical references. See also [Allen \(1985\)](#), [Fudenberg and Tirole \(1990\)](#), and [Chiappori et al. \(1994\)](#) for research introducing credit markets and saving into the analysis. Similarly, the consequences for general economic equilibrium of market incompleteness brought about, among other causes, by moral hazard has become a central theme of research in economics: see, e.g., [Polemarchakis \(1990\)](#). On the moral hazard issue, at least, developments in insurance economics were closely related to developments in general economic theory.

Turning to empirical work, and focussing on moral hazard in insurance contracts, evidence for an impact of moral hazard on insured losses has been documented in several studies taking advantage of natural experiments provided by changes in legislation, starting with [Dionne and St-Michel \(1991\)](#) for workers' compensation and continuing with [Cohen and Dehejia \(2004\)](#) for automobile insurance, as well as [Chiappori et al. \(1998\)](#) and [Klick and Stratmann \(2007\)](#) for health insurance. In contrast, [Abbring et al. \(2003\)](#) do not find any evidence of moral hazard in multi-period data provided by the French system of *bonus-malus* in automobile insurance. A *malus*, which results from prior accident history and increases the cost of insurance for the policyholder, does not lead to a significant reduction in insured losses. In addition, even if a drop in insurance claims is observed following the introduction of experience rating, evidence from Canada suggests that much of the decline is due to an increased incentive not to report claims (see [Robinson and Zheng 2010](#)). In this case, policy changes introduced to address the *ex ante* moral hazard issue stimulate the development of a kind of *ex post* moral hazard.³⁷ In the case of fraud—an extreme version of moral hazard—[Hoyt et al. \(2006\)](#) report that antifraud laws introduced in the USA in the period 1988–1999 had mixed effects on automobile insurance fraud. Some laws had no statistically significant effects and others actually increased fraud. To sum up, although there are strong theoretical reasons to believe that moral hazard represents a major issue in insurance, and experience rating a powerful tool to deal with it, the empirical evidence so far is not compelling. This is probably due to the difficulty to set up tests that isolate the moral hazard from other influences, given the information limits on actual incentives and behavior among insureds.

1.4.2 Adverse Selection

A central development in the study of adverse selection was the article by [Rothschild and Stiglitz \(1976\)](#). This article assumed two classes in the insured population: "good risks" and "bad risks."

³⁷[Dionne et al. \(2011\)](#) claim to have found evidence of moral hazard in the statistical relationship between traffic violations and accumulated "demerit points" in the system of driving license suspension threat introduced in Quebec in 1978, but they do not find such evidence when they test the effect of the 1992 insurance pricing scheme on the relationship between "demerit points" and car accidents: road infractions were reduced by 15%, with no significant effect on car accidents.

The two classes differ only with respect to their accident probability. The authors showed that a competitive insurance market does not necessarily reach an equilibrium under adverse selection, and that, if it does, the “good risks” suffer a welfare loss. More specifically, under the assumptions of the model, including the assumption of myopic behavior by insurers (pure Cournot-Nash strategy), equilibrium obtains if the proportion of good risks in the economy is not “too large.” The equilibrium situation involves the supply of discriminating contracts providing full insurance at a high price to the bad risks and partial coverage at a low price to the good risks.³⁸ Compared to the symmetric information case, the bad risks get the same expected utility, but the good risks suffer a welfare loss. The policy implication of the model is that, in some circumstances, insurance markets may fail, and monopolistic insurance (under government supervision) or compulsory insurance may be justified as a second best.³⁹

Extensions of the basic Rothschild–Stiglitz model are due to [Wilson \(1977\)](#), [Spence \(1978\)](#), and [Riley \(1979\)](#), who dropped the assumption of myopic behavior by insurers. Then, an equilibrium exists always, either as a separating equilibrium (Riley, Wilson), or as a pooling equilibrium (Wilson). Moreover, Spence showed that this equilibrium is efficient if the discriminating insurance contracts are combined with cross-subsidization among risk classes, the low risks subsidizing the high risks.⁴⁰ More recent extensions concern the case where the individuals face a random loss distribution ([Doherty and Jung 1993](#); [Doherty and Garven 1995](#); [Landsberger and Meilijson 1996](#); [Young and Browne 1997](#)), the case where they differ with respect to both accident probability and degree of risk aversion ([Smart 2000](#)), the case where some of them are overconfident ([Sandroni and Squintani 2007](#)), and the case where they are exposed to multiple risks, or background risk ([Fluet and Pannequin 1997](#); [Crocker and Snow 2008](#)). [Allard et al. \(1997\)](#) have also shown that the Rothschild–Stiglitz results are not robust to the introduction of transaction costs: for arbitrary small fixed set-up costs pooling equilibria may exist in a competitive insurance market, and high risk individuals (rather than low risk individuals) are rationed. In addition, it is important to note that a separating equilibrium may be invalidated if insureds have the opportunity to purchase coverage for the same risk from different insurers. For this reason, [Hellwig \(1988\)](#) extended the model to take into account the sharing of information by insurers about the policyholders.

These models were empirically tested by [Dahlby \(1983,1992\)](#) for the Canadian automobile insurance market, and by [Puelz and Snow \(1994\)](#), who used individual data provided by an automobile insurer in the state of Georgia. Both studies reported strong evidence of adverse selection and provided empirical support for the separating equilibrium outcome; in addition, the former study found evidence of cross-subsidization among risk classes, whereas the latter found no such evidence.

However, more recent studies returned less clear results: for instance, focussing on automobile insurance, [Chiappori and Salanié \(2000\)](#) reported that drivers with comprehensive insurance have no statistically different accident frequency compared to drivers with minimum coverage, controlling for all observable characteristics. [Richaudeau \(1999\)](#) and [Saito \(2006\)](#) obtained similar conclusions. [Dionne et al. \(2001\)](#) showed that the results of [Puelz and Snow \(1994\)](#) were due to an improper econometric specification. They concluded that there is no residual adverse selection on risk type, once the information provided by risk classification has been taken into account.⁴¹ This led to raise

³⁸Insurance contracts are defined in terms of price *and* quantity, instead of price for any quantity. Insureds reveal their class by their choice in the menu of contracts. There is no “pooling” equilibrium, but a “separating” equilibrium.

³⁹[Stiglitz \(1977\)](#) studied the monopolistic insurance case. Under asymmetric information, the monopolist insurer maximizes profit by supplying a menu of discriminating contracts. At the equilibrium situation, the high risks get some consumer surplus, but the low risks are restricted to partial insurance and do not get any surplus.

⁴⁰See [Crocker and Snow \(1985\)](#) for a review of these models, and [Dionne and Doherty \(1992\)](#) for an early survey of adverse selection theory.

⁴¹On the other hand, [Cohen \(2005\)](#) finds some evidence of adverse selection for drivers with more than 3 years of driving experience.

fundamental questions about the proper tests for adverse selection (see [Cohen and Siegelman 2010](#), for a complete review of empirical tests). More precisely, it seems that adverse selection plays a significant role in some insurance markets (annuities,⁴² crop insurance⁴³), but not in others (automobile, life insurance⁴⁴), and that the evidence is mixed for still other markets (health⁴⁵). This is due partly to the inability of individuals to use their information, or to their lack of informational advantage. This is also due to the difficulty to dissociate adverse selection from moral hazard in actual observations. Evidence of adverse selection requires that individuals with comprehensive insurance coverage report higher average claims than individuals with partial coverage, or uninsured individuals. But higher average claims for fully insured individuals may also be due to different *ex post* behavior, i.e., moral hazard. For this reason, a positive correlation between observed risk and insurance coverage does not necessarily signal the presence of adverse selection—although a negative correlation signals that adverse selection, as well as moral hazard, do not play a role. Moreover, as soon as empirical tests are considered, a simplifying assumption of the original [Rothschild and Stiglitz \(1976\)](#) model is enhanced: the model assumes identical individuals, except for their accident probability. In particular, they all have the same degree of risk aversion. Of course, in reality, attitudes toward risk differ. As the degree of risk aversion is one factor influencing the demand for insurance coverage, it becomes difficult to decide whether individuals who get more coverage from their insurers can be considered as “high risks” or not. It may also happen that they belong to the “good risk” group and demand more insurance simply because they are more risk averse. The problem gets worse if, as [Einav and Finkelstein \(2011, p. 124\)](#) remark, “in many instances individuals who value insurance more may also take action to lower their expected cost: drive more carefully, invest in preventive health care, and so on.” Such a remark opens the door to the possibility of “advantageous selection”: the insureds with high degree of coverage are those with the lowest accident probability. They demand more insurance, even at a high price, not because they are “high risks,” but because they are on average more risk averse than the high risks, and the heterogeneity in risk aversion coefficients exceeds the heterogeneity in endowed riskiness.⁴⁶ Advantageous selection is not only a textbook curiosity. It has been documented recently in several markets, such as long-term care insurance ([Finkelstein and McGarry 2006](#)) and supplemental insurance ([Fang et al. 2008](#)). In these markets, the correlation between observed risk and insurance coverage is negative, instead of positive.

To overcome these pitfalls in testing for adverse selection, [Einav et al. \(2010\)](#) use identifying variations in the price of health insurance provided by one specific insurer to estimate the demand for insurance. The resulting variations in quantity, together with cost data, may then be used to estimate the marginal cost of additional policies. This information allows them to test for adverse selection (the marginal cost of contracts should be decreasing) and for the associated welfare loss. Their study provides evidence of adverse selection, but the welfare impact of this inefficiency seems to be small, in both absolute and relative terms.

When adverse selection is present, other insurance devices to deal with it are *experience rating* and *risk categorization*. They may be used as substitutes or complements to discriminating contracts. [Dionne \(1983\)](#) and [Dionne and Lasserre \(1985\)](#) on one hand, and [Cooper and Hayes \(1987\)](#) on the other hand, extended [Stiglitz \(1977\)](#) monopoly model to multi-period contracts, respectively with an

⁴²See [Finkelstein and Poterba \(2002, 2004\)](#).

⁴³See [Makki and Somwaru \(2001\)](#).

⁴⁴See [Cawley and Philipson \(1999\)](#) and [Hendel and Lizzeri \(2003\)](#).

⁴⁵See [Cutler and Reber \(1998\)](#) and [Cardon and Hendel \(2001\)](#).

⁴⁶Advantageous selection can lead to too much insurance being purchased if there are transaction costs and competition among insurers drives profits to zero. In equilibrium, the marginal cost of insurance exceeds the market price (see [Einav and Finkelstein 2011](#)). The possibility of advantageous selection was first introduced by [Hemenway \(1990\)](#), who termed it “propitious” selection, and analyzed later on by [De Meza and Webb \(2001\)](#).

infinite horizon and a finite horizon, and with full commitment by the insurer to the terms of the contract.⁴⁷ Hosios and Peters (1989) extended the finite horizon case to limited commitment. In this case, contract renegotiation becomes relevant, as information on the risk types increases over time. In addition, strategic use of accident underreporting becomes an issue.

Cooper and Hayes (1987) also extended the Rothschild and Stiglitz (1976) model to a two-period framework. They were able to demonstrate the beneficial effect of experience rating under full commitment by insurers, even when the insureds have the opportunity to switch to a different insurer in the second period (semi-commitment). At equilibrium, the competitive insurer earns a profit on good risks in the first period, compensated by a loss in the second period on those good risks who do not report an accident. This temporal profit pattern was labelled as “highballing” by D’Arcy and Doherty (1990). A different model, without any commitment, and assuming myopic behavior by insureds, was proposed by Kunreuther and Pauly (1985). The non-enforceability of contracts imply that sequences of one-period contracts are written. Private information by insurers about the accident experience of their customers allow negative expected profits in the first period and positive expected profits on the policies they renew in subsequent periods (“lowballing”).⁴⁸ Later on, Dionne and Doherty (1994) proposed a model assuming private information by the insurer about the loss experience of their customer and “semi-commitment with renegotiation”: the insured has the option to renew his contract on prespecified conditions (future premiums are conditional on prior loss experience). This latter assumption seems to come closer to actual practices in insurance markets. They derive an equilibrium with first-period semipooling⁴⁹ and second-period separation. Their model predicts “highballing,” since a positive rent must be paid in the second period to the high risk individuals who experienced no loss in the first period, and this is compensated by a positive expected profit on the pooling contract in the first period.⁵⁰ Their empirical test based on data from Californian automobile insurers provides some support to this prediction: they conclude that some (but not all) insurers use semi-commitment strategies to attract portfolio of predominantly low-risk drivers. In contrast, the prediction of “lowballing” had previously received empirical support in D’Arcy and Doherty (1990).

More recently, Crocker and Snow (2011) have brought the attention to the fact that multidimensional screening is routinely used by insurers to cope with adverse selection. With n mutually exclusive perils, insurers “can now exploit n signaling dimensions to screen insurance applicants” (p. 293). The “good risks” tend to accept higher deductibles for perils that they are less likely to be exposed to, for instance theft. This allows insurance markets to circumvent the nonexistence problem identified by Rothschild and Stiglitz. As the authors themselves remark, using multidimensional screening at a point in time presents an analogy with (and may be a substitute to) using repeated insurance contracts in a dynamic framework.⁵¹

Risk categorization, which uses statistical information on correlations between risk classes and observable variables (such as age, sex, and domicile), was first studied by Hoy (1982), Crocker and Snow (1986), and Rea (1992). Their work shows that risk categorization enhances efficiency when classification is costless, but its effect is ambiguous when statistical information is costly (see

⁴⁷In the monopoly case, insureds cannot switch to an other insurer over time.

⁴⁸In Kunreuther and Pauly (1985), the insurers have no information about the other contracts that their customers might write. For this reason, price–quantity contracts are unavailable. The equilibrium is a pooling equilibrium with partial insurance for the good risks, as in Pauly (1974).

⁴⁹In the first period, insureds may choose either a pooling contract with partial coverage and possible renegotiation in the second year, or the Rothschild–Stiglitz contract designed for high risks.

⁵⁰For good risks who do not file a claim in the first period the reward takes the form of additional coverage in the second period.

⁵¹See also Bonato and Zweifel (2002) on the use of multiple risks to improve the assessment of loss probability.

also [Bond and Crocker 1991](#)). The latter result was recently challenged by [Rothschild \(2011\)](#) who shows that a ban on risk categorization is always suboptimal—even when categorization is costly. He introduces a distinction between a regime where categorization is *employed* by insurers (as in [Crocker and Snow 1986](#)) and a regime where categorization is *permitted*, but may or may not be employed in equilibrium. He then shows that a ban on risk categorization is always (whatever the insurance market regime) Pareto-dominated by having the government introduce a partial social insurance and simultaneously lifting the ban on risk categorization for private supplemental coverage. Quoting from [Rothschild \(2011, p. 269\)](#).

“The intuition behind the effectiveness of social insurance for preventing the negative consequences of lifting categorical pricing bans is simple. Categorical pricing bans are potentially desirable insofar as they implicitly transfer resources from individuals in low-risk categories to individuals in high-risk categories. (...) Providing partial social insurance effectively socializes the provision of this cross-subsidy. Lifting a categorical pricing ban then allows the market to employ categorical information to improve efficiency without risking undoing the cross-subsidy.”

These results are of utmost political importance, given the ethical critics on the use of observable personal attributes, such as sex and race, in insurance rating. The problem of risk categorization is even more acute, when the personal attributes are not observable *a priori* but may be revealed to the insurer and/or the insured after some informational steps have been decided, as in the case of genetic diseases. [Rothschild and Stiglitz \(1997\)](#) point out that this results in a conflict between the social value of insurance and competition among insurers: if valuable information about the probability (or certainty) for the insured to suffer from a particular genetic disease can be made available, insurers will want to get this information. But this will result in less insurance coverage: the insureds who are virtually certain to get the disease will not be able to get insurance, whereas those who are revealed to be immune to the disease will not need insurance any longer.⁵² For ethical reason, society prohibits the use of genetic information by insurers to categorize risks. But this means that adverse selection problems are enhanced, at least in medical insurance: as [Doherty and Posey \(1998\)](#) have shown, private testing is encouraged when test results are confidential and there is a treatment option available,⁵³ but the insurers are unable to charge different prices to different customers with private information about their genetic patrimony. Combining partial social insurance with supplemental private insurance, as suggested by [Rothschild \(2011\)](#), could be a way out of this conflict between the efficiency of insurance pricing and the mutuality principle.⁵⁴

Like moral hazard, adverse selection is an important problem beyond the domain of insurance. It is mainly encountered in labor markets, where the employers are uninformed about the productivity of the prospective employees, and in financial markets, where banks and finance companies lack information on the reimbursement prospects of different borrowers. The insurance economics literature on adverse selection reviewed above has thus led to applications to other economic domains: see, e.g., [Miyazaki \(1977\)](#) for an application to the labor market and [Stiglitz and Weiss \(1981\)](#) for an application to credit markets. Note, however, that in these cases, quality signaling by the informed agents represents a feasible strategy to circumvent the asymmetric information problem ([Spence 1973](#)). For example, education and dividend payments find an additional justification in these

⁵²This is an example of the well-known result that additional public information may have adverse welfare consequences (see, e.g., [Arrow 1978](#)).

⁵³In contrast, [Doherty and Thistle \(1996\)](#) find that additional private information has no value if there is no treatment option conditional on this information.

⁵⁴Note, however, that there exists alternative views on the welfare effect of asymmetric information. Using a two-period model where insureds have the option to switch insurers in the second period, [de Garidel-Thoron \(2005\)](#) shows that information sharing among insurers is welfare-decreasing. The reason is that this reduces the set of viable long-term contracts available to individuals in the first period competition game.

circumstances. In contrast, signaling does not generally occur in insurance markets: insureds do not engage in specific activities to signal that they are good risks.

1.4.3 *Moral Hazard and Adverse Selection*

Progress in analyzing moral hazard and adverse selection together has remained very limited. This was noted already by [Arnott \(1992\)](#) in the early 1990s and the situation has not changed significantly since then. This has for long limited the significance of empirical investigation in the economics of insurance, since both problems combine in actual insurance markets. A positive correlation between insurance indemnities and insurance coverage may be interpreted as signaling the presence of adverse selection, or moral hazard, or both. First attempts to address the two problems jointly were made by [Dionne and Lasserre \(1987\)](#) in the monopoly case and by [Eisen \(1990\)](#) in the competitive case, but did not find an echo in the literature. In the same period, [Bond and Crocker \(1991\)](#) pointed out that risk categorization may be endogenous if it is based on information on consumption goods that are statistically correlated with an individual's risk (*correlative products*). Thus, adverse selection and moral hazard becomes related. If individual consumption is not observable, taxation of correlative products by the government may be used to limit moral hazard and this would reduce the need for self-selection mechanisms as an instrument for dealing with adverse selection. However, this did not provide a general model.

Advances on this research front seem today more promising at the empirical level, using the materials provided by longitudinal data on insurance purchasing and loss experience. Adverse selection is due to differences in the dynamics of learning about the insured's true risk type for the insured himself and for the insurer. Once adverse selection has been identified (or not), using longitudinal data, the residual effect of moral hazard may be tested. This is the approach followed by [Dionne et al. \(2013\)](#) using data on automobile insurance and car accidents in France. They calibrate a simulation model for the optimal behavior of car owners, using the specific features of auto insurance in France and show that adverse selection and moral hazard should be expected. They then test for the presence of asymmetric learning on one hand and of moral hazard on the other hand. The results differ according to the experience of drivers. For drivers with less than 15 years of experience, they find strong evidence of moral hazard but little evidence of asymmetric learning. The latter occurs only for drivers with less than 5 years of experience. In contrast, for drivers with more than 15 years of experience, there is no evidence of moral hazard or adverse selection. These results are promising. It is likely that they will stimulate further research along the same line in other insurance contexts.

1.5 Developments: Insurance Market Structure

Numerous studies on the insurance sector have followed the lead provided by [Joskow \(1973\)](#). The availability of data and better incentives to perform economic research explain that most of these studies pertain to the US market.

- Insurance distribution systems were analyzed by several researchers, more particularly [Cummins and VanDerhei \(1979\)](#) and [Berger et al. \(1997\)](#).⁵⁵ In agreement with [Joskow \(1973\)](#), direct writing is generally found to be more cost efficient than independent agents. However, the differences in

⁵⁵See also [Zweifel and Ghermi \(1990\)](#) for a study using Swiss data.

profit efficiency are not significant, which may be interpreted as an indication that independent agents provide valuable services. This interpretation has received support in several contributions, e.g., [Barrese et al. \(1995\)](#) for the USA and [Eckart and R athke-D oppner \(2010\)](#) for Germany. A comprehensive recent study on this topic is [Cummins and Doherty \(2006\)](#). The authors show that insurance intermediaries (brokers and independent agents) have a valuable role in improving the efficiency of the market. Over the past 20 years, insurance markets in several European and Asian countries have witnessed the marketing of insurance contracts through the banking channel—“bancassurance.” The efficiency of this distribution system has been investigated in some recent studies, with mixed results so far: for instance, [Chang et al. \(2011\)](#) do not report efficiency gains for this system in Taiwan.

- Returns to scale in the insurance industry were submitted to empirical investigation by numerous authors in the 1980s, e.g., [Doherty \(1981\)](#) and [Fecher et al. \(1991\)](#). However, this question does not seem to have attracted much attention recently.
- The various forms of organizational structure in the insurance industry—stock companies, mutuals, Lloyds’ underwriters—were analyzed in an agency theory framework by Mayers and Smith in a series of articles: (1981, 1986, 1988) among others. They verified that conflicts of interest between owners, managers, and policyholders affect the choice of organizational form for different insurance branches (see also [Hansmann 1985](#); [Cummins et al. 1999](#)). Mutuals tend to prevail when the relationship between owners and policyholders triggers substantial agency costs. However, mutuals are constrained by their lack of access to external capital, with the result that mutuals with strong growth choose to convert to the stock structure when the constraint on their expansion becomes too costly: see also [Mayers and Smith \(2002\)](#) and [Harrington and Niehaus \(2002\)](#) for more recent references.
- [Shim \(2011\)](#) investigated the performance of property-liability insurers following mergers & acquisitions and diversification strategies. The results show that the performance of acquiring firms decreases during the gestation period after the M&As, and that more focused insurers outperform the product-diversified insurers.
- Following the lead provided by [Joskow \(1973\)](#), the effects of rate and solvency regulation were scrutinized in numerous researches, such as [Borch \(1974\)](#), [Ippolito \(1979\)](#), [Munch and Smallwood \(1980\)](#), [Danzon \(1983\)](#), [Finsinger and Pauly \(1984\)](#), [Pauly et al. \(1986\)](#), [Harrington \(1984, 1987\)](#), [Cummins and Harrington \(1987\)](#), [D’Arcy \(1988\)](#), [Harrington and Danzon \(1994\)](#), and [Cummins et al. \(2001\)](#). These studies were stimulated by the traditional government regulation of insurance activities, a general trend toward deregulation in the 1980s and 1990s,⁵⁶ and consumers’ pressures for re-regulation (mainly in California and Florida) after major catastrophic events such as hurricane Andrew in 1992 and the Northridge earthquake in 1994. [Dionne and Harrington \(1992\)](#) concluded their survey of research on insurance regulation by noting: first, that “not much is presently known about the magnitude of the effects of regulatory monitoring and guaranty funds on default risk” (p. 32); and second, that rate regulation seems to have produced a variety of effects. It favored high risk groups, increased market size, and encouraged insurers’ exits, but nonetheless reduced the ratio of premiums to losses and operating expenses. More recently, [Klein et al. \(2002\)](#) found that price regulation tends to increase leverage, while [Doherty and Phillips \(2002\)](#) remarked that, during the 1990s, with a trend toward deregulation, the role of rating agencies was enhanced: stringency in the rating procedures provided an incentive to decrease leverage and seemed to substitute for tight regulations. [Rees et al. \(1999\)](#), considering the focus of the European Commission on solvency regulation instead of rate regulation, suggest that “the

⁵⁶[Berry-St ozle and Born \(2012\)](#) provide an empirical account of the deregulation introduced in Germany in 1994. They find evidence of a significant price decrease in highly competitive lines, offset by higher prices in the other lines.

role of regulation in insurance markets should be confined to providing customers with information about the default risk of insurers” (p. 55).

Debates on insurance regulation were reinforced by the financial crisis in 2007–2008 and the doubts about insurers’ solvency following the collapse of Lehman Brothers and the rescue of AIG by the federal government. [Eling and Schmeiser \(2010\)](#) derived ten consequences of the crisis for insurance supervision, while [Lehmann and Hofmann \(2010\)](#) stressed the differences between insurance and banking. [Harrington \(2009\)](#) reviewed the AIG case and questioned the exposure of the insurance sector to systemic risk. He noted that this sector remained largely on the periphery of the crisis, in contrast to AIG.⁵⁷ He also noted that the crisis revealed the imperfect nature of federal regulation of banks and related institutions. These considerations led him to reject the plans for creating a federal systemic risk regulator for insurers and other nonbank institutions designated as systemically significant. He also rejected the claim that the AIG crisis strengthens arguments for federal regulation of insurance, either optional or mandatory. In his view, “an overriding goal of any regulatory changes in response to the AIG anomaly should be to avoid further extension of explicit or implicit ‘too big too fail’ policies beyond banking” (p. 815). Notwithstanding these strong arguments against federal involvement in US insurance regulation, the debate goes on. In a recent comprehensive review of insurance regulation procedures, [Klein \(2012\)](#)—see also [Klein and Wang \(2009\)](#)—spells out the principles for insurance regulation and compares the traditional system of detailed state by state regulation still in force in the USA with the principles-based approach currently introduced in the EU member countries under Solvency II.⁵⁸ He concludes that, compared to the latter European developments, “the systems for solvency and market conduct regulation in the United States warrant significant improvement,” and that “the (US) states should move forward with full deregulation of insurance prices” (p. 175).

- A related avenue of research, not considered by [Joskow \(1973\)](#), deals with cycles in the insurance industry. It has been noticed in the 1970s that insurance company profits seem to be submitted to more or less regular cycles, and that this phenomenon is reflected in cyclical capacity and premium rates. The Geneva Association sponsored one of the first investigations in this area ([Mormino 1979](#)). The most often quoted articles were published a few years later by [Venezian \(1985\)](#), [Cummins and Outreville \(1987\)](#), and [Doherty and Kang \(1988\)](#). As pointed out by [Weiss \(2007, p. 31\)](#), “in tracking underwriting cycles, most of the attention tends to be directed at insurance pricing, or, conversely, insurance underwriting profits, rather than the amount of coverage available.” The US insurance liability “crisis” of the mid-1980s and the over-capitalization of property-liability insurers during the 1990s stimulated research on insurance cycles (see [Harrington 1988](#); [Cummins and Doherty 2002](#)). [Haley \(1993\)](#) and [Grace and Hotchkiss \(1995\)](#) document an impact of external factors—mainly interest rates—on underwriting profits, but the latter authors find that external unanticipated real economic shocks have little effect on underwriting performance. Other research suggests that delays in the adjustment of premiums to expected claims costs, due to regulation or structural causes, external shocks to supply capacity and variations in insurer insolvency risk are responsible for cyclical effects: see [Winter \(1994\)](#), [Gron \(1994\)](#), [Cagle and Harrington \(1995\)](#), [Doherty and Garven \(1995\)](#), and [Cummins and Danzon \(1997\)](#). More recently, [Choi et al. \(2002\)](#) compare six alternative insurance pricing models as theories of the underwriting cycle. They show that two models are consistent with short run and long run data on underwriting profits: the capacity constraint model and the actuarial pricing model. [Cummins and Nini \(2002\)](#) provide empirical evidence that the over-capitalization of property-liability insurers during the 1990s was mainly due

⁵⁷AIG failure is mainly attributed to two causes. First, a subsidiary of AIG—AIG Financial Products—became heavily involved in the writing of credit default swaps (CDS). Second, an other subsidiary, operating in the life branch, had engaged in securities lending programs that were severely hurt by the outburst of the subprime crisis. In either case, insurance operations were not concerned.

⁵⁸The Solvency II regulation is presented and analyzed in [Eling et al. \(2007\)](#).

to capital gains during the stock market boom and to retained earnings. They interpret their results as providing evidence that insurers tend to hoard capital in favorable periods as a hedge against adverse shocks in the future. This behavior affects negatively underwriting profits and is a source of cycles in profitability.

Following the lead provided by [Cummins and Outreville \(1987\)](#), research on insurance cycles has also been conducted at the international level, and provided evidence that these cycles are not specific to the US market: see [Lamm-Tennant and Weiss \(1997\)](#), [Chen et al. \(1999\)](#), [Leng and Meier \(2006\)](#), and [Meier and Outreville \(2006\)](#).

- The economic analysis of practical problems that the insurance industry has been facing over the past years also attracted the attention of researchers. One of these problems, the insurance of catastrophes, has become a major concern for the industry and the subject of intensive academic research. Beyond the insurance industry, catastrophes have become an issue for the economy at large. Events like Hurricane Katrina on the Gulf Coast in 2005 or the Fukushima catastrophe in Japan in 2011 with its sequence of “earthquake-tsunami-major nuclear accident” had repercussions for the international economy and not only on the local scene. Given the resurgence of major catastrophic events every year somewhere in a globalized world, it has become inappropriate to continue to define catastrophes as “Low-probability/High-consequences events” (see [Kunreuther and Michel-Kerjan 2009](#), p. 351). The major journals in the economics of insurance and some general economics journals devoted special issues to this topic over the past two decades. Books and contributed volumes have also addressed this issue.⁵⁹ Researchers have tended to take a broad view of the subject, so that the term “catastrophe” has been used to encompass different kinds of situations: not only natural catastrophes (like earthquakes, tsunamis, floods, and hurricanes) and man-made catastrophes (such as Tchernobyl or Bhopal); but also socioeconomic developments that result in catastrophic accumulation of claims to insurers (see, e.g., [Zeckhauser 1995](#)). The prominent example is the liability crisis in the USA, due to the adoption of strict producers’ liability and the evolution in the courts’ assessments of compensations to victims, as in the cases of asbestos, breast implants, pharmaceuticals, etc. (see [Viscusi 1995](#)). To cope with the financial consequences of catastrophes, traditional insurance and reinsurance are often considered as insufficient (see [Kunreuther 1996](#); [Froot 1999](#); [Cummins et al. 2002](#)). Some researchers invoke difficulties individuals would have in dealing with low-probability/high-loss events ([Kunreuther and Pauly 2004](#)). Others invoke capital market imperfections and market failure in reinsurance supply ([Froot 2001](#); [Zanjani 2002](#); [Froot and O’Connell 2008](#)). Still others point to US insurance price regulation in catastrophe-prone lines of business as a major source of inefficiency in insurance and reinsurance markets ([Cummins 2007](#)). Several researchers have advocated more government involvement (see, e.g., [Lewis and Murdock 1996](#); [Kunreuther and Pauly 2006](#)),⁶⁰ but others argue that the government has no comparative advantage to the market in providing coverage for catastrophic losses ([Priest 1996](#)) and call instead for less government intervention by deregulating insurance prices ([Cummins 2007](#)). Alternative solutions may be found in financial innovation, either in the design of insurance contracts, by introducing a decomposition of insurance risk into a systemic and a diversifiable component (see [Doherty and Dionne 1993](#); [Schlesinger 1999](#); [Doherty and Schlesinger 2002](#)), or in the design of new financial securities (see Sect. 1.6 below), or both.
- At the other end of the insurability spectrum, microinsurance emerged as a new topic for research in insurance economics. The fact that a large fraction of the world population has no access to the benefits of insurance coverage stimulated practical initiatives to remedy this situation and interest among researchers and international organizations—the ILO (International Labour Office) for

⁵⁹See, in particular, [Froot \(1999\)](#), [OECD \(2005\)](#), [Wharton Risk Management Center \(2007\)](#), [Kunreuther and Michel-Kerjan \(2009\)](#), as well as [Courbage and Stahel \(2012\)](#).

⁶⁰[Monti \(2011\)](#) provides a recent review of public-private arrangements already existing in the OECD area.

example. A recent study (Biener and Eling 2012) reviews the current situation of microinsurance. The authors point out that the microinsurance industry has experienced strong growth in the recent years (10 % annually on average), but that much remains to be done and that further developments are constrained by well-known insurability problems: risk assessment, asymmetrical information, and lack of financial resources in the uninsured population. They also provide tentative solutions to overcome these problems.

- Corporate governance issues in the insurance industry have attracted more attention from researchers in the wake of the 2008 financial crisis and the collapse of AIG. The impact of corporate governance and institutional ownership on efficiency (Huang et al. 2011), risk-taking (Cheng et al. 2011), mergers and acquisitions (Boubakri et al. 2008), and CEO turnover (He and Sommer 2011), among other issues, were recently investigated.⁶¹
- Let us mention, finally, a topic which was not covered by Joskow (1973) and which does not seem to have concerned many researchers: the issues raised by international insurance trade. Research on this topic remained relatively limited and concentrated in Europe: see Dickinson (1977) for an early reference, Pita Barros (1993) for additional analysis, and Arkell (2011) for a recent report stressing the essential role of insurance services for trade growth and development.

1.6 New Approaches: Finance and Insurance

Apart from the tremendous developments summarized in the three preceding sections, risk and insurance economics has witnessed a major reorientation in the 1970s and 1980s: insurance has been analyzed more and more in the general framework of financial theory. This change of perspective was implicit in the definition of Arrow (1970): “insurance is an exchange of money for money.” It was also foreshadowed by the recognition that insurers were financial intermediaries (Gurley and Shaw 1960). It became soon impossible to maintain a dichotomy in the analysis of the insurance firm: insurance operations on one hand, financial investment on the other hand. As a result, insurance research became deeply influenced by advances in the theory of finance. The more so that finance underwent a major revolution in the 1970s, with the development of option theory, and that this revolution stressed the similarity between insurance products and new concepts due to financial innovation (e.g., *portfolio insurance*).⁶²

1.6.1 Portfolio Theory and the CAPM

The influence of portfolio theory on the analysis of insurance demand was mentioned in Sect. 1.3. But this theory had also a profound influence on the theory of insurance supply. It was soon recognized that financial intermediaries could be analyzed as a joint portfolio of assets and liabilities (Michaelson and Goshay 1967), and this global approach was applied to insurance company management. Under this view, insurers have to manage a portfolio of correlated insurance liabilities and investment assets, taking into account balance sheet and solvency constraints, and there is no justification for separating the operations in two distinct domains: what matters is the overall return on equity (see Kahane and Nye 1975; Kahane 1977).⁶³

⁶¹See Boubakri (2011) and the September 2011 Special Issue of *The Journal of Risk and Insurance* for a recent survey of corporate governance in the insurance industry.

⁶²The similarity between option contracts and insurance policies was stressed by Briys and Loubergé (1983).

⁶³See also Loubergé (1983) for an application to international reinsurance operations, taking foreign exchange risk into account, and MacMinn and Witt (1987) for a related model.

This way of looking at insurance operations led to a theory of insurance rating, reflecting the move observed a decade earlier in finance from portfolio theory to the capital asset pricing model. Applying this model to insurance, it turns out that equilibrium insurance prices will reflect the undiversifiable risk of insurance operations. If insurance risks are statistically uncorrelated with financial market risk, equilibrium insurance prices are given by the present value of expected claims costs (in the absence of transaction costs). If they are statistically correlated, a positive *or negative* loading is observed in equilibrium. The model was developed by [Biger and Kahane \(1978\)](#), [Hill \(1979\)](#), and [Fairley \(1979\)](#). It was empirically evaluated by [Cummins and Harrington \(1985\)](#). It was also applied to determine the “fair” regulation of insurance rating in Massachusetts ([Hill and Modigliani 1986](#)).⁶⁴

1.6.2 Option Pricing Theory

A main limitation of the capital asset pricing model is that it does not take into account nonlinearities arising from features such as limited liability and asymmetric tax schedules. These aspects are best analyzed using option pricing theory, since it is well known that optional clauses imply nonlinearities in portfolio returns. [Doherty and Garven \(1986\)](#) and [Cummins \(1988\)](#) analyzed the influence of limited liability and default risk on insurance prices, while [Garven and Loubergé \(1996\)](#) studied the effects of asymmetric taxes on equilibrium insurance prices and reinsurance trade among risk-neutral insurers. A major implication of these studies is that loaded premiums are not only the reflect of transaction costs and asymmetric information, or insurers’ risk aversion. They reflect undiversifiable risk arising from institutional features, and they lead to prices implying risk-sharing in equilibrium, even when market participants are risk neutral.

The importance of option theory for the economics of insurance has also been recently observed in the domain of life insurance. This resulted from the fact that competition between insurers and bankers, to attract saving, has led to the inclusion of numerous optional features (hidden options) in life insurance contracts. Advances in option theory have thus been often used to value life insurance contracts (see, e.g., [Brennan and Schwartz 1976](#); [Ekern and Persson 1996](#); [Nielsen and Sandmann 1996](#)), or to assess the effects of life insurance regulation ([Briys and de Varenne 1994](#)).

1.6.3 Insurance and Corporate Finance

The portfolio approach to insurance demand led to a paradox when applied to corporations. The latter are owned by stockholders who are able to diversify risks in a stock portfolio. If insurance risks, such as accident and fire, are diversifiable in the economy, the approach leads to the conclusion that corporations should not bother to insure them. They would increase shareholders’ wealth by remaining uninsured instead of paying loaded premiums ([Mayers and Smith 1982](#)).⁶⁵ The paradox was solved using the modern theory of corporate finance, where the firm is considered as a nexus of contracts between various stakeholders: managers, employees, suppliers, bondholders, banks, stockholders,

⁶⁴[Myers and Cohn \(1986\)](#) extended the model to multi-period cash flows, while [Kraus and Ross \(1982\)](#) considered the application to insurance of the more general arbitrage pricing theory.

⁶⁵The same kind of argument was used by [Doherty and Tinic \(1981\)](#) to question the motivation of reinsurance demand by insurers.

consumers, etc. Reduction of contracting and bankruptcy costs provides an incentive to manage risk and to purchase insurance, even if the premium is loaded and shareholders are indifferent to insurance risk: see [Main \(1982\)](#), [Mayers and Smith \(1982, 1990\)](#), and [Stulz \(1984\)](#). In addition, increasing marginal cost of external financing and convex tax schedules arising from progressive tax rates and incomplete loss offset offer other explanations for concern with insurance risk management in widely held corporations: see [Froot et al. \(1993\)](#), [Smith and Stulz \(1985\)](#), and [Smith et al. \(1990\)](#).

These considerations have changed the relationship of corporate managers to risk management in general and insurance in particular. These tools are no longer used simply because risks arise. They must find a justification in the overall firm objective of value maximization. Following these premises, several studies addressed the relationship between corporate risk management and the capital structure decision or the dividend policy. For instance, [Auñón-Nerin and Ehling \(2008\)](#) find that higher leverage increases the demand for corporate insurance and the use of derivatives, while hedging has in general a significant positive effect on leverage (see also [Zou and Adams 2008](#)). This is in accordance with corporate concern for bankruptcy and agency costs. They also find that corporate hedging is negatively related to the dividend payout ratio. This is related to the use of cash flows as a possible substitute for insurance (on this aspect see also [Rochet and Villeneuve 2011](#)).⁶⁶ In addition, as [Doherty \(1997\)](#) noted, the development of financial engineering in the 1980s challenged traditional insurance strategies in corporate risk management. Traditional insurance strategies often involve large transaction costs, and they fail if the risk is not diversifiable, as in the case of the US liability crisis. For this reason, innovative financial procedures, such as finite risk plans and financial reinsurance, represent alternative instruments for dealing with corporate risks. Of course, they widen the competitive interface between banks and insurers.

The theory of corporate finance was also used by [Garven \(1987\)](#) to study the capital structure decision of the insurance firm. His article shows that redundant tax shields, default risk, bankruptcy costs, and the above-mentioned agency costs influence the insurer's capital structure decision. More recently, [Plantin \(2006\)](#) has emphasized that reinsurance purchases and capital structure decisions are linked. Professional reinsurers are used by insurers as a signal of credible monitoring sent to the financial market. Reinsurance is not only used as a device to mutualize risks, as in [Borch \(1962\)](#), or to address agency problems, as in [Mayers and Smith \(1990\)](#). It is also used as a complement in the insurer's capital structure strategy.

At the empirical level, [Garven and Lamm-Tenant \(2003\)](#), as well as [Powell and Sommer \(2007\)](#), provided evidence that reinsurance purchases are positively related to insurer leverage. More recently, [Shiu \(2011\)](#) has used data from the UK non-life insurance industry to test the two-way relationship between reinsurance and insurers' capital structure. His results show that leverage exerts a positive influence on reinsurance purchases and that higher leverage is associated with more reinsurance purchases. However, he also finds that the use of financial derivatives by insurers has a moderating impact on this two-way relationship.

Taking a more general view, [Hoyt and Liebenberg \(2011\)](#) have investigated whether an integrated risk management approach—as defined by [Meulbroek \(2002\)](#)—has a positive influence on insurers' value. They use Tobin's Q as a measure of firm value and a maximum-likelihood procedure to estimate joint equations for the determinants of an integrated risk management policy and its impact on Q for a sample of 117 publicly traded US insurers.⁶⁷ They find that insurers engaged in integrated risk

⁶⁶[Rochet and Villeneuve \(2011\)](#) show that cash-poor firms should hedge using financial derivatives but not insure, whereas the opposite is true for cash-rich firms.

⁶⁷Tobin's Q is defined in this case as the market value of equity plus the book value of liabilities divided by the book value of assets.

management “are valued roughly 20 percent higher than other insurers after controlling for other value determinants and potential endogeneity bias” (p. 810). They also find that those insurers are larger, with less leverage, and relying less on reinsurance than other insurers.

This latter result, added to those obtained above by [Shiu \(2011\)](#), can be related to earlier considerations by [Doherty \(1997\)](#) that insurers’ management has been deeply influenced by developments in the financial markets. The concept of asset-liability management, which has its roots in the portfolio approach mentioned above, means that insurers are less relying on reinsurance as the natural instrument to hedge their risks and send signals to their partners. Indeed, developments in the financial markets over the past 20 years have seen the emergence of derivative products intended to complement traditional reinsurance treaties in an integrated risk management view.

1.6.4 Insurance and Financial Markets

In 1973, the insurance/banking interface was a sensitive subject. It was generally not well considered, in the insurance industry, to state that insurance was a financial claim and that insurers and bankers performed related functions in the economy. Some 40 years later, and after numerous experiences of mergers and agreements between banks and insurers, the question is not whether the two activities are closely related,⁶⁸ but where do they differ.⁶⁹

It is easy for an economist of risk and insurance to provide a general answer to this question. The answer is founded on Borch’s mutuality principle (see Sect. 1.2) and on subsequent work on risk-sharing. Insurance and banking, like all financial activities, are concerned with the transfer of money across the two-dimensional space of time and states of nature. Insurance deals mainly—but not exclusively (see life insurance)—with transfers across states that do not necessarily involve a change in social wealth. In contrast, banking and financial markets perform transfers across states which often involve a change in social wealth. In other words, insurance is mainly concerned with diversifiable risk; banks and finance companies (such as mutual funds and hedge funds) are mainly concerned with undiversifiable (social) risk.

This kind of distinction has been used before to draw a line between private and public (social) insurance. According to this view, social insurance is called for when the limits of private insurability are reached in the sense that the insured events are not independent, so that diversifiability does not obtain: epidemic diseases, losses from natural catastrophes, unemployment, etc.⁷⁰ But, social insurance is limited by national frontiers, and in the absence of redistributive concerns, or of market incompleteness due to moral hazard, it has become more and more obvious that financial markets are able to perform some social insurance functions, in addition to their traditional function of sharing production risk.

A case in point is the evolution in the natural catastrophes branch of insurance. As a matter of fact, since losses from natural catastrophes are correlated, they should be excluded from the private insurance area. Nonetheless, private insurance companies used to cover this risk because geographical dispersion seemed possible using the international reinsurance market. However, over the last two decades, the private insurability of this risk has been challenged by various developments: an increased

⁶⁸The convergence between reinsurance and investment banking was emphasized by [Cummins \(2005\)](#).

⁶⁹The debate has regained importance after the 2008 financial market crisis and the collapse of AIG. Large insurance companies have been ranked with banks in the group of “Systemic Important Financial Institutions” (SIFI) and are threatened to be subject to the same regulations as banks. This is an occasion for the insurance industry to underline the differences between banking and insurance (see [Lehmann and Hofmann 2010](#); [Geneva Association 2010](#)).

⁷⁰Public insurance may also be justified on equity considerations, e.g., in medical insurance.

frequency of hurricanes, huge losses, and a concentration of insured values in selected exposed areas of the globe: the USA (mainly California and Florida), Japan, and Western Europe (mainly the South). As a result, potential losses have exceeded the financial capacity of the catastrophe reinsurance market (see [Kielholz and Durrer 1997](#); [Cummins et al. 2002](#)).

One possible solution to the insurability problem is the traditional recourse to government insurance using increased taxation, i.e., social insurance. This is the solution which was adopted in France ([Magnan 1995](#)) and in some other countries⁷¹: a reserve fund financed by specific taxes on property-liability insurance contracts indemnifies victims from natural catastrophes. The viability of this solution is however endangered in the long run by increasing risk due to wrong incentives (development of activities and constructions in areas exposed to cat risk), and by pressure on the government to enlarge the scope of coverage while maintaining low rates.

A second solution is the transfer of the risk using special purpose derivative markets. This was the solution proposed by the Chicago Board of Trade (CBOT) with the catastrophe options and futures contracts launched in December 1992: see [D'Arcy and France \(1992\)](#), [Cummins and Geman \(1995\)](#), and [Aase \(1999\)](#) for an analysis of these contracts.⁷² However, the CBOT contracts were withdrawn after some years due to lack of success.⁷³ Following Hurricane Katrina in 2005, new contracts of the same type were nevertheless launched in 2007 by the Chicago Mercantile Exchange (CME) and the Insurance Futures Exchange (IFEX). A main difference with the earlier CBOT contracts is their focus on US hurricanes and US tropical wind. However, given the experience with the CBOT contracts, experts have doubts about the ultimate success of this new venture (see [Cummins 2012](#)).

A third solution is the securitization of the risk using more familiar securities, such as coupon bonds, issued by a special purpose company (on behalf of an insurer, a reinsurer or a non financial company), or by a public agency (on behalf of the State): see [Litzenberger et al. \(1996\)](#) and [Loubergé et al. \(1999\)](#) for early presentations and analysis of insurance-linked bonds (widely known as "Cat Bonds"). In a cat bond arrangement, a special-purpose reinsurer (SPR) issues a coupon bond on behalf of the sponsoring entity and improves the return on the bonds with a premium paid by the sponsor. The principal is then invested into first-class securities, such as government bonds. However, on the investor side, the principal and the coupons are at risk, in the sense that they may be lost, partially or even totally, if a catastrophe occurs and the cat bond is triggered. In this case, the proceeds of the investment is used by the SPR to pay indemnities to the sponsor. The catastrophic risk has been transferred to the financial market using familiar securities as transfer vehicle. In contrast to CBOT derivatives, these insurance-linked securities were well received by the market. Their success has been based on the huge pool of financial capacity provided by worldwide capital markets and the prospects for risk diversification made available to investors: catastrophic insurance losses are, in principle, uncorrelated with financial market returns. In addition, cat bonds that have been based on an index of losses due to a specific catastrophic event, or triggered by such a specific event

⁷¹In the USA, where a National Flood Insurance program already exists for long, and where California has established a government earthquake insurance program (the California Earthquake Authority), the possible creation of state or regional catastrophe funds is being hotly debated, given the unconvincing example of the two above-mentioned programs (see [Klein and Wang 2009](#)).

⁷²The early options and futures on four narrow-based indices of natural catastrophes were replaced in October 1995 by call spreads on nine broad-based indices. [Lewis and Murdock \(1996\)](#) proposed to have the same kind of contract supplied by Federal authorities, in order to complete the reinsurance market.

⁷³[Harrington and Niehaus \(1999\)](#) had reached the conclusion that basis risk would not be a significant problem for PCS derivative contracts, but later on [Cummins et al. \(2004\)](#) reached a different conclusion: they attribute the lack of success to basis risk. One may add that, possibly, the failure was due to the absence of arbitrage trading. Arbitrage trading between a derivative market and the market for the underlying instrument is essential to the provision of liquidity in derivatives trading for hedging and speculation purposes. However, in the case of PCS option contracts such trading was impossible. The only market for the trading of insurance portfolios is the reinsurance market, not liquid enough to be used as a vehicle in arbitrage trading.

(parametric trigger), have allowed to avoid the moral hazard arising from products based on the record of losses experienced by the sponsor.⁷⁴ On the supply side, cat bonds provide sponsors with coverage that extends over several years, at fixed terms (unlike reinsurance contracts), and that is free from default risk since the proceeds from the bond issue are fully collateralized using highly rated securities.⁷⁵ Cat bonds have attracted a wide interest among insurance practitioners (see Swiss Re 2009)⁷⁶ and academic researchers (see Barrieu and Karoui 2002; Lee and Yu 2002; Nell and Richter 2004; Cummins 2008; Michel-Kerjan and Morlaye 2008; Barrieu and Loubergé 2009; Finken and Laux 2009).⁷⁷ The development of the market for these securities indicates that they filled a gap in the reinsurance market, although the success has not been as huge as initially anticipated: cat bond issues started with a few issues prior to 2000, then the market peaked with 27 issues in 2007, and regained momentum in 2010 (22 issues) after a drop to 13 issues in 2008, due to the financial crisis. The market is nevertheless developing over time, with positive and negative shocks provoked by natural catastrophes and financial crises: see Cummins (2012) for a comprehensive report on the state of the market at year-end 2011.

A fourth solution available to an insurer to hedge catastrophic risk outside of the reinsurance market is provided by *Catastrophic Equity Puts* (Cat-E-Puts). Under this arrangement, the insurer or reinsurer purchases from the option writer the right to issue preferred stocks at a specific price following the occurrence of a catastrophe. This allows the insurer to take advantage of fresh funding at a predetermined cost in a situation where recourse to the capital market would be prohibitive for him. It illustrates the increased integration of insurance and investment banking, both activities performing a fundamental economic function, the transfer of risks.⁷⁸

1.7 Conclusion

In the early 1970s, it was not clear what would be the development of risk and insurance economics over the years to come. Some 40 years later, it is comforting to realize that considerable developments have taken place: the length of the reference list below, unconventionally divided in pre-1973 and post-1973 references gives an account of the quantitative aspects of these developments.

As this chapter shows, the developments have mainly taken place along three avenues of research:

1. The theory of risk-taking behavior in the presence of multiple risks, which encompasses the theory of optimal insurance coverage, the theory of optimal portfolio investment, and the theory of optimal risk prevention.

⁷⁴Exposure to moral hazard for the investor is traded against basis risk for the sponsor.

⁷⁵The risk of default by the reinsurance provider is a concern in the high-layer segment of the reinsurance market.

⁷⁶Still, it remains that the use of insurance-linked securities raises sensitive issues in terms of regulation. Not because these instruments would represent a danger for the stability of the financial system, but because regulators, more particularly in the USA, are reluctant to consider them as genuine alternative mechanisms for risk transfer: see Klein and Wang (2009).

⁷⁷The success with cat bonds stimulated interest for other insurance-linked securities, particularly in the life insurance sector (mortality bonds, longevity bonds): see Cowley and Cummins (2005), Lin and Cox (2005), Albertini and Barrieu (2009), Cummins and Weiss (2009), and Chen and Cox (2009).

⁷⁸Other innovations, such as *sidecars* and *ILWs* (Industry Loss Warranties), are different in nature from those presented in this section. They represent innovations that improve the capacity of the reinsurance market, without introducing an alternative or complement to reinsurance contracts.

2. The issues raised by asymmetric information for contracts design and market equilibrium, a theme which extends beyond insurance economics and concerns all contractual relations in the economy, e.g., on labor markets, products markets, and financial markets.
3. The applications of new financial paradigms, such as contingent claims analysis, to the analysis of insurance firms, insurance markets and corporate risk management, a development which links more closely insurance economics to financial economics, and insurance to finance.

Risk and insurance economics represents nowadays a major theme in general economic theory. This does not mean that risk and insurance education, per se, has become a predominant theme—although important developments took place also at this level. But risk and insurance issues have become pervasive in economic education, more particularly in microeconomics. To support this statement, one may verify in the second section of the following list of references that many important contributions for the advancement of risk and insurance theory were published in general economic and financial journals, and not only in the leading specialized reviews. Indeed, given that this goal of the 1970s was reached, it may be wondered whether an other objective, the development of specialized risk and insurance education and research, which had been given less importance then, should not be reevaluated today. From the experience with the tremendous research activity we have witnessed in the study of financial markets over the past years, we are allowed to infer that specialized research in insurance economics would receive a major impulse from the creation of complete, reliable, and easily accessible insurance databases. True, compared with the situation at the end of the 1990s, the last 12 years have been characterized by a breakthrough of empirical research on insurance themes, most notably in the asymmetric information area where the implications of models have been subject to empirical tests. These tests represent a fundamental progress in the economics of risk and insurance. They provide results that enhance our understanding of insurance markets and the authors must be congratulated for their efforts. But they are still too often based on proprietary data, made available on a case by case basis, not on widely available insurance data bases. The availability of such data bases would certainly trigger more interest for dissertations on risk and insurance themes among beginning doctoral students in economics.

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Chapter 2

Higher-Order Risk Attitudes

Louis Eeckhoudt and Harris Schlesinger

Abstract Risk aversion has long played a key role in examining decision making under uncertainty. But we now know that prudence, temperance, and other higher-order risk attitudes also play vital roles in examining such decisions. In this chapter, we examine the theory of these higher-order risk attitudes and show how they entail a preference for combining “good” outcomes with “bad” outcomes. We also show their relevance for non-hedging types of risk-management strategies, such as precautionary saving. Although higher-order attitudes are not identical to preferences over moments of a statistical distribution, we show how they are consistent with such preferences. We also discuss how higher-order risk attitudes might be applied in insurance models.

Keywords Hedging • Expected utility • Precautionary motives • Prudence • Risk • Temperance

2.1 Introduction

Ever since Daniel Bernoulli (1738), risk aversion has played a key role in examining decision making under uncertainty. Within an expected-utility framework, this property corresponds to the simple feature that the utility function is concave. Although somewhat newer, the higher-order risk attitude of “prudence” and its relationship to precautionary savings also has become a common and accepted assumption. The term “prudence” was coined by Kimball (1990), although its importance in determining a precautionary savings demand was noted much earlier by Leland (1968) and Sandmo (1970). Indeed, Kimball’s (1990) analysis is compelling, in part, due to the way he extends the “logic” of risk aversion to a higher order. Since then, numerous empirical contributions have used prudence to test for a precautionary demand for saving.

Risk aversion is defined in several different ways. Some, assuming an expected-utility framework, might say that the von Neumann–Morgenstern utility function u is concave. Others might define risk aversion in a more general setting, equating it to an aversion to mean-preserving spreads, as defined

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by [Rothschild and Stiglitz \(1970\)](#). Such a definition allows the concept of risk aversion to be applied in a broader array of settings, not confined within expected utility. It also helps to obtain a deeper understanding of the concept, even within expected utility.

Ask someone to define what it means for the individual to be “prudent” and they might say that marginal utility is convex ($u''' > 0$) as defined in [Kimball \(1990\)](#), but they also might define prudence via behavioral characteristics. For example, [Gollier \(2001, p. 236\)](#) defines an agent as prudent “if adding an uninsurable zero-mean risk to his future wealth raises his optimal saving.” Interestingly, prudence was defined by Kimball in order to address the issue of precautionary saving. But such characterizations necessarily introduce aspects of particular decision problems into definitions of risk attitudes. They also are typically derived within a specific type of valuation model, most commonly expected utility. In this chapter, we describe an alternative approach to defining higher-order risk attitudes, such as prudence. Since our definitions are perfectly congruous to those based within expected utility, it helps to give a deeper understanding of their application to risk-management decisions.

In an expected-utility framework, it is interesting to note that an assumption of a third derivative of utility being positive was often seen as “more severe” than assuming the generally accepted property of decreasing absolute risk aversion (DARA)—even though the latter assumption is stricter mathematically. Indeed, the early articles of [Leland \(1968\)](#) and [Sandmo \(1970\)](#) both point out how $u''' > 0$ will lead to a precautionary demand for saving. But assumptions about derivatives seemed rather ad hoc and technical at that time. Both of these authors pointed out that DARA, whose intuition had already been discussed in the literature, is sufficient to obtain a precautionary demand for saving.

Although it predates [Kimball \(1990\)](#), the concept of “downside risk aversion” as defined by [Menezes et al. \(1980\)](#), which we now know is equivalent to prudence, helps in our understanding. A pure increase in “downside risk” does not change the mean or the variance of a risky wealth prospect, but it does decrease the skewness. More generally, prudence plays an important role in the tradeoff between risk and skewness for economic decisions made under uncertainty, as shown by [Chiu \(2005\)](#). Hence, prudence (downside risk aversion) can be quite important for empirical economists, wanting to measure such tradeoffs.

A lesser known higher-order risk attitude affecting behavior towards risk is *temperance*, a term also coined by [Kimball \(1992\)](#). [Gollier and Pratt \(1996\)](#) and [Eeckhoudt et al. \(1996\)](#) show how temperance plays an important role in decision making in the presence of an exogenous background risk. As was the case with prudence, first notions of temperance relied upon its application to certain decision problems, and they were also explained in terms of utility, more particularly as a negative fourth derivative of the utility function.

Although not a perfect analog, in the same way that risk aversion is not a perfect analog for aversion to a higher variance ([Rothschild and Stiglitz 1970](#)), a temperate individual generally dislikes kurtosis. In an expected-utility setting, [Eeckhoudt and Schlesinger \(2008\)](#) show that temperance is both necessary and sufficient for an increase in the downside risk of future labor income to always increase the level of precautionary saving.

More recently, prudence and temperance, as well as even higher-order risk attitudes, have been defined without using an expected-utility context. In particular, [Eeckhoudt and Schlesinger \(2006\)](#) define these higher-order risk attitudes as preferences over particular classes of lottery pairs. What makes these characterizations particularly appealing is their simplicity, as they are stated in terms of comparing simple 50–50 lottery pairs. The intuition behind such preference is described via a concept defined as “risk apportionment.”

In this chapter, we summarize many of the interesting results about these higher-order risk attitudes. The lottery preferences that are defined here are basic, and they do not require any particular model: neither expected utility nor a particular framework for non-expected utility. Since much of insurance theory is based on expected-utility models and since much of what we know about higher-order risk attitudes is easy to characterize in an expected-utility setting, this chapter is mainly (though

not exclusively) focused on expected utility. Since this area of research is relatively new, it is our hope that this chapter will stimulate new research—both theoretical and empirical/experimental—in this relatively nascent topic. We are especially interested in ways that our basic results extend to non-expected utility models and to behavioral models.

We first give a very brief overview of the [Eeckhoudt and Schlesinger \(2006\)](#) lottery preference approach, and we explain the rationale behind what we refer to as “risk apportionment.” Then, in Sect. 2.3, we show how these results have quite simple ties to expected-utility theory. In Sect. 2.4, we generalize the concept of risk apportionment, which can be described as preference for “disaggregating the harms,” to a preference for mixing “good outcomes” with “bad outcomes.” In Sect. 2.5, we examine how our results can be applied to the best known of higher-order risk effects, namely, to precautionary motives. Section 2.6 extends the analysis to cases where preferences are bivariate, such as preferences over both wealth and health status. Section 2.7 looks at the special case of univariate preferences, but where various risks are jointly applied in a multiplicative manner, such as when stochastic nominal wealth is multiplied by a factor representing a purchasing power index. Finally, we conclude by summarizing the key points and mentioning a few areas in which more research is needed.

2.2 Higher-Order Attitudes as Risk Apportionment

We start by reintroducing the well-known concept of risk aversion, which is a second-order risk attitude. An individual has an initial wealth $W > 0$. The individual is assumed to prefer more wealth to less wealth. Let $k_1 > 0$ and $k_2 > 0$ be positive constants. Consider the following two lotteries expressed via probability trees, as shown in Fig. 2.1. We assume that all branches have a probability of occurrence of one-half and that all variables are defined so as to maintain a strictly positive total wealth. This latter assumption avoids complications to the model associated with bankruptcy.

In lottery B_2 , the individual always receives one of the two “harms,” either a sure loss of k_1 or a sure loss of k_2 . The only uncertainty in lottery B_2 is which of the two losses will occur. In lottery A_2 , the individual has a 50–50 chance of either receiving both harms together (losing both k_1 and k_2) or receiving neither one. An individual is defined as being risk averse if he/she prefers lottery B_2 to lottery A_2 for every arbitrary k_1, k_2 , and W satisfying the above constraints. Put differently suppose that the consumer already has the lottery paying W in state 1 and paying $W - k_1$ in state 2, where each state has a probability of 0.5. If forced to add a second loss k_2 in one of the two states, a risk averter always prefers to add the second loss in state 1, the state where k_1 does not occur.

The risk averter prefers to “apportion” the sure losses k_1 and k_2 by placing one of them in each state. [Eeckhoudt and Schlesinger \(2006\)](#), who define the concept of risk apportionment, describe this type of behavior as a preference for “disaggregating the harms.” It is trivial for the reader to verify that the above definition of risk aversion can only be satisfied with a concave utility function, if preferences are given by expected utility. It is also easy to verify that lottery A_2 is riskier than lottery B_2 in the sense of [Rothschild and Stiglitz \(1970\)](#).¹

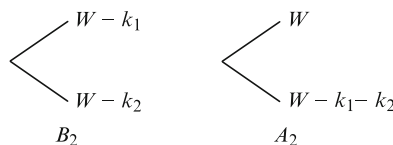


Fig. 2.1 Lottery preference as risk aversion

¹The lottery A_2 is easily seen to be a simple mean-preserving spread of the lottery B_2 .

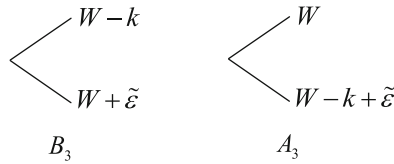


Fig. 2.2 Lottery preference as prudence

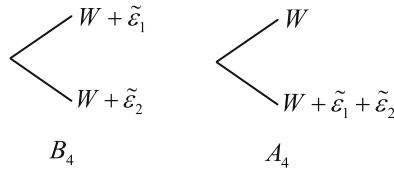


Fig. 2.3 Lottery preference as temperance

To view the third-order risk attitude of prudence, let $k > 0$ denote a positive constant and let $\tilde{\varepsilon}$ denote a zero-mean random variable. Someone who is risk averse will dislike the random wealth variable $\tilde{\varepsilon}$. We assume that $W - k + \varepsilon > 0$ for all realizations of the random variable $\tilde{\varepsilon}$. Although we do not need risk aversion to define prudence, it makes the interpretation a bit simpler, since in this case we now have a new pair of “harms,” namely, losing k and adding $\tilde{\varepsilon}$. A prudent individual is one who always prefers to disaggregate these two harms. This is illustrated in Fig. 2.2.

In lottery B_3 , the individual always receives one of the two “harms,” either a sure loss of k or the addition of a zero-mean random wealth change $\tilde{\varepsilon}$. In lottery A_3 , the individual has a 50–50 chance of either receiving both harms together or of receiving neither one. Eeckhoudt and Schlesinger (2006) define an individual as being *prudent* if he/she always prefers lottery B_3 to lottery A_3 . Alternatively, one could describe the behavior as preferring to attach the zero-mean lottery $\tilde{\varepsilon}$ to the state with the higher wealth vis-à-vis the state with the lower wealth.² Equivalently, we could describe it as preferring to attach the sure loss k to the state with no risk, as opposed to the state with the risk $\tilde{\varepsilon}$. Although this definition is not specific to expected utility, if we assume a model with differentiable utility, prudence is equivalent to a positive third derivative of the utility function, as we show in the next section.

Once again, our definition is expressed in terms of risk apportionment: a prudent individual prefers to apportion the two harms by placing one in each state. To define temperance, which is a fourth-order effect, Eeckhoudt and Schlesinger (2006) simply replace the “harm” of losing the fixed amount of wealth k with the “harm” of a second zero-mean risk. To this end, let $\tilde{\varepsilon}_1$ and $\tilde{\varepsilon}_2$ be two distinct zero-mean risks, where we assume that $\tilde{\varepsilon}_1$ and $\tilde{\varepsilon}_2$ are statistically independent of one another. An individual is defined as being temperate, if he/she always prefers to apportion the two harms ($\tilde{\varepsilon}_1$ and $\tilde{\varepsilon}_2$) by placing one in each state.

In Fig. 2.3, again with equally likely states of nature, the temperate decision maker always prefers lottery B_4 to lottery A_4 . Again, this is a preference for “disaggregating the harms.” Given a risk in one of these two states, the individual prefers to locate a second independent risk in the other state.³

²A similar observation was made by Eeckhoudt et al. (1995) and by Hanson and Menezes (1971), who all confined their analysis to EU.

³The rationale for statistical independence here should be apparent. For example, if $\tilde{\varepsilon}_1$ and $\tilde{\varepsilon}_2$ were identically distributed and perfectly negatively correlated, every risk averter would prefer to have the two risks in the same state, since they would then “cancel” each other.

Note that all of the definitions as given above are not dependent on expected utility or any other specific model of preferences. In a certain sense, these definitions are “model free” and can be examined within both expected-utility and non-expected-utility types of models.⁴

By nesting the above two types of lotteries in an inductive way, [Eeckhoudt and Schlesinger \(2006\)](#) generalize the concepts of prudence and temperance to even higher orders.⁵ In our view, this nesting makes everything a bit less transparent, but the idea of risk apportionment remains the same. Although our focus in this chapter will be on risk attitudes no greater than order four (temperance), we introduce a way to view even higher-order risk attitudes later in the chapter, when we discuss a generalization that involves combining “good” with “bad” outcomes.

2.3 Risk Attitudes and Expected Utility

Suppose that preferences can be expressed using expected utility and let the individual’s utility of wealth be given by the strictly increasing function u . We assume that u is continuous and is continuously differentiable.⁶ Of course, risk aversion is equivalent to having u be a concave function, as is well known. Under our differentiability assumption, this implies that $u'' < 0$.⁷

Within an expected-utility framework, prudence is equivalent to $u''' > 0$, exactly as in [Kimball \(1990\)](#), and temperance is equivalent to $u''' < 0$, as in [Kimball \(1992\)](#). The “tool” in deriving these results is the utility premium, measuring the degree of “pain” involved in adding risk. To the best of our knowledge, the first direct look at the utility premium was the work of [Friedman and Savage \(1948\)](#). Although this measure actually predates more formal analyses of behavior under risk, as pioneered by [Arrow \(1965\)](#) and [Pratt \(1964\)](#), it has been largely ignored in the literature.⁸ One reason for ignoring the utility premium is that it cannot be used to compare individuals. However, our interest here is examining choices made by a single individual. As such, the utility premium turns out to be an extremely useful tool.

We define the utility premium for the risk $\tilde{\varepsilon}_1$, given initial wealth W as follows:

$$v(W) \equiv \text{Eu}(W + \tilde{\varepsilon}_1) - u(W). \quad (2.1)$$

The utility premium is the amount of utility added by including the risk $\tilde{\varepsilon}_1$ with initial wealth. Of course, for a risk averter, the individual loses utility by adding the zero-mean risk $\tilde{\varepsilon}_1$; hence,

⁴It is easy to see in [Fig. 2.2](#) that the means and variances for A_3 and B_3 are identical, but B_3 has a higher skewness (is more right skewed). For two distributions with the same first two moments, it can be shown that it is impossible for every prudent individual to prefer the distribution with a lower skewness. If the two zero-mean risks in [Fig. 2.3](#) are symmetric, then the first three moments of A_4 and B_4 are identical, but with A_4 having a higher kurtosis (fatter tails). For two distributions with the same first three moments, it can be shown that it is impossible for every temperate individual to prefer the distribution with a higher kurtosis.

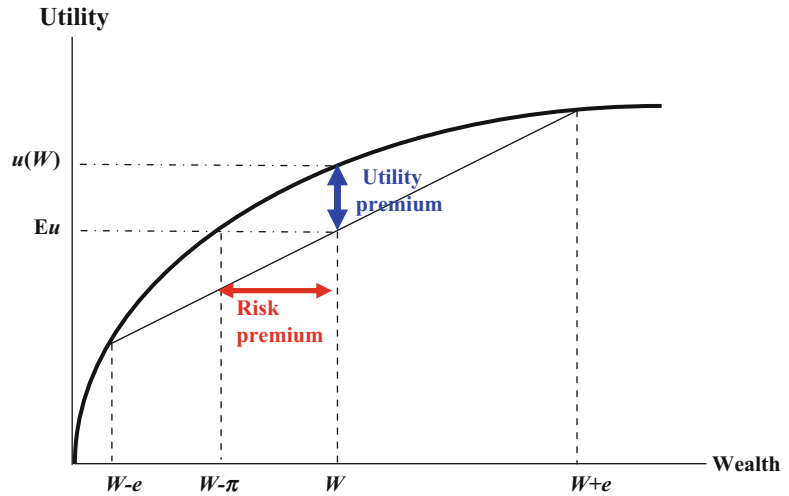
⁵These higher orders are already known to be important in various contexts. For example, standard risk aversion as defined by [Kimball \(1993\)](#), as well as risk vulnerability as defined by [Gollier and Pratt \(1996\)](#), each require temperance. [Lajeri-Chaherli \(2004\)](#) looks at a rationale to use 5th-order risk attitudes. Both of these higher-order risk preferences are also given intuitive economic interpretations by [Courbage and Rey \(2010\)](#).

⁶Although utility-based models can also be derived without differentiability, most of the literature assume that these derivatives exist.

⁷For the mathematically astute, we admit that this is a slight exaggeration. Strict risk aversion also allows for $u'' = 0$ at some wealth levels, as long as these wealth levels are isolated from each other. See [Pratt \(1964\)](#) for more details.

⁸An article by [Hanson and Menezes \(1971\)](#) made this same observation more than 40 years ago!

Fig. 2.4 Utility premium and risk premium



$v(W) < 0$. This follows easily from Jensen’s inequality since u is concave.⁹ To the extent that utility is used to measure an individual’s welfare, the utility premium measures the level of “pain” associated with adding risk $\tilde{\epsilon}_1$ to wealth, where “pain” is measured as the loss of utility.

An example of the utility premium is illustrated in Fig. 2.4 for the case where $\tilde{\epsilon}_1$ is a 50–50 chance of either gaining or losing wealth e . In Fig. 2.4, Eu denotes the expected utility of wealth prospect $W + \tilde{\epsilon}_1$. Pratt’s (1964) risk premium, denoted here by π , is the amount of wealth that the individual is willing to give up to completely eliminate the risk $\tilde{\epsilon}_1$. The utility premium (which is the negative of the amount drawn in Fig. 2.4) shows exactly how much utility is lost by the addition of $\tilde{\epsilon}_1$. Since the utility function representing an individual’s preferences is not unique, the utility premium will change if the utility scale changes.¹⁰ For example, if we double all of the utility numbers, the utility premium will also double. Pratt’s risk premium, on the other hand, is invariant to such changes. For this reason, we can use Pratt (1964) to compare preferences between individuals, but we cannot use the utility premium.

We can use the utility premium to easily show how our earlier definitions of prudence and temperance relate to expected utility. To this end, differentiate the utility premium with respect to initial wealth to obtain

$$v'(W) \equiv Eu'(W + \tilde{\epsilon}_1) - u'(W). \tag{2.2}$$

Using only Jensen’s inequality, it follows from (2.2) that $v'(W) > 0$ whenever u' is a convex function, i.e., when $u'''(y) > 0 \forall y$. Since the utility premium is negative, we interpret $v'(W) > 0$ as meaning that the size of the utility premium gets smaller as initial wealth W increases.

Now consider our earlier definition of prudence. A prudent individual would prefer to attach the zero-mean risk $\tilde{\epsilon}_1$ to the state with the higher wealth W , as opposed to attaching it to the state with the lower wealth, $W - k$. This is due to the fact that $\tilde{\epsilon}_1$ causes less “pain” at the higher wealth level, where pain in our expected-utility model is measured via utility. In other words, prudence is equivalent to saying that the size of our utility premium decreases with wealth, i.e., $u''' > 0$.

More formally, a decreasing utility premium, $v'(W) > 0$, is equivalent to saying that, for all $k > 0$,

⁹In the original article by Friedman and Savage (1948), the risks that were considered had positive expected payoffs and could thus have a positive utility premium, even for a risk averter. In this chapter, we only consider zero-mean risks.

¹⁰The utility function is only unique up to a so-called affine transformation. See Pratt (1964).

$$\text{Eu}(W + \tilde{\varepsilon}_1) - u(W) > \text{Eu}(W - k + \tilde{\varepsilon}_1) - u(W - k). \quad (2.3)$$

Rearranging (2.3) and multiplying by 1/2 yields

$$\frac{1}{2}[\text{Eu}(W + \tilde{\varepsilon}_1) + u(W - k)] > \frac{1}{2}[u(W) + \text{Eu}(W - k + \tilde{\varepsilon}_1)], \quad (2.4)$$

which is the expected-utility representation of the lottery preference depicted in Fig. 2.2.

To show that temperance is equivalent to assuming that $u'''' < 0$, we need to first differentiate the utility premium a second time with respect to wealth to obtain

$$v''(W) \equiv \text{Eu}''(W + \tilde{\varepsilon}_1) - u''(W). \quad (2.5)$$

It follows from (2.5), using Jensen's inequality, that $v''(W) < 0$ whenever u'' is a concave function, i.e., whenever the fourth derivative of utility is negative, $u'''' < 0$. If we also have a decreasing utility premium (prudence), this can be interpreted as saying that the rate of decrease in the utility premium lessens as wealth increases.

We will still let $v(W)$ denote the utility premium for adding the risk $\tilde{\varepsilon}_1$ to wealth W . To understand how this relates to temperance, we need to consider adding a second independent zero-mean risk $\tilde{\varepsilon}_2$. Consider the change in the utility premium from this addition of $\tilde{\varepsilon}_2$. We are particularly interested in the case where the presence of risk $\tilde{\varepsilon}_2$ exacerbates the loss of utility from risk $\tilde{\varepsilon}_1$.¹¹ Since the utility premium is negative, this condition is equivalent to

$$E v(W + \tilde{\varepsilon}_2) - v(W) < 0, \quad (2.6)$$

which itself holds for all W and for all zero-mean $\tilde{\varepsilon}_2$ if and only if v is a concave function. From (2.5), we see that the inequality in (2.6) holds whenever $u'''' < 0$. We can now use the definition of the utility premium in (2.2) to expand the left-hand side of the inequality (2.6). Rearranging the result and multiplying by 1/2 shows that the inequality in (2.6) is equivalent to

$$\frac{1}{2}[\text{Eu}(W + \tilde{\varepsilon}_1) + u(W + \tilde{\varepsilon}_2)] > \frac{1}{2}[u(W) + \text{Eu}(W + \tilde{\varepsilon}_1 + \tilde{\varepsilon}_2)]. \quad (2.7)$$

Of course, the inequality in (2.7) is simply the expected-utility representation of the lottery preference depicted in Fig. 2.3.

2.4 Pairing Good Outcomes with Bad Ones

Another approach to viewing higher-order risk attitudes extends the concept of “mitigating the harms,” as was discussed in Sect. 2.2. To implement this approach, we first need to provide a definition of an N th-degree increase in risk, as introduced by Ekern (1980). Assume that all random variables only take on values strictly between a and b . Consider a random wealth variable with cumulative distribution function $F(x)$. Define $F^{(1)}(x) \equiv F(x)$ and then define $F^{(i)}(x) \equiv \int_a^x F^{(i-1)}(t)dt$ for all $i \geq 2$.

¹¹Replacing the second condition in the definition with $F^{(i)}(b) \leq G^{(i)}(b)$ yields a definition of N th-order stochastic dominance. The results in this section easily extend to stochastic dominance, as shown by Eeckhoudt et al. (2009).

Definition: The distribution G is an N th-degree increase in risk over F if $F^{(N)}(x) \leq G^{(N)}(x)$ for all $a \leq x \leq b$ and $F^{(i)}(b) = G^{(i)}(b)$ for $i = 2, \dots, N - 1$.¹²

As an example that might be more familiar to some readers, when $N = 2$, a second-degree increase in risk is identical to a “mean-preserving increase in risk” as defined by Rothschild and Stiglitz (1970). As another example, for $N = 3$, a third-degree increase in risk is identical to an “increase in downside risk” as defined by Menezes et al. (1980).

From the definition above, it follows that the first $N - 1$ moments of F and G are identical. For $N = 2$, if G is a second-degree increase in risk over F , G must have a higher variance than F . However, the reverse implication does not hold: for two distributions with the same mean, a higher variance for G does not necessarily imply that G is a second-degree increase in risk over F .

Before proceeding further, we require the following result, which is due to Ekern (1980).

Theorem (Ekern): The following two statements are equivalent:

(i) G is an increase in N th-degree risk over F .

(ii) $\int_a^b u(t)dF \geq \int_a^b u(t)dG$ for all functions u such that $\text{sgn}[u^{(N)}(t)] = (-1)^{N+1}$.

As a matter of notation, if the random variables \tilde{X} and \tilde{Y} have distribution functions F and G , respectively, where G is an increase in N th-degree risk over F , we will write $\tilde{X} \succ_N \tilde{Y}$. Now consider four random variables, each of which might possibly be a degenerate random variable (i.e., a constant): $\tilde{X}_1, \tilde{Y}_1, \tilde{X}_2, \tilde{Y}_2$. We assume that $\tilde{X}_1 \succ_N \tilde{Y}_1$ and $\tilde{X}_2 \succ_M \tilde{Y}_2$ for some N and M . From Ekern’s theorem, we see that \tilde{X}_1 is preferred to \tilde{Y}_1 for any individual with $\text{sgn}[u^{(N)}(t)] = (-1)^{N+1}$. In a certain sense, we can thus think of \tilde{X}_1 as being “good” relative to \tilde{Y}_1 , which is relatively “bad.” In a similar manner, \tilde{X}_2 is preferred to \tilde{Y}_2 for any individual with $\text{sgn}[u^{(M)}(t)] = (-1)^{M+1}$, so that \tilde{X}_2 is “good” relative to \tilde{Y}_2 for this person.

Now consider a choice between two lotteries. The first lottery, lottery B , is a 50–50 chance of receiving either $\tilde{X}_1 + \tilde{Y}_2$ or $\tilde{Y}_1 + \tilde{X}_2$. The second lottery, lottery A , is a 50–50 chance of receiving either $\tilde{X}_1 + \tilde{X}_2$ or receiving $\tilde{Y}_1 + \tilde{Y}_2$. In other words, lottery B always yields one “good” outcome added to one “bad” outcome. Lottery A , on the other hand, yields either the sum of both “good” outcomes or the sum of both “bad” outcomes. The following result, which is due to Eeckhoudt et al. (2009) formalizes a certain type of preference for combining “good” with “bad.”¹³

Proposition 1. Given $\tilde{X}_1, \tilde{Y}_1, \tilde{X}_2, \tilde{Y}_2$ with the lotteries A and B as described above, lottery A has more $(N + M)$ th degree risk than lottery B . In other words, $B \succ_{N+M} A$.

From Ekern’s theorem, Proposition 1 implies that anyone with utility satisfying $\text{sgn}[u^{(N+M)}(t)] = (-1)^{N+M+1}$ will prefer lottery B to lottery A . To see how this proposition generalizes the results of Sect. 2.3, consider the following examples. In each of the examples below, we assume that $\tilde{\varepsilon}_1$ and $\tilde{\varepsilon}_2$ are statistically independent zero-mean risks.

Example 1. (Risk aversion) Let $\tilde{X}_1 = W$, $\tilde{Y}_1 = W - k_1$, $\tilde{X}_2 = 0$, $\tilde{Y}_2 = -k_2$. Lotteries A and B are thus identical to the lotteries A_2 and B_2 in Fig. 2.1. It is easy to see from the definition that $\tilde{X}_1 \succ_1 \tilde{Y}_1$ and $\tilde{X}_2 \succ_1 \tilde{Y}_2$. Thus, $N = M = 1$ in applying Proposition 1. Hence, everyone who is risk averse, with $u^{(2)}(t) < 0 \forall t$, will prefer lottery B to lottery A .

Example 2. (Prudence) Let $\tilde{X}_1 = W$, $\tilde{Y}_1 = W - k$, $\tilde{X}_2 = 0$, $\tilde{Y}_2 = \tilde{\varepsilon}$. Lotteries A and B are then identical to the lotteries A_3 and B_3 in Fig. 2.2. It follows from the definition that $\tilde{X}_1 \succ_1 \tilde{Y}_1$ and

¹²Kimball (1993) refers to the two risks in this case as “mutually aggravating.” Pratt and Zeckhauser (1987) came very close to making this same observation. Their basic difference was considering independent risks ε_i that were disliked by a particular individual, rather than zero-mean risks, which are disliked by every risk averter. Menezes and Wang (2005) offer an example that is also quite similar and refer to this case as “aversion to outer risk.”

¹³These authors also provide a proof of this result, which we do not reproduce here.

$\tilde{X}_2 \succ_2 \tilde{Y}_2$. Thus, $N = 1$ and $M = 2$ in applying Proposition 1. Hence, everyone who is prudent, with $u^{(3)}(t) > 0 \forall t$, will prefer lottery B to lottery A .

Example 3. (Temperance) Let $\tilde{X}_1 = W$, $\tilde{Y}_1 = W + \tilde{\varepsilon}_1$, $\tilde{X}_2 = 0$, $\tilde{Y}_2 = \tilde{\varepsilon}_2$. Lotteries A and B are thus identical to the lotteries A_4 and B_4 in Fig. 2.3. In this example, we have $\tilde{X}_1 \succ_2 \tilde{Y}_1$ and $\tilde{X}_2 \succ_2 \tilde{Y}_2$. Thus, $N = M = 2$ in applying Proposition 1. Hence, everyone who is temperate, with $u^{(4)}(t) < 0 \forall t$, will prefer lottery B to lottery A .

In each of these examples, the “bad” outcome is either losing a fixed amount of money or adding a zero-mean risk. We can view the absence of the harm as a relatively “good” outcome and the inclusion of the harm as a relatively “bad” outcome. So our former description of “disaggregating the harms” is now reinterpreted as a preference for “mixing good with bad outcomes.” But notice how the current story allows for additional applications of “good” and “bad.” Moreover, this approach often allows for alternative interpretations. Take, for example, the case of temperance. Instead of using $N = M = 2$ in applying Proposition 1, we can also let $N = 1$ and $M = 3$ as in the following example:

Example 4. (Temperance) Let $\tilde{X}_1 = W$, $\tilde{Y}_1 = W - k$, $\tilde{X}_2 = \tilde{\theta}_1$, $\tilde{Y}_2 = \tilde{\theta}_2$. Here we assume that $E\tilde{\theta}_1 = E\tilde{\theta}_2 = 0$ and that $\text{Var}(\tilde{\theta}_1) = \text{Var}(\tilde{\theta}_2)$, but that $\tilde{\theta}_2 \succ_3 \tilde{\theta}_1$, i.e., that $\tilde{\theta}_2$ has more 3rd-degree risk (more “downside risk”) than $\tilde{\theta}_1$. By the definition above, this implies that $\tilde{\theta}_2$ must be more skewed to the left than $\tilde{\theta}_1$. Proposition 1 implies that a temperate individual would prefer to add $\tilde{\theta}_2$ in the state with higher wealth, with $\tilde{\theta}_1$ added to the state with lower wealth, as opposed to reversing the locations of the two $\tilde{\theta}$ risks. Again we see how this interpretation can be made with regard to apportioning the risks.

Proposition 1 extends easily to the more common ordering of stochastic dominance, as shown by [Eeckhoudt et al. \(2009\)](#). We note here that the random variable \tilde{Y} has more N th-degree risk than the random variable \tilde{X} , which implies that \tilde{X} dominates \tilde{Y} via N th-order stochastic dominance and that the first $N-1$ moments of \tilde{X} and \tilde{Y} are identical. The extension of Proposition 1 to stochastic dominance can be written as follows:

Corollary 1. *Given $\tilde{X}_1, \tilde{Y}_1, \tilde{X}_2, \tilde{Y}_2$ with the lotteries A and B as defined in Proposition 1, lottery B dominates lottery A via $(N+M)$ th-order stochastic dominance.*

2.5 Precautionary Motives

Since this topic is dealt with elsewhere in this handbook, we only wish to give some insight into the logic behind precautionary motives. To the best of our knowledge, the first articles dealing with this topic in an expected-utility framework were by [Leland \(1968\)](#) and [Sandmo \(1970\)](#). Both considered the effect of risky future income on current saving. To the extent that future risk increased the level of current saving, this additional saving was referred to as “precautionary saving.” The notion of this precautionary motive for saving was introduced by [Keynes \(1930\)](#), and it was embedded into the macroeconomics literature on the permanent income hypothesis by [Bewley \(1977\)](#).

Both Leland and Sandmo discovered that a precautionary-saving motive would be ensured if and only if the consumer’s differentiable utility function exhibited prudence, $u''' > 0$. However, since the term “prudence” did not exist prior to [Kimball \(1990\)](#) and since the requirement $u''' > 0$ might need some motivation at the time, both Leland and Sandmo were quick to point out that the well-accepted principle of DARA was sufficient to obtain their results. Although DARA is actually a stronger property, it had an intuitive economic rationale and thus was probably easier to justify.

However, as we now see from (2.2), the size of the utility premium for adding a zero-mean risk to some initial wealth level will always be decreasing in the wealth level if and only if u' is a convex

function, i.e., if and only if $u''' > 0$ when utility is differentiable. Before examining the rationale for a precautionary motive, let us first be careful to note the distinction between prudence and DARA. For example, if utility exhibits the well-known property of constant absolute risk aversion (CARA), we will still have prudence, $u''' > 0$. Indeed, under CARA, the size of the utility premium, as defined in (2.1), is decreasing wealth. Thus, the level of pain from a zero-mean risk will decrease as the individual becomes wealthier. At first thought, this might seem counter to the basic property under CARA that the individual's willingness to pay to completely eliminate the risk is independent of his/her wealth level. However, one needs to also consider the fact that our individual is risk averse, which implies that the marginal utility of money is decreasing in wealth. Under CARA, a zero-mean risk will cause less pain as the individual becomes wealthier. However, as the individual becomes wealthier, his/her willingness to pay to remove each unit of pain will increase (since money is worth less at the margin). Under CARA, these two effects exactly offset and the individual pays the same total amount to remove the risk at every wealth level. See, for example, [Eeckhoudt and Schlesinger \(2009\)](#).

As another example, consider the often used quadratic form of the utility function $u(w) = w - bw^2$, where $b > 0$ and we restrict $w < (2b)^{-1}$. Since $u'''(w) = 0$ for all w , it follows from (2.2) that the level of pain from adding a zero-mean risk will be constant at all levels of initial wealth. However, since we still have decreasing marginal utility, the willingness to pay to eliminate each unit of pain will increase as the individual becomes wealthier. This leads to the undesirable property of increasing absolute risk aversion for this utility function, as is well known.

Now let us consider a different interpretation for the risk apportionment story. Rather than consider the 50–50 lotteries, such as those in Fig. 2.2, let us consider sequentially receiving each of the two lottery outcomes, one in each period. Denote these two outcomes as \tilde{x}_1 and \tilde{x}_2 , with the understanding that the outcomes might or might not both be random. We previously considered the expected utility of a lottery, which was defined as $\frac{1}{2}\text{Eu}(\tilde{x}_1) + \frac{1}{2}\text{Eu}(\tilde{x}_2)$. But if we simply add the utility from the two outcomes, $\text{Eu}(\tilde{x}_1) + \text{Eu}(\tilde{x}_2)$, we can reinterpret the model as a two-period (undiscounted) lifetime utility.

Thus, from Fig. 2.2, we see that a preference for B_3 over A_3 implies that the individual prefers to have more wealth in the time period with the zero-mean risk, whenever the individual is prudent. Worded differently, the individual can decrease the pain from this zero-mean risk by shifting wealth to the period with the risky income. In the precautionary-saving model, this implies shifting more wealth to the second period via an increase in saving.

[Eeckhoudt and Schlesinger \(2008\)](#) extend this reasoning to cases where the risk in the second period changes. Since increasing wealth in the second period via additional saving is itself a first-order change, we can apply the results of Sect. 2.4 to consider N th-degree changes in the riskiness of second-period income. If the second-period income is risky, but riskiness increases via a second-degree increase in risk, the individual can mitigate some of this extra pain by increasing saving if the individual is prudent. The application of Proposition 1 is identical to that used in Example 2 of the previous section, with $N = 1$ and $M = 2$.

However, the link between prudence and precautionary change is broken if we consider other types of changes in the riskiness of future income. Suppose, for example, that future risky income undergoes a first-degree deterioration. This would be the case, for instance, when there is an increased risk of being unemployed in period 2. We can then apply Proposition 1 as in Example 1, with $N = M = 1$. Any risk-averse individual would increase his/her saving in response to such a change in the riskiness of future income. Thus, prudence is no longer necessary to induce precautionary saving. On the other hand, suppose that the first two moments of risky future income remained unchanged, but that there was a third-degree deterioration in the risk connoting more downside risk. In that case, we apply our Proposition 1 with $N = 1$ and $M = 3$. Thus, prudence is no longer sufficient to induce precautionary saving, and we need to assume temperance to guarantee an increase in saving.

Obviously, models employing joint decisions about saving and insurance will find all of the above analysis useful. However, precautionary motives can also be found in decision models that do not

include saving. For example, consider a simple model of insurance with two loss states: loss and no-loss, where a loss of size L occurs with probability p .¹⁴ The individual's initial wealth is $W > 0$. Coinsurance is available that pays a fraction α of any loss for a premium of $\alpha(1 + \lambda)pL$, where $\lambda \geq 0$ denotes the so-called premium loading factor. It is straightforward to show that the first-order condition for the choice of an optimal level of coinsurance in an expected-utility framework is

$$\frac{dEu}{d\alpha} = pL[1 - (1 + \lambda)p]u'(y_1) - pL[1 - (1 + \lambda)p + \lambda]u'(y_2) = 0, \quad (2.8)$$

where $y_1 \equiv W - \alpha(1 + \lambda)pL - L + \alpha L$ and $y_2 \equiv W - \alpha(1 + \lambda)pL$.¹⁵ Let α^* denote the optimal level of insurance chosen.

Now suppose that we introduce an additive noise term $\tilde{\varepsilon}$, with $E\tilde{\varepsilon} = 0$, but that this noise only occurs in the loss state. Examining the derivative in the first-order condition (2.8), but with the noise term added, yields

$$\frac{dEu}{d\alpha} \Big|_{\alpha^*} = pL[1 - (1 + \lambda)p]Eu'(y_1 + \tilde{\varepsilon}) - pL[1 - (1 + \lambda)p + \lambda]u'(y_2). \quad (2.9)$$

If the individual is prudent, we know that $Eu'(y_1 + \tilde{\varepsilon}) > u'(y_1)$. Comparing (2.9) with (2.8), it follows that $\frac{dEu}{d\alpha} \Big|_{\alpha^*} > 0$, so that more insurance will be purchased when the noise is present.

Note that the extra insurance does nothing to protect against the loss L . Rather, the extra insurance lowers the “pain” from the zero-mean noise that exists only in the loss state. Although there is no saving in this model, the individual can increase his/her wealth in the loss state by increasing the level of insurance purchased. This additional insurance is thus due solely to a precautionary motive, and it is dependent on having such a precautionary motive, which in this case requires prudence.

The reader can easily examine the case where the zero-mean loss occurs only in the no-loss state. In that case, if we assume prudence, a precautionary effect induces the individual to increase his/her wealth in the no-loss state. In our insurance model, this is achieved by reducing the level of insurance and thus spending less money on the insurance premium.

2.6 Multivariate Preferences

In this section, we examine an extension of the model that has much applicability in insurance models, namely, the case where preferences depend on more than just wealth. Quite often, preferences over wealth in the loss state are not the same as in the no-loss state. As a concrete example, consider one's health. To this end, let y denote the individual's wealth and h denote the individual's health status. To make the model viable, we need to assume that h is some objective measure, such as the remaining number of years of life.¹⁶ We also assume that an increase in h is always beneficial and that the individual is risk-averse in h , so that the individual would always prefer to live another 10 years for certain as opposed to having a 50–50 chance of living either 5 years or 15 years.

Suppose that an individual with initial wealth W and initial health H faces a loss of size $k > 0$ in wealth and a loss of size $c > 0$ in health. Consider the following two 50–50 lotteries as shown in Fig. 2.5.

¹⁴This example is adapted from Fei and Schlesinger (2008).

¹⁵The second-order sufficient condition for a maximum follows trivially if we assume risk aversion.

¹⁶For another interesting application, see Gollier (2010), who lets h denote the quality of the planet's environment.

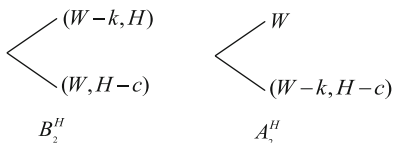


Fig. 2.5 Lottery preference as correlation aversion

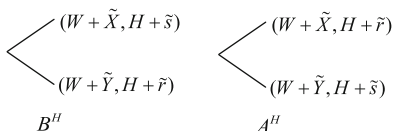


Fig. 2.6 Lottery preference as multivariate risk apportionment

In lottery B_2^H , the individual incurs either a reduction in wealth or a reduction in health, each with a 50% chance. In lottery A_2^H , the individual either has neither reduction or has a simultaneous reduction in both wealth and health. If we extend the earlier concept of mitigating the two “harms,” then the individual would prefer lottery B_2^H to lottery A_2^H . The individual prefers to apportion the two “harms” by placing them in separate states of nature. Likewise, we can interpret this lottery preference as preference for combining “good with bad.”

Such preference is defined as “correlation aversion” by [Epstein and Tanny \(1980\)](#). To the best of our knowledge, this concept was first introduced to the literature by [Richard \(1975\)](#), who used a different terminology. For preferences represented by a bivariate utility function $u(y, h)$, [Richard \(1975\)](#) and [Eeckhoudt et al. \(2007\)](#) show that this preference follows if and only if the cross-partial derivative $u_{12} \equiv (\partial^2 u) / (\partial y \partial h)$ is everywhere negative.

We should note that such preference is not one that is universally assumed in the literature. In fact, the empirical evidence is mixed on the direction of the lottery preference. Indeed, this topic has been debated in the literature, as summarized well by [Rey and Rochet \(2004\)](#). The main thrust of the counterargument is that one cannot enjoy wealth in poor states of health, so that it might be better to pair lower wealth with lower health. In other words, a case can be made that it might be preferable to pair bad with bad and pair good with good, counter to the arguments made above. If this preference always occurs, then the cross-partial derivative $u_{12} \equiv (\partial^2 u) / (\partial y \partial h)$ is everywhere positive in an expected-utility setting.

The implication of such assumptions can have a big impact in models of insurance choice. For instance, consider our two state insurance example from the previous section, without any noise. Assume further that the financial loss of size L occurs only when the individual also receives a reduction in his/her health status from H to $H - c$. This additional assumption requires only that we adapt the first-order condition (2.8) by changing $u'(y_1)$ to $u_1(y_1, H - c)$ and by changing $u'(y_2)$ to $u_1(y_2, H)$. Without losing generality, we can scale utility so that, if the individual is correlation averse, we have $u_1(y_1, H - c) > u'(y_1)$ and $u_1(y_2, H) < u'(y_2)$. It then follows in a straightforward manner from (2.8) that the optimal level of insurance would need to be increased, when the financial loss of size L is accompanied by a loss in health status of amount c . Note that this additional insurance provides a bit more wealth in the loss state and that wealth in the loss state now provides the additional benefit of reducing the “pain” due to the lower health status.

Although the risk attitude of correlation aversion has existed in the literature since [Richard \(1975\)](#), it has only recently begun to receive much attention. Moreover, the concept has been extended by [Eeckhoudt et al. \(2007\)](#), [Tsetlin and Winkler \(2009\)](#), and others to higher orders of multivariate risk attitudes.

As we did in Sect. 2.4, consider the (possibly degenerate) random wealth variables \tilde{X} and \tilde{Y} . We assume that \tilde{Y} has more N th-degree risk than \tilde{X} . Let \tilde{r} and \tilde{s} denote two (possibly degenerate) health-status variables, where \tilde{s} has more M th-degree risk than \tilde{r} . Hence, we can view \tilde{X} and \tilde{r} as each being relatively “good,” whereas \tilde{Y} and \tilde{s} are relatively “bad.” Consider the 50–50 lotteries in Fig. 2.6.

In lottery B^H , the individual mixes good with bad. In lottery A^H , the individual mixes good with good and mixes bad with bad. A preference for B^H over A^H thus represents a type of multivariate risk apportionment.¹⁷

Consider the case where $N = M = 1$. This case corresponds to correlation aversion. Indeed, as shown by Tsetlin and Winkler (2009), in an expected-utility model, this preference can be guaranteed to hold if and only if $u_{12}(y, h)$ is everywhere negative. In Fig. 2.6, our earlier definition of correlation aversion is illustrated by setting $\tilde{X} = \tilde{r} = 0$, $\tilde{Y} = -k$, and $\tilde{s} = -c$. Once again, both definitions turn out to be equivalent.

The case where $N = 1$ and $M = 2$ is labeled “cross prudence in wealth” by Eeckhoudt et al. (2007). For an individual displaying such preference, more wealth mitigates the “harm” of a riskier health, where “riskier” means more second-degree risk. The case in which $N = 2$ and $M = 1$ is labeled “cross prudence in health.” This preference implies that a riskier (in the second degree) wealth is better tolerated when the individual is healthier. If $N = M = 2$, we obtain what Eeckhoudt et al. (2007) label “cross temperance.” Their interpretation considers the special case where $\tilde{X} = \tilde{r} = 0$ and where \tilde{Y} and \tilde{s} are zero-mean risks. Such an individual would prefer a 50–50 lottery with either risky wealth or risky health, as compared to 50–50 lottery with simultaneous risky wealth and risky health versus no risk.

In each of the above settings, the lottery B^H is necessarily preferred to lottery A^H in an expected-utility framework if and only if $(-1)^{N+M-1} \frac{\partial^{N+M} u(y, h)}{\partial y^N \partial h^M} > 0$. Several examples of how these results can be applied to decision problems can be found in Eeckhoudt et al. (2007). As an insurance example, consider the two-state insurance model of Sect. 2.5, where a financial loss of size L occurs with probability p . Here we first assume that only wealth is random and that health status is constant at level H . The first-order condition for an optimal choice of coinsurance is thus

$$\frac{dEu}{d\alpha} = pL[1 - (1 + \lambda)p]u_1(y_1, H) - pL[1 - (1 + \lambda)p + \lambda]u_1(y_2, H) = 0. \quad (2.10)$$

Denote the solution to (2.10) by the insurance level α^* .

Now suppose that the mean health status is not affected, but that health status becomes noisy in the state where there is a financial loss. In particular, health status in this state becomes $H + \tilde{s}$, where \tilde{s} is a zero-mean random health variable. Thus,

$$\frac{dEu}{d\alpha} \Big|_{\alpha^*} = pL[1 - (1 + \lambda)p]Eu_1(y_1, H + \tilde{s}) - pL[1 - (1 + \lambda)p + \lambda]u_1(y_2, H). \quad (2.11)$$

Comparing (2.11) with (2.10), it follows that the level of insurance will increase whenever $Eu_1(y_1, H + \tilde{s}) > u_1(y_1, H)$. From Jensen’s inequality, this will hold whenever the function $u_1(y, h)$ is convex in h , i.e., whenever $u_{122} > 0$, which by definition is whenever the individual is cross prudent in wealth. Intuitively, the extra insurance in this case helps to mitigate the “pain” caused by introducing noise into the health status. Note that if we had $u_{122} < 0$, denoting cross-imprudence, it would follow that less insurance is purchased under a noisy health status.

¹⁷This analysis is based on a generalization and extension of the results in Tsetlin and Winkler (2009), who confine themselves to expected-utility models.

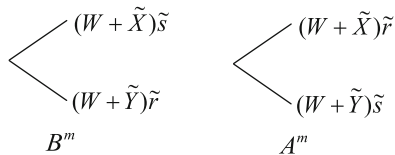


Fig. 2.7 Lottery preference as multiplicative risk apportionment

2.7 Multiplicative Risks

In the first five sections of this chapter, preferences were univariate over wealth alone. Moreover, the various components of wealth were all additive. In Sect. 2.6, we considered general multivariate preferences. Let us change the multivariate notation slightly so that the utility function in the multivariate case is written $\mathcal{U}(y, h)$. The additive univariate model can be obtained as special case by simply interpreting h as a second additive wealth term and then defining utility equal to $\mathcal{U}(y, h) = u(y + h)$. In this setup, for example, it is easy to see that $\mathcal{U}_{112}(y, h) = \mathcal{U}_{122}(y, h) = u'''(y + h)$. Thus, both multivariate cases of “cross prudence” correspond to the simple univariate additive case of “prudence,” with the simple requirement that $u''' > 0$. Other higher-order risk attitudes over wealth can be similarly derived in the same manner.

In several applications of decision making, there are two (or more) sources of risk that are multiplicative. For example, stochastic wealth might be multiplied by a stochastic price deflator or stochastic portfolio returns in a foreign currency might be adjusted via multiplying by a stochastic exchange rate factor. When preferences are univariate over wealth, but the components are multiplicative, we can model this as another special case of multivariate preference.

As we did in Sect. 2.4, consider the (possibly degenerate) random wealth variables \tilde{X} and \tilde{Y} , where \tilde{Y} has more N th-degree risk than \tilde{X} . We also consider \tilde{r} and \tilde{s} as two (possibly degenerate) additional variables that are used to rescale overall wealth, where \tilde{s} has more M th-degree risk than \tilde{r} . Hence, we can view \tilde{X} and \tilde{r} as each being relatively “good,” whereas \tilde{Y} and \tilde{s} are relatively “bad.” Consider the 50–50 lotteries in Fig. 2.7.

In lottery B^m , the individual mixes good with bad. In lottery A^m , the individual mixes good with good and mixes bad with bad. A preference for B^m over A^m thus represents a type of multiplicative risk apportionment. Let us consider first the case of correlation aversion. Here we have $N = M = 1$. For example, Eeckhoudt et al. (2009) consider the special case where $\tilde{X} = 0$, $\tilde{Y} = -k$, $\tilde{r} = 1$, and $\tilde{s} = c < 1$. As illustrated in Fig. 2.7, an individual who exhibits multiplicative correlation aversion prefers lottery B^m to lottery A^m . From Sect. 2.6, this behavior follows if and only if $\mathcal{U}_{12}(y, h) = u'(yh) + yhu''(yh) < 0$. Straightforward manipulation shows that this last inequality is equivalent to having relative risk aversion be everywhere larger than one, i.e., $-yhu''(yh)/u'(yh) > 1$.

Eeckhoudt and Schlesinger (2008) and Eeckhoudt et al. (2009) show that for $N = 1$ and $M = 2$, “cross prudence,” $\mathcal{U}_{112}(y, h) = \mathcal{U}_{122}(y, h) = u'''(y + h)$, holds for all y and h if and only if relative prudence is greater than 2, i.e., $-yhu'''(yh)/u''(yh) > 2$.¹⁸ In this setting, we can let $\tilde{X} = 0$, $\tilde{Y} = -k$ and let \tilde{s} and \tilde{r} be random variables with \tilde{s} exhibiting more second-degree risk than \tilde{r} . For example, let both \tilde{s} and \tilde{r} have a mean of one, so that $W - \tilde{X} = W$ and $W - \tilde{Y} = W - k$ represent expected wealth in the two states of nature. For instance, \tilde{r} might take values of 0.95 or 1.05—either adding or losing five percent of total wealth—each with a 50–50 chance, and \tilde{s} might take on equally likely values of 0.90 or 1.10—either adding or losing 10% of total wealth. Since \tilde{r} has less second-degree risk, multiplying any wealth level by \tilde{r} , as opposed to \tilde{s} , is preferred by every risk averter.

¹⁸For a generalization of the multiplicative case to any arbitrary order n , see Wang and Li (2010).

From what we learned about precautionary motives in Sect. 2.5, we know that the “pain” from a (second-degree) riskier wealth in the state with \tilde{s} can be mitigated by having *more* wealth in that state. On the other hand, having more wealth, this state means that the dollar risk will be higher, since \tilde{s} is multiplied by a higher dollar amount. In other words, the dollar risk could be reduced by having less *wealth* in the state with the higher risk \tilde{s} . In order to have more wealth in the state with \tilde{s} be the better of the two alternatives, the precautionary effect must be strong enough to dominate. The result above makes this notion precise, by telling us that this precautionary effect will always dominate if and only if the measure of absolute prudence is everywhere larger than two.¹⁹

2.8 Concluding Remarks

In this handbook chapter, we introduce some fundamentals about higher-order risk attitudes. Although much is known about risk aversion (a second-order risk attitude) and a bit is known about prudence (a third-order risk attitude), much less is known about higher orders. The analysis by [Eeckhoudt and Schlesinger \(2006\)](#) marked a break in the direction of research in this area. Whereas most research had focused on specific choice problems and their comparative statics, this new direction focused on preferences between pairs of simple lotteries. This direction is a bit similar to the way in which [Rothschild and Stiglitz \(1970\)](#) characterized risk aversion as an aversion to mean-preserving spreads.

Within an expected-utility framework, our lottery preference typically relates to the sign of various derivatives of the utility function. These lottery preferences also can be described as preferences for “risk apportionment,” which tell us a general rule for how an individual likes to combine various components of risk. For example, risk aversion was seen as a preference for “disaggregating the harms,” where the harms were two potential sure losses of wealth. By redefining the “harms” in a particular way, we can obtain all of the higher-order risk attitudes. Equivalently, these attitudes were shown to be a preference for combining “good” with “bad,” with good and bad being defined via N th-degree differences in risk à la [Ekern \(1980\)](#). Not surprisingly, at least to us, extensions to multivariate preferences also depended upon the signs of the derivatives, often the cross-partial derivatives, of the multivariate utility function.

The analysis becomes a bit more complicated if we consider the analysis about multiplicative risks, in Sect. 2.7. In that section, note that we were not able to equate higher-order risk attitudes based on lottery preference with only signs of the derivatives of the original utility function. In particular, the signs of the cross derivatives of the bivariate utility function depended on more than just the signs of derivatives of the univariate utility function. For example, we showed that $\mathcal{U}_{12}(y, h) < 0$ requires that relative risk aversion of the utility function u exceeds unity. In a similar vein, $\mathcal{U}_{112}(y, h) = \mathcal{U}_{122}(y, h) > 0$ requires relative prudence exceeding two. Thus, our lottery preference depends not only on the individual’s being risk averse or being prudent but also on the degree of risk aversion or magnitude of prudence.

The value of measuring intensities of risk aversion was introduced by [Pratt \(1964\)](#) and [Arrow \(1965\)](#). The analysis was extended to intensity measures of prudence by [Kimball \(1990\)](#).²⁰ Essentially, these measures were used to aid in determining the qualitative changes of decisions made within specific choice problems. For example, when will some small change in the initial conditions lead to the purchase of more insurance?

¹⁹Note that for commonly used CRRA utility functions, relative prudence always equals the measure of relative risk aversion plus one, so that relative risk aversion exceeding one is equivalent to relative prudence exceeding two.

²⁰[Caballé and Pomansky \(1996\)](#) further extended these measures to arbitrarily high orders.

However, the literature on higher-order risk has shown that other intensity measures can be important for comparative statics in decision problems.²¹ How these alternative measures relate to lottery preference is an interesting area of current research, for which we do not yet know very many answers.

Given the analysis presented in this chapter, empirical-relevance issues remain. Are individuals prudent? Are they temperate? Obviously, behavioral issues complicate the situation. For example, most all of the experimental evidence shows that risk aversion does not occur universally, although risk aversion is generally accepted as a relevant trait for models of decision making. The extant empirical evidence seems to show that individuals behave in a mostly prudent manner. Likewise, most of the evidence lean towards temperate behavior.²²

Over the years, we have progressively learned much about risk aversion, and that knowledge has permeated models of decision making under risk, such as models of insurance choice. As we continue to learn more and more about higher-order risk attitudes, such knowledge will become more important as it integrates into insurance economics and other areas of risky decision making. We are quite curious ourselves to see where this all takes us over the next decade or two.

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²¹A short summary of these existing measures is provided by [Eeckhoudt \(2012\)](#).

²²See [Tarazona-Gomez \(2004\)](#), [Deck and Schlesinger \(2010\)](#), [Ebert and Wiesen \(2011, 2012\)](#), [Maier and Rügler \(2011\)](#) and [Noussair et al. \(2013\)](#).

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Chapter 3

Non-Expected Utility and the Robustness of the Classical Insurance Paradigm

Mark J. Machina

Abstract This chapter uses the technique of “generalized expected utility analysis” to explore the robustness of some of the basic results in classical insurance theory to departures from the expected utility hypothesis on agents’ risk preferences. The topics include individual demand for coinsurance and deductible insurance, the structure of Pareto-efficient bilateral insurance contracts, the structure of Pareto-efficient multilateral risk sharing agreements, self-insurance vs. self-protection, and insurance decisions under ambiguity. Most, though not all, of the basic results in these areas are found to be quite robust to dropping the expected utility hypothesis.

Keywords Insurance • Risk sharing • Non-expected utility • Expected utility

3.1 Introduction

The purpose of this chapter is to explore what the classical theory of insurance and non-expected utility theory might have to contribute to each other.

For the benefit of readers more familiar with insurance theory than with non-expected utility, we begin by describing what non-expected utility risk preferences are, along with some ways—both algebraic and graphical—to represent and analyze them. The first point to be made is that non-expected utility is *not* an *alternative* to expected utility. Rather, it is a *generalization* of it, in much the same way that calculus provides a general technique for analyzing the properties of specific functional forms.

Think of analyzing the robustness of the classical expected utility-based theory of insurance as analogous to the case of someone who has developed the theory of consumer demand using only Cobb–Douglas utility functions. Such a Cobb–Douglas scientist has an easy and tractable model to work with, and he or she is likely to discover and prove many results, such as the Slutsky equation, or that income elasticities are all identically unity, or that cross-price demand elasticities are identically zero. But we know that while the Slutsky equation is a general property of all utility functions over commodity bundles, the two elasticity results are specific to the Cobb–Douglas functional form, and most definitely not true of more general utility functions. It is hard to see how our scientist could have known the robust results from the non-robust results, unless he or she at least took a peek at more general “non-Cobb–Douglas” preferences.

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The goal of this chapter is to examine some of the classic theoretical results in individual and market insurance theory from the more general non-expected utility point of view, and determine which of these classic results are robust (like the Slutsky equation) and which are not. As mentioned, this chapter is ultimately about what non-expected utility theory and insurance theory can contribute to each other. The identification of the robust results can contribute to insurance theory, by determining which theorems can be most heavily relied upon for further theoretical implications. The identification of the non-robust results can contribute to non-expected utility theory, by determining which parts of current insurance theory are in effect testable implications of the expected utility hypothesis. Since insurance provides the largest, most systematic, and most intensive set of field data on both individual and market choices under uncertainty, this would provide non-expected utility researchers with a very useful opportunity to apply real-world data to the testing of the expected utility model, and the calibration of more general models of choice under uncertainty.

The results examined in this chapter are selected for breadth rather than depth. This reflects that fact that it is no longer possible to present *all* results in the theory of insurance in a single chapter (hence the need for the present volume). It also reflects the fact that the more specific and sophisticated results often require more specialized assumptions (such as convexity of marginal utility, or HARA utility functions), whose natural generalizations to non-expected utility have yet to be fully worked out. But most of all, I also feel we can learn most about robustness by starting out with an examination of the most basic and fundamental results in each of the various branches of insurance theory.

As mentioned, Sect. 3.2 of this chapter introduces the concept of non-expected utility preferences over lotteries, and describes how they can be represented and analyzed, both graphically and algebraically. The next several sections use these tools to examine the robustness of classic results in insurance theory to these more general risk preferences. Section 3.3 covers the individual's demand for insurance, taking the form of the insurance contract (coinsurance or deductible) as given. Section 3.4 examines the optimal form of insurance contract. Section 3.5 considers general conditions for Pareto-efficient risk sharing among many individuals. Section 3.6 examines self-insurance versus self-protection. Section 3.7 explores non-differentiabilities (“kinks”) in preferences over payoffs levels. Section 3.8 considers a specific and widely used model of risk preferences, namely the “rank-dependent” form. 3.9 illustrates how the insurability of some risks can actually induce non-expected utility preferences over other risks. 3.10 reports on how the presence of ambiguity and ambiguity aversion affects insurance decisions and insurance markets. Section 3.11 concludes.

3.2 Non-expected Utility Preferences and Generalized Expected Utility Analysis

Non-expected utility theory typically works with the same objects of choice as standard insurance theory, namely lotteries over final wealth levels, which can be represented by discrete probability distributions of the form $\mathbf{P} = (x_1, p_1; \dots; x_n, p_n)$, or in more general analyses, by cumulative distribution functions $F(\cdot)$.¹ Non-expected utility theory also follows the standard approach by assuming—or positing axioms sufficient to imply—that the individual's preference relation over such lotteries can be represented by means of a *preference function* $\mathcal{V}(\mathbf{P}) = \mathcal{V}(x_1, p_1; \dots; x_n, p_n)$. Just as with preferences over commodity bundles, the preference function $\mathcal{V}(\cdot)$ can be analyzed both graphically, by means of its indifference curves, and algebraically.

¹Depending upon the context, the probabilities in these distributions can either be actuarially determined chances, or a decision-maker's personal or “subjective probabilities” over states of nature or events.

When examining general non-expected utility preferences, it is useful to keep in mind the “benchmark” special case of expected utility. Recall that under the expected utility hypothesis, $\mathcal{V}(\cdot)$ takes the specific form:

$$\mathcal{V}(x_1, p_1; \dots; x_n, p_n) \equiv \sum_{i=1}^n U(x_i) \cdot p_i \quad (3.1)$$

for some *von Neumann–Morgenstern utility function* $U(\cdot)$.

The normative appeal of the expected utility axioms is well known. However, in their role as *descriptive* economists, non-expected utility theorists wonder whether restricting attention solely to the functional form (3.1) might not be like the “Cobb–Douglas hypothesis” of the above scientist. They would like to determine which results of classic risk and insurance theory follow *because* of that functional form, and which might follow from the properties of risk aversion and/or first-order stochastic dominance preference *in general*, without requiring the functional form (3.1). To do this, we begin by illustrating how one can analyze general non-expected utility preference functions $\mathcal{V}(x_1, p_1; \dots; x_n, p_n)$, and compare them to expected utility.

3.2.1 Graphical Depictions of Non-expected Utility Preferences

Two diagrams can illustrate the key similarities and differences between expected utility and non-expected utility preferences, by depicting how preferences over probability distributions $\mathbf{P} = (x_1, p_1; \dots; x_n, p_n)$ depend upon (a) changes in the outcomes $\{x_1, \dots, x_n\}$ for a fixed set of probabilities $\{\bar{p}_1, \dots, \bar{p}_n\}$, and (b) changes in the probabilities $\{p_1, \dots, p_n\}$ for a fixed set of outcomes $\{\bar{x}_1, \dots, \bar{x}_n\}$.

Preferences over changes in the *outcomes* can be illustrated in the classic “Hirshleifer–Yaari diagram” [Hirshleifer (1965, 1966); Yaari (1965, 1969); Hirshleifer and Riley (1979, 1992)]. Assume there are two states of nature, with fixed probabilities (\bar{p}_1, \bar{p}_2) adding to one, so we can restrict attention to probability distributions of the form $(x_1, \bar{p}_1; x_2, \bar{p}_2)$, which can be represented by points in the (x_1, x_2) plane, as in Fig. 3.1. A family of *expected utility* indifference curves in this diagram are the level curves of some expected utility preference function $\mathcal{V}(\mathbf{P}) = U(x_1) \cdot \bar{p}_1 + U(x_2) \cdot \bar{p}_2$, with slope (marginal rate of substitution) given by

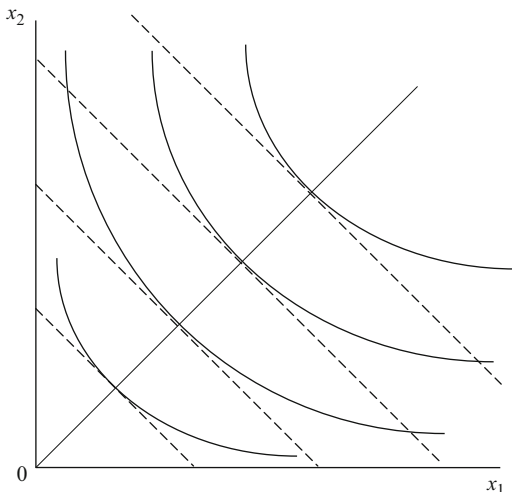
$$MRS_{EU}(x_1, x_2) \equiv -\frac{U'(x_1) \cdot \bar{p}_1}{U'(x_2) \cdot \bar{p}_2}. \quad (3.2)$$

Besides indifference curves, Fig. 3.1 also contains two other constructs. The 45° line consists of all sure prospects (x, x) , and is accordingly termed the *certainty line*. The parallel dashed lines are loci of constant *expected value* $x_1 \cdot \bar{p}_1 + x_2 \cdot \bar{p}_2$, with slope accordingly given by the (negative of) the *odds ratio* \bar{p}_1/\bar{p}_2 . In insurance theory these lines are frequently termed “fair odds lines”—here we shall call them *iso-expected value lines*.

Formula (3.2) can be shown to imply two very specific properties of expected utility indifference curves in the Hirshleifer–Yaari diagram:

“*MRS at certainty = odds ratio*”: The *MRS* at every point (x, x) on the 45° line equals the odds ratio \bar{p}_1/\bar{p}_2 .

Fig. 3.1 Risk averse expected utility indifference curves in the Hirshleifer–Yaari diagram



“*Rectangle property*”: Given the corner points $(x_1^*, x_2^*), (x_1^*, x_2^{**}), (x_1^{**}, x_2^*), (x_1^{**}, x_2^{**})$ of any rectangle in the diagram, the products of the *MRSs* at diagonally opposite pairs are equal.²

Besides these two properties, the indifference curves in Fig. 3.1 exhibit three other features of risk preferences on the part of the underlying preference function $\mathcal{V}(\cdot)$ that generates them. The first feature is that they are downward sloping. To see what this reflects, note that any north, east, or northeast movement in the diagram will, by raising x_1 and/or x_2 , lead to a first-order stochastically dominating probability distribution. Accordingly, any set of indifference curves that is downward sloping is reflecting *first-order stochastic dominance preference* on the part of its underlying preference function $\mathcal{V}(\cdot)$. Of course, under expected utility, this is equivalent to the condition that $U(\cdot)$ is an increasing function of x .

The second feature of these indifference curves is that they are *steeper* than the iso-expected value lines in the region above the 45° line, and *flatter* than the iso-expected value lines in the region below the 45° line. To see what this reflects, note that starting at any point (x_1, x_2) and moving along its iso-expected value line in a direction *away from the certainty line* serve to further increase the larger outcome of the probability distribution, and further decrease the smaller outcome, and do so in a manner which preserves the expected value of the prospect. This is precisely a mean-preserving increase in risk.³ Thus, indifference curves that are steeper/flatter than the iso-expected values lines in the region above/below the certainty line are made worse off by all such increases in risk, and hence reflect the property of *risk aversion* on the part of their underlying preference function $\mathcal{V}(\cdot)$. Under expected utility, this property is equivalent to the condition that $U(\cdot)$ is a concave function of x .

The third feature of the indifference curves in Fig. 3.1 is that they are “bowed-in” toward the origin. This means that any convex combination $(\lambda \cdot x_1 + (1 - \lambda) \cdot x_1^*, \lambda \cdot x_2 + (1 - \lambda) \cdot x_2^*)$ of any two indifferent points (x_1, x_2) and (x_1^*, x_2^*) will be preferred to these points. Expressed more generally, we term this property *outcome-convexity*: namely, for any set of probabilities $\{\bar{p}_1, \dots, \bar{p}_n\}$:

²An interpretive note: The rectangle property is essentially the condition that (smooth) expected utility preferences are separable across mutually exclusive states of nature. Given the rectangle property, the *MRS* at certainty property is equivalent to “state-independent” preferences, a property we shall assume throughout this chapter. For important analyses of *state-dependent* preferences under both expected utility and non-expected utility, see Karni (1985,1987). For a specific application to insurance theory, see Cook and Graham (1977).

³For example, Rothschild and Stiglitz (1970,1971).

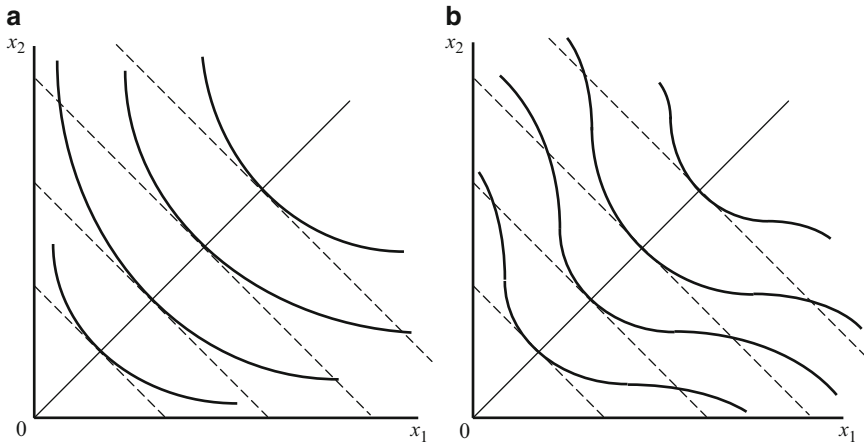


Fig. 3.2 (a) and (b) Risk averse non-expected utility indifference curves (outcome convex and non-outcome convex)

$$(x_1, \bar{p}_1; \dots; x_n, \bar{p}_n) \sim (x_1^*, \bar{p}_1; \dots; x_n^*, \bar{p}_n) \Rightarrow (\lambda \cdot x_1 + (1 - \lambda) \cdot x_1^*, \bar{p}_1; \dots; \lambda \cdot x_n + (1 - \lambda) \cdot x_n^*, \bar{p}_n) \succeq (x_1, \bar{p}_1; \dots; x_n, \bar{p}_n) \quad (3.3)$$

for all $\lambda \in (0, 1)$.⁴ This property of risk preferences has been examined, under various names, by [Tobin \(1958\)](#), [Debreu \(1959, Ch.7\)](#), [Yaari \(1965, 1969\)](#), [Dekel \(1989\)](#), and [Karni \(1992\)](#). Under expected utility, it is equivalent to the condition that $U(\cdot)$ is concave.

Note what these last two paragraphs imply: Since under expected utility the properties of both risk aversion and outcome-convexity are equivalent to concavity of $U(\cdot)$, it follows that expected utility indifference curves in the plane—and expected utility preferences in general— will be risk averse *if and only if* they are outcome convex. We’ll see the implications of this below.

A family of *non-expected utility* indifference curves, on the other hand, consists of the level curves of some general preference function $\mathcal{V}(\mathbf{P}) = \mathcal{V}(x_1, \bar{p}_1; x_2, \bar{p}_2)$, with slope therefore given by

$$MRS_{\mathcal{V}}(x_1, x_2) \equiv - \frac{\partial \mathcal{V}(x_1, \bar{p}_1; x_2, \bar{p}_2) / \partial x_1}{\partial \mathcal{V}(x_1, \bar{p}_1; x_2, \bar{p}_2) / \partial x_2} \quad (3.4)$$

Two such examples, derived from two different preference functions, are illustrated in [Fig. 3.2a, b](#). In each figure, just as in [Fig. 3.1](#), the indifference curves are generated by some underlying preference function defined over the probability distributions implied by each (x_1, x_2) pair under the well-defined state probabilities (\bar{p}_1, \bar{p}_2) —we refer to such preferences over (x_1, x_2) bundles as *probabilistically sophisticated*.

Expected utility and non-expected utility preference functions, and hence their respective indifference maps, have two features in common, and two important differences. Their first common feature is first-order stochastic dominance preference. This property is the stochastic analogue of “more money is better,” and makes just as much sense under non-expected utility as under expected utility. As we have seen, this translates into downward sloping indifference curves in the Hirshleifer–Yaari diagram, and is reflected in both [Fig. 3.2a, b](#).

⁴An alternative term for property (3.3) is *quasiconvexity in the outcomes*.

The second common feature is the “*MRS* at certainty = odds ratio” condition, as seen in Fig. 3.2a, b. The non-expected utility version of this property, namely, that any sufficiently “smooth” non-expected utility preference function $\mathcal{V}(\cdot)$ must satisfy

$$MRS_{\mathcal{V}}(x, x) \equiv - \left. \frac{\partial \mathcal{V}(x_1, \bar{p}_1; x_2, \bar{p}_2) / \partial x_1}{\partial \mathcal{V}(x_1, \bar{p}_1; x_2, \bar{p}_2) / \partial x_2} \right|_{x_1=x_2=x} = - \frac{\bar{p}_1}{\bar{p}_2} \quad (3.5)$$

follows from an early result of Samuelson (1960, pp. 34–37, eq. 5). Note that it implies that we can “recover” a non-expected utility (or expected utility) maximizer’s subjective *probabilities* from their indifference curves over state-indexed *outcomes* in the Hirshleifer–Yaari diagram.

The first of the two important *differences* between expected utility and non-expected utility should not come as a surprise. Any departure from the additively separable expected utility form (3.1) means that the so-called “rectangle property” on *MRS*’s will no longer hold. This is a well-known consequence of indifference curves over any kind of commodities, once we drop the assumption of separability of the preference function that generates them.

We come now to the second important difference between expected utility and non-expected utility indifference curves—the one that will play a very important role in our analysis. Note that while the non-expected utility indifference curves of Fig. 3.2a needn’t satisfy the rectangle property for *MRS*’s, they do satisfy both risk aversion⁵ and outcome-convexity—just like the expected utility indifference curves of Fig. 3.1. However, the non-expected utility indifference curves of Fig. 3.2b are risk averse but *not* outcome convex. In other words, in the absence of the expected utility hypothesis, *risk aversion is no longer equivalent to outcome-convexity*, and as Dekel (1989) has formally shown, it is quite possible for a preference function $\mathcal{V}(\cdot)$ (and hence its indifference curves) to be globally risk averse but not outcome convex.⁶

On the other hand, Dekel has shown that if a non-expected utility $\mathcal{V}(\cdot)$ is outcome convex then it must be risk averse. Although this is a formal result that applies to preferences over general probability distributions, the graphical intuition can be seen from Fig. 3.2a: Recall that non-expected utility indifference curves must be tangent to the iso-expected value lines. Thus, if they are also outcome-convex, they must be steeper than these lines above the 45° line and flatter than them below the 45° line, which is exactly the condition for risk aversion in the diagram.

Thus, in the absence of expected utility, risk aversion is seen to be a logically distinct—and weaker—property than outcome-convexity. This means that when dropping the expected utility hypothesis and examining the robustness of some insurance result that “only requires risk aversion,” we’ll have to determine whether it really was “only risk aversion” that had been driving the result in question, or whether it was risk aversion *plus* outcome-convexity that had been doing so.

Let’s now illustrate preferences over changes in the *probabilities*, for fixed outcome values. Specifically, pick any three values $\bar{x}_1 < \bar{x}_2 < \bar{x}_3$, and consider the set of all probability distributions of the form $(\bar{x}_1, p_1; \bar{x}_2, p_2; \bar{x}_3, p_3)$. Since we must have $p_2 = 1 - p_1 - p_3$, we can plot each of these distributions as a point (p_1, p_3) triangle, as in Fig. 3.3a, b. Once again, a family of *expected utility* indifference curves will consist of the level curves of some expected utility preference function $\mathcal{V}(\mathbf{P}) = U(\bar{x}_1) \cdot p_1 + U(\bar{x}_2) \cdot p_2 + U(\bar{x}_3) \cdot p_3$, which, after substituting for p_2 , takes the form

⁵As before, they satisfy risk aversion since they are steeper/flatter than the iso-expected value lines in the region above/below the 45° line, so mean-preserving increases in risk make them worse off.

⁶For an explicit example, based on the proof of Dekel’s Proposition 1, let $\mathcal{V}(\mathbf{P}) \equiv [\sum \sqrt{x_i} \cdot p_i - 5]^3 + 8 \cdot [\sum x_i \cdot p_i - 49]^3$. Since the cube function is strictly increasing over all positive *and negative* arguments, this preference function is strictly increasing in each x_i and satisfies strict first-order stochastic dominance preference. Since any mean-preserving spread lowers the first bracketed term yet preserves the second, $\mathcal{V}(\cdot)$ is also strictly risk averse. Calculation reveals that $\mathcal{V}(\$100, \frac{1}{2}; \$0, \frac{1}{2}) = \mathcal{V}(\$49, \frac{1}{2}; \$49, \frac{1}{2}) = 8$ but $\mathcal{V}(\$74.5, \frac{1}{2}; \$24.5, \frac{1}{2}) \approx 6.74$. But since the latter probability distribution is a 50:50 outcome mixture of the first two, $\mathcal{V}(\cdot)$ is not outcome convex.

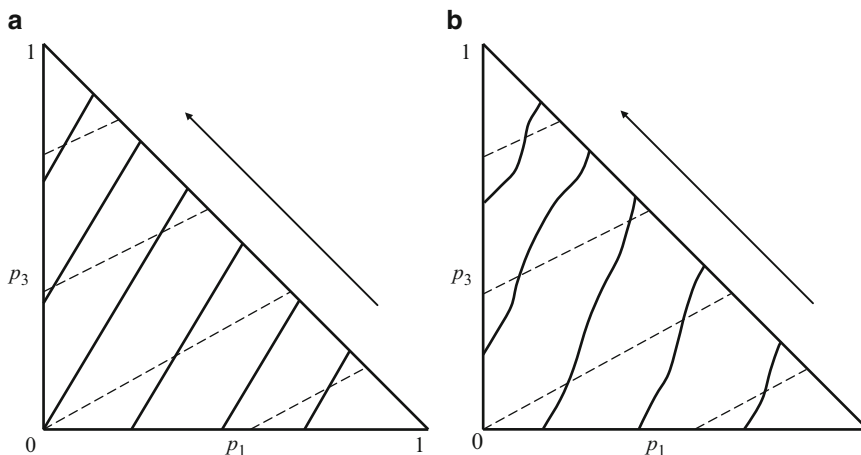


Fig. 3.3 (a) and (b) Risk averse indifference curves in the probability triangle diagram (expected utility and non-expected utility)

$$U(\bar{x}_2) + [U(\bar{x}_3) - U(\bar{x}_2)] \cdot p_3 - [U(\bar{x}_2) - U(\bar{x}_1)] \cdot p_1 \tag{3.6}$$

with *MRS* accordingly given by

$$MRS_{EU}(p_1, p_3) \equiv - \frac{U(\bar{x}_2) - U(\bar{x}_1)}{U(\bar{x}_3) - U(\bar{x}_2)} \tag{3.7}$$

and with the direction of increasing preference indicated by the arrows in the figures.

A family of *non-expected utility* indifference curves in the (p_1, p_3) diagram consists of the level curves of some general preference function $\mathcal{V}(\bar{x}_1, p_1; \bar{x}_2, p_2; \bar{x}_3, p_3)$, again subject to $p_2 = 1 - p_1 - p_3$. Substituting in to obtain the expression $\mathcal{V}(\bar{x}_1, p_1; \bar{x}_2, 1 - p_1 - p_3; \bar{x}_3, p_3)$ we have that the slope of these indifference curves at any point (p_1, p_3) is given by the formula

$$MRS_{\mathcal{V}}(p_1, p_3) \equiv - \left. \frac{\frac{\partial \mathcal{V}(\mathbf{P})}{\partial p_2} - \frac{\partial \mathcal{V}(\mathbf{P})}{\partial p_1}}{\frac{\partial \mathcal{V}(\mathbf{P})}{\partial p_3} - \frac{\partial \mathcal{V}(\mathbf{P})}{\partial p_2}} \right|_{\mathbf{P}=(\bar{x}_1, p_1, \bar{x}_2, 1-p_1-p_3; \bar{x}_3, p_3)} \tag{3.8}$$

Figure 3.3a highlights the single most significant feature of expected utility preferences, namely the property of “linearity in the probabilities.” As the level curves of a linear function (formula (3.1) or (3.6)), expected utility indifference curves in the probability diagram are parallel straight lines. This is the source of much of the predictive power of the expected utility model, since it implies that knowledge of the indifference curves in the neighborhood of any one point in the triangle implies knowledge of them over the whole triangle.

As we did for the Hirshleifer–Yaari diagram, we can also ask what the properties of first-order stochastic dominance preference and risk aversion look like in the probability triangle. A pure *northward* movement in the triangle implies a rise in p_3 , along (of course) with a matching drop in p_2 . This corresponds to shifting probability from the outcome \bar{x}_2 up to the higher outcome \bar{x}_3 . A *westward* movement implies a drop in p_1 with matching rise in p_2 . An exact (45°) *northwestward* movement implies a rise in p_3 with equal drop in p_1 (no change in p_2). All three of these movements shift probability mass from some lower outcome up to some higher outcome, and hence are stochastically

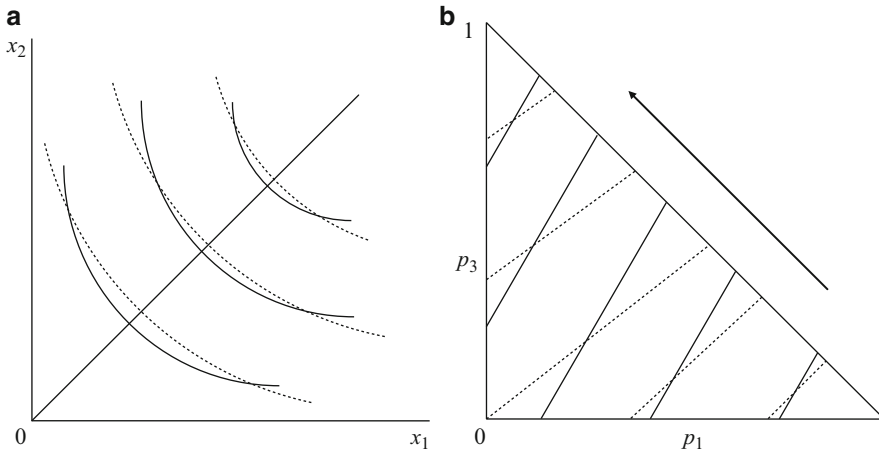


Fig. 3.4 (a) and (b) Comparative risk aversion for expected utility indifference curves

dominating shifts. Since the indifference curves in both Fig. 3.3a, b are upward sloping, they prefer such shifts, and hence, reflect first-order stochastic dominance preference.

The property of risk aversion is once again illustrated by reference to iso-expected value lines. In the probability triangle, they are the (dashed) level curves of the formula

$$\bar{x}_1 \cdot p_1 + \bar{x}_2 \cdot (1 - p_1 - p_3) + \bar{x}_3 \cdot p_3 = \bar{x}_2 + [\bar{x}_3 - \bar{x}_2] \cdot p_3 - [\bar{x}_2 - \bar{x}_1] \cdot p_1 \quad (3.9)$$

and hence have slope $[\bar{x}_2 - \bar{x}_1]/[\bar{x}_3 - \bar{x}_2]$. Northeast movements along these lines increase both of the outer (i.e., the “tail”) probabilities p_1 and p_3 at the expense of the middle probability p_2 , in a manner which does not change the expected value, so they represent the mean-preserving spreads in the triangle. Since the indifference curves in both Fig. 3.3a, b are steeper than these lines, they are made worse off by such increases in risk, and hence are risk averse.

Besides risk aversion *per se*, these diagrams can also illustrate *comparative risk aversion*—i.e., the property that one individual is *more risk averse* than another. Arrow (1965b) and Pratt (1964) have shown that the algebraic condition for comparative risk aversion under expected utility is that a pair of utility functions $U_1(\cdot)$ and $U_2(\cdot)$ satisfies the equivalent conditions:

$$U_1(x) \equiv \varphi(U_2(x)) \text{ for some increasing concave } \varphi(\cdot) \quad (3.10)$$

$$-\frac{U_1''(x)}{U_1'(x)} \geq -\frac{U_2''(x)}{U_2'(x)} \text{ for all } x \quad (3.11)$$

$$-\frac{U_1'(x^*)}{U_1'(x)} \leq \frac{U_2'(x^*)}{U_2'(x)} \text{ for all } x^* > x \quad (3.12)$$

Figure 3.4a, b illustrates the implications of these algebraic conditions for indifference curves in the Hirshleifer–Yaari and the triangle diagrams. The indifference curves of the more risk averse utility function $U_1(\cdot)$ are solid; those of $U_2(\cdot)$ are dotted. In the Hirshleifer–Yaari diagram, the *MRS* formula (3.2) and inequality (3.12) imply that the indifference curves of the more risk averse $U_1(\cdot)$ are flatter than those of $U_2(\cdot)$ below the 45° line, and steeper than them above it. In the triangle diagram, the *MRS* formula (3.7) and a bit of calculus applied to either (3.11) or (3.12) yield that the indifference curves of the more risk averse $U_1(\cdot)$ are steeper than those of $U_2(\cdot)$.

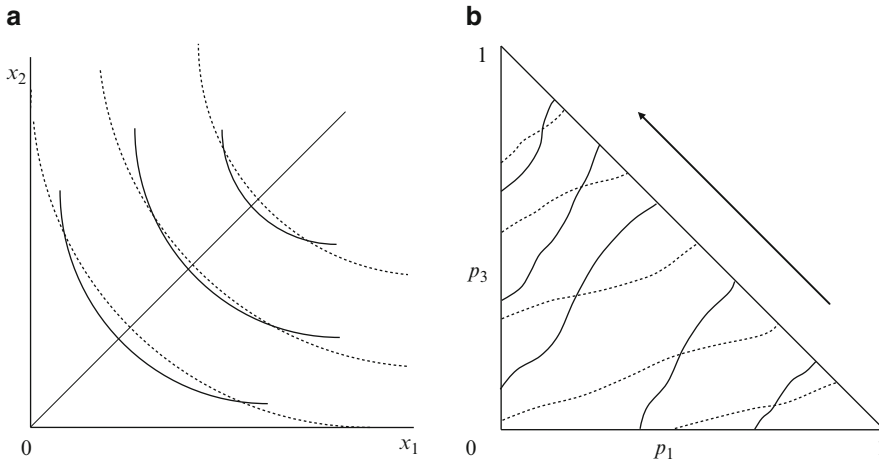


Fig. 3.5 (a) and (b) Comparative risk aversion for non-expected utility indifference curves

Comparing Fig. 3.4a, b with Figs. 3.1 and 3.3a reveals that in each case, the relative slope conditions for *comparative* risk aversion are simply a generalization of the slope conditions for risk aversion *per se*. This is such a natural result that we would want to adopt it for *non-expected utility* indifference curves as well. In other words, when we come to determine the *algebraic* condition for comparative risk aversion under non-expected utility, we would insist that it imply these same relative slope conditions on indifference curves as in Fig. 3.5a, b.

3.2.2 Algebraic Analysis of Non-expected Utility Preferences

What about algebraic analysis in the absence of expected utility? Consider how we might reassure our Cobb–Douglas scientist, puzzled at how we could drop the well-structured formula $c_1^{\alpha_1} \dots c_m^{\alpha_m}$ in favor of a shapeless general preference function $\mathcal{U}(c_1, \dots, c_m)$. We would say that we’d conduct our analysis in terms of the *derivatives* $\{\frac{\partial \mathcal{U}(\mathbf{C})}{\partial c_1}, \dots, \frac{\partial \mathcal{U}(\mathbf{C})}{\partial c_m}\}$ of such general functions and that conditions on these derivatives (including their ratios) give theorems about behavior.

One branch of non-expected utility theory—termed “generalized expected utility analysis”⁷—proceeds similarly, by working with derivatives of the preference function $\mathcal{V}(\cdot)$, and it is here that much of the robustness of expected utility analysis reveals itself. By way of motivation, recall some of the classical results of expected utility theory. For purposes of this exercise, assume that the set of potential outcome values $x_1 < \dots < x_n$ is fixed, so that only the probabilities $\{p_1, \dots, p_n\}$ are independent variables. Now, given an expected utility preference function $\mathcal{V}(\mathbf{P}) = \sum_{i=1}^n U(x_i)p_i$, don’t think of $U(x_i)$ in its psychological role as the “utility of receiving outcome x_i ,” but rather in its purely mathematical role as the *coefficient* of $p_i = \text{prob}(x_i)$. If we plot these probability coefficients against x_i , as in Fig. 3.6a, we can state the three most fundamental results of expected utility theory as follows:

First-Order Stochastic Dominance Preference: $\mathcal{V}(\cdot)$ exhibits first-order stochastic dominance preference if and only if its probability coefficients $\{U(x_1), \dots, U(x_n)\}$ form an increasing sequence, as in Fig. 3.6a.

⁷For example, Machina (1982,1983).

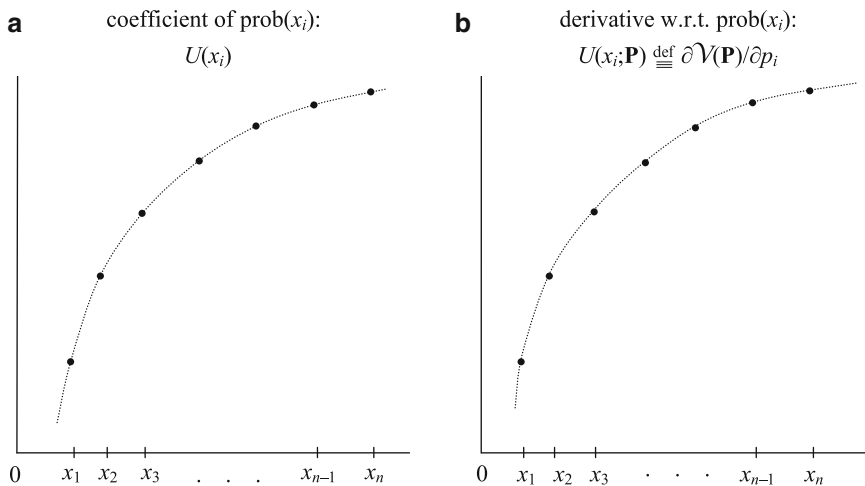


Fig. 3.6 (a) and (b) Expected utility probability coefficients and non-expected utility probability derivatives plotted against their corresponding outcome values

Risk Aversion: $\mathcal{V}(\cdot)$ is risk averse if and only if its probability coefficients $\{U(x_1), \dots, U(x_n)\}$ form a concave sequence,⁸ as in Fig. 3.6a.

Comparative Risk Aversion: $\mathcal{V}_1(\cdot)$ is at least as risk averse as $\mathcal{V}_2(\cdot)$ if and only if the sequence of probability coefficients $\{U_1(x_1), \dots, U_1(x_n)\}$ is at least as concave⁹ as the sequence of probability coefficients $\{U_2(x_1), \dots, U_2(x_n)\}$.

Now consider a general *non-expected utility preference function* $\mathcal{V}(\mathbf{P}) = \mathcal{V}(x_1, p_1; \dots; x_n, p_n)$, and continue to treat the outcomes $x_1 < \dots < x_n$ as fixed and the probabilities $\{p_1, \dots, p_n\}$ as the independent variables. Since $\mathcal{V}(\cdot)$ is not linear in the probabilities (not expected utility), it won't have probability coefficients. However, as long as $\mathcal{V}(\cdot)$ is differentiable, it will have a set of *probability derivatives* $\left\{ \frac{\partial \mathcal{V}(\mathbf{P})}{\partial p_1}, \dots, \frac{\partial \mathcal{V}(\mathbf{P})}{\partial p_n} \right\}$ at each distribution \mathbf{P} , and calculus tells us that in many cases, theorems based on the *coefficients of a linear function* will also apply to the *derivatives of a nonlinear function*.

In fact, this is precisely the case with the above three results, and this type of extension from probability coefficients to probability derivatives is the essence of generalized expected utility analysis. In other words, for any non-expected utility preference function $\mathcal{V}(\cdot)$, pick a distribution \mathbf{P} , and plot the corresponding sequence of probability derivatives $\left\{ \frac{\partial \mathcal{V}(\mathbf{P})}{\partial p_1}, \dots, \frac{\partial \mathcal{V}(\mathbf{P})}{\partial p_n} \right\}$ as in Fig. 3.6b. If these form an increasing sequence (as in the figure), then any *infinitesimal* stochastically dominating shift—say an infinitesimal drop in p_i and matching rise in p_{i+1} —will clearly be preferred. If the derivatives form a concave sequence (as in the figure), then any *infinitesimal* mean-preserving increase in risk—such as an infinitesimal drop in p_i coupled with a mean-preserving rise in p_{i-1} and p_{i+1} —will make the individual worse off.

Of course, these results are “local,” since they link the derivatives $\left\{ \frac{\partial \mathcal{V}(\mathbf{P})}{\partial p_1}, \dots, \frac{\partial \mathcal{V}(\mathbf{P})}{\partial p_n} \right\}$ at a distribution \mathbf{P} only to infinitesimal changes from \mathbf{P} . However, we can take advantage of another

⁸Algebraically, $\{U(x_1), \dots, U(x_n)\}$ forms a concave sequence if and only if its point-to-point slopes $(U(x_2) - U(x_1))/(x_2 - x_1)$, $(U(x_3) - U(x_2))/(x_3 - x_2)$, etc. are successively nonincreasing.

⁹ $\{U_1(x_1), \dots, U_1(x_n)\}$ is at least as concave than $\{U_2(x_1), \dots, U_2(x_n)\}$ if and only if each ratio of adjacent point-to-point slopes $[(U(x_{i+1}) - U(x_i))/(x_{i+1} - x_i)]/[(U(x_i) - U(x_{i-1}))/ (x_i - x_{i-1})]$ is no greater for $\{U_1(\cdot)\}$ than for $\{U_2(\cdot)\}$.

feature of calculus, namely, that *global* conditions on derivatives are frequently equivalent to *global* properties of a function. This is the case with our three fundamental results. Thus, if the derivatives $\{\frac{\partial \mathcal{V}(\mathbf{P})}{\partial p_1}, \dots, \frac{\partial \mathcal{V}(\mathbf{P})}{\partial p_n}\}$ are seen to form an increasing and concave sequence at *all* such distributions \mathbf{P} , then *global* stochastically dominating shifts will always be preferred, and *global* increase in risk will always make the individual worse off. Formally, we can prove:

First-Order Stochastic Dominance Preference: A non-expected utility preference function $\mathcal{V}(\cdot)$ exhibits global first-order stochastic dominance preference if and only if at each distribution \mathbf{P} , its probability derivatives $\{\frac{\partial \mathcal{V}(\mathbf{P})}{\partial p_i}\}$ form an increasing sequence, as in Fig. 3.6b.

Risk Aversion: $\mathcal{V}(\cdot)$ is globally averse to all (small and large) mean-preserving increases in risk if and only if at each \mathbf{P} its probability derivatives $\{\frac{\partial \mathcal{V}(\mathbf{P})}{\partial p_i}\}$ form a concave sequence, as in Fig. 3.6b.

Comparative Risk Aversion: $\mathcal{V}_1(\cdot)$ is globally at least as risk averse as¹⁰ $\mathcal{V}_2(\cdot)$ if and only if at each \mathbf{P} , the sequence of probability derivatives $\{\frac{\partial \mathcal{V}_1(\mathbf{P})}{\partial p_i}\}$ is at least as concave as the sequence of probability derivatives $\{\frac{\partial \mathcal{V}_2(\mathbf{P})}{\partial p_i}\}$

In light of this correspondence between expected utility's *probability coefficients* $\{U(x_i)\}$ and non-expected utility's *probability derivatives* $\{\frac{\partial \mathcal{V}(\mathbf{P})}{\partial p_i}\}$, we adopt the suggestive notation $U(x_i; \mathbf{P}) = \frac{\partial \mathcal{V}(\mathbf{P})}{\partial p_i}$, and call the family of partial derivatives $\{\frac{\partial \mathcal{V}(\mathbf{P})}{\partial p_1}, \dots, \frac{\partial \mathcal{V}(\mathbf{P})}{\partial p_n}\}$ the *local utility index* of $\mathcal{V}(\cdot)$ at \mathbf{P} .

An important point: Do we really have to restrict ourselves just to changes in the probabilities of the *original outcomes* $\{x_1, \dots, x_n\}$? No. At any distribution $\mathbf{P} = (x_1, p_1; \dots; x_n, p_n)$, we can define the local utility index $U(x; \mathbf{P})$ for any *other* outcome level x , by observing that

$$\mathbf{P} = (x_1, p_1; \dots; x_n, p_n) = (x_1, p_1; \dots; x_n, p_n; x, 0) \quad (3.13)$$

so that we can define

$$U(x; \mathbf{P}) \equiv \frac{\partial \mathcal{V}(\mathbf{P})}{\partial \text{prob}(x)} \equiv \left. \frac{\partial \mathcal{V}(x_1, p_1; \dots; x_n, p_n; x, \wp)}{\partial \wp} \right|_{\wp=0} \quad (3.14)$$

Thus, $U(\cdot; \mathbf{P})$ is really a local utility *function* over all outcome values x , and the isolated dots in Fig. 3.6b—like the isolated utility values in Fig. 3.6a—are really points on an entire *curve*. In this more complete setting, the non-expected utility conditions for first-order stochastic dominance preference, risk aversion, and comparative risk aversion are that at every \mathbf{P} , the function $U(x; \mathbf{P})$ must respectively be increasing in x , concave in x , and more concave in x —just like the conditions on $U(x)$ under expected utility theory. See Machina (1982, 1983, 1989), Allen (1987), Chew, Epstein and Zilcha (1988), Karni (1987, 1989) and Wang (1993) for additional extensions and applications of this kind of analysis.

Although the above suggests that the key to generalizing expected utility analysis is to think in terms of the *probability derivatives* of the preference function $\mathcal{V}(\mathbf{P}) = \mathcal{V}(x_1, p_1; \dots; x_n, p_n)$, it is clear that the analysis of insurance and risk sharing problems will involve its *outcome derivatives* as well. Fortunately, we can show that, as long as we continue to think of $U(x; \mathbf{P}) = \frac{\partial \mathcal{V}(\mathbf{P})}{\partial \text{prob}(x)}$ as the “local utility function,” the standard expected utility outcome derivative formula also generalizes to non-expected utility.¹¹ That is to say, if the local utility function $U(x; \mathbf{P}) = U(x; \mathbf{P}) = \frac{\partial \mathcal{V}(\mathbf{P})}{\partial \text{prob}(x)}$ is differentiable in x at every distribution \mathbf{P} , then

¹⁰For the appropriate definition of “at least as risk averse as” under non-expected utility, see Machina (1982, 1984).

¹¹This follows from applying Machina (1982, eq. 8) to the path $F(\cdot; \alpha) \equiv (x_1, p_1; \dots; x_{i-1}, p_{i-1}; \alpha, p_i; x_{i+1}, p_{i+1}; \dots; x_n, p_n)$.

$$\frac{\partial \mathcal{V}(\mathbf{P})}{\partial x_i} \equiv \frac{\partial \mathcal{V}(x_1, p_1; \dots; x_n, p_n)}{\partial x_i} \equiv \frac{\partial U(x_i; \mathbf{P})}{\partial x_i} \equiv U'(x_i; \mathbf{P}) \cdot p_i \quad (3.15)$$

This gives us an immediate generalization of the expected utility *MRS* formula for non-expected utility indifference curves, namely

$$MRS_{\mathcal{V}(x_1, x_2)} \equiv -\frac{\partial \mathcal{V}(x_1, \bar{p}_1; x_2, \bar{p}_2)/\partial x_1}{\partial \mathcal{V}(x_1, \bar{p}_1; x_2, \bar{p}_2)/\partial x_2} \equiv -\frac{U'(x_1; \mathbf{P}_{x_1, x_2}) \cdot \bar{p}_1}{U'(x_2; \mathbf{P}_{x_1, x_2}) \cdot \bar{p}_2} \quad (3.16)$$

where $\mathbf{P}_{x_1, x_2} = (x_1, p_1; x_2, p_2)$ is the probability distribution corresponding to the point (x_1, x_2) for fixed probabilities (p_1, p_2) . It also gives us a generalization of the “marginal expected utility” formula, namely

$$\left. \frac{d\mathcal{V}(x_1 + k, p_1; \dots; x_n + k, p_n)}{dk} \right|_{k=1} \equiv \sum_{i=1}^n U'(x_i; \mathbf{P}) \cdot p_i. \quad (3.17)$$

It should come as no surprise that formulas like (3.15), (3.16) and (3.17) will come in handy in checking the robustness of standard expected utility-based insurance theory.

A settling of accounts: If a non-expected utility preference function $\mathcal{V}_1(\cdot)$ is at least as risk averse as another one $\mathcal{V}_2(\cdot)$, so that at each \mathbf{P} its local utility function $U_1(\cdot; \mathbf{P})$ is at least as concave as $U_2(\cdot; \mathbf{P})$, then the Arrow–Pratt theorem and the *MRS* formula (3.16) directly imply the relative slope condition illustrated in Fig. 3.5a. Similarly, the Arrow–Pratt theorem, *MRS* formula (3.8), and a little calculus imply the relative slope condition illustrated in Fig. 3.5b. Just as required!¹²

3.3 Individual Demand for Insurance

The previous section presented a set of tools—graphical and algebraic—for representing and analyzing non-expected utility risk preferences. It also showed that the analysis of non-expected utility preferences is much closer to classical expected utility theory than one might have thought. We now turn toward applying these tools to examining the robustness of standard insurance theory¹³ in the absence of the expected utility hypothesis.

For most of this chapter, we shall assume that risk preferences—expected utility or otherwise—are differentiable both in the outcomes and in the probabilities.¹⁴ In addition, since the results of insurance theory also almost all depend upon the property of risk aversion, even under the expected utility hypothesis, we retain that assumption when undertaking our non-expected utility examination. But as noted above, since risk aversion under expected utility also means outcome-convexity, we could never be sure whether the result in question was really driven by risk aversion alone, or by outcome-convexity as well.¹⁵ Thus, when examining insurance theory in the *absence* of the expected utility

¹²In some of our more formal analysis below (including the formal theorems), we use the natural extension of these ideas to the case of a preference function $\mathcal{V}(F)$ over cumulative distribution functions $F(\cdot)$ with local utility function $U(\cdot; F)$, including the smoothness notion of “Fréchet differentiability” (see Machina 1982).

¹³The reader wishing self-contained treatments of the vast body of insurance results can do no better than the excellent survey by Dionne and Harrington (1992, pp.1–48) and volume by Eeckhoudt and Gollier (1995). For more extensive treatments of specific topics, see the rest of the chapters in Dionne and Harrington (1992), as well as Schlesinger (2013) and the other chapters in the present volume.

¹⁴We consider non-differentiabilities (“kinks”) in the outcomes and probabilities in Sects. 3.7 and 3.8.

¹⁵This point is nicely made by Karni (1992).

hypothesis, our “robustness check” could reveal each expected utility-based insurance result to be in one of the following categories:

- The result only requires the assumption of *risk aversion*, without either outcome-convexity or expected utility.
- The result requires *outcome-convexity* (and hence also *risk aversion*), but not expected utility.
- The result simply *doesn't hold at all* without the expected utility hypothesis.

Naturally, when checking any given result, the higher up its category in this listing, the nicer it would be for non-expected utility theorists. And since robustness is a virtue, the nicer it would be for standard insurance theorists as well.

In the following, we assume that the individual possesses an initial wealth level w and faces the prospect of a random loss \tilde{l} , with probability distribution $(l_1, p_1; \dots; l_n, p_n)$ (with each $l_i \leq 0$, and at least one $l_i = 0$). An insurance policy consists of an *indemnity function* $I(l)$ such that the individual receives payment $I(l)$ in the event of a loss of l , as well as a *premium* of π , which must be paid no matter what. Thus, the individual's random wealth upon taking a policy (or “contract”) $(I(\cdot), \pi)$ becomes¹⁶

$$w - \pi - \tilde{l} + I(\tilde{l}) \quad (3.18)$$

Of course, different forms of insurance involve different families $\{(I_\alpha(\cdot), \pi_\alpha)|\alpha \in A\}$ of indemnity functions $I_\alpha(\cdot)$ and their corresponding premiums, from which the individual may choose. In many cases, the premium for a given indemnity function $I(\cdot)$ takes the form $\pi = (1 + \lambda) \cdot E[I(\tilde{l})]$, where $\lambda \geq 0$ is a *loading factor*. The results of standard insurance theory involve both characterization theorems and comparative statics theorems concerning individual maximization, bilateral efficiency, and group efficiency using the above framework.

For notational simplicity, we shall frequently work directly with random variables, such as \tilde{l} or $w - \tilde{l}$, rather than with their probability distributions $(l_1, p_1; \dots; l_n, p_n)$ or $(w - l_1, p_1; \dots; w - l_n, p_n)$. In other words, given a random variable \tilde{x} with probability distribution $(x_1, p_1; \dots; x_n, p_n)$, we shall use the term $\mathcal{V}(\tilde{x})$ as shorthand for $\mathcal{V}(x_1, p_1; \dots; x_n, p_n)$. Thus, for example, $\mathcal{V}(w - \pi - \tilde{l} + I(\tilde{l}))$ denotes $\mathcal{V}(w - \pi - l_1 + I(l_1), p_1; \dots; w - \pi - l_n + I(l_n), p_n)$.

3.3.1 Demand for Coinsurance

The very simplest results in insurance theory involve individual demand for a level of *coinsurance*, given a fixed loading factor $\lambda \geq 0$. Formally, this setting consists of the set of policies $\{(I_\alpha(\cdot), \pi_\alpha)|\alpha \in [0, 1]\}$, with

$$\begin{aligned} \text{Indemnity function : } I_\alpha(l) &\equiv \alpha \cdot l \\ \text{Premium : } \pi_\alpha &= (1 + \lambda) \cdot \alpha \cdot E[\tilde{l}] \quad \text{for } \alpha \in [0, 1] \end{aligned} \quad (3.19)$$

In the expected utility framework, the individual's choice problem can therefore be written as

$$\begin{aligned} &\max_{\alpha \in [0, 1]} E[U(w - \alpha \cdot (1 + \lambda) \cdot E[\tilde{l}] - \tilde{l} + \alpha \cdot \tilde{l})] \\ \text{or} &\quad \max_{\alpha \in [0, 1]} E[U(w - (1 + \lambda) \cdot E[\tilde{l}] - (1 - \alpha) \cdot (\tilde{l} - (1 + \lambda) \cdot E[\tilde{l}]))] \end{aligned} \quad (3.20)$$

¹⁶The case when the individual faces additional “background risk” is considered in Sect. 3.9.

Denote the optimal choice in this problem by α^* . This setting was studied early on, in classic articles by Borch (1961), Mossin (1968), and Smith (1968). From the right side of (3.20) we see that a marginal change in insurance coverage adds/subtracts the random variable $(\tilde{l} - (1 + \lambda) \cdot E[\tilde{l}])$ to/from the individual's random wealth. Accordingly, we can term the random variable $(\tilde{l} - (1 + \lambda) \cdot E[\tilde{l}])$ the *marginal insurable risk variable*.

The most basic analytical results for coinsurance are:

CO.1 The first-order condition for an interior optimum—i.e., a *necessary* condition for an interior global maximum—is that the expectation of the marginal insurable risk variable times the marginal utility of wealth is zero:

$$E[(\tilde{l} - (1 + \lambda) \cdot E[\tilde{l}]) \cdot U'(w - \alpha \cdot (1 + \lambda) \cdot E[\tilde{l}] - \tilde{l} + \alpha \cdot \tilde{l})] = 0 \quad (3.21)$$

and under risk aversion, this is a *sufficient* condition for a global optimum.

CO.2 If the individual is risk averse, then full insurance will be demanded if and only if it is *actuarially fair*. In other words, $\alpha^* = 1$ if and only if $\lambda = 0$.

CO.3 If two risk averse individuals face the same choice problem except that the first is *at least as risk averse* as the second, then the first will demand at least as much insurance as the second. In other words, if $U_1(\cdot)$ is a concave transformation of $U_2(\cdot)$, then $\alpha_a^* \geq \alpha_b^*$.¹⁷

Results CO.2 and CO.3 can both be illustrated in the Hirshleifer–Yaari diagram.¹⁸ Consider Fig. 3.7a, where the original uninsured position, point A , lies off the 45° line, its corresponding full-insurance point would lie exactly on the 45° line, and the coinsurance “budget line” connects the two points. The value $\alpha \in [0, 1]$ corresponds to the position along the budget line from the uninsured point to the fully insured point. To see CO.2, note first that when insurance is actuarially fair, this budget corresponds to the (dashed) iso-expected value line emanating from A , and from risk aversion clearly implies that the optimal point on this line is its corresponding full-insurance point B . Next, note that when insurance is actuarially unfair, the budget line from A is now *flatter* than the iso-expected value lines, so it is no longer tangent to the indifference curve through the (new) full-insurance point C . This implies that the new optimal point, namely D , will involve less than full insurance. To see CO.3, consider Fig. 3.7b and recall from Fig. 3.4a (or Eqs. (3.2) and (3.12)) that for expected utility maximizers, the (solid) indifference curves of the more risk averse person must be flatter than the (dotted) indifference curves of the less risk averse one in the region below the 45° line. This fact, coupled with the outcome-convexity property of risk averse expected utility indifference curves, guarantees that, when both start from the same uninsured point A' , the more risk averse person will choose a greater level of coinsurance—point F rather than point E .

How about non-expected utility maximizers? In this case, the coinsurance problem becomes

$$\begin{aligned} & \max_{\alpha \in [0,1]} \mathcal{V}(w - \alpha \cdot (1 + \lambda) \cdot E[\tilde{l}] - \tilde{l} + \alpha \cdot \tilde{l}) \\ \text{or} & \max_{\alpha \in [0,1]} \mathcal{V}(w - (1 + \lambda) \cdot E[\tilde{l}] - (1 - \alpha) \cdot (\tilde{l} - (1 + \lambda) \cdot E[\tilde{l}])) \end{aligned} \quad (3.22)$$

for some general non-expected utility preference function $\mathcal{V}(\cdot)$. Do any of the above expected utility-based results still hold? And if so, do they require just risk aversion, or do they also need outcome-convexity?

¹⁷As demonstrated in Pratt (1964), further results which link increasing/decreasing absolute and/or relative risk aversion to changes in as an individual's wealth changes can be derived as corollaries of result CO.3.

¹⁸So can result CO.1, if one calculates the slope of the budget lines in Fig. 3.7a and b.

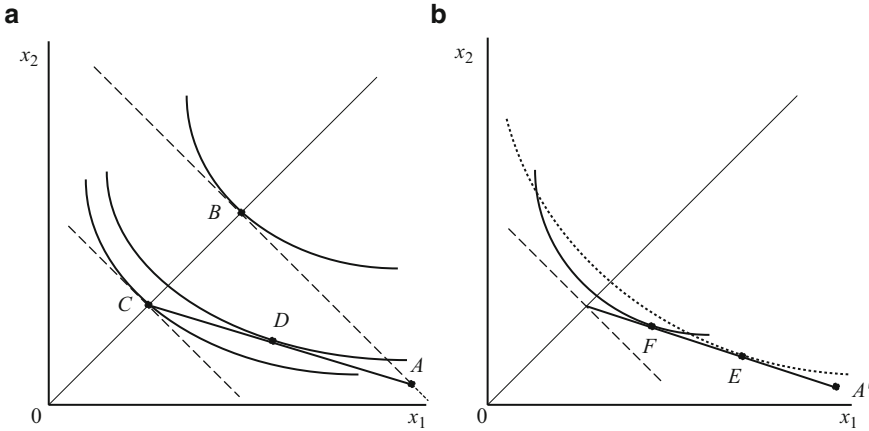


Fig. 3.7 (a) and (b) Optimal coinsurance and effect of greater risk aversion on coinsurance for risk averse expected utility preferences

To examine the robustness of CO.1, write (3.22) as

$$\max_{\alpha \in [0,1]} \mathcal{V}(w - \alpha \cdot (1 + \lambda) \cdot E[\tilde{l}] - l_1 + \alpha \cdot l_1, p_1; \dots; w - \alpha \cdot (1 + \lambda) \cdot E[\tilde{l}] - l_n + \alpha \cdot l_n, p_n) \quad (3.23)$$

Formula (3.15) allows us to differentiate with respect to α to get the non-expected utility first-order condition

$$\begin{aligned} & \frac{d\mathcal{V}(w - \alpha \cdot (1 + \lambda) \cdot E[\tilde{l}] - l_1 + \alpha \cdot l_1, p_1; \dots; w - \alpha \cdot (1 + \lambda) \cdot E[\tilde{l}] - l_n + \alpha \cdot l_n, p_n)}{d\alpha} \\ &= \sum_{i=1}^n (l_i - (1 + \lambda) \cdot E[\tilde{l}]) \cdot U'(w - \alpha \cdot (1 + \lambda) \cdot E[\tilde{l}] - l_i + \alpha \cdot l_i; \mathbf{P}_\alpha) \cdot p_i \\ &= E \left[(\tilde{l} - (1 + \lambda) \cdot E[\tilde{l}]) \cdot U'(w - \alpha \cdot (1 + \lambda) \cdot E[\tilde{l}] - \tilde{l} + \alpha \cdot \tilde{l}; \mathbf{P}_\alpha) \right] = 0 \end{aligned} \quad (3.24)$$

where \mathbf{P}_α denotes the wealth distribution $w - \alpha \cdot (1 + \lambda) \cdot E[\tilde{l}] - \tilde{l} + \alpha \cdot \tilde{l}$ arising from the purchase of α coinsurance. This is precisely the analogue of the expected utility first-order condition (3.21) with the von Neumann–Morgenstern utility function $U(\cdot)$ replaced by the *local* utility function $U(\cdot; \mathbf{P}_\alpha)$ at the wealth distribution \mathbf{P}_α ¹⁹ where

$$\mathbf{P}_\alpha = w - \alpha \cdot \lambda \cdot E[\tilde{l}] - \tilde{l} + \alpha \cdot \tilde{l} \quad (3.25)$$

Note that the *necessity* of condition (3.24) does not even require risk aversion, just differentiability. However, it should be clear from the Hirshleifer–Yaari diagram that it will only be *sufficient* under full outcome-convexity. Otherwise, an indifference curve could be tangent to the budget line from *below*, and the point of tangency would be a (local or global) minimum.

Extending result CO.2 to the non-expected utility case is straightforward, and doesn't require outcome-convexity at all. When insurance is actuarially fair ($\lambda = 0$), we have that for any $\alpha < 1$, the random wealth

¹⁹This close correspondence of expected utility and non-expected utility first-order conditions will come as no surprise to those who have read [Chew, Epstein and Zilcha \(1988\)](#), and will appear again.

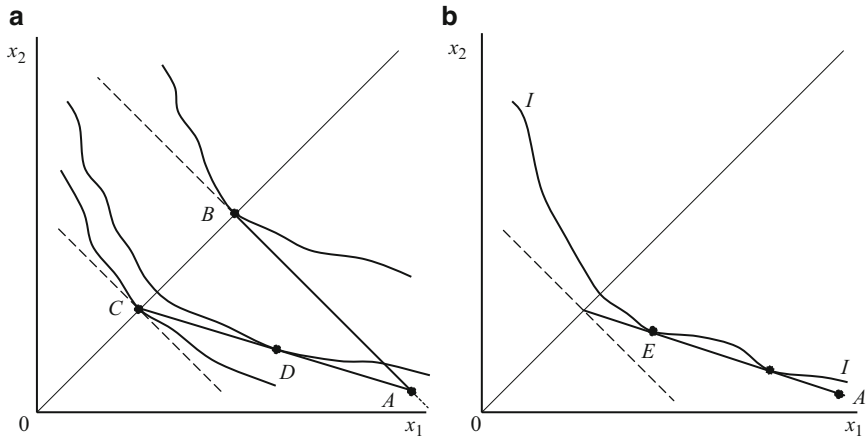


Fig. 3.8 (a) and (b) Optimal coinsurance and effect of freater risk aversion on coinsurance for non-expected utility preferences that are risk averse but not outcome convex

$$w - \alpha \cdot E[\tilde{l}] - \tilde{l} + \alpha \cdot \tilde{l} \equiv w - E[\tilde{l}] - (1 - \alpha) \cdot (\tilde{l} - E[\tilde{l}]) \tag{3.26}$$

differs from the full-insurance ($\alpha = 1$) wealth of $w - E[\tilde{l}]$ by the addition of a zero-mean random variable. Accordingly, risk aversion alone implies that when coinsurance is actuarially fair, full coverage is optimal. Similarly, when insurance is unfair ($\lambda > 0$), we have that

$$\begin{aligned} \frac{d\mathcal{V}(w - \alpha \cdot \lambda \cdot E[\tilde{l}] - \tilde{l} + \alpha \cdot \tilde{l})}{d\alpha} \Big|_{\alpha=1} &= E[(\tilde{l} - \lambda \cdot E[\tilde{l}]) \cdot U'(w - \lambda \cdot E[\tilde{l}]; \mathbf{P}_1)] \\ &= (1 - \lambda) \cdot E[\tilde{l}] \cdot U'(w - \lambda \cdot E[\tilde{l}]; \mathbf{P}_1) < 0, \end{aligned} \tag{3.27}$$

where \mathbf{P}_1 is the degenerate distribution of the full-insurance wealth level $w - (1 + \lambda) \cdot E[\tilde{l}]$.²⁰ Thus, there will be values $\alpha < 1$ that are strictly preferred to the full-insurance position $\alpha = 1$. This is all illustrated in Fig. 3.8a, where indifference curves are risk averse but not outcome convex.²¹

It would seem that *if any* coinsurance result depended crucially on the assumption of outcome-convexity, it would be result CO.3, which links greater risk aversion to greater coinsurance. This type of global comparative statics theorem is precisely the type of result we would expect to depend upon the proper curvature of indifference curves, and a glance at Fig. 3.7b would seem to reinforce this view. However, one of the most important points of this chapter, which will appear a few times, is that even for a result like this, outcome-convexity is not needed.

²⁰We consider the nondifferentiable case in Section 8 below.

²¹A *NOTE ON BELIEFS*: Although CO.2 accordingly survives dropping the assumption of expected utility *risk preferences*, it *does not* survive dropping the assumption that the individual’s subjective probabilities *exactly match* those of the “market,” that is, the probabilities by which an insurance policy is judged to be actuarially fair or unfair. If—for reasons of moral hazard, adverse selection, or simply personal history—the individual assigns a higher probability to state 2 than does the market, then the indifference curves in Fig. 3.7a will be flatter than and *cut* the dashed lines at all certainty points, and an individual with a smooth (differentiable) $U(\cdot)$ may well select point C on an actuarially unfair budget line like $A-C$. How far must beliefs diverge for this to happen? Consider earthquake insurance priced on the basis of an actuarial probability of .0008 and a loading factor of 25%. Every smooth risk averter with a subjective probability greater than .001 will buy full insurance.

The essence of this argument can be gleaned from Fig. 3.8b. Recall that if preferences are risk averse but not outcome convex, then there is the possibility of multiple global optima, as with the indifference curve in the figure. However, the essence of the comparative statics result CO.3 is *not* that each individual must have a unique solution, but that the less risk averse individual must *always* buy less insurance than the more risk averse individual.

To see that this still holds under non-expected utility, recall (from (3.16) or Fig. 3.5a) that the non-expected utility condition for comparative risk aversion is that at each point below the 45° line, the indifference curves of the more risk averse person are flatter than those of the less risk averse person. This means that any southeast movement along one of the *less* risk averse person's indifference curves must *lower* the preference function of the *more* risk averse person.

Now, to see that *every* optimum of the less risk averse person involves less insurance than *every* optimum of the more risk averse person, consider point E in Fig. 3.8b, which is that optimum for the less risk averse person that involves the *most* insurance for them, and consider their indifference curve through E (call it $I-I$). Of course, $I-I$ must lie everywhere on or above the insurance budget line. By the previous paragraph, any *more risk averse* person would prefer E to each point on $I-I$ lying southeast of E , and hence (by the previous sentence) prefer E to every point on the *budget line* lying southeast of E . This then establishes that the *very least* amount of coinsurance this more risk averse person would buy is at E . If the more risk averse person is in fact *strictly* more risk averse, the two persons' indifference curves cannot *both* be tangent to the budget line at E . Rather, the indifference curve of the more risk averse person will be flatter at that point, which implies that the *least* insurance they would ever buy is strictly more than the *most* insurance that the less risk averse person would ever buy (namely, E). Risk aversion (and comparative risk aversion) alone ensures this result, and outcome-convexity is not needed at all.²²

A formal algebraic statement of this result, which includes general probability distributions and allows for a corner solution (at zero insurance), is:

Theorem 1. *Let $w_0 > 0$ be base wealth, $\tilde{l} \geq 0$ a random loss, and $\lambda > 0$ a loading factor, such that $w_0 - \tilde{l}$ and $w_0 - (1 + \lambda) \cdot E[\tilde{l}]$ are both nonnegative. Assume that the non-expected utility preference functions $\mathcal{V}_1(\cdot)$ and $\mathcal{V}_2(\cdot)$ are twice continuously Fréchet differentiable (see Note 12), strictly risk averse, and that $\mathcal{V}_1(\cdot)$ is strictly more risk averse than $\mathcal{V}_2(\cdot)$ in the sense that $-U_1''(x; F)/U_1'(x; F) > -U_2''(x; F)/U_2'(x; F)$ for all x and $F(\cdot)$. Consider the problem:*

$$\max_{\alpha \in [0,1]} \mathcal{V}_i(w_0 - \alpha \cdot (1 + \lambda) \cdot E[\tilde{l}] - \tilde{l} + \alpha \cdot \tilde{l}) \quad i = 1, 2 \quad (3.28)$$

If α_1^ is the smallest solution to this problem for $\mathcal{V}_1(\cdot)$, and α_2^* is the largest solution for $\mathcal{V}_2(\cdot)$, then $\alpha_1^* \geq \alpha_2^*$, with strict inequality unless $\alpha_1^* = 0$. Proof in Appendix.*

In other words, regardless of the possible multiplicity of optima due to non-outcome-convexity, we will never observe the more risk averse first individual purchasing a smaller amount of insurance than the second individual, and the only time they would ever purchase the same amount is if the terms are so unattractive that zero insurance is an optimum even for the first individual, in which case it is the *only* optimum for the second individual.

²²Readers will recognize this argument (and its formalization in the proofs of the theorems) as an application of the well-known "single-crossing property" argument from incentive theory, as in Mirrlees (1971), Spence (1974), and Guesnerie and Laffont (1984), and generalized and extended by Milgrom and Shannon (1994).

To sum up our robustness check on coinsurance: except for the additional status of the necessary condition (3.21) as a sufficient condition as well (which also requires outcome-convexity), *all three* of the coinsurance results CO.1, CO.2, and CO.3 generalize to non-expected utility preferences under the assumption of simple risk aversion alone. In other words, at least at this most basic level, the standard theory of demand for coinsurance is very robust.

3.3.1.1 Demand for Deductible Insurance

A second type of insurance contract, distinct from the coinsurance contract considered above, is *deductible* insurance. Given a fixed actuarial loading factor $\lambda \geq 0$, this setting consists of the set of contracts $\{(I_\alpha(\cdot), \pi_\alpha) | \alpha \in [0, M]\}$, where l is the deductible limit, M is the largest possible value of the loss l , and

$$\begin{aligned} \text{Indemnity function : } I_\alpha(l) &\equiv \max\{l - \alpha, 0\} \\ \text{Premium : } \pi_\alpha &= (1 + \lambda) \cdot E[I_\alpha(\tilde{l})] \quad \text{for } \alpha \in [0, M] \end{aligned} \quad (3.29)$$

In the expected utility framework, the individual's choice problem can therefore be written as

$$\begin{aligned} &\max_{\alpha \in [0, M]} E[U(w - (1 + \lambda) \cdot E[I_\alpha(\tilde{l})] - \tilde{l} + \max\{\tilde{l} - \alpha, 0\})] \\ \text{or } &\max_{\alpha \in [0, M]} E[U(w - (1 + \lambda) \cdot E[\max\{\tilde{l} - \alpha, 0\}] - \min\{\tilde{l}, \alpha\})] \end{aligned} \quad (3.30)$$

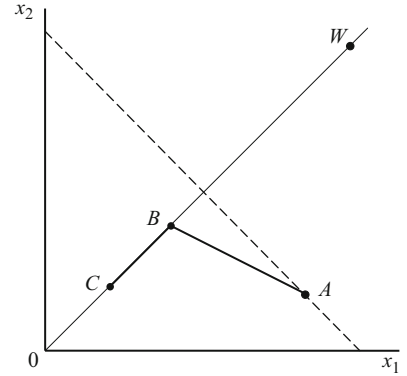
Denote the optimal choice by α^* . This problem has been studied by, among others, Mossin (1968), Gould (1969), Pashigian, Schkade, and Menefee (1966), Moffet (1977), Schlesinger (1981), Drèze (1981), Karni (1983, 1985), and Eeckhoudt, Gollier, and Schlesinger (1991).

The insurance budget line for this problem in the case of two states is illustrated in Fig. 3.9. Given an initial (pre-loss) wealth point $W = (w, w)$, the uninsured point A reflects a small loss l_1 in state 1 and a larger loss l_2 in state 2. The thick line in the figure represents the kinked insurance budget line when insurance is actuarially unfair (the actuarially fair line would be the dashed iso-expected value line through A). Starting at the deductible level $\alpha = l_2$ (i.e., no insurance) each unit drop in α lowers wealth in state 1 by the premium $(1 + \lambda) \cdot \bar{p}_2$, and raises wealth in state 2 by $1 - (1 + \lambda) \cdot \bar{p}_2$, while lowering the overall expected value of wealth. This generates a linear budget line from point A to the certainty line at point B , where wealth has dropped by $(l_2 l_1)$ (so now $\alpha = l_1$), and the individual's wealth is equal to $w - l_1(1 + \lambda) \cdot \bar{p}_2(l_2 l_1)$ in each state. Note that while a *still smaller* deductible $\alpha < l_1$ is possible, this is basically further insuring what is now a sure prospect, and doing so at actuarially unfair rates, so it would move the individual *down* the 45° line. In the limit, when $\alpha = 0$, wealth in each state would be $w - (1 + \lambda) \cdot (\bar{p}_1 \cdot l_1 + \bar{p}_2 \cdot l_2)$ (i.e., point C).

The point of presenting Fig. 3.9 is to show that, *for the two-state case*, the budget line for deductible insurance (at least the relevant part $A-B$) is so similar to the budget line for coinsurance that all of the graphical intuition obtained from Figs. 3.7a,b and 3.8a,b concerning coinsurance will carry over to Fig. 3.9 and to deductible insurance. But given the fact that most of the “action” of the deductible problem (3.30) occurs in the case of a *multitude* (or continuum) of states, we do not repeat the graphical analyses of Figs. 3.7a,b and 3.8a,b here.

Rather, we proceed directly to our algebraic robustness check. To avoid the types of “kinks” that occur as α crosses the value of some discrete (i.e., positive probability) loss value l_i , we assume that the random variable \tilde{l} has a sufficiently smooth cumulative distribution function $F(\cdot)$ with support $[0, M]$. We consider the corresponding basic results for deductible insurance:

Fig. 3.9 Insurance budget line for deductible insurance



DE.1 The first-order condition for an interior optimum (i.e., the *necessary* condition for an interior global maximum) is:

$$E[(1 + \lambda) \cdot (1 - F(\alpha)) - \text{sgn}(\max\{\tilde{l} - \alpha, 0\})] \cdot U'(w - (1 + \lambda) \cdot E[\max\{\tilde{l} - \alpha, 0\}] - \min\{\tilde{l}, \alpha\}) = 0 \quad (3.31)$$

where $\text{sgn}(z) = +1/0/-1$ as $z > / = / < 0$.²³

DE.2 If the individual is risk averse, then full insurance will be demanded if and only if it is *actuarially fair*. In other words, $\alpha^* = 0$ if and only if $\lambda = 0$.

DE.3 If two risk averse individuals face the same choice problem except that the first is *at least as risk averse* as the second, then the first will demand at least as much insurance as (i.e., have a lower deductible than) the second. In other words, if $U_1(\cdot)$ is a concave transformation of $U_2(\cdot)$, then $\alpha_1^* \leq \alpha_2^*$.²⁴

The non-expected utility version of the deductible problem (3.30) is

$$\begin{aligned} & \max_{\alpha \in [0, M]} \mathcal{V}(w - (1 + \lambda) \cdot E[I_\alpha(\tilde{l})] - \tilde{l} + \max\{\tilde{l} - \alpha, 0\}) \\ \text{or} & \max_{\alpha \in [0, M]} \mathcal{V}(w - (1 + \lambda) \cdot E[\max\{\tilde{l} - \alpha, 0\}] - \min\{\tilde{l}, \alpha\}) \end{aligned} \quad (3.32)$$

Formula (3.15) allows us to differentiate these objective functions with respect to α , to get the non-expected utility first-order condition:

$$\int_0^M [(1 + \lambda) \cdot (1 - F(\alpha)) - \text{sgn}(\max\{\tilde{l} - \alpha, 0\})] \cdot U'(w - (1 + \lambda) \cdot E[\max\{\tilde{l} - \alpha, 0\}] - \min\{\tilde{l}, \alpha\}; F_\alpha) \cdot dF(l) = 0 \quad (3.33)$$

where $F_\alpha(\cdot)$ is the distribution of the random variable $w - (1 + \lambda) \cdot E[\max\{\tilde{l} - \alpha, 0\}] - \min\{\tilde{l}, \alpha\}$. This is once again seen to be equivalent to the expected utility first-order condition (3.31), with the von Neumann–Morgenstern utility function $U(\cdot)$ replaced by the *local* utility function $U(\cdot; F_\alpha)$ at the distribution $F_\alpha(\cdot)$ implied by the optimal choice. Thus, DE.1 generalizes to non-expected utility.

²³Thus, $\text{sgn}(\max\{\tilde{l} - \alpha, 0\})$, equals 1 when $l >$ and equals 0 when $l \leq \alpha$.

²⁴This was shown by Schlesinger (1981) and Karni (1983).

The “if” part of result DE.2, namely full insurance under actuarial fairness, follows immediately from risk aversion without outcome-convexity, just as it did in the case of coinsurance. To see that the “only if” part does not require outcome-convexity either, consider the case $\lambda > 0$ and evaluate the left-hand side of (3.33) at the full-insurance point $\alpha = 0$, to obtain

$$\left. \frac{d\mathcal{V}(w - (1 + \lambda) \cdot E[\max\{\tilde{l} - \alpha, 0\}] - \min\{\tilde{l}, \alpha\})}{d\alpha} \right|_{\alpha=0} = \lambda \cdot U'(w - (1 + \lambda) \cdot E[\tilde{l}]; F_0) > 0 \quad (3.34)$$

where $F_0(\cdot)$ is the degenerate distribution of the full-insurance wealth level $w - (1 + \lambda) \cdot E[\tilde{l}]$. Thus, in this case there will be values $\alpha > 1$ which are strictly preferred to the full-insurance level $\alpha = 0$.

Finally, we turn to the comparative statics result DE.3: As it turns out, the argument behind Fig. 3.8b and Theorem 1 applies to the case of deductible insurance as well:

Theorem 2. *Let $w_0 > 0$ be base wealth, let \tilde{l} be a random loss with support $[0, M]$ ($M < w_0$) and continuous cumulative distribution function $F_i(\cdot)$, and let $\lambda > 0$ be a loading factor. Assume that the non-expected utility preference functions $\mathcal{V}_1(\cdot)$ and $\mathcal{V}_2(\cdot)$ are twice continuously Fréchet differentiable, strictly risk averse, and that $\mathcal{V}_1(\cdot)$ is strictly more risk averse than $\mathcal{V}_2(\cdot)$ in the sense that $U_1''(x; F)/U_1'(x; F) > U_2''(x; F)/U_2'(x; F)$ for all x and $F(\cdot)$. Consider the problem:*

$$\max_{\alpha \in [0, M]} \mathcal{V}_i(w_0 - (1 + \lambda) \cdot E[\max\{\tilde{l} - \alpha, 0\}] - \tilde{l} + \max\{\tilde{l} - \alpha, 0\}) \quad i = 1, 2 \quad (3.35)$$

If α_1^ is the largest solution to this problem for $\mathcal{V}_1(\cdot)$, and α_2^* is the smallest solution for $\mathcal{V}_2(\cdot)$, then $\alpha_1^* \leq \alpha_2^*$, with strict inequality unless $\alpha_1^* = M$. Proof in Appendix.*

That is, regardless of the possible multiplicity of optima due to non-outcome-convexity, we will never observe the more risk averse first individual choosing a higher level of deductible (i.e., less insurance) than the second, and the only time they would choose the same level is if the terms are so unattractive that no insurance ($\alpha = M$) is an optimum even for the first individual, in which case it is the *only* optimum for the second. In a similar vein, Karni (1992) has shown that without expected utility, but with outcome-convexity, one individual’s optimal level of deductible for a conditional risk is greater than another’s *if and only if* the former is more risk averse.

Perhaps surprisingly, or perhaps not, our robustness findings for at least the most basic aspects of deductible insurance parallel those of coinsurance.

3.4 Pareto-Efficient Bilateral Insurance Contracts

The results of the previous section have examined the customer’s optimal *amount* of insurance, taking the form of the insurance contract (either coinsurance or deductible) as given. However, an important set of results in insurance theory attempts to determine the optimal (i.e., Pareto- efficient) *form* of insurance contract, given the nature of the insurer’s costs and risk preferences. Will these results be robust to dropping the expected utility hypothesis?

The basic theorems on Pareto-efficient bilateral insurance contracts concern the case where the insurer possesses an increasing cost function $C(I)$ for indemnity payments $I \geq 0$. These costs include the indemnity payment itself plus any additional processing or transactions costs. In the expected utility case, a Pareto-efficient contract $(I(\cdot), \pi)$ can be represented as the solution to:

$$\max_{I(\cdot), \pi} E[U_1(w_1 - \pi - \tilde{l} + I(\tilde{l}))] \quad \text{s.t. : } \begin{cases} E[U_2(w_2 + \pi - C(I(\tilde{l}))) = U_2(w_2) \\ 0 \leq I(l) \leq l \end{cases} \quad (3.36)$$

where $U_1(\cdot)$ is the concave utility function of the *insured*, $U_2(\cdot)$ is the utility function of the *insurer*, and w_1 and w_2 are their respective initial wealth levels. The loss variable \tilde{l} is assumed to have a continuous cumulative distribution function $F(\cdot)$ over some interval $[0, M]$.

Arrow (1971)²⁵ considered the simplest case where the cost function takes the linear form $C(I)(1 + \lambda) \cdot I$ (for $\lambda > 0$), and the insurer is risk neutral. Under these assumptions, the upper constraint in (3.36) directly implies the standard loading formula

$$\pi = (1 + \lambda) \cdot E[I(\tilde{l})] \quad (3.37)$$

and Arrow showed that the Pareto-efficient indemnity function $I(\cdot)$ must take the deductible form

$$I(l) \equiv \min \{l - \alpha, 0\}. \quad (3.38)$$

Needless to say, this forms an important justification for studying the individual's demand for insurance under the deductible structure, as we did in Sect. 3.3.1.1.

This result has been extended in a few directions by Raviv (1979), so that we can now consider the set of expected utility-based results:

- PE.1 Given risk neutrality of the insurer and a linear cost function (with $\lambda > 0$), the Pareto-efficient bilateral insurance contract must take the deductible form (3.38), for a positive deductible .
- PE.2 Given strict *risk aversion* of the insurer and a linear cost function (with 0), the Pareto-efficient bilateral insurance contract must take the form of coinsurance above a nonnegative deductible , i.e.,

$$\begin{aligned} I(l) &= 0 & \text{for } l \leq \alpha \\ 0 < I(l) < l & \text{for } l > \alpha \\ 0 < I'(l) < 1 & \text{for } l > \alpha \end{aligned} \quad (3.39)$$

- PE.3 Given risk neutrality of the insurer and a strictly *convex* cost function $C(\cdot)$ (i.e., $C''(\cdot) > 0$), the Pareto-efficient bilateral insurance contract must again take the form of coinsurance above a deductible, as in (3.39), where the deductible is strictly positive.

Just as Arrow's original result (our PE.1) gave a justification for the study of deductibles, the results PE.2 and PE.3 provide a justification for the study of the demand for coinsurance as we undertook in Sect. 3.3.1.²⁶

Do these results extend to non-expected utility maximizers, and if so, is risk aversion sufficient to obtain them, or do we also need to assume outcome-convexity? Under non-expected utility, the Pareto-efficient contracts are characterized by the solutions to

$$\max_{I(\cdot), \pi} \mathcal{V}_1(w_1 - \pi - \tilde{l} + (I(\tilde{l}))) \quad \text{s.t.} : \begin{cases} \mathcal{V}_2(w_2 + \pi - C(I(\tilde{l}))) = \mathcal{V}_2(w_2) \\ 0 \leq I(l) \leq l \end{cases} \quad (3.40)$$

Concerning PE.1, note that under its assumptions, the standard loading formula (3.37) continues to follow from the constraint in (3.40). In such a case, Karni (1992) has proven that, given differentiability of $\mathcal{V}_1(\cdot)$, risk aversion alone ensures that any Pareto-efficient insurance contract must continue to take the pure deductible form (3.38). Gollier and Schlesinger (1996) and Vergnaud (1997)

²⁵See also Arrow (1974), Blazenko (1985), Gollier (1987), and Marshall (1992), and the survey by Gollier (1992, Sect. 2).

²⁶Note, however, that derivative $I'(l)$ in PE.2 or PE.3 need not be constant, but as Raviv (1979, pp. 90,91) has shown, depends upon each party's levels of risk aversion, as well as marginal indemnity cost $C'(I)$.

have also provided proofs of PE.1 based solely on first- and second-order stochastic dominance preference, and hence similarly independent of the expected utility hypothesis.

The robustness of PE.2 and PE.3 to non-expected utility can be demonstrated by using the same type of proof that Karni used to generalize PE.1. We present an informal sketch here. Let $(I^*(\cdot), \pi^*)$ be a Pareto-efficient insurance contract between $\mathcal{V}_1(\cdot)$ (which is risk averse) and $\mathcal{V}_2(\cdot)$, under the assumptions of either PE.2 or PE.3.²⁷ In such a case, no joint differential change²⁸ $(dI(\cdot), d\pi)$ from $(I^*(\cdot), \pi^*)$ that continues to satisfy the conditions $\mathcal{V}_2(w_2 + \pi - C(I(\tilde{l}))) = \mathcal{V}_2(w_2)$ and $0 \leq I(l) \leq l$ should be able to raise the value of $\mathcal{V}_1(w_1 - \pi - \tilde{l} + I(l))$. However, from the cumulative distribution function version of (3.15), the effect of any such differential change $(dI(\cdot), d\pi)$ from $(I^*(\cdot), \pi^*)$ upon the value of $\mathcal{V}_1(w_1 - \pi - \tilde{l} + I(l))$ is given by the expression

$$\int_0^M U'_1(w_1 - \pi^* - l + I^*(l)); F_{w_1 - \pi^* - \tilde{l} + I^*(\tilde{l})} \cdot [dI(l) - d\pi] \cdot dF_{\tilde{l}}(l) \quad (3.41)$$

and similarly, the effect of any differential change $(dI(\cdot), d\pi)$ from $(I^*(\cdot), \pi^*)$ upon the value of $\mathcal{V}_2(w_2 + \pi - C(I(\tilde{l})))$ is given by

$$\int_0^M U'_2(w_2 + \pi^* - C(I^*(l)); F_{w_2 + \pi^* - C(I^*(\tilde{l}))} \cdot [d\pi - C'(I^*(l)) \cdot dI(l)] \cdot dF_{\tilde{l}}(l). \quad (3.42)$$

Thus, any solution $(I^*(\cdot), \pi^*)$ to (3.40) must satisfy the following property:

“No differential change $(dI(\cdot), d\pi)$ that makes (3.42) equal to zero can make (3.41) positive.” However, this is precisely the statement that the contract $(I^*(\cdot), \pi^*)$ satisfies the first-order conditions for the *expected utility* problem (3.36), for the fixed von Neumann–Morgenstern utility functions $U_1(\cdot) = U_1(\cdot; F_{w_1 - \pi^* + I^*(\tilde{l})})$ (which is concave) and $U_2(\cdot) = U_2(\cdot; F_{w_2 - \pi^* + I^*(\tilde{l})})$ (which under PE.2 is also concave), and we know from the expected utility versions of PE.2 and PE.3 that any pair $(I(\cdot), \pi)$ that satisfies these first-order conditions, including therefore the pair $(I^*(\cdot), \pi^*)$, must satisfy the “coinsurance above a deductible” condition (3.39). Furthermore, under the assumptions of PE.3, they must satisfy the additional property that the deductible is positive. Note that, like Karni, we needed to assume risk aversion of $\mathcal{V}_1(\cdot)$ (and also of $\mathcal{V}_2(\cdot)$ for PE.2), but not outcome-convexity.²⁹

Thus, another set of basic results in insurance theory seem to be quite robust to dropping the expected utility hypothesis.

3.5 Pareto-Efficient Multilateral Risk Sharing

An important part of the theory of insurance is the joint risk sharing behavior of a *group* of individuals. Research in this area was first initiated by Borch (1960, 1961, 1962) and Wilson (1968), and the modern theory of insurance markets can truly be said to stem from these articles.³⁰

Under expected utility, this framework consists of a set $\{\theta\}$ of states of nature, and m individuals, each with von Neumann–Morgenstern utility function $U_i(\theta)$ and random endowment

²⁷Thus, $(I^*(\cdot), \pi^*)$ is a solution to problem (3.40) for some given w_1 and w_2 , though it needn't be a *unique* solution.

²⁸By way of clarification, note that $d\pi$ is a differential change in the scalar π , while $dI(\cdot)$ is a differential change in the *entire function* $I(\cdot)$, in the sense being some differential change $dI(l)$ in $I(l)$ for every value of l .

²⁹Readers intrigued by this type of argument are referred to Chew, Epstein, and Zilcha (1988) who, under slightly different assumptions (namely, uniqueness of maxima), demonstrate its surprising generality.

³⁰See also Gerber (1978), Moffet (1979), Bühlman and Jewell (1979), and Eliashberg and Winkler (1981) for important subsequent contributions, and Lemaire (1990) and Gollier (1992, Sect. 1) for insightful surveys.

$w_i(\theta)$. In this section, we consider the special case where there are a finite number of states $\{\theta_1, \dots, \theta_T\}$, and where agents agree on their probabilities $\{\text{prob}(\theta_1), \dots, \text{prob}(\theta_T)\}$ (all positive).³¹ A *risk sharing rule* is then a set of functions $\{s_i(\cdot) | i = 1, \dots, m\}$ that determines person i 's allocation as a function of the state of nature θ_t . Under such a rule, person i 's expected utility is given by

$$\sum_{t=1}^T U_i(s_i(\theta_t)) \cdot \text{prob}(\theta_t). \quad (3.43)$$

A sharing rule $\{s_i(\cdot) | i = 1, \dots, m\}$ is *feasible* if it satisfies the constraint:

$$\sum_{t=1}^m (s_i(\theta_t)) \equiv \sum_{\theta_t} \sum_{i=1}^m w_i(\theta_t). \quad (3.44)$$

and it is *Pareto-efficient* if there exists no other feasible rule which preserves or increases the expected utility of each member, with a strict increase for at least one member. Finally, define the *risk tolerance measure*³² of a utility function $U_i(\cdot)$ by

$$\rho_i(x) \equiv -U_i'(x)/U_i''(x) \quad (3.45)$$

In this framework, the three most basic analytical results for Pareto-efficient risk sharing are:

RS.1 A necessary condition for a risk sharing rule $\{s_i(\cdot) | i = 1, \dots, m\}$ to be Pareto-efficient is that there exist nonnegative weights $\{\lambda_1, \dots, \lambda_m\}$ such that

$$\lambda_i \cdot U_i'(s_j(\theta_t)) \equiv \lambda_j \cdot U_j'(s_i(\theta_t)) \quad i, j = 1, \dots, m \quad (3.46)$$

and under risk aversion, this is a *sufficient* condition.

RS.2 Any Pareto-efficient risk sharing rule will satisfy the *mutuality principle* (e.g., [Gollier \(1992, p.7\)](#)), namely, that the share $s_i(\theta_t)$ depends upon the state of nature θ_t *only* through the total group endowment $w(\theta_t) = \sum_{k=1}^m w_k(\theta_t)$ in state θ_t . In other words, there exist functions $\{x_i(\cdot) | i = 1, \dots, m\}$ such that

$$s_i(\theta_t) \equiv x_i(w(\theta_t)) \quad (3.47)$$

RS.3 In the case of a *continuum* of states of nature, members' *incremental shares* $\{x_i'(w)\}$ will be proportional to their respective risk tolerances, evaluated along the optimal sharing rule:

$$x_i'(w) \equiv \frac{\rho_i(x_i(w))}{\sum_{k=1}^m \rho_k(x_k(w))}. \quad (3.48)$$

Do these results extend to non-expected utility? To check, take a set of m non-expected utility maximizers with preference functions $\{\mathcal{V}_1(\cdot), \dots, \mathcal{V}_m(\cdot)\}$. The natural generalization of condition (3.46) would be that there exists a set of nonnegative weights $\{1, \dots, m\}$ such that

$$\lambda_i \cdot U_i'(s_i(\theta_t); \mathbf{P}_i^*) \equiv \lambda_j \cdot U_j'(s_j(\theta_t); \mathbf{P}_j^*) \quad i, j = 1, \dots, m \quad (3.49)$$

where $U_i(\cdot; \mathbf{P})$ and $U_j(\cdot; \mathbf{P})$ are the local utility functions of $\mathcal{V}_i(\cdot)$ and $\mathcal{V}_j(\cdot)$, and \mathbf{P}_i^* and \mathbf{P}_j^* are the probability distributions of the variables $s_i(\theta_t)$ and $s_j(\theta_t)$, respectively. To check the robustness of RS.1, assume (3.49) did not hold, so that there are some states θ_a, θ_b and individuals i, j such that

³¹We consider what happens when agents may not have subjective probabilities at all in Sect. 3.10.

³²We say *risk tolerance* since $\rho_i(x)$ is the reciprocal of the standard Arrow–Pratt measure of absolute risk aversion.

$$\frac{U'_i(s_i(\theta_a); \mathbf{P}_i^*)}{U'_i(s_i(\theta_b); \mathbf{P}_i^*)} \neq \frac{U'_j(s_j(\theta_a); \mathbf{P}_j^*)}{U'_j(s_j(\theta_b); \mathbf{P}_j^*)} \quad (3.50)$$

and hence

$$\frac{U'_i(s_i(\theta_a); \mathbf{P}_i^*)}{U'_i(s_i(\theta_b); \mathbf{P}_i^*)} \cdot \frac{\text{prob}(\theta_a)}{\text{prob}(\theta_b)} \neq \frac{U'_j(s_j(\theta_a); \mathbf{P}_j^*)}{U'_j(s_j(\theta_b); \mathbf{P}_j^*)} \quad (3.51)$$

But from the n -state version of the *MRS* formula (3.16),³³ this would mean that the two individuals' marginal rates of substitution between consumption in states θ_a and θ_b are strictly unequal, so they would have an opportunity for mutually beneficial trade. Thus, the original sharing rule was not Pareto-efficient. This establishes that (3.49) is indeed a *necessary* condition for Pareto-efficiency. A standard Edgeworth box argument will establish that is also a *sufficient* condition provided outcome-convexity holds, though not otherwise.

To check result RS.2, observe that if it did not hold, there would be two states θ_a , θ_b and an individual i such that $\sum_{k=1}^m w_k(\theta_a) = \sum_{k=1}^m w_k(\theta_b)$, but $s_i(\theta_a) > s_i(\theta_b)$. But by the feasibility condition (3.44), this means that there must exist some *other* individual j such that $s_j(\theta_a) < s_j(\theta_b)$. By risk aversion (concavity of local utility functions), this would imply

$$\frac{U'_i(s_i(\theta_a); \mathbf{P}_i^*)}{U'_i(s_i(\theta_b); \mathbf{P}_i^*)} \cdot \frac{\text{prob}(\theta_a)}{\text{prob}(\theta_b)} < \frac{\text{prob}(\theta_a)}{\text{prob}(\theta_b)} < \frac{U'_j(s_j(\theta_a); \mathbf{P}_j^*)}{U'_j(s_j(\theta_b); \mathbf{P}_j^*)} \cdot \frac{\text{prob}(\theta_a)}{\text{prob}(\theta_b)} \quad (3.52)$$

so that, as before, the two individuals have different marginal rates of substitution between consumption in states θ_a and θ_b , so the original sharing rule could not have been Pareto-efficient. Thus, the mutuality principle (RS.2) and the formula (3.47) also hold for non-expected utility risk sharers in this same setting. Observe that only risk aversion, and not outcome-convexity, is needed for this result.

Finally, to show that the continuum-state-space result RS.3 also generalizes, combine (3.47) and (3.49) (which both continue to hold with a continuum of states) to write

$$\lambda_i \cdot U'_i(x_i(w); F_i^*) \equiv \lambda_j \cdot U'_j(x_j(w); F_j^*) \quad i, j = 1, \dots, m \quad (3.53)$$

where $F_i^*(\cdot)$ and $F_j^*(\cdot)$ are the cumulative distribution functions of the (continuous) random variables $s_i(\theta)$ and $s_j(\theta)$. Differentiating (3.53) with respect to w and then dividing by (3.53) yields

$$\frac{U''_i(x_i(w); F_i^*)}{U'_i(x_i(w); F_i^*)} \cdot x'_i(w) \equiv \frac{U''_j(x_j(w); F_j^*)}{U'_j(x_j(w); F_j^*)} \cdot x'_j(w) \quad i, j = 1, \dots, m \quad (3.54)$$

and hence

$$\frac{\rho_j(x_j(w); F_j^*)}{\rho_i(x_i(w); F_i^*)} \cdot x'_i(w) \equiv x'_j(w), \quad (3.55)$$

where $\rho_i(x; F) \equiv -U'_i(x; F)/U''_i(x; F)$ is the risk tolerance measure of the local utility function $U_i(\cdot; F)$. Summing over $j = 1, \dots, m$, noting that feasibility implies $\sum_{j=1}^n x'_j \equiv_w = 1$, and solving gives

$$x'_i(w) \equiv_w \frac{\rho_i(x_i(w); F_i^*)}{\sum_{k=1}^m \rho_k(x_k(w); F_k^*)} \quad i = 1, \dots, m \quad (3.56)$$

³³Like the 2-state formula (3.16), its n -state equivalent follows immediately from Eq. (3.15).

In other words, each member's incremental share is proportional to their local risk tolerance, evaluated along the optimal sharing rule. (Recall that since $F_1^*(\cdot), \dots, F_m^*(\cdot)$ are the distributions of $s_1(\theta), \dots, s_m(\theta)$, they are determined directly by the optimal sharing rule.)

What does this all imply? It is true that we need outcome-convexity to guarantee the *sufficiency* of the Pareto-efficiency condition (3.49). However, it remains a *necessary* property of any Pareto-efficient allocation even without outcome-convexity. Otherwise, risk aversion alone (and sometimes not even that) suffices to generalize the basic risk sharing results RS.1, RS.2, and RS.3 to the case of non-expected utility maximizers.

3.6 Self-Insurance versus Self-Protection

This topic stems from the seminal article of Ehrlich and Becker (1972), who examined two important *nonmarket* risk reduction activities, namely *self-insurance*, where resources are expended to reduce the magnitude of a possible loss, and *self-protection*, where resources are expended to reduce the probability of that loss. In a two-state framework (the one they considered), the individual's initial position can be represented as the probability distribution $(w - l, p; w, 1 - p)$, that is to say, base wealth w with a p chance of a loss of l .

The technology of self-insurance can be represented by function $l(\cdot)$ of an expenditure variable $\alpha \in [0, M]$, such that the first state loss becomes $l(\alpha)$, where $l'(\alpha) < 0$. In that case, an expected utility maximizer's decision problem is

$$\max_{\alpha \in [0, M]} [p \cdot U(w - l(\alpha) - \alpha) + (1 - p) \cdot U(w - \alpha)] \quad (3.57)$$

The technology of self-protection can be represented by function $p(\cdot)$ of an expenditure variable $\beta \in [0, M]$, such that the probability of the loss becomes $p(\beta)$, where $p'(\beta) < 0$. In that case, an expected utility maximizer's decision problem is

$$\max_{\beta \in [0, M]} [p(\beta) \cdot U(w - l - \beta) + (1 - p(\beta)) \cdot U(w - \beta)] \quad (3.58)$$

Needless to say, these activities could be studied in conjunction with each other, as well as in conjunction with *market* insurance, and Ehrlich and Becker do precisely that. Since then, the self-insurance/self-protection framework (with or without market insurance) has been extensively studied—see, for example, Boyer and Dionne (1983, 1989), Dionne and Eeckhoudt (1985), Chang and Ehrlich (1985), Hibert (1989), Briys and Schlesinger (1990), Briys, Schlesinger, and Schulenburg (1991), and Sweeney and Beard (1992).

Dionne and Eeckhoudt (1985) have shown that under expected utility, greater risk aversion leads to greater self-insurance. Konrad and Skaperdas (1993) have shown that this result extends to the case of a specific non-expected utility model, namely the “rank-dependent” form examined in Sect. 3.8 below. They find that most (though not all) of the expected utility-based results on self-insurance generalize to this non-expected utility model, whereas expected utility's generally ambiguous results on self-protection³⁴ must, of necessity, remain ambiguous in this more general setting. Here we formally show that Dionne and Eeckhoudt's result on self-insurance extends to all smooth risk averse non-expected utility maximizers, whether or not they are outcome convex:

³⁴For example, Jullien, Salanié, and Salanié (1999, Sect. 3), Eeckhoudt and Gollier (2005).

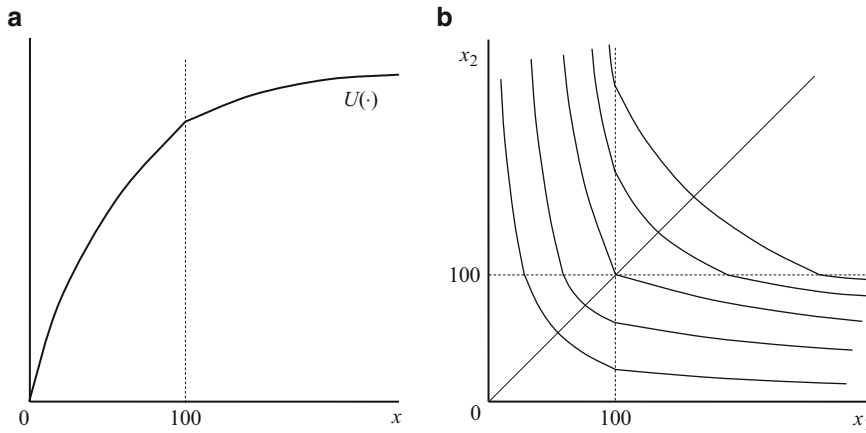


Fig. 3.10 (a) and (b) A kinked von Neumann–Morgenstern utility function and its indifference curves

Theorem 3. Assume that there are two states of nature with fixed positive probabilities \bar{p} and $(1-\bar{p})$. Let $w_0 > 0$ be base wealth, $\alpha \in [0, M]$ expenditure on self-insurance, and $l(\alpha) > 0$ be the loss in the first state, where $l'(\alpha) < 0$ and $M < w_0$. Assume that the non-expected utility preference functions $\mathcal{V}_1(\cdot)$ and $\mathcal{V}_2(\cdot)$ are twice continuously Fréchet differentiable, strictly risk averse, and that $\mathcal{V}_1(\cdot)$ is strictly more risk averse than $\mathcal{V}_2(\cdot)$ in the sense that $U_1''(x; F)/U_1'(x; F) > U_2''(x; F)/U_2'(x; F)$ for all x and $F(\cdot)$. Consider the problem:

$$\max_{\alpha \in [0, M]} \mathcal{V}_i(w_0 - l(\alpha) - \alpha, \bar{p}; w_0 - \alpha, 1 - \bar{p}) \quad i = 1, 2 \tag{3.59}$$

If α_1^* is the smallest solution to this problem for $\mathcal{V}_1(\cdot)$, and α_2^* is the largest solution for $\mathcal{V}_2(\cdot)$, then $\alpha_1^* \geq \alpha_2^*$, with strict inequality unless $\alpha_1^* = 0$ or $\alpha_2^* = M$.

Proof in Appendix

In other words, regardless of the possible multiplicity of optima due to non-outcome-convexity, we will never observe the more risk averse first individual choosing less self-insurance than the second individual, and the only time they would ever choose the same level is if the productivity of self-insurance is so weak that zero is an optimum even for the first individual (in which case it is the *only* optimum for the second) or else the productivity is so strong that full self-insurance ($\alpha = M$) is an optimum even for the second individual (in which case it is the *only* optimum for the first).

3.7 Outcome Kinks and First-Order Risk Aversion

Although the expected utility axioms neither require nor imply that preferences be differentiable in the *outcome levels*, the classical theory of insurance has followed the standard theory of risk aversion in usually assuming that $U(\cdot)$ is once (or twice) differentiable in wealth. But this needn't always be the case, and in this section we present some of the classical insurance model's results concerning kinked utility functions, and explore their robustness.

There are several situations where an expected utility maximizer's utility function—that is, the utility function they apply to their insurance decisions—might exhibit outcome kinks, even though their *underlying* risk preferences may be smooth in the payoffs. The simplest and probably most

pervasive are piecewise linear income tax schedules, which imply that the utility of *before-tax* income will have kinks at the boundaries of each tax bracket. However, other cases where the marginal utility of money may discontinuously change include bankruptcy, and cases where a certain minimum level of wealth is needed for the acquisition of some indivisible good.

Figure 3.10a, b illustrates a risk averse von Neumann–Morgenstern utility function $U(\cdot)$ with a kink at $x = 100$, and its indifference curves in the Hirshleifer–Yaari diagram for fixed state probabilities \bar{p}_1, \bar{p}_2 . Since $MRS_{EU}(x_1, x_2) = (U'(x_1)\bar{p}_1)/(U'(x_2)\bar{p}_2)$ (eq. (3.2)), these indifference curves will be smooth and tangent to the iso-expected value lines³⁵ at all certainty points (x, x) *except* the point $(100,100)$, where there will be a convex (bowed toward the origin) kink. The curves will also be smooth at all *uncertainty points* (x_1, x_2) except where x_1 or x_2 equals 100 (i.e., along the vertical and horizontal dashed lines), where they will again have convex kinks. But even at these kinks we have a version of the MRS formula (3.2), this time between the left/right derivatives of $U(\cdot)$ and what may be called the *left/right marginal rates of substitution*:

$$MRS_{EU,L}(x_1, x_2) = -\frac{U'_L(x_1) \cdot \bar{p}_1}{U'_R(x_2) \cdot \bar{p}_2} \quad MRS_{EU,R}(x_1, x_2) = -\frac{U'_R(x_1) \cdot \bar{p}_1}{U'_L(x_2) \cdot \bar{p}_2} \quad (3.60)$$

Besides (3.60), the directional outcome derivatives also satisfy more general properties. For example, even at its kink points $(x_1, 100)$, $(100, x_2)$, or $(100,100)$, we obtain the standard formulas linking the directional *total* derivatives and directional *partial* derivatives, for example,

$$\left. \frac{d\mathcal{V}_{EU}(x_1 + \alpha \cdot t, \bar{p}_1; x_2 + \beta \cdot t, \bar{p}_2)}{dt^R} \right|_{t=0} = \alpha \cdot \frac{\partial \mathcal{V}_{EU}(x_1, \bar{p}_1; x_2, \bar{p}_2)}{\partial x_1^R} + \beta \cdot \frac{\partial \mathcal{V}_{EU}(x_1, \bar{p}_1; x_2, \bar{p}_2)}{\partial x_2^R} \quad (3.61)$$

$\alpha, \beta > 0$

Similarly, even when integrating along a line of kink points, say from $(50,100)$ to $(150,100)$, the fundamental theorem of calculus continues to link the global change in the preference function with its directional partial derivatives along the path, e.g.,

$$\mathcal{V}_{EU}(150, \bar{p}_1; 100, \bar{p}_2) - \mathcal{V}_{EU}(50, \bar{p}_1; 100, \bar{p}_2) = \int_{50}^{150} \frac{\partial \mathcal{V}_{EU}(x_1, \bar{p}_1; 100, \bar{p}_2)}{\partial x_1^R} \cdot dx_1 \quad (3.62)$$

That is, even if $U(\cdot)$ has a kink (or several kinks), the outcome kinks of the expected utility preference function $\mathcal{V}_{EU}(x_1, \bar{p}_1; x_2, \bar{p}_2) = U(x_1) \cdot \bar{p}_1 + U(x_2) \cdot \bar{p}_2$ (and its general form $\mathcal{V}_{EU}(x_1, p_1; \dots; x_n, p_n) = \sum_{i=1}^n U(x_i) p_i$) are seen to be “well behaved,” in that they satisfy the above local and global properties of what is sometimes called the *calculus of directional derivatives*.

On the other hand, such expected utility maximizers do not satisfy result CO.2 of Sect. 3.3.1—that is, they may purchase full insurance even when it is actuarially unfair. This is illustrated in Fig. 3.11a, where an individual with an uninsured position at point C , and facing an actuarially unfair budget line, maximizes expected utility by choosing the fully insured point $(100,100)$. However, if $U(\cdot)$ only has a single kink (or isolated kinks), this will be a knife-edge phenomenon: It is true that it can occur for any uninsured point C lying above the iso-expected value line through $(100,100)$ and below the subtangents of the indifference curve at that point. However, from any such \hat{C} here is *exactly one* loading factor that will lead the individual to choose full insurance. Any greater or lesser loading factor from C leads to a *partial insurance* optimum on a higher or lower indifference curve than the one through $(100,100)$, and off of the certainty line.

³⁵For clarity, the iso-expected values lines are not shown in Figs. 3.10b or 3.11b, but do appear in Fig. 3.11a.

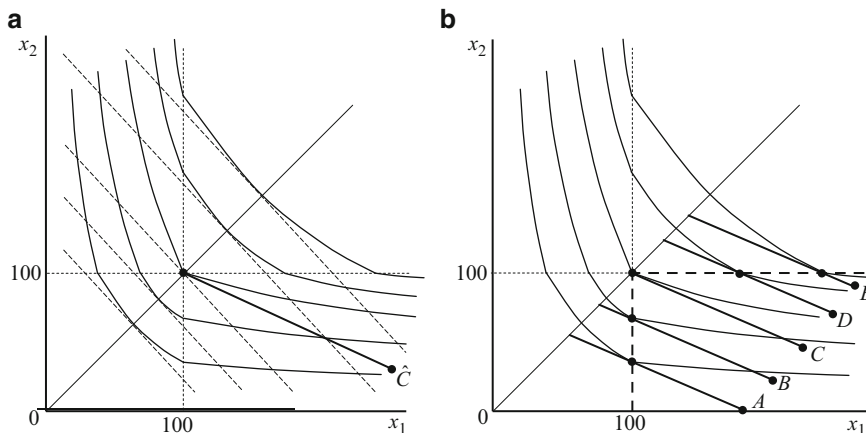


Fig. 3.11 (a) and (b) Full purchase of actuarially unfair insurance; wealth effects on the demand for coinsurance

Figure 3.11b illustrates another implication of kinked utility which is *not* a knife-edge phenomenon. The uninsured positions *A, B, C, D, E* lie along a line of slope one, that is, they differ from each other only in the addition/subtraction of some sure amount of wealth. As such wealth increases raise the initial position from *A* to *E*, the optimal point first moves straight *upward* to (100,100) and then straight *rightward*. In other words, as wealth grows, the amount of loss insured rises to completeness and then starts to drop, so the Engle curve for insurance is first rising and then falling. To see that this is not a knife-edge implication, observe that since the optimal points are all convex kinks, this can occur for a range of loading factor values.

Segal and Spivak (1990) have defined and characterized the general behavior property corresponding to outcome kinks at certainty, and the sense in which risk preferences about such kinks are qualitatively different from smooth preferences about certainty points. Given an initial wealth x^* and a nondegenerate zero-mean risk $\tilde{\epsilon}$, let $\pi(t)$ denote the individual’s risk premium for the additive risk $t\tilde{\epsilon}$, so the individual is indifferent between the sure wealth $x^*(t) \cdot \tilde{\epsilon}$ and the risky wealth $x^* + t \cdot \tilde{\epsilon}$. Note that $\pi(0) = 0$. Segal and Spivak define a risk averter as exhibiting

first - order risk aversion at x^* if $\pi'(0) \neq 0$

second - order risk aversion at x^* if $\pi'(0) = 0$ but $\pi''(0) \neq 0$

Segal and Spivak show that if an individual (expected utility or otherwise) exhibits first-order risk aversion at wealth level x^* , then for small enough positive k , they will strictly prefer x^* over the random variable $x^* + t(k + \tilde{\epsilon})$ for all sufficiently small $t > 0$. This can be seen in Fig. 3.11a, with $x^* = 100$ and $x^* + 1(k + \tilde{\epsilon})$ being the pre-insurance point *C* (with greater risk and greater expected value than x^*), and where the property “ $x^* \succ B x^* + t(k + \tilde{\epsilon})$ for small enough t ” is seen by the fact that the sure point (100,100) is strictly preferred to nearby points on the insurance budget line. Segal and Spivak (1990) provide the following expected utility results linking properties of a utility function to its order of risk aversion about wealth x^* :

- SS.1 If a risk averse von Neumann–Morgenstern utility function $U(\cdot)$ is not differentiable at x^* but has well-defined and distinct left and right derivatives at x^* , then the individual exhibits first-order risk aversion at x^* .
- SS.2 If a risk averse von Neumann–Morgenstern utility function $U(\cdot)$ is twice differentiable at x^* with $U''(x) < 0$, then the individual exhibits second-order risk aversion at x^* .

Segal and Spivak’s ideas, and their relevance to insurance, are not limited to preferences about complete certainty. An individual with the utility function as in Fig. 3.10a, with a kink at x^* , will also exhibit *conditional first-order risk aversion* about wealth level x^* : Consider any risk of the form [p chance of $x^* + t\tilde{\epsilon}$: $(1 - p)$ chance of \tilde{x}]. Such distributions can arise in cases of *uninsured states*, such as war or certain “acts of God,” in which no insurance indemnity is paid. Many (most?) insurance contracts explicitly specify such states, and usually retain the premium payment if they occur. The risk premium $\pi(t)$ in such cases solves

$$p \cdot E[U(x^* + t \cdot \tilde{\epsilon})] + (1 - p) \cdot E[U(\tilde{x})] = p \cdot U(x^* - \pi(t)) + (1 - p) \cdot E[U(\tilde{x} - \pi(t))]. \quad (3.63)$$

For contracts that *refund* the premium if an uninsured state occurs, the final term in this equation becomes $(1 - p) \cdot E[U(\tilde{x})]$. In either case, we will again get $\pi(0) = 0$ and $\pi'(0) \neq 0$.³⁶

Are these expected utility results robust when *linearity* in the probabilities is relaxed to *smoothness* in the probabilities? Segal and Spivak (1990, 1997) have already generalized SS.1 and SS.2 from von Neumann–Morgenstern utility to local utility functions: Given a risk averse non-expected utility $\mathcal{V}(\cdot)$, if its local utility function $U(x; \mathbf{P}_{x^*})$ at the degenerate distribution $\mathbf{P}_{x^*} = (x^*, 1)$ has a kink at $x = x^*$, then $\mathcal{V}(\cdot)$ will exhibit *first-order risk aversion* at x^* . Similarly, if $\mathcal{V}(\cdot)$ ’s local utility functions are all twice differentiable (and $U(x; \mathbf{P})$, $U'(x; \mathbf{P})$, $U''(x; \mathbf{P})$ are all continuous in \mathbf{P}), then $\mathcal{V}(\cdot)$ will exhibit *second-order risk aversion* at all wealth levels. Their robustness proofs can also be extended to cover *conditional* first- and second-order risk aversion.

The above diagrammatic and comparative statics analysis is also robust to the case of smoothness in the probabilities. For example, let $\phi(x)$ denote the after-tax income corresponding to a pretax income of x , and let $\phi(\cdot)$ have a kink (with left/right derivatives) at $x = 100$. Given any underlying preference function $\mathcal{V}(\cdot)$ over probability distributions of *after-tax* income that is outcome-smooth (i.e., satisfies (3.15)), the individual’s preferences over probability distributions of *pretax* income are given by the preference function $\mathcal{V}(\mathbf{P}) \equiv \mathcal{V}(x_1, p_1; \dots; x_n, p_n) \equiv \mathcal{V}(\phi(x_1), p_1; \dots; \phi(x_n), p_n) \equiv \mathcal{V}(\phi(\mathbf{P}))$, where \mathbf{P} denotes the probability distribution $(\phi(x_1), p_1; \dots; \phi(x_n), p_n)$. $\mathcal{V}(\cdot)$ ’s outcome kinks can be shown to be “well behaved” in the sense described above, and $\mathcal{V}(\cdot)$ has local utility function and regular/directional outcome derivatives

$$U(x; \mathbf{P}) \equiv \frac{\partial \mathcal{V}(x_1, p_1; \dots; x_n, p_n)}{\partial \text{prob}(x)} \equiv \frac{\partial \hat{\mathcal{V}}(\phi(x_1), p_1; \dots; \phi(x_n), p_n)}{\partial \text{prob}(\phi(x))} \equiv \hat{U}(\phi(x); \phi(\mathbf{P})), \quad (3.64)$$

$$\frac{\partial \mathcal{V}(\mathbf{P})}{\partial x_i^{B/L/R}} = \frac{\partial \hat{\mathcal{V}}(\phi(x_1), p_1; \dots; \phi(x_n), p_n)}{\partial \phi(x_i)} \cdot \phi'_{B/L/R}(x_i), \quad (3.65)$$

where “ $B/L/R$ ” denotes either the regular (“bidirectional”) derivative if it exists, or otherwise the appropriate left/right derivative. Together, (3.64), (3.65), and outcome-smoothness of $\mathcal{V}(\cdot)$ imply the regular/directional derivative version of the key generalized expected utility formula (3.15):

$$\frac{\partial \mathcal{V}(\mathbf{P})}{\partial x_i^{B/L/R}} = \hat{U}'_{B/L/R}(\phi(x_i); \phi(\mathbf{P})) \cdot p_i \cdot \phi'_{B/L/R}(x_i) = U'_{B/L/R}(x_i; \mathbf{P}) \cdot p_i \quad (3.66)$$

This again yields the *MRS* formula $MRS_{\mathcal{V}(x_1, x_2)} = -(U'(x_1; \mathbf{P}_{x_1, x_2})\bar{p}_1)/(U'(x_2; \mathbf{P}_{x_1, x_2})\bar{p}_2)$ at all smoothness points (where $x_1 \neq 100x_2$), and the left/right *MRS* formulas

³⁶Can Fig. 3.11a and b also be used to illustrate the demand for conditional insurance in states 1 and 2 when states 3, ..., n are uninsured? Only when the insurance contract refunds the premium in every uninsured state. If the premium is retained in every state, then moving along the coinsurance budget line in the figure also changes the outcomes in states 3, ..., n , so the x_1, x_2 indifference curves in the figure will shift.

$$MRS_{\mathcal{V},L}(x_1, x_2) = -\frac{U'_L(x_1; \mathbf{P}_{x_1,x_2}) \cdot \bar{p}_1}{U'_R(x_2; \mathbf{P}_{x_1,x_2}) \cdot \bar{p}_2} \quad MRS_{\mathcal{V},R}(x_1, x_2) = -\frac{U'_R(x_1; \mathbf{P}_{x_1,x_2}) \cdot \bar{p}_1}{U'_L(x_2; \mathbf{P}_{x_1,x_2}) \cdot \bar{p}_2} \quad (3.67)$$

when x_1 and/or x_2 equals 100. Thus, $\mathcal{V}(\cdot)$'s indifference curves are again smooth except for kinks at (100,100) and on the vertical/horizontal lines $x_1 = 100$ and $x_2 = 100$. Finally, if preferences are also outcome convex, then $\mathcal{V}(\cdot)$'s indifference curves will look almost exactly like those in Fig. 3.10b, except that they will generally not satisfy the rectangle property of Sect. 3.2.1. This implies that both the full-insurance phenomenon and “increasing then decreasing absolute risk aversion” phenomenon of payoff-kinked expected utility preferences will continue to hold.³⁷ In other words, these expected utility implications of non-differentiabilities in the *outcomes* (“outcome kinks”) are robust to dropping linearity in the *probabilities*. Further analysis of payoff kinks in non-expected utility preferences is undertaken in Machina (2001).

3.8 RankDependent Risk Preferences

The previous sections of this chapter have explored the robustness of the classical theory of insurance demand to the case of very general non-expected utility preferences, assuming little more than “smoothness in the probabilities.” However, researchers have also implications of specific models of non-expected risk preferences—that is, specific functional forms for the preference function $\mathcal{V}(x_1, p_1; \dots; x_n, p_n)$.

Examples of such forms, and researchers who have proposed and/or studied them, include:

moments of utility $g(\sum_{i=1}^n v(x_i) \cdot p_i, \sum_{i=1}^n v(x_i)^2 \cdot p_i, \sum_{i=1}^n v(x_i)^3 \cdot p_i)$ Hagen (1979)

quadratic in probabilities $\sum_{i=1}^n \sum_{j=1}^n K(x_i, x_j) \cdot p_i p_j$ Chew, Epstein and Segal (1991)

weighted utility $[\sum_{i=1}^n v(x_i) \cdot p_i] / [\sum_{i=1}^n \tau(x_i) \cdot p_i]$ Chew (1983)

Since they are each generalizations of expected utility, these forms all share its flexibility in representing attitudes toward risk. And so long as the function $g(\cdot, \cdot)$ in the Hagen (1979) form is smooth, they will all be differentiable in the probabilities, so that the generalized expected utility results we have derived will apply. Fixed-location outcome kinks can be represented by introducing kinks in the functions $v(\cdot)$, $K(\cdot, \cdot)$, or $\tau(\cdot)$, in which case these forms will continue to satisfy the robustness results of Sect. 3.7.

The family of non-expected utility forms which has proven to be the most analytically useful³⁸ arises from the model proposed by Quiggin (1982), now known as the “expected utility with rank-dependent probabilities” or simply *rank-dependent* form. In our setting of finite-outcome distributions, it takes the form

$$\begin{aligned} \mathcal{V}(x_1, p_1; \dots; x_n, p_n) &= v(\hat{x}_1) \cdot G(\hat{p}_1) \\ &\quad + v(\hat{x}_2) \cdot [G(\hat{p}_1 + \hat{p}_2) - G(\hat{p}_1)] \\ &\quad + v(\hat{x}_3) \cdot [G(\hat{p}_1 + \hat{p}_2 + \hat{p}_3) - G(\hat{p}_1 + \hat{p}_2)] \\ &\quad \vdots \\ &\quad + v(\hat{x}_{n-1}) \cdot [G(\hat{p}_1 + \dots + \hat{p}_{n-1}) - G(\hat{p}_1 + \dots + \hat{p}_{n-2})] \end{aligned}$$

³⁷Since the kinks generated here are convex kinks, this may occur even without full outcome-convexity.

³⁸See, for example, Quiggin (1982,1993), Ritzenberger (1996), Röell (1987), and Bleichrodt and Quiggin (1997).

$$\begin{aligned}
& + v(\hat{x}_n) \cdot [G(1) - G(\hat{p}_1 + \dots + \hat{p}_{n-1})] \\
& = \sum_{i=1}^n v(\hat{x}_i) \cdot \left[G \left(\sum_{j=1}^i \hat{p}_j - G \sum_{j=1}^{i-1} \hat{p}_j \right) \right] \quad (3.68)
\end{aligned}$$

where the outcomes and their associated probabilities are labeled so that \hat{x}_1 denotes the *largest* of the possible outcomes, \hat{x}_2 denotes the *second largest*, etc.

Provided $G(\cdot)$ is differentiable, the rank-dependent form will be differentiable in the probabilities at any $\mathbf{P} = (\hat{x}_1, \hat{p}_1; \dots; \hat{x}_n, \hat{p}_n)$, and as shown by [Chew, Karni, and Safra \(1987\)](#) (or by Eq. (3.14)), has local utility function³⁹

$$U(x; \mathbf{P}) = v(x) \cdot G'(\sum_{j=1}^k \hat{p}_j) + \sum_{i=k+1}^n v(\hat{x}_i) \cdot \left[G'(\sum_{j=1}^i \hat{p}_j) - G'(\sum_{j=1}^{i-1} \hat{p}_j) \right] \quad (3.69)$$

$U(\cdot; \mathbf{P})$ is seen to consist of “piecewise affine transformations” of the function $v(\cdot)$, over the successive intervals $[\hat{x}_1, \hat{x}_2), \dots, [\hat{x}_k, \hat{x}_{k+1}), \dots$ ⁴⁰ The rank-dependent form exhibits first-order stochastic dominance preference if and only if $v(\cdot)$ is an increasing function, which from (3.69) is equivalent to the condition that $U(\cdot; \mathbf{P})$ is increasing in x at all \mathbf{P} . [Chew, Karni, and Safra \(1987\)](#) showed that the form is globally averse to mean-preserving spreads if and only if $v(\cdot)$ and $G(\cdot)$ are concave, which is equivalent to $U(\cdot; \mathbf{P})$ being concave in x at all \mathbf{P} .⁴¹ They also showed that one rank-dependent preference function $\mathcal{V}^*(\cdot)$ is more risk averse than another one $\mathcal{V}(\cdot)$ if and only if $v^*(\cdot)$ and $G^*(\cdot)$ are concave transformations of $v(\cdot)$ and $G(\cdot)$, which is equivalent to the condition that at each \mathbf{P} , $U^*(\cdot; \mathbf{P})$ is some concave transformation of $U(\cdot; \mathbf{P})$.⁴² Thus, many of the basic results of generalized expected utility analysis from Sect. 3.2.2 do apply to the rank-dependent form. [Heilpern \(2003\)](#) and [Kaluszka and Krzeszowiec \(2012\)](#), for example, demonstrate how the standard zero-utility principle of insurance pricing generalizes when consumers have rank-dependent preferences. A predominant feature of rank-dependent preferences is that even when $v(\cdot)$ is smooth, their indifference curves in the Hirshleifer–Yaari diagram will have kinks along the 45° line, so that many of the results of Sect. 3.7 will apply (see in particular the analysis of [Dupuis and Langlais \(1997\)](#)).

A special case of the [Quiggin \(1982\)](#) form proposed by [Yaari \(1987\)](#), in which the utility of wealth function is linear, is termed the *dual theory*:⁴³

$$\mathcal{V}(x_1, p_1; \dots; x_n, p_n) = \sum_{i=1}^n \hat{x}_i \cdot \left[G(\sum_{j=1}^i \hat{p}_j) - G(\sum_{j=1}^{i-1} \hat{p}_j) \right] \quad \hat{x}_1 \leq \dots \leq \hat{x}_n \quad (3.70)$$

[Doherty and Eeckhoudt \(1995\)](#) find that, because of their linearity in wealth, individuals with dual theory preferences will go to corner solutions for any linear insurance contract, although many

³⁹For the following equation, define \hat{x}_0 (resp. \hat{x}_{n+1}) as any value lower (resp. higher) than all of the outcomes in \mathbf{P} .

⁴⁰That is, $U(\cdot; \mathbf{P}) \equiv a_k \cdot v(\cdot) + b_k$ over $[\hat{x}_k, \hat{x}_{k+1})$, where $a_k = G'(\sum_{j=1}^k \hat{p}_j)$ and $b_k = \sum_{i=k+1}^n v(\hat{x}_i) \cdot [G'(\sum_{j=1}^i \hat{p}_j) - G'(\sum_{j=1}^{i-1} \hat{p}_j)]$ are constant over each interval $[\hat{x}_k, \hat{x}_{k+1})$.

⁴¹From Note 39, $v(\cdot)$ concave is necessary and sufficient for $U(\cdot; \mathbf{P})$ to be concave *within* each interval $[\hat{x}_k, \hat{x}_{k+1})$, in which case $G(\cdot)$ concave (hence $G'(\cdot)$ decreasing) is necessary and sufficient for $U(\cdot; \mathbf{P})$ to be concave *across* these intervals.

⁴²Again from Note 39, comparative concavity of $v^*(\cdot)$ and $v(\cdot)$ is necessary and sufficient for comparative concavity of $U^*(\cdot; \mathbf{P})$ and $U(\cdot; \mathbf{P})$ *within* each interval $[x_i, x_{i+1})$, in which case comparative concavity of $G^*(\cdot)$ and $G(\cdot)$ ($G^*(\cdot)$ decreasing proportionately faster than $G'(\cdot)$) is necessary and sufficient for comparative concavity of $U^*(\cdot; \mathbf{P})$ and $U(\cdot; \mathbf{P})$ *across* these intervals.

⁴³So called because the linearity/nonlinearity properties of payoff and probability are reversed relative to the expected utility form.

standard expected utility results involving nonlinear contracts are robust. Courbage (2001) explores the relationship between market insurance, self-insurance, and self-protection under the Dual Theory, and finds that the Ehrlich and Becker (1972) expected utility results that market insurance and self-insurance are substitutes, and market insurance and self-protection need not be, are robust. Young and Browne (2000) showed that many, though not all, expected utility results concerning separating contracts for different classes of risk are robust.⁴⁴

An extension of the rank-dependent form (3.68) to the case of subjective uncertainty is examined in Sect. 3.10.

3.9 Insurance as a Source of Nonexpected Utility Preferences

Throughout this chapter, we have explored how the extension from expected utility to more general non-expected utility preferences does, or does not, affect the classical theory of insurance. As final topic, we consider the opposite direction of influence—namely, how an individual's opportunity to insure against *some* risks will generally induce non-expected utility preferences over the *other* risks they face.⁴⁵

The theory of insurance in the presence of uninsurable risks has been well studied in the literature.⁴⁶ Consider an individual whose final wealth $\tilde{w} = \tilde{x} + \tilde{y}$ consists of a *foreground risk* variable \tilde{x} and a stochastically independent *background risk* variable \tilde{y} , with respective distributions $\mathbf{P} = (x_1, p_1; \dots; x_n, p_n)$ and $\mathbf{Q} = (y_1, q_1; \dots; y_m, q_m)$. The distribution of \tilde{w} is thus given by the *additive convolution* $\mathbf{P} \oplus \mathbf{Q}$ of these two distributions, that is, by the distribution

$$P \oplus Q = \underbrace{(x_1 + y_1, p_1 \cdot q_1; \dots; x_i + y_j, p_i \cdot q_j; \dots; x_n + y_m, p_n \cdot q_m)}_{\substack{i=1, \dots, n \\ j=1, \dots, m}} \quad (3.71)$$

We assume that the individual's underlying preference function $\mathcal{V}(\cdot)$ takes the expected utility form, with von Neumann–Morgenstern utility function $U(\cdot)$. The expected utility of wealth $\tilde{w} = \tilde{x} + \tilde{y}$ can then be written as

$$\mathcal{V}(\mathbf{P} \oplus \mathbf{Q}) \equiv \sum_{i=1}^n \sum_{j=1}^m U(x_i + y_j) \cdot p_i q_j \equiv \sum_{i=1}^n \left[\sum_{j=1}^m U(x_i + y_j) \cdot q_j \right] \cdot p_i \equiv \sum_{i=1}^n U_{\mathbf{Q}}(x_i) \cdot p_i, \quad (3.72)$$

where for any distribution $\mathbf{Q} = (y_1, q_1; \dots; y_m, q_m)$, the utility function $U_{\mathbf{Q}}(\cdot)$ is defined by

$$U_{\mathbf{Q}}(x) \stackrel{\text{def}}{=} \sum_{j=1}^m U(x + y_j) \cdot q_j. \quad (3.73)$$

⁴⁴See Wang (1995), Wang and Young (1998), and van der Hoek and Sherris (2001) for the development of some measures of risk along the lines of the Dual model and their application to insurance, and Sung, Yam, Yung, and Zhou (2011) for an analysis of optimal insurance policies under the general rank-dependent form.

⁴⁵The following is an example of the general observation of Markowitz (1959, Ch.11), Mossin (1969), Spence and Zeckhauser (1972), and others that induced risk preferences are generally not expected utility maximizing.

⁴⁶For example, Alarie, Dionne, and Eeckhoudt (1992), Eeckhoudt and Kimball (1992), Gollier and Eeckhoudt (2013), Gollier and Pratt (1996), Mayers and Smith (1983), Pratt (1988), and Schlesinger and Doherty (1985).

Note that for any background risk variable \tilde{y}_0 with *fixed* distribution \mathbf{Q}_0 , the individual's preferences over alternative foreground risks \tilde{x} —that is, their preferences over \mathbf{P} distributions—are given by the *expected utility* preference function

$$\mathcal{V}_{\mathbf{Q}} \equiv \mathcal{V}(\mathbf{P} \oplus \mathbf{Q}_0) \equiv \sum_{i=1}^n U_{\mathbf{Q}_0}(x_i) \cdot p_i. \quad (3.74)$$

Equation (3.74) is a very important result in the standard expected utility theory of insurance. It states that as long as the background risk \tilde{y}_0 is independent and has a fixed distribution \mathbf{Q}_0 , the individual's preferences over alternative foreground risks \tilde{x} will inherit the expected utility form, with \mathbf{Q}_0 influencing the shape, but not the existence, of the induced von Neumann–Morgenstern $U_{\mathbf{Q}_0}(\cdot)$. In other words, fixed-distribution background risk does *not* lead to departures from expected utility preferences over foreground risk variables. Since virtually all real-world insurance policies leave at least some background risk, Eq. (3.74) provides a crucial justification for the assumption of expected utility preferences in the analysis of real-world insurance problems.⁴⁷

However, say the background variable \tilde{y} constitutes some *insurable* form of risk. That is, say the individual has the option of purchasing some form and/or level of insurance on \tilde{y} , such as full or partial coinsurance, or full or partial deductible. In the most general terms, we can represent this by saying that the individual can select a particular variable \tilde{y} , with distribution

$$\mathbf{Q}_{\omega} = (y_{1,\omega}, q_{1,\omega}; \dots; y_{m,\omega}, q_{m,\omega}) \quad (3.75)$$

out of some set $\{\tilde{y}_{\omega} | \omega \in \Omega\}$, where the index represents the forms and/or levels of insurance available to the individual. (Note that not only do the payoffs $y_{j,\omega}$ and probabilities $q_{j,\omega}$ depend upon, but so can the *number* of different outcomes m_{ω} . This reflects the fact that insurance can sometimes affect the number of distinct possible outcomes faced.)

Given this, the individual's preferences over foreground risks \tilde{x} (i.e., \mathbf{P} distributions) are represented by the *induced preference function*

$$\mathcal{V}^*(\mathbf{P}) \stackrel{\text{def}}{\equiv} \max_{\omega \in \Omega} \mathcal{V}(\mathbf{P} \oplus \mathbf{Q}_{\omega}) \equiv \mathcal{V}(\mathbf{P} \oplus \mathbf{Q}_{\omega(\mathbf{P})}) \equiv \sum_{i=1}^n U_{\mathbf{Q}_{\omega(\mathbf{P})}}(x_i) \cdot p_i, \quad (3.76)$$

where

$$\omega(\mathbf{P}) \stackrel{\text{def}}{\equiv} \arg \max_{\omega \in \Omega} \mathcal{V}(\mathbf{P} \oplus \mathbf{Q}_{\omega}). \quad (3.77)$$

Observe how the “insurable background risk” preference function $\mathcal{V}^*(\cdot)$ from (3.76) differs from the “fixed-background risk” function $\mathcal{V}_{\mathbf{Q}_0}(\cdot)$ from (3.74). Since the choice of \mathbf{P} can now affect the background risk distribution $\mathbf{Q}_{\omega(\mathbf{P})}$ and hence the function $U_{\mathbf{Q}_{\omega(\mathbf{P})}}(\cdot)$, the preference function $\mathcal{V}^*(\cdot)$ over foreground risk distributions \mathbf{P} *no longer* takes the expected utility form, even though the individual's *underlying* preferences over wealth distributions *are* expected utility.

Such preferences depart from linearity in the probabilities in a very specific direction. Any induced preference function $\mathcal{V}^*(\cdot)$ from (3.76) must be *quasiconvex in the probabilities*: that is, if the distributions $\mathbf{P} = (x_1, p_1; \dots; x_n, p_n)$ and $\mathbf{P}^* = (x_a^*, p_1^*; \dots; x_n^*, p_n^*)$ satisfy $\mathcal{V}^*(\mathbf{P}) = \mathcal{V}^*(\mathbf{P}^*)$, then

$$\mathcal{V}^*(\lambda \cdot \mathbf{P} + (1-\lambda) \cdot \mathbf{P}^*) \leq \mathcal{V}^*(\mathbf{P}) = \mathcal{V}^*(\mathbf{P}^*) \quad \text{for all } \lambda \in [0, 1], \quad (3.78)$$

⁴⁷See Pratt (1964, Thm.5), Kreps and Porteus (1979), and Nachman (1982) for analyses of how various properties of the underlying utility function $U(\cdot)$ do or do not carry over to the derived utility function $U_{\mathbf{Q}}(\cdot)$.

where the $\lambda : (1 - \lambda)$ probability mixture of \mathbf{P} and \mathbf{P}^* is defined by⁴⁸

$$\lambda \cdot \mathbf{P}(1 - \lambda) \cdot \mathbf{P}^* \stackrel{\text{def}}{\equiv} (x_1, \lambda \cdot p_1; \dots; x_n, \lambda \cdot p_n; x_1^*, (1 - \lambda) \cdot p_1^*; \dots; x_n^*, (1 - \lambda) \cdot p_n^*) \quad (3.79)$$

To see that $\mathcal{V}^*(\cdot)$ will be quasiconvex in the probabilities, note that since $\mathcal{V}(\cdot)$ is linear in the probabilities, we have $\mathcal{V}(\lambda \cdot \mathbf{P} + (1 - \lambda) \cdot \mathbf{P}^*) \equiv \lambda \cdot \mathcal{V}(\mathbf{P}) + (1 - \lambda) \cdot \mathcal{V}(\mathbf{P}^*)$, so that

$$\begin{aligned} \mathcal{V}^*(\lambda \cdot \mathbf{P} + (1 - \lambda) \cdot \mathbf{P}^*) &= \mathcal{V}((\lambda \cdot \mathbf{P} + (1 - \lambda) \cdot \mathbf{P}^*) \oplus \mathbf{Q}_{\omega(\lambda \cdot \mathbf{P} + (1 - \lambda) \cdot \mathbf{P}^*)}) \\ &= \lambda \cdot \mathcal{V}(\mathbf{P} \oplus \mathbf{Q}_{\omega(\lambda \cdot \mathbf{P} + (1 - \lambda) \cdot \mathbf{P}^*)}) + (1 - \lambda) \cdot \mathcal{V}(\mathbf{P}^* \oplus \mathbf{Q}_{\omega(\lambda \cdot \mathbf{P} + (1 - \lambda) \cdot \mathbf{P}^*)}) \\ &\leq \lambda \cdot \max_{\omega \in \Omega} \mathcal{V}(\mathbf{P} \oplus \mathbf{Q}_{\omega}) + (1 - \lambda) \cdot \max_{\omega \in \Omega} \mathcal{V}(\mathbf{P}^* \oplus \mathbf{Q}_{\omega}) \\ &= \lambda \cdot \mathcal{V}^*(\mathbf{P}) + (1 - \lambda) \cdot \mathcal{V}^*(\mathbf{P}^*) \\ &= \mathcal{V}^*(\mathbf{P}) = \mathcal{V}^*(\mathbf{P}^*) \end{aligned} \quad (3.80)$$

In other words, the insurability (even partial insurability) of *background* risk induces preferences over *foreground* risks that depart from expected utility by exhibiting a weak (and what could well be strict) preference against probability mixtures of indifferent lotteries.

In those situations where the distribution \mathbf{Q}_{ω} is smoothly indexed by (e.g., coinsurance), and when the optimal choice (\mathbf{P}) varies smoothly in \mathbf{P} , induced preferences will turn out to be smooth in the probabilities. In such cases, the special structure of (3.76) allows us to apply the envelope theorem to obtain a class of very powerful results. Since the first-order condition for the maximization problem (3.77) is

$$\begin{aligned} 0 &= \mathcal{V}(\mathbf{P} \oplus \mathbf{Q}_{\omega(\mathbf{P})+d\omega}) - \mathcal{V}(\mathbf{P} \oplus \mathbf{Q}_{\omega(\mathbf{P})}) \quad \text{for all } d\omega \text{ such that} \\ &= \sum_{i=1}^n U_{\mathbf{Q}_{\omega(\mathbf{P})+d\omega}}(x_i) \cdot p_i - \sum_{i=1}^n U_{\mathbf{Q}_{\omega(\mathbf{P})}}(x_i) \cdot p_i \quad \omega(\mathbf{P}) + d\omega \in \Omega \end{aligned} \quad (3.81)$$

it follows from (3.76) that the local utility function $U^*(\cdot; \mathbf{P})$ of $\mathcal{V}^*(\cdot)$ is given by

$$\begin{aligned} U^*(x; \mathbf{P}) &\equiv \frac{\partial \mathcal{V}^*(\mathbf{P})}{\partial \text{prob}(x)} \equiv \frac{d \sum_{i=1}^n U_{\mathbf{Q}_{\omega(\mathbf{P})}}(x_i) \cdot p_i}{d \text{prob}(x)} \\ &\equiv U_{\mathbf{Q}_{\omega(\mathbf{P})}}(x) + \left. \frac{d \sum_{i=1}^n U_{\mathbf{Q}_{\omega}}(x_i) \cdot p_i}{d \omega} \right|_{\omega=\omega(\mathbf{P})} \cdot \frac{\partial \omega(\mathbf{P})}{\partial \text{prob}(x)} \\ &\equiv U_{\mathbf{Q}_{\omega(\mathbf{P})}}(x) \equiv \sum_{j=1}^{m_{\omega}} U(x + y_j(\omega)) \cdot q_j(\omega) \end{aligned} \quad (3.82)$$

This implies, for example, that concavity of $U(\cdot)$ will be inherited by the local utility function $U^*(\cdot; \mathbf{P})$ at every \mathbf{P} , so that risk averse underlying preferences will imply a risk averse preference function $\mathcal{V}^*(\cdot)$ over foreground risks. Similarly, the property of third-order stochastic dominance preference (positive third derivative of $U(\cdot)$)⁴⁹ is inherited by the local utility functions $U^*(\cdot; \mathbf{P})$, and hence by $\mathcal{V}^*(\cdot)$. Thus, although the property of *expected utility maximization* is not robust to

⁴⁸Thus, $\lambda \mathbf{P} + (1 - \lambda) \cdot \mathbf{P}^*$ is the single-stage equivalent of a coin flip that yields probability of winning the distribution \mathbf{P} and probability $(1 - \lambda)$ of winning \mathbf{P}^* .

⁴⁹For example, Whitmore (1970).

the existence of insurable background risk, properties such as *risk aversion* and *third-order stochastic dominance preference* can be robust. Further analyses of such induced preferences can be found in [Kreps and Porteus \(1979\)](#), [Machina \(1984\)](#), and [Kelsey and Milne \(1999\)](#).

3.10 Insurance in the Presence of Ambiguity and Ambiguity Aversion

The phenomenon of “ambiguity” in the general sense of imprecise information or ill-defined risk is a feature of virtually all real-world risks or hazards, and has been recognized by economists as early as [Knight \(1921\)](#). Starting with [Ellsberg \(1961\)](#), the phenomena of ambiguity and ambiguity aversion have become the subject of a large and growing body of explicit research in the economics of uncertainty,⁵⁰ which has included theoretical, experimental, and empirical work on the effect of ambiguity on insurance decisions and insurance markets.

The classic distinction between casino-type *gambling decisions* and real-world *insurance decisions* is that the former involve objective probabilities which are well specified and agreed upon, whereas the latter involve individuals’ and firms’ subjective beliefs over the likelihoods of alternative events or states of nature. Up to this point, we have examined the implications of non-expected utility risk preferences upon insurance decisions under the hypothesis that subjective beliefs could be represented by well-defined *subjective probabilities* over the states. This feature, known as *probabilistic sophistication*, has been formally axiomatized for both expected utility and non-expected utility risk preferences.⁵¹ By way of contrast, a choice situation is said to involve *ambiguity* when one does not have well-defined probabilistic beliefs, or in the words of [Hogarth and Kunreuther](#), experiences “uncertainty about one’s own uncertainty.”

The pioneering work on the effect of ambiguity on insurance decisions is that of [Hogarth and Kunreuther \(1985, 1989, 1992a\)](#), who conducted various experiments on MBA students and professional actuaries which elicited buying and selling prices, and willingness to trade, for insurance contracts on non-ambiguous versus ambiguous events. Not surprisingly, they found that ambiguity raised firms’ required selling price for insurance. For low to moderate likelihood events, ambiguity also raised consumers’ willingness to pay for insurance, although this effect was found to reverse for higher likelihood events. Using survey data, [Kunreuther, Hogarth, and Meszaros \(1993\)](#) and [Kunreuther, Meszaros, Hogarth, and Spranca \(1995\)](#) found that ambiguity increased the recommended premiums of real-world actuaries, primary insurance underwriters, and reinsurance underwriters.⁵² [Hogarth and Kunreuther \(1992b\)](#) found that the tendency of ambiguity to raise suggested selling prices was exacerbated when risks were correlated. In surveys of professional insurers and actuarial students, [Cabantous \(2007\)](#) found that the effect of ambiguity on raising required premiums was greater when there was conflict between different sources of information. In field studies, [Bryan \(2010a, 2010b\)](#) found that ambiguity aversion reduces the demand for index insurance among African farmers, a phenomenon which is theoretically modeled by [Clarke \(2007\)](#). [Brunette, Cabantous, Couture, and Stenger \(2012\)](#) found that ambiguity continues to increase the willingness to pay for insurance in the presence of government assistance.

Theoretical results on the effect of ambiguity on self-insurance decisions, self-protection decisions, and the structure of insurance contracts have been mixed. [Snow \(2011\)](#) demonstrates how ambiguity aversion will generally increase the optimal levels of both self-insurance and self-protection, but [Alary,](#)

⁵⁰See, for example, the surveys of [Camerer and Weber \(1992\)](#), [Siniscalchi \(2008\)](#), [Hey, Lotito, and Maffioletti \(2010\)](#), [Etner, Jeleva, and Tallon \(2011\)](#), and [Gilboa and Marinacci \(2012\)](#).

⁵¹For example, [Savage \(1954\)](#), [Machina and Schmeidler \(1992\)](#).

⁵²The implications of such findings for insurance against environmental risks are discussed in [Kunreuther \(1989\)](#).

Gollier, and Treich (2012) provide conditions under which ambiguity aversion can raise the demand for self-insurance, but decrease the demand for self-protection. Alary, Gollier, and Treich also show how Arrow's (1971) result that the optimal insurance contract involves a straight deductible may well be robust to the presence of ambiguity and ambiguity aversion, although Gollier (2013a) shows that this may depend upon the whether the ambiguity is concentrated at high or low loss levels, and Martinez-Correa (2012) gives an example where it could be dominated by a coinsurance contract.

In experimental studies comparing the effect of ambiguity on self-insurance versus self-protection choices, di Mauro and Maffioletti (1996) and Ozdemir (2007) found little difference between the two forms, with ambiguity having a weak effect on valuations in both cases. In double-oral auction market experiments, Camerer and Kunreuther (1989) found that ambiguity had little effect on prices, but some effect on the quantity of insurance issued.

In a world where objective probabilities don't exist, or where agents may have different subjective probabilities over different events, or where agents may not have subjective probabilities at all, preferences can no longer be defined over lotteries $\mathbf{P} = (x_1, p_1; \dots; x_n, p_n)$, but must be defined directly over *subjective acts* of the form $f(\cdot) = [x_1 \text{ if } E_1; \dots; x_n \text{ if } E_n]$, which specify the payoff x_i to be received should event E_i occur, for some mutually exclusive and exhaustive collection of events $\{E_1, \dots, E_n\}$. In this framework, a \$100,000 dollar earthquake policy with a \$200 premium would take the form [\$100,000–\$200 if earthquake;–\$200 if no earthquake]. If it had a \$5,000 deductible, it would take the form [max(actual loss–\$5,000,\$0)–\$200 if earthquake;–\$200 if no earthquake]. If it had a \$5,000 maximum payoff, it would take the form [min(actual loss,\$5,000)–\$200 if earthquake;–\$200 if no earthquake].

Along the lines of Sect. 3.8, the specific model of preferences over subjective acts which has been most extensively analyzed is the so-called *Choquet* model of Schmeidler (1989).

$$\begin{aligned}
 \mathcal{V}(x_1, p_1; \dots; x_n, p_n) &= v(\hat{x}_1) \cdot G(\hat{p}_1) \\
 &\quad + v(\hat{x}_2) \cdot [G(\hat{p}_1 + \hat{p}_2) - G(\hat{p}_1)] \\
 &\quad + v(\hat{x}_3) \cdot [G(\hat{p}_1 + \hat{p}_2 + \hat{p}_3) - G(\hat{p}_1 + \hat{p}_2)] \\
 &\quad \vdots \\
 &\quad + v(\hat{x}_{n-1}) \cdot [G(\hat{p}_1 + \dots + \hat{p}_{n-1}) - G(\hat{p}_1 + \dots + \hat{p}_{n-2})] \\
 &\quad + v(\hat{x}_n) \cdot [G(1) - G(\hat{p}_1 + \dots + \hat{p}_{n-1})] \\
 &= \sum_{i=1}^n v(\hat{x}_i) \cdot \left[G\left(\sum_{j=1}^i \hat{p}_j\right) - G\left(\sum_{j=1}^{i-1} \hat{p}_j\right) \right] \tag{3.83}
 \end{aligned}$$

where $C(\cdot)$ is a nonadditive measure—termed a *capacity*—over events, and as in its objective analogue (3.68), \hat{x}_1 , denotes the largest outcome, \hat{x}_2 the second largest outcome, etc. Nonadditivity of the capacity $C(\cdot)$ makes the model flexible enough to allow departures from probabilistic sophistication, and in particular, Ellsberg-type ambiguity aversion.

Jeleva (2000) studies the effect of background risk on the optimal amount of insurance for individuals with Choquet preferences, and shows that even if they are risk averse, such individuals may prefer full coverage of actuarially unfair insurance. In addition, the effect of background risk upon insurance demand will depend in a qualitative manner upon the correlation of the two risks: when they are positively correlated across events,⁵³ attitudes toward insurance will depend solely on wealth preferences (the function $U(\cdot)$), but when they are negatively correlated, they will depend upon both

⁵³In the Choquet model, risks that are positively correlated across events are termed *comonotonic*.

$U(\cdot)$ and the nature of the individual's departure from probabilistic sophistication, as modeled by the capacity $C(\cdot)$. Mashayekhi (2013) gives conditions under which Arrow's result on the optimality of the deductible form generalizes to Choquet preferences,⁵⁴ and Chateauneuf, Dana, and Tallon (2000) and Billot, Chateauneuf, and Tallon (2002), respectively, explore risk- and belief-sharing for individuals with Choquet preferences.

More generally, and without adopting either probabilistic beliefs or Choquet preferences, Quiggin (2002) uses the subjective uncertainty approach to derive upper and lower bounds on willingness to pay for environmental hazard reduction, based on observable expenditures on self-protection with a known technology.

Because economists have yet to agree on their formal definitions of ambiguity and ambiguity aversion, the robustness of classical insurance theory to these phenomena has yet to be fully determined. Along the lines of Sect. 3.2, Machina (2005) provides some initial results on the robustness of classical subjective expected utility theory to "event-smooth" subjective preference functions of the form $\mathcal{V}(x_1 \text{ if } E_1; \dots; x_n \text{ if } E_n)$, though without specific application to insurance decisions.

3.11 Conclusion

Although the reader was warned that this robustness check would be more "broad" than "deep," even so, it is of incomplete breadth. There are several other important topics in the theory of insurance that remain unexamined. One is the effect of changes in risk (as opposed to risk aversion) upon the demand for insurance. This has been studied in the expected utility framework by Alarie, Dionne, and Eeckhoudt (1992). The results of Machina (1989) on the robustness of the classic Rothschild–Stiglitz (1971) comparative statics analysis suggest that this might be another area in which standard expected utility-based results would generally extend.

Another potentially huge area is that of insurance under asymmetric information. This has already played an important role in the motivation of much of insurance theory, as for example, in the theory of adverse selection (e.g., Akerlof 1970; Pauly 1974; Rothschild and Stiglitz 1976) the theory of moral hazard (e.g., Arrow 1963, 1968; Pauly 1968; Drèze 1986; Shavell 1979).⁵⁵ Although this work has been primarily built on the basis of individual expected utility maximization, many of its classic results do not depend upon the expected utility property and hence can be expected to be robust.⁵⁶ For example, the classic "lemons problem" of Akerlof (1970) derives from the effect of adverse selection on *beliefs* (i.e., actuarial or subjective probabilities) and hence is presumably quite robust to whether *risk preferences* are or are not expected utility. Similarly, the well-known Rothschild and Stiglitz (1976) analysis of pooling versus separating equilibria in insurance markets is conducted in the Hirshleifer–Yaari diagram, and although they do assume expected utility maximization, their results can be seen to follow from risk aversion and outcome-convexity of indifference curves.⁵⁷

Important contributions on non-expected utility and insurance, from various perspectives, include Cohen (1995), Doherty and Eeckhoudt (1995), Gollier (2013b), Karni (1992, 1995), Rigotti and

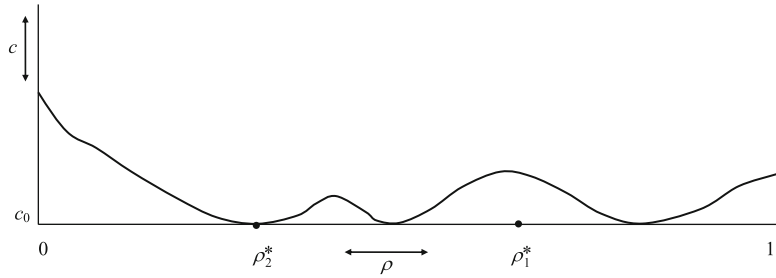
⁵⁴See, however, the predominantly negative findings of Ryan and Vaithianathan (2003).

⁵⁵See also Winter (2013), Dionne, Doherty, and Fombaron (2013), and the other related chapters in this volume.

⁵⁶See Jeleva and Villeneuve (2004), however, for some expected utility results that do not carry over.

⁵⁷The expected utility property only enters the Rothschild–Stiglitz analysis in their Eq. (3.4) (p.645), which gives conditions for an optimal insurance contract. As in the above analyses, these first-order conditions will continue to hold for general (risk averse, outcome convex) non-expected utility preferences, with individuals' von Neumann–Morgenstern utility functions replaced by their local utility functions.

Fig. 3.12 Indifference curve for the preference function $\phi_2(\rho, c)$



Shannon (2012), Schlee (1995), Schlesinger (1997), Schmidt (1996), and Viscusi (1995). Non-expected utility researchers have been, and will continue to be, beholden to the fundamental contributions of expected utility theorists in the study of insurance. For the most part, the increased analytical and empirical power that non-expected utility models and analysis can contribute to insurance theory will not require that we abandon or the many fundamental and foundational insights we have received from the expected utility model.

Appendix: Proofs of Theorems

Proof of Theorem 1: For notational simplicity, we can equivalently rewrite (3.28) as

$$\max_{\rho \in [0,1]} \mathcal{V}_i(c_0 + \rho \cdot \tilde{z}) \quad i = 1, 2 \tag{3.84}$$

where $c_0 = w_0 - (1 + \lambda) \cdot E[\tilde{\ell}]$, $\rho \equiv (1 - \alpha)$, and $\tilde{z} \equiv (1 + \lambda) \cdot E[\tilde{\ell}] - \tilde{\ell}$ with cumulative distribution function $F_{\tilde{z}}(\cdot)$. Proving the theorem is then equivalent to proving that if ρ_1^* is the largest solution to (3.84) for $\mathcal{V}_1(\cdot)$, and ρ_2^* is the smallest solution for $\mathcal{V}_2(\cdot)$, then $\rho_1^* \leq \rho_2^*$, with strict inequality unless $\rho_1^* = 1$.

For all $\rho \in [0, 1]$ and $c \geq c_0$, define the preference functions

$$\phi_i(\rho, c) \equiv \mathcal{V}_i(F_{c+\rho\tilde{z}}) \quad i = 1, 2, \tag{3.85}$$

where $F_{c+\rho\tilde{z}}(\cdot)$ is the cumulative distribution function of the random variable $c + \rho \cdot \tilde{z}$. By construction, each function $\phi_i(\rho, c)$ is continuously differentiable and possesses indifference curves over the set $\{(\rho, c) | \rho \in [0, 1], c \geq c_0\}$ which are “inherited” from $\mathcal{V}_i(\cdot)$, as in Fig. 3.12. Since first-order stochastic dominance preference ensures that $\partial\phi_i(\rho, c)/\partial c > 0$, these indifference curves cannot be either “backward bending” or “forward bending,” although they can be either upward and/or downward sloping. Note that the horizontal line $c = c_0$ in the figure corresponds to the one-dimensional feasible set in the maximization problem (3.84). In other words, $\phi_i(\rho, c_0)$ equals the objective function in (3.84), so ρ_1^* and ρ_2^* are the largest and the smallest global maxima of $\phi_1(\rho, c_0)$ and $\phi_2(\rho, c_0)$, respectively.

We first show that, at any point in the set $\{(\rho, c) | \rho \in (0, 1), c \geq c_0\}$, the marginal rates of substitution for the preference functions $\phi_1(\rho, c)$ and $\phi_2(\rho, c)$ must satisfy

$$MRS_1(\rho, c) \equiv -\frac{\partial\phi_1(\rho, c)/\partial\rho}{\partial\phi_1(\rho, c)/\partial c} > -\frac{\partial\phi_2(\rho, c)/\partial\rho}{\partial\phi_2(\rho, c)/\partial c} \equiv MRS_2(\rho, c). \tag{3.86}$$

To demonstrate this inequality, assume it is false, so that at some such point (ρ, c) we had⁵⁸

$$-\frac{\partial\phi_1(\rho, c)/\partial\rho}{\partial\phi_1(\rho, c)/\partial c} \leq k \leq -\frac{\partial\phi_2(\rho, c)/\partial\rho}{\partial\phi_2(\rho, c)/\partial c} \quad (3.87)$$

for some value k . Since k could have any sign, $c - \rho \cdot k$ could be either negative or nonnegative. If $c - \rho \cdot k < 0$: In this case, $c + \rho \cdot \tilde{z} \geq 0$ ⁵⁹ implies $\rho \cdot \tilde{z} + \rho \cdot k > 0$ and hence $\tilde{z} + k > 0$, which implies

$$0 < \int (z + k) \cdot U'_2(c + \rho \cdot z; F_{c+\rho\tilde{z}}) \cdot dF_{\tilde{z}}(z). \quad (3.88)$$

(3.88), (3.15), and (3.85) then imply

$$k > -\frac{\int z \cdot U'_2(c + \rho \cdot z; F_{c+\rho\tilde{z}}) \cdot dF_{\tilde{z}}(z)}{\int U'_2(c + \rho \cdot z; F_{c+\rho\tilde{z}}) \cdot dF_{\tilde{z}}(z)} = -\frac{\partial\mathcal{V}_2(c + \rho \cdot \tilde{z})/\partial\rho}{\partial\mathcal{V}_2(c + \rho \cdot \tilde{z})/\partial c} = -\frac{\partial\phi_2(\rho, c)/\partial\rho}{\partial\phi_2(\rho, c)/\partial c} \quad (3.89)$$

which is a contradiction, since it violates (3.87).

If $c - \rho \cdot k \geq 0$: In this case, (3.87), (3.86), and (3.15) imply

$$k \geq -\frac{\partial\mathcal{V}_1(F_{c+\rho\tilde{z}})/\partial\rho}{\partial\mathcal{V}_1(F_{c+\rho\tilde{z}})/\partial c} = -\frac{\int z \cdot U'_1(c + \rho \cdot z; F_{c+\rho\tilde{z}}) \cdot dF_{\tilde{z}}(z)}{\int U'_1(c + \rho \cdot z; F_{c+\rho\tilde{z}}) \cdot dF_{\tilde{z}}(z)}. \quad (3.90)$$

so that we have

$$\begin{aligned} 0 &\leq \int (z + k) \cdot \frac{U'_1(c + \rho \cdot z; F_{c+\rho\tilde{z}})}{U'_1(c - \rho \cdot k; F_{c+\rho\tilde{z}})} \cdot dF_{\tilde{z}}(z) \\ &= \int_{z+k>0} (z + k) \cdot \frac{U'_1(c + \rho \cdot z; F_{c+\rho\tilde{z}})}{U'_1(c - \rho \cdot k; F_{c+\rho\tilde{z}})} \cdot dF_{\tilde{z}}(z) + \int_{z+k<0} (z + k) \cdot \frac{U'_1(c + \rho \cdot z; F_{c+\rho\tilde{z}})}{U'_1(c - \rho \cdot k; F_{c+\rho\tilde{z}})} \cdot dF_{\tilde{z}}(z) \\ &< \int_{z+k>0} (z + k) \cdot \frac{U'_2(c + \rho \cdot z; F_{c+\rho\tilde{z}})}{U'_2(c - \rho \cdot k; F_{c+\rho\tilde{z}})} \cdot dF_{\tilde{z}}(z) + \int_{z+k<0} (z + k) \cdot \frac{U'_2(c + \rho \cdot z; F_{c+\rho\tilde{z}})}{U'_2(c - \rho \cdot k; F_{c+\rho\tilde{z}})} \cdot dF_{\tilde{z}}(z) \\ &= \int (z + k) \cdot \frac{U'_2(c + \rho \cdot z; F_{c+\rho\tilde{z}})}{U'_2(c - \rho \cdot k; F_{c+\rho\tilde{z}})} \cdot dF_{\tilde{z}}(z) \end{aligned} \quad (3.91)$$

where the strict inequality for the “ $z + k > 0$ ” integrals follows since in this case we have $c + \rho \cdot z > c - \rho \cdot k$, so comparative risk aversion implies $0 < U'_1(c + \rho \cdot z; F_{c+\rho\tilde{z}})/U'_1(c - \rho \cdot k; F_{c+\rho\tilde{z}}) < U'_2(c + \rho \cdot z; F_{c+\rho\tilde{z}})/U'_2(c - \rho \cdot k; F_{c+\rho\tilde{z}})$. Strict inequality for the “ $z + k < 0$ ” integrals follows since in this case we have $c + \rho \cdot z < c - \rho \cdot k$, so the comparative risk aversion condition implies $U'_1(c + \rho \cdot z; F_{c+\rho\tilde{z}})/U'_1(c - \rho \cdot k; F_{c+\rho\tilde{z}}) > U'_2(c + \rho \cdot z; F_{c+\rho\tilde{z}})/U'_2(c - \rho \cdot k; F_{c+\rho\tilde{z}}) > 0$, but these ratios are each multiplied by the negative quantity $(z + k)$. This once again implies (3.88) and hence (3.89) and a contradiction. This then establishes inequality (3.86).

Inequality (3.86) implies that, throughout the entire region $\{(\rho, c) | \rho \in (0, 1), c \geq c_0\}$, leftward movements along any $\phi_1(\rho, c)$ indifference curve must strictly lower $\phi_2(\rho, c)$, and rightward movements along any $\phi_2(\rho, c)$ indifference curve must strictly lower $\phi_1(\rho, c)$.

⁵⁸From here until the end of the paragraph following (3.91), all equations and discussion refer to this point (ρ, c) .

⁵⁹Since $c + \rho \cdot \tilde{z} \geq c_0 + \rho \cdot \tilde{z} = w_0 - (1 + \lambda) \cdot E[\tilde{\ell}] + \rho \cdot ((1 + \lambda) \cdot E[\tilde{\ell}] - \tilde{\ell}) = \rho \cdot (w_0 - \tilde{\ell}) + (1 - \rho) \cdot (w_0 - (1 + \lambda) \cdot E[\tilde{\ell}])$, nonnegativity of $c + \rho \cdot \tilde{z}$ on the set $\{(\rho, c) | \rho \in [0, 1], c \geq c_0\}$ follows from nonnegativity of $w_0 - \tilde{\ell}$ and $w_0 - (1 + \lambda) \cdot E[\tilde{\ell}]$. Note that since $c \geq c_0 > 0$, the condition $c - \rho \cdot k < 0$ also implies that ρ must be nonzero, and hence positive.

Assume $\rho_2^* < \rho_1^*$, as illustrated in Fig. 3.12. In this case, consider the point (ρ_2^*, c_0) . As we move rightward along the $\phi_2(\rho, c)$ indifference curve that passes through this point, the value of $\phi_1(\rho, c)$ must strictly drop, so that $\phi_1(\rho, c)$ strictly prefers the point (ρ_2^*, c_0) to every point on the curve that lies to the right of (ρ_2^*, c_0) . But since (ρ_2^*, c_0) is a global optimum for $\phi_2(\rho, c_0)$, this indifference curve must lie everywhere on or above the horizontal line $c = c_0$. Since $\partial\phi_1(\rho, c)/\partial c > 0$, this implies that $\phi_1(\rho, c)$ strictly prefers the point (ρ_2^*, c_0) to every point on the line $c = c_0$ that lies to the right of (ρ_2^*, c_0) , which contradicts the assumption that there is a global maximum ρ_1^* which exceeds (i.e., lies to the right of) ρ_2^* . This, then, establishes that $\rho_1^* \leq \rho_2^*$.

To complete the proof, we must rule out $\rho_1^* = \rho_2^*$ unless $\rho_1^* = 1$. In the case $\rho_1^* < 1$, CO.2 and $\lambda > 0$ imply $\rho_2^* < 1$ so we would have $0 < \rho_2^* = \rho_1^* < 1$. However this case of identical interior optima would imply that both individuals' indifference curves had zero slope at the interior point $(\rho_1^*, c_0) = (\rho_2^*, c_0)$, which violates (3.86).

Q.E.D.

Proof of Theorem 2: For notational simplicity, define

$$\eta(\ell, \alpha) \equiv (1 + \lambda) \cdot E[\max\{\tilde{l} - \alpha, 0\}] + \ell - \max\{\ell - \alpha, 0\} \begin{cases} (1 + \lambda) \cdot \int_{\alpha}^M (\varepsilon - \alpha) \cdot dF_{\tilde{\ell}}(\varepsilon) + \alpha & \text{if } \ell \geq \alpha \\ (1 + \lambda) \cdot \int_{\alpha}^M (\varepsilon - \alpha) \cdot dF_{\tilde{\ell}}(\varepsilon) + \ell & \text{if } \ell \leq \alpha \end{cases} \quad (3.92)$$

This implies $\eta(\ell, \alpha) = \eta(\alpha, \alpha)$ if $\ell \geq \alpha$, and $\eta(\ell, \alpha) < \eta(\alpha, \alpha)$ if $\ell < \alpha$. We also have

$$\frac{\partial\eta(\ell, \alpha)}{\partial\alpha} = \begin{cases} -(1 + \lambda) \cdot \int_{\alpha}^M 1 \cdot dF_{\tilde{\ell}}(\varepsilon) + 1 = -(1 + \lambda) \cdot [1 - F_{\tilde{\ell}}(\alpha)] + 1 & \text{if } \ell > \alpha \\ -(1 + \lambda) \cdot \int_{\alpha}^M 1 \cdot dF_{\tilde{\ell}}(\varepsilon) = -(1 + \lambda) \cdot [1 - F_{\tilde{\ell}}(\alpha)] & \text{if } \ell < \alpha \end{cases} \quad (3.93)$$

For all $\alpha \in [0, M]$ and $w \geq w_0$, let $F_{\alpha, w}(\cdot)$ denote the cumulative distribution function of the random variable

$$w - (1 + \lambda) \cdot E[\max\{\tilde{l} - \alpha, 0\}] - \tilde{l} + \max\{\tilde{l} - \alpha, 0\} \equiv w - \eta(\tilde{l}, \alpha) \quad (3.94)$$

and define the preference functions

$$\phi_i(\alpha, w) \equiv \mathcal{V}_i(F_{\alpha, w}) \quad i = 1, 2. \quad (3.95)$$

By construction, each function $\phi_i(\alpha, w)$ is continuously differentiable and possesses indifference curves over the set $\{(\alpha, w) | \alpha \in [0, M], w \geq w_0\}$ which are “inherited” from $\mathcal{V}_i(\cdot)$, as in Fig. 3.13. Since first-order stochastic dominance preference ensures that $\partial\phi_i(\alpha, w)/\partial w > 0$, these indifference curves cannot be either “backward bending” or “forward bending,” although they can be either upward and/or downward sloping. Note that the horizontal line $w = w_0$ in the figure corresponds to the one-dimensional feasible set in the problem (3.35). In other words, $\phi_i(\alpha, w_0)$ equals the objective function in (3.35), so α_1^* and α_2^* are the largest and the smallest global maxima of $\phi_1(\alpha, w_0)$ and $\phi_2(\alpha, w_0)$, respectively.

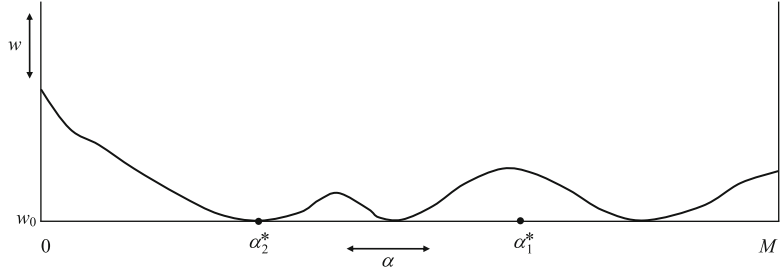
We first show that, at any point in the set $\{(\alpha, w) | \alpha \in (0, M), w \geq w_0\}$, the marginal rates of substitution for the preference functions $\phi_1(\alpha, w)$ and $\phi_2(\alpha, w)$ must satisfy

$$MRS_1(\alpha, w) \equiv -\frac{\partial\phi_1(\alpha, w)/\partial\alpha}{\partial\phi_1(\alpha, w)/\partial w} > -\frac{\partial\phi_2(\alpha, w)/\partial\alpha}{\partial\phi_2(\alpha, w)/\partial w} \equiv MRS_2(\alpha, w). \quad (3.96)$$

To demonstrate this inequality, assume it is false, so that at some such point (α, w) we had⁶⁰

⁶⁰From here until (3.101), all equations and discussion refer to this point (α, w) .

Fig. 3.13 Indifference curve for the preference function $\phi_2(\alpha, w)$



$$-\frac{\partial \phi_1(\alpha, w)/\partial \alpha}{\partial \phi_1(\alpha, w)/\partial w} \leq k \leq -\frac{\partial \phi_2(\alpha, w)/\partial \alpha}{\partial \phi_2(\alpha, w)/\partial w} \quad (3.97)$$

for some k . Since k could have any sign, $k + (1 + \lambda) \cdot [1 - F_{\bar{\ell}}(\alpha)]$ could be either nonpositive or positive.

If $k + (1 + \lambda) \cdot [1 - F_{\bar{\ell}}(\alpha)] \leq 0$: In this case, note from (3.93) that at the point (α, w) , a differential increase in α of $d\alpha$ combined with a differential change in w of $dw = -(1 + \lambda) \cdot [1 - F_{\bar{\ell}}(\alpha)] \cdot d\alpha$ has zero differential effect on $w - \eta(\ell, \alpha)$ for each $\ell < \alpha$, and a strictly negative differential effect on $w - \eta(\ell, \alpha)$ for each $\ell > \alpha$. Since $\alpha \in (0, M)$ so that $\text{prob}(\bar{\ell} > \alpha) > 0$, this implies a strictly negative differential effect on $\mathcal{V}_1(F_{\alpha, w})$. Hence, the value of dw necessary to have zero differential effect on $\mathcal{V}_1(F_{\alpha, w})$ must be greater than $-(1 + \lambda) \cdot [1 - F_{\bar{\ell}}(\alpha)] \cdot d\alpha$, and hence greater than $k \cdot d\alpha$. This implies that $MRS_1(\alpha, w) > k$, which is a contradiction since it violates (3.97).

If $k + (1 + \lambda) \cdot [1 - F_{\bar{\ell}}(\alpha)] > 0$: From (3.93), this implies that $k - \partial \eta(\ell, \alpha)/\partial \alpha > 0$ for $\ell < \alpha$. (3.97), (3.95), and (3.15) imply

$$k \geq -\frac{\partial \mathcal{V}_1(F_{\alpha, w})/\partial \alpha}{\partial \mathcal{V}_1(F_{\alpha, w})/\partial w} = -\frac{\int \left(-\frac{\partial \eta(\ell, \alpha)}{\partial \alpha}\right) \cdot U'_1(w - \eta(\ell, \alpha); F_{\alpha, w}) \cdot dF_{\bar{\ell}}(\ell)}{\int U'_1(w - \eta(\ell, \alpha); F_{\alpha, w}) \cdot dF_{\bar{\ell}}(\ell)} \quad (3.98)$$

so that

$$\begin{aligned} 0 &\leq \int \left(k - \frac{\partial \eta(\ell, \alpha)}{\partial \alpha}\right) \cdot \frac{U'_1(w - \eta(\ell, \alpha); F_{\alpha, w})}{U'_1(w - \eta(\alpha, \alpha); F_{\alpha, w})} \cdot dF_{\bar{\ell}}(\ell) \\ &= \int_{\ell \geq \alpha} \left(k - \frac{\partial \eta(\ell, \alpha)}{\partial \alpha}\right) \cdot \frac{U'_1(w - \eta(\ell, \alpha); F_{\alpha, w})}{U'_1(w - \eta(\alpha, \alpha); F_{\alpha, w})} \cdot dF_{\bar{\ell}}(\ell) + \int_{\ell < \alpha} \left(k - \frac{\partial \eta(\ell, \alpha)}{\partial \alpha}\right) \cdot \frac{U'_1(w - \eta(\ell, \alpha); F_{\alpha, w})}{U'_1(w - \eta(\alpha, \alpha); F_{\alpha, w})} \cdot dF_{\bar{\ell}}(\ell) \\ &= \int_{\ell \geq \alpha} \left(k - \frac{\partial \eta(\ell, \alpha)}{\partial \alpha}\right) \cdot \frac{U'_1(w - \eta(\alpha, \alpha); F_{\alpha, w})}{U'_1(w - \eta(\alpha, \alpha); F_{\alpha, w})} \cdot dF_{\bar{\ell}}(\ell) + \int_{\ell < \alpha} \left(k - \frac{\partial \eta(\ell, \alpha)}{\partial \alpha}\right) \cdot \frac{U'_1(w - \eta(\ell, \alpha); F_{\alpha, w})}{U'_1(w - \eta(\alpha, \alpha); F_{\alpha, w})} \cdot dF_{\bar{\ell}}(\ell) \\ &< \int_{\ell \geq \alpha} \left(k - \frac{\partial \eta(\ell, \alpha)}{\partial \alpha}\right) \cdot \frac{U'_2(w - \eta(\alpha, \alpha); F_{\alpha, w})}{U'_2(w - \eta(\alpha, \alpha); F_{\alpha, w})} \cdot dF_{\bar{\ell}}(\ell) + \int_{\ell < \alpha} \left(k - \frac{\partial \eta(\ell, \alpha)}{\partial \alpha}\right) \cdot \frac{U'_2(w - \eta(\ell, \alpha); F_{\alpha, w})}{U'_2(w - \eta(\alpha, \alpha); F_{\alpha, w})} \cdot dF_{\bar{\ell}}(\ell) \\ &= \int_{\ell \geq \alpha} \left(k - \frac{\partial \eta(\ell, \alpha)}{\partial \alpha}\right) \cdot \frac{U'_2(w - \eta(\ell, \alpha); F_{\alpha, w})}{U'_2(w - \eta(\alpha, \alpha); F_{\alpha, w})} \cdot dF_{\bar{\ell}}(\ell) + \int_{\ell < \alpha} \left(k - \frac{\partial \eta(\ell, \alpha)}{\partial \alpha}\right) \cdot \frac{U'_2(w - \eta(\ell, \alpha); F_{\alpha, w})}{U'_2(w - \eta(\alpha, \alpha); F_{\alpha, w})} \cdot dF_{\bar{\ell}}(\ell) \\ &= \int \left(k - \frac{\partial \eta(\ell, \alpha)}{\partial \alpha}\right) \cdot \frac{U'_2(w - \eta(\ell, \alpha); F_{\alpha, w})}{U'_2(w - \eta(\alpha, \alpha); F_{\alpha, w})} \cdot dF_{\bar{\ell}}(\ell) \end{aligned} \quad (3.99)$$

Note that the “ $\ell \geq \alpha$ ” integrals in the third and fourth lines of (3.99) are exactly equal. The strict inequality in (3.99) derives from the “ $\ell < \alpha$ ” integrals in these two lines, since for these integrals

we have (i) $w - \eta(\ell, \alpha) > w - \eta(\alpha, \alpha)$, so the comparative risk aversion condition implies $U'_2(w - \eta(\ell, \alpha))/U'_2(w - \eta(\alpha, \alpha)) > U'_1(w - \eta(\ell, \alpha))/U'_1(w - \eta(\alpha, \alpha)) > 0$; (ii) the term $(k - \partial\eta(\ell, \alpha)/\partial\alpha)$ is positive; and (iii) since $\alpha \in (0, M)$, the distribution $F_{\bar{\ell}}(\cdot)$ assigns positive probability to the range $\ell \in [0, \alpha)$.

From (3.99) we have

$$0 < \int \left(k - \frac{\partial\eta(\ell, \alpha)}{\partial\alpha} \right) \cdot U'_2(w - \eta(\ell, \alpha); F_{\alpha, w}) \cdot dF_{\bar{\ell}}(\ell) \quad (3.100)$$

and hence

$$k > \frac{\int \frac{\partial\eta(\ell, \alpha)}{\partial\alpha} \cdot U'_2(w - \eta(\ell, \alpha); F_{\alpha, w}) \cdot dF_{\bar{\ell}}(\ell)}{\int U'_2(w - \eta(\ell, \alpha); F_{\alpha, w}) \cdot dF_{\bar{\ell}}(\ell)} = -\frac{\partial\mathcal{V}_2(F_{\alpha, w})/\partial\alpha}{\partial\mathcal{V}_2(F_{\alpha, w})/\partial w} = -\frac{\partial\phi_2(\alpha, w)/\partial\alpha}{\partial\phi_2(\alpha, w)/\partial w}, \quad (3.101)$$

which is a contradiction since it violates (3.97). This then establishes inequality (3.96).

Inequality (3.96) implies that, throughout the entire region $\{(\alpha, w) | \alpha \in (0, M), w \geq w_0\}$, leftward movements along any $\phi_1(\alpha, w)$ indifference curve must strictly lower $\phi_2(\alpha, w)$, and rightward movements along any $\phi_2(\alpha, w)$ indifference curve must strictly lower $\phi_1(\alpha, w)$.

Assume $\alpha_2^* < \alpha_1^*$, as illustrated in Fig. 3.13. In this case, consider the point (α_2^*, w_0) . As we move rightward along the $\phi_2(\alpha, w)$ indifference curve that passes through this point, the value of $\phi_1(\alpha, w)$ must strictly drop, so that $\phi_1(\alpha, w)$ strictly prefers the point (α_2^*, w_0) to every point on the curve that lies to the right of (α_2^*, w_0) . But since (α_2^*, w_0) is a global optimum for $\phi_2(\alpha, w_0)$, this indifference curve must lie everywhere on or above the horizontal line $w = w_0$. Since $\partial\phi_1(\alpha, w)/\partial w > 0$, this implies that $\phi_1(\alpha, w)$ strictly prefers the point (α_2^*, w_0) to every point on the line $w = w_0$ that lies to the right of (α_2^*, w_0) , which contradicts the assumption that there is a global maximum α_1^* which exceeds (i.e., lies to the right of) α_2^* . This, then, establishes that $\alpha_1^* \leq \alpha_2^*$.

To complete the proof, we must rule out $\alpha_1^* = \alpha_2^*$ unless $\alpha_1^* = M$. In the case $\alpha_1^* < M$, DE.2 and $\lambda > 0$ imply $\alpha_2^* > 0$, so that equality of α_1^* and α_2^* would imply $0 < \alpha_2^* = \alpha_1^* < M$. However, this case of identical interior optima would imply that both individuals' indifference curves had zero slope at the interior point $(\alpha_1^*, w_0) = (\alpha_2^*, w_0)$, which violates (3.96).

Q.E.D.

Proof of Theorem 3: For all $\alpha \in [0, M]$ and $w \geq w_0$, define the probability distribution

$$\mathbf{P}_{\alpha, w} \equiv (w_0 - l(\alpha) - \alpha, \bar{p}; w_0 - \alpha, 1 - \bar{p}) \quad (3.102)$$

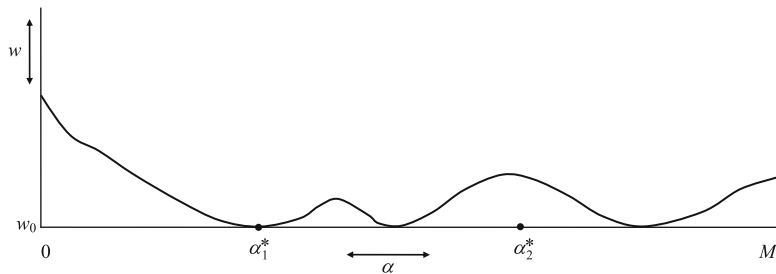
and define the preference functions

$$\phi_i(\alpha, w) \equiv \mathcal{V}_i(\mathbf{P}_{\alpha, w}) \quad i = 1, 2 \quad (3.103)$$

By construction, each function $\phi_i(\alpha, w)$ is continuously differentiable and possesses indifference curves over the set $\{(\alpha, w) | \alpha \in [0, M], w \geq w_0\}$ which are “inherited” from $\mathcal{V}_i(\cdot)$, as in Fig. 3.14. Since first-order stochastic dominance preference ensures that $\partial\phi_i(\alpha, w)/\partial w > 0$, these indifference curves cannot be either “backward bending” or “forward bending,” although they can be either upward and/or downward sloping. Note that the horizontal line $w = w_0$ in the figure corresponds to the one-dimensional feasible set in the problem (3.59). In other words, $\phi_i(\alpha, w_0)$ equals the objective function in (3.59), so α_1^* and α_2^* are the smallest and largest global maxima of $\phi_1(\alpha, w_0)$ and $\phi_2(\alpha, w_0)$, respectively.

We first show that, at any point in the set $\{(\alpha, w) | \alpha \in (0, M), w \geq w_0\}$, the marginal rates of substitution for the preference functions $\phi_1(\alpha, w)$ and $\phi_2(\alpha, w)$ must satisfy

Fig. 3.14 Indifference curve for the preference function $\phi_1(\alpha, w)$



$$MRS_1(\alpha, w) \equiv -\frac{\partial\phi_1(\alpha, w)/\partial\alpha}{\partial\phi_1(\alpha, w)/\partial w} < -\frac{\partial\phi_2(\alpha, w)/\partial\alpha}{\partial\phi_2(\alpha, w)/\partial w} \equiv MRS_2(\alpha, w). \quad (3.104)$$

From (3.103) and (3.15), we have

$$\begin{aligned} \frac{\partial\phi_1(\alpha, w)/\partial\alpha}{\partial\phi_1(\alpha, w)/\partial w} &= \frac{(1 + \ell'(\alpha)) \cdot U'_1(w - \ell(\alpha) - \alpha; \mathbf{P}_{\alpha, w}) \cdot \bar{p} + U'_1(w - \alpha; \mathbf{P}_{\alpha, w}) \cdot (1 - \bar{p})}{U'_1(w - \ell(\alpha) - \alpha; \mathbf{P}_{\alpha, w}) \cdot \bar{p} + U'_1(w - \alpha; \mathbf{P}_{\alpha, w}) \cdot (1 - \bar{p})} \\ &= 1 + \frac{\ell'(\alpha)}{1 + \left(\frac{U'_1(w - \alpha; \mathbf{P}_{\alpha, w})}{U'_1(w - \ell(\alpha) - \alpha; \mathbf{P}_{\alpha, w})}\right) \cdot \left(\frac{1 - \bar{p}}{\bar{p}}\right)} \\ &< 1 + \frac{\ell'(\alpha)}{1 + \left(\frac{U'_2(w - \alpha; \mathbf{P}_{\alpha, w})}{U'_2(w - \ell(\alpha) - \alpha; \mathbf{P}_{\alpha, w})}\right) \cdot \left(\frac{1 - \bar{p}}{\bar{p}}\right)} \\ &= -\frac{\partial\phi_2(\alpha, w)/\partial\alpha}{\partial\phi_2(\alpha, w)/\partial w}, \end{aligned} \quad (3.105)$$

where the strict inequality follows since (a) $w - \alpha > w - \ell(\alpha) - \alpha$ so the comparative risk aversion condition implies $U'_2(w - \alpha; \mathbf{P}_{\alpha, w})/U'_2(w - \ell(\alpha) - \alpha; \mathbf{P}_{\alpha, w}) > U'_1(w - \alpha; \mathbf{P}_{\alpha, w})/U'_1(w - \ell(\alpha) - \alpha; \mathbf{P}_{\alpha, w}) > 0$; (b) these ratios occur in *denominators*; and (c) $\ell'(\alpha) < 0$.

Inequality (3.104) implies that, throughout the entire region $\{(\alpha, w) | \alpha \in (0, M), w \geq w_0\}$, rightward movements along any $\phi_1(\alpha, w)$ indifference curve must strictly lower $\phi_2(\alpha, w)$, and leftward movements along any $\phi_2(\alpha, w)$ indifference curve must strictly lower $\phi_1(\alpha, w)$.

Assume $\alpha_1^* < \alpha_2^*$, as illustrated in Fig. 3.14. In this case, consider the point (α_1^*, w_0) . As we move rightward along the $\phi_1(\alpha, w)$ indifference curve that passes through this point, the value of $\phi_2(\alpha, w)$ must strictly drop, so that $\phi_2(\alpha, w)$ strictly prefers the point (α_1^*, w_0) to every point on the curve that lies to the right of (α_1^*, w_0) . But since (α_1^*, w_0) is a global optimum for $\phi_1(\alpha, w_0)$, this indifference curve must lie everywhere on or above the horizontal line $w = w_0$. Since $\partial\phi_2(\alpha, w)/\partial w > 0$, this implies that $\phi_2(\alpha, w)$ strictly prefers the point (α_1^*, w_0) to every point on the *line* $w = w_0$ that lies to the right of (α_1^*, w_0) , which contradicts the assumption that there is a global maximum α_2^* which exceeds (i.e., lies to the right of) α_1^* . This, then, establishes that $\alpha_2^* \leq \alpha_1^*$.

To complete the proof, we must rule out $\alpha_1^* = \alpha_2^*$ unless either $\alpha_1^* = 0$ or $\alpha_2^* = M$. If neither of these cases hold, we have $\alpha_1^* > 0$ and $\alpha_2^* < M$, so that equality of α_1^* and α_2^* would imply $0 < \alpha_1^* = \alpha_2^* < M$. However, this case of identical *interior* optima would imply that both individuals' indifference curves had zero slope at the interior point $(\alpha_1^*, w_0) = (\alpha_2^*, w_0)$, which violates (3.104).

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Chapter 4

The Economics of Optimal Insurance Design

Christian Gollier

Abstract This chapter provides a survey on optimal insurance when insurers and policyholders have symmetric information about the distribution of potential damages. Under general conditions on the policyholder risk aversion and on transaction costs, the optimal insurance contract contains full insurance of losses above a straight deductible. This is proven without assuming expected utility. The use of expected utility generates additional results, e.g., in the case of nonlinear transaction costs.

4.1 Introduction

Sharing risk is a crucial element in the functioning of our modern economies. A well-known and intuitive result is that it is socially efficient for risk-neutral agents to fully insure other risk-averse agents. This optimal risk-sharing arrangement allows for the elimination of costly risk premia that would have been borne by some risk-averse agents otherwise. In competitive markets for risks, that would be an equilibrium allocation if all parties would have the same information about the distribution of existing risks and if there would not be any transaction costs. This last hypothesis is clearly unrealistic, as insurance companies usually bear costs that amount up to 30% of their cash flows on lines as standard as automobile insurance or homeowner insurance. Marketing costs, management costs and costs to audit claims are the three main sources of expenses for insurers.

When risk transfers are costly, it is in general not efficient to transfer all risks to risk-neutral agents, even in the absence of agency problems. A reduction in the indemnity paid in some states of the world has now the additional benefit to reduce transaction costs, which in turn generates a reduction in the insurance premium. The main problem that is addressed in the literature on optimal insurance is to determine the states of nature under which it is best to reduce insurance coverage. Symmetrically, starting from no insurance, one can address the question of the states of the world that agents would like to insure first. Intuitively, insurance indemnities are the most desirable, at the margin, where the wealth level is the smallest, if marginal utility is decreasing. Thus, when the marginal cost of insurance is constant, agents who are seeking for costly insurance should select a policy in which large losses are better indemnified than smaller losses, in absolute terms. This is the intuition behind the optimality of a straight deductible, a result first proven by [Arrow \(1971, 1974\)](#). A straight deductible is the insurance clause that maximizes the minimum final wealth level with a given insurance budget. It organizes a

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best compromise between the benefits of insurance coverage for risk-averse policyholders and the willingness to limit (proportional) transaction costs.

Under expected utility (EU), the inverse relationship between marginal utility and wealth explains why it is better to cover the largest loss first.¹ But [Zilcha and Chew \(1990\)](#), [Karni \(1992\)](#), [Schlesinger \(1997\)](#), and [Gollier and Schlesinger \(1996\)](#) have shown that the Arrow's result is robust to any non-expected utility decision model that satisfies the second-degree stochastic dominance property. The objective of this chapter is to show how several results that exist in this literature can be obtained under conditions that are much weaker than EU. As an example, when an agent faces several sources of risk, we know from [Gollier and Schlesinger \(1995\)](#) that it is optimal under EU to cover them through an "umbrella policy," i.e., a policy in which the indemnity is a function of the aggregate loss alone. We show in this chapter that this remains true when EU is replaced by second-order stochastic dominance.

The results described above just rely on the concept of risk aversion, not on its measurement or intensity. However, a specific decision model is required when one turns to the question of the size of the optimal deductible. Clearly, it depends upon the degree of risk aversion of the policyholder. Depending upon how we model risk aversion, we will obtain different answers to this question. Other limits of a model-free analysis are when the insurer is risk-averse, or when one examines the optimal insurance contract with transaction costs that depend upon the size of the indemnity in a nonlinear way. In any of these cases, a more precise description of preferences must be made. Because of its long anteriority, most of the existing researches in this field have been performed by using the expected utility model. We will cover this literature in this survey.

4.2 The Basic Framework

4.2.1 The Model

There is a set $\{\theta_1, \dots, \theta_T\}$ of potential states of the world in the economy.² The uncertainty is represented by a vector of probabilities (π_1, \dots, π_T) where $\pi_t = \text{Prob}[\tilde{\theta} = \theta_t] > 0$ and $\sum_t \pi_t = 1$. These probabilities are common knowledge. Finally, the realization of $\tilde{\theta}$ is perfectly observable. A risk-averse agent faces a risk of aggregate loss $x(\tilde{\theta})$ to his initial wealth w_0 . The market provides insurance contracts for this risk. A contract is characterized by a premium P and indemnity schedule $I(\theta)$. By selling this contract, the insurer gets P ex ante, and he promises to pay $I(\theta_t)$ if state θ_t occurs ex post, $t = 1, \dots, T$.

Insurers are all identical and risk-neutral. They face a deadweight loss $c(I)$ whenever an indemnity I is paid. Function c is nondecreasing. We assume perfect competition on the insurance market. Therefore, the insurance tariff is given by the following equation:

$$P = E[I(\tilde{\theta}) + c(I(\tilde{\theta}))]. \quad (4.1)$$

The final wealth w_f of the policyholder purchasing policy (P, I) is

$$w_f(\theta) = w_0 - x(\theta) + I(\theta) - P, \quad (4.2)$$

¹[Eeckhoudt and Gollier \(1995\)](#) provide a complete analysis of the insurance problem under EU.

²For simplicity, we assume a finite number of states. All results remain true under continuous or mixed distribution functions.

in state θ . Finally, one generally assumes that insurance markets are constrained to provide policies with nonnegative indemnity schedules: $I(\theta) \geq 0$ for all θ . In other words, identifying a negative indemnity as an ex post premium, ex post increases in premium are prohibited. There is a technical justification for imposing this constraint. Indeed, the condition $c' > 0$ is not realistic when the indemnity is negative. In this case, an increase in the transfer would *reduce* transaction costs!³

4.2.2 The Concepts of Risk Aversion

The attitude towards risk of the policyholder is characterized by a real-valued preference functional $V(w_f(\tilde{\theta}))$. This means that risk $w_{f_1}(\tilde{\theta})$ is preferred to risk $w_{f_2}(\tilde{\theta})$ if and only if $V(w_{f_1}(\tilde{\theta}))$ is larger than $V(w_{f_2}(\tilde{\theta}))$. If V is linear in probabilities—a condition that can be derived from the independence axiom—the model simplifies to the EU criterion.

In most of this chapter, two basic assumptions will be made on the attitude towards risk of the policyholder. First, we assume that it satisfies first-degree stochastic dominance (FSD). That is, if $\hat{w}(\tilde{\theta})$ dominates $w(\tilde{\theta})$ in the sense of FSD, then the policyholder prefers $\hat{w}(\tilde{\theta})$ to $w(\tilde{\theta})$: $V(\hat{w}(\tilde{\theta})) \geq V(w(\tilde{\theta}))$. An FSD deterioration in risk is obtained by transferring probability masses from higher wealth states to lower wealth states. It can also be obtained by reducing wealth in any state of the world. Under EU, the FSD property holds if and only if utility is increasing in wealth.

The second assumption on the preference functional V is that if one risk $\hat{w}(\tilde{\theta})$ is a mean-preserving contraction (MPC) of another risk $w(\tilde{\theta})$, then the agent prefers the first to the second: $V(\hat{w}(\tilde{\theta})) \geq V(w(\tilde{\theta}))$. Risk $\hat{w}(\tilde{\theta})$ dominates risk $w(\tilde{\theta})$ in the sense of an MPC if w is obtained from \hat{w} by adding a white noise to it:

$$w(\tilde{\theta}) =_d \hat{w}(\tilde{\theta}) + \epsilon(\tilde{\theta}),$$

where $E[\epsilon(\tilde{\theta}) \mid \hat{w}(\tilde{\theta}) = z] = 0$, for all z . Thus, the MPC property means that the agent dislikes any zero-mean lottery that would be added to his final wealth. This is a strong notion of risk aversion. It is a generalization of weak risk aversion, which is meant as the preference of the expectation $E\tilde{x}$ over the random variable \tilde{x} . The strong and the weak notion of risk aversion are equivalent in the EU model. They are both equivalent to the concavity of the utility function. But they are in general two separate concepts for more general preference functionals. In order to derive results on optimal insurance policies, we will need to rely on the strong concept of risk aversion.⁴

4.2.3 On the Optimality of Partial Insurance

Before going to the specific analysis of the optimal insurance policy design, it is noteworthy that it is never optimal to get a positive indemnity in all states, because of the presence of transaction costs. More precisely, combining FSD with $c' > 0$ yields the following result:

Proposition 1. *Suppose that c' is positive. If the preference functional V satisfies the FSD property, then there exists at least one state of nature in which no indemnity is paid to the policyholder.*

³Gollier (1987a) and Breuer (2004) allow for negative indemnities by assuming that transaction costs depend upon the absolute value of the indemnity. Surprisingly enough, in most cases, removing the constraint on the nonnegativity of claims has no effect on the optimal contract.

⁴Cohen (1995) provides an excellent analysis of the various definitions of risk aversion and their connexions to each other.

Proof. Suppose by contradiction there exists a scalar $k > 0$ such that $I(\theta) \geq k$ for all θ . Consider an alternative contract with $\hat{I}(\theta, k) = I(\theta) - k \geq 0$ for all θ . The premium to pay for this new contract is

$$\hat{P}(k) = E[\hat{I}(\tilde{\theta}, k) + c(\hat{I}(\tilde{\theta}, k))].$$

Observe that

$$\hat{P}'(0) = -1 - E[c'(I(\tilde{\theta}))].$$

The final wealth with the new contract is $\hat{w}_f(\theta, k) = w_0 - x(\theta) + \hat{I}(\theta, k) - \hat{P}(k)$ in state θ . Differentiating with respect to k yields

$$\left. \frac{\partial \hat{w}}{\partial k} \right|_{k=0} = -1 - \hat{P}'(0) = E[c'(I(\tilde{\theta}))],$$

which is positive by assumption. Since this is true for all θ , this proves that the new contract FSD dominates the initial contract, a contradiction. ■

It is noteworthy that this result does not rely on the expected utility hypothesis. Because indemnities generate deadweight losses, a uniform reduction in them across states has no other effect than to reduce these costs. The reduction in the indemnity in each state is entirely offset by the parallel reduction in premium. This uniform reduction will thus be done as long as it does not violate the constraint on the nonnegativity of indemnities. In conclusion, this constraint will be binding in a subset of states of positive measure.

4.3 The Case of Linear Transaction Costs

In this section, we assume that costs are linear with respect to the level of the indemnity: $c(I) = c_0 + \lambda I$. It implies that the insurance tariff is linear in the actuarial value of the policy:

$$P = c_0 + (1 + \lambda)E[I(\tilde{\theta})].$$

Parameter c_0 can be seen as an entry fee for the policyholder. It has no other effect on the optimal insurance contract than the one generated by the induced reduction in wealth, which in turn affects the attitude towards risk. Notice also that if c_0 is too large, the agent may prefer not to buy coverage at all. Two main results are obtained in this framework: the inefficiency of random indemnity schedules and the efficiency of deductible policies among deterministic schedules.

4.3.1 Deterministic Indemnity Schedule

Insurance is a device to reduce risk. Therefore, it is not a surprise that randomizing state-contingent indemnities will never be an equilibrium. This is the substance of the following result, which is very general in nature:

Proposition 2. *Consider the case of linear costs. Suppose that the policyholder is risk-averse in the sense that V satisfies the MPC property. Then the optimal indemnity depends upon the state of nature*

only through the aggregate loss suffered by the policyholder in that state: $\left[x(\theta_1) = x(\theta_2) \implies I(\theta_1) = I(\theta_2) \right]$.

Proof. Suppose by contradiction that $x(\theta_1) = x(\theta_2)$ but $I(\theta_1) < I(\theta_2)$. Consider another policy (\hat{P}, \hat{I}) where $\hat{I}(\theta) = I(\theta)$ for all $\theta \neq \theta_1, \theta_2$ and

$$\hat{I}(\theta_1) = \hat{I}(\theta_2) = \frac{\pi_1 I(\theta_1) + \pi_2 I(\theta_2)}{\pi_1 + \pi_2}.$$

It implies that the actuarial value of the policy is unchanged. Therefore, \hat{P} equals P . Let $\hat{w}_f(\theta)$ be the final wealth with the new contract. Let also \hat{W} denote $\hat{w}_f(\theta_1) = \hat{w}_f(\theta_2)$. We now prove that the risk $\hat{w}_f(\tilde{\theta})$ is an MPC of risk $w_f(\tilde{\theta})$. To do this, let us show that $w_f(\tilde{\theta})$ is obtained from $\hat{w}_f(\tilde{\theta})$ by adding a white noise $\epsilon(\tilde{\theta})$ to it. Using this condition as a definition for ϵ , we obtain that

- $\epsilon(\tilde{\theta}) \mid \hat{w}_f(\tilde{\theta}) \neq \hat{W}$ is degenerated at zero.
- $\epsilon(\tilde{\theta}) \mid \hat{w}_f(\tilde{\theta}) = \hat{W}$ takes value e_1 with probability $\frac{\pi_1}{\pi_1 + \pi_2}$, and value e_2 with probability $\frac{\pi_2}{\pi_1 + \pi_2}$, with

$$e_1 = -\frac{\pi_2}{\pi_1 + \pi_2}(I(\theta_2) - I(\theta_1)),$$

and

$$e_2 = \frac{\pi_1}{\pi_1 + \pi_2}(I(\theta_2) - I(\theta_1)).$$

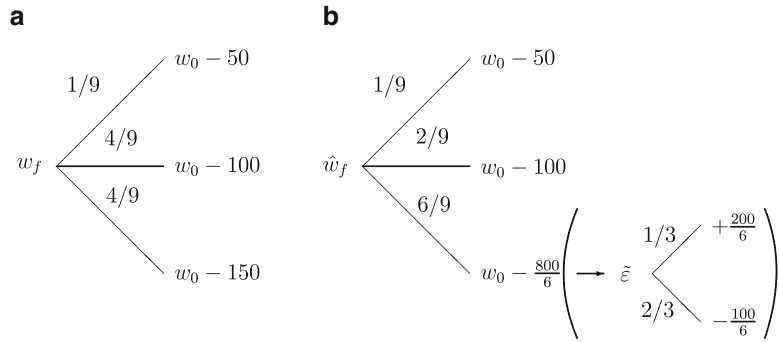
Observe that the expectation of $\epsilon(\tilde{\theta})$ conditional to any realization of $\hat{w}_f(\tilde{\theta})$ is zero. Therefore $\hat{w}_f(\tilde{\theta})$ dominates $w_f(\tilde{\theta})$ in the sense of MPC. Thus, all risk-averse policyholders dislike the old contract, which may not be efficient. ■

This proposition means that the indemnity is a deterministic function of the aggregate loss.⁵ Adding noise to it would be detrimental to risk-averse policyholders, without increasing profits for insurers. If there are two states in which the aggregate losses are the same, but the indemnities differ, then there exists another contract that dominates the first in the sense of MPC. Consequently, only the aggregate loss suffered by the policyholder matters to determine the indemnity to be paid. This principle is usually violated in the real world. Indeed, it implies that the agent should not insure each risk separately. Rather, an “umbrella” policy is optimal, as shown by [Gollier and Schlesinger \(1995\)](#) in the specific case of expected utility. This result is obvious when the different risks faced by the agent are correlated. In particular, negative correlation allows for a homemade insurance that saves on external insurance costs.

To illustrate the benefit of an umbrella policy in the case of independent risks, let us consider the following numerical example. The agent faces two risks of loss, \tilde{x}_1 and \tilde{x}_2 . These random variables are independent and identically distributed. They take value 0, 50 and 100 with equal probabilities. Observe that there are nine states of nature in this economy. Let us also assume that $c_0 = 0$ and $\lambda = 0.5$. Consider first the strategy to purchase two separate contracts, one for each risk. Consider in particular separate contracts with a straight deductible of 50. This means that an indemnity of 50 is paid on a contract only if the worst loss occurs for the corresponding risk. The actuarial value of the contract is 50/3, the premium is 25, and the total insurance expense is 50. The distribution of final wealth is represented in Fig. 4.1a. With probability 1/9, the agent incurs no loss, and he finishes with wealth $w_0 - 50$, the initial wealth minus the insurance expense. With probability 4/9, he suffers two

⁵It has been proven by [Eeckhoudt et al. \(1991\)](#) for the specific case of a binomial distribution.

Fig. 4.1 (a) Separate contracts with deductibles equal to 50. (b) Umbrella policy with a deductible $D = 500/6$



losses of at least 50, ending up with wealth $w_0 - 150$, taking into account the premiums paid and the retained loss (50) on each risk. Finally, with probability $4/9$, he suffers a loss on one risk and no loss on the other risk, yielding final wealth $w_0 - 100$. By Proposition 1, this insurance strategy may not be optimal. Indeed, there are four states in which the aggregate losses are the same, but the aggregate indemnities differ. In particular, an aggregate loss of 100 may result from two partial losses of 50, or from a single loss of 100. In the former case, no indemnity at all is paid, whereas an indemnity of 50 is paid in the latter case.

Consider alternatively an umbrella policy with a deductible on the aggregate loss amounting to $D = 500/6$. One can verify that the premium for such a contract is 50 and that the distribution of final wealth is as in Fig. 4.1b. With probability $2/9$, the aggregate loss is 50, yielding final wealth equalling w_0 minus the premium (50) and minus the retained loss (50). With probability $6/9$, the aggregate loss exceeds $D < 100$, generating a final wealth w_0 minus the premium and the deductible D .

Observe that the distribution in Fig. 4.1a can be obtained from the one in Fig. 4.1b by adding a zero-mean noise $\tilde{\epsilon} = (\frac{200}{6}, 1/3; -\frac{100}{6}, 2/3)$ to its worst realization. This explains why no risk-averse agent, EU maximizer or not, will purchase separate contracts, even when risks are independent. Explaining why separate contracts exist in reality is an important challenge for further research in this field.

We hereafter assume without loss of generality that $x(\theta) = \theta$ for all θ .

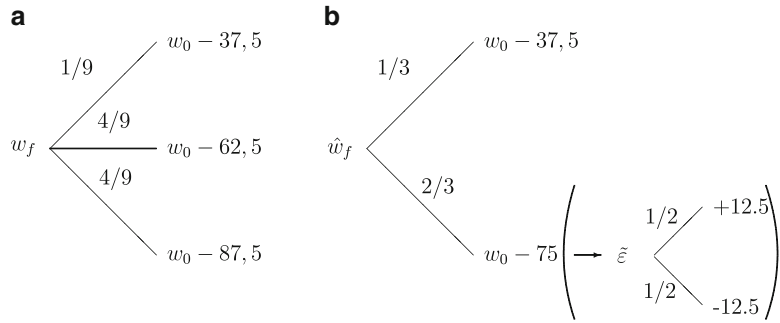
4.3.2 Optimality of a Deductible Policy

In this section, we prove the Arrow’s result on the optimality of a straight deductible, without using expected utility. Arrow (1971) used basic tools of variational calculus to get the result. Raviv (1979) used dynamic optimization techniques. More recently, Spaeter and Roger (1997) introduced a topological concept named the angular norm to prove the optimality of a straight deductible. But Zilcha and Chew (1990), Karni (1992), and Gollier and Schlesinger (1996)⁶ showed that this result is not dependent upon a decision model as specific as EU. Our proof is in the vein of Gollier and Schlesinger (1996) and Schlesinger (1997), who used the integral condition of Rothschild and Stiglitz (1970) to define an MPC. We do it here with the notion of transferring probability masses from the center of the distribution to its tails. From our point of view, this makes the proof shorter and more intuitive. See also Gerber (1978).

Proposition 3. *Consider the case of linear costs. Suppose that the policyholder is risk-averse in the sense that V satisfies the MPC property. Then the optimal contract contains a straight deductible D : $I(x) = \max(0, x - D)$.*

⁶Zilcha and Chew (1990) and Karni (1992) used the restriction of Frechet differentiability, whereas Gollier and Schlesinger (1996) did not make any restriction on the model.

Fig. 4.2 (a) $I(x) = \frac{x}{2}$,
 (b) $I(x) = \max(0, x - 37,5)$



Proof. A deductible policy is characterized by the property that once a positive indemnity is paid in a state x_1 , any marginal increase in the loss is fully indemnified. Suppose by contradiction that there exist two levels of loss, x_1 and x_2 , with $x_1 < x_2$, such that $I(x_1) > 0$ and $I(x_2) < I(x_1) + x_2 - x_1$. The latter inequality is equivalent to

$$w_0 - x_2 + I(x_2) - P < w_0 - x_1 + I(x_1) - P,$$

or $w_f(x_2) < w_f(x_1)$. Now, consider an alternative indemnity schedule \hat{I} , which is unchanged with respect to I , except in case of loss x_1 or x_2 . Take

$$\hat{I}(x_1) = I(x_1) - \epsilon,$$

and

$$\hat{I}(x_2) = I(x_2) + \frac{\pi_1}{\pi_2}\epsilon.$$

Observe that, by construction, this change has no effect on the premium, as the actuarial value of the policy is not affected. If ϵ is positive but small, the constraint on the nonnegativity of claims is not violated. This change affects the distribution of final wealth in the following way:

$$w_f(x_1) < w_f(x_1) \text{ and } w_f(x_2) > w_f(x_2).$$

The expected final wealth is unchanged, but the larger final wealth level is reduced, whereas the smaller one is increased. This is an MPC.⁷ No risk-averse agent would thus select the initial contract, which is inefficient. A symmetric proof can be done when $I(x_1) > 0$ and $I(x_2) > I(x_1) + x_2 - x_1$. ■

To illustrate, let us consider again the case of risk \tilde{x}_1 which takes value 0, 50 or 100 with equal probabilities. Assuming $c_0 = 0$ and $\lambda = 0,5$, a contract with a pure coinsurance rate of 50%, i.e., with $I(x) = x/2$, can be purchased for a premium $P = 37,5$. The distribution of final wealth in this case is represented in Fig. 4.2a. Consider alternatively a contract with a straight deductible $D = 37,5$. The premium for this contract is also equal to 37,5. The final wealth is distributed as in Fig. 4.2b if such a contract is purchased.

Observe that the distribution in Fig. 4.2a can be obtained by adding a noise $\tilde{\epsilon} = (+12,5, 1/2; -12,5, 1/2)$ to the worse realization of the random variable in Fig. 4.2b. Since this noise has a zero mean, the distribution in Fig. 4.2b is less risky in the sense of an MPC. We conclude that a contract

⁷The equivalence between this characterization of an MPC and the definition using white noises is in Rothschild and Stiglitz (1970).

with a 50% coinsurance rate will never be purchased, as it is dominated by a contract with a straight deductible. Proposition 3 shows that this technique can be extended to any contract that is not a straight deductible.

The intuition of this result has been presented in the introduction. In short, as it is apparent in Fig. 4.2, a straight deductible efficiently concentrates the effort of indemnification on large losses. On the contrary, a contract with a constant coinsurance rate, for example, provides an inefficiently large amount of money when losses are small and an inefficiently small amount when losses are large. The optimality of a straight deductible is the expression of the relevance of insurance for large risks. Small risks, i.e., risks whose largest potential loss is less than the optimal deductible, should not be insured. I am willing to purchase insurance against the important risk for my kids and wife in case of my premature death. I am willing to purchase insurance for my house, which is my most valuable asset. Given the cost of insurance, I am not willing to purchase insurance against the risk of broken glasses, or even against damages to my old car. I would be ready to bear the risk of paying for standard medical care, but I would like to get a large indemnity from my insurer in case of a costly surgical procedure. This is exactly what a policy with straight deductible provides.

4.3.3 Optimal Deductible

To sum up, under linear transaction costs, efficient indemnity schedules are deterministic functions of the loss, and they take the form of policies with a straight deductible. This has been obtained by assuming risk aversion alone, with no reference to any specific decision model. We now turn to the problem of the selection of the optimal deductible D .

Notice that adding the assumption of FSD for the preference functional implies that D is nonnegative. Otherwise, the indemnity would always be positive. This may not be optimal, as proven in Proposition 1. When the loading factor λ is zero, the optimal deductible vanishes. This corresponds to the optimality of full insurance. This is a trivial result, as a marginal increase in coverage would not change final wealth in expectation, whereas it would reduce its variability in the sense of an MPC.

The analysis is more complex when the loading factor λ is positive, as shown by Schlesinger (1981). In that case, a marginal increase in coverage, that is obtained by a reduction of D , reduces the expected final wealth. The agent must weight the benefit of insurance—which is to reduce the variability of wealth—with the cost of insurance. Let us consider the strategy of moving D from some small positive value to zero. Let \tilde{x} be 0 with probability π_0 and \tilde{y} with probability $1 - \pi_0$. Parameter $1 - \pi_0$ is the probability of an accident, and \tilde{y} is the severity of the loss that can be a random variable. The increase in the actuarial value of the full insurance policy D can be approximated as $(1 - \pi_0)D$. It implies that the reduction in expected wealth by selecting full insurance rather than contract D is $\lambda(1 - \pi_0)D$. This is the marginal net cost of insurance. The marginal cost of the last dollar of coverage or deductible is thus $\lambda(1 - \pi_0)$, which is strictly positive.

The benefit of reducing D to zero is the risk premium associated to the retained risk under policy D . The retained risk is $D\tilde{z}$, where \tilde{z} takes value 0 with probability π_0 and value 1 otherwise. D is thus the size of the retained risk. Now remember that, in the EU model with a smooth utility function, the risk premium is approximately proportional to the variance of the retained risk, which is itself proportional to D^2 . Thus, the *marginal* benefit of reducing D to zero is zero. Since we have shown that the marginal cost of the last dollar of deductible is positive, it may not be optimal to purchase it. This result is in Mossin (1968).

Proposition 4. *Consider the case of linear costs in the expected utility framework. Suppose that the policyholder is risk-averse in the sense that V satisfies the MPC property. If $\lambda = 0$, then the optimal deductible is zero. If $\lambda > 0$, then the optimal deductible is positive.*

Schlesinger (1997) provides a detailed analysis of this proposition. This result has been generalized by Karni (1992) and Machina (1995) for non-expected utility models satisfying Frechet differentiability. Observe that the proof of this proposition relies on the assumption that the risk premium is proportional to the variance of the retained risk, at least when the risk is small. This assumption holds for other models than the EU one. It is called second-order risk aversion.⁸ When risk aversion is of order 1, that is, when the risk aversion is approximately proportional to the standard deviation of the random variable, as in the EURDP model, the policyholder could optimally select full insurance even if λ is positive. This is because he has a positive benefit to the last dollar of coverage. Doherty and Eeckhoudt (1995) describe the case of the Yaari's dual model, where risk aversion is of the first order.

Some authors tried to quantify the optimal level of the deductible when λ is positive, using the EU model. The decision problem is to maximize $H(D) = Eu(w_0 - \min(\tilde{x}, D) - P(D))$ where $P(D) = (1 + \lambda)E \max(0, \tilde{x} - D)$. The first-order condition is written as

$$H'(D) = (1 - F(D)) [(1 + \lambda)Eu'(w_0 - \min(\tilde{x}, D) - P(D)) - u'(w_0 - D - P(D))] = 0, \quad (4.3)$$

where F is the cumulative distribution of the random loss \tilde{x} . Drèze (1981) and Gollier (1992), using a Taylor approximation for this first-order condition of the deductible selection problem, obtained the following conditions:

$$\frac{\lambda t}{1 + \lambda} \leq \frac{D}{w_0 - D - P} \leq \frac{\lambda t}{\pi_0(1 + \lambda)}, \quad (4.4)$$

where π_0 is the probability of no loss and t is the index of relative tolerance, $t = -\frac{u'(w_0 - D - P)}{(w_0 - D - P)u''(w_0 - D - P)}$. When $\pi_0 \cong 1$, as for many insurance lines, we see that the optimal deductible of the umbrella policy, expressed as a fraction of total wealth, can be approximated by the product of the loading factor and the relative risk tolerance. A realistic value of λ is 0.3. The debate on realistic values for t is still open, but an acceptable interval would be $t \in [0.2, 0.5]$. This gives us an optimal deductible around 5–15% of total wealth.

We now turn to the comparative statics analysis of the optimal deductible in the EU model:

- We know from Mossin (1968) that an increase in risk aversion reduces the optimal D .⁹ This is simple to understand from the observation that an increase in risk aversion raises the marginal benefit of reducing the deductible. This can be easily shown by using the first-order condition (4.3).
- This result directly implies that an increase in w_0 increases D under decreasing absolute risk aversion. Indeed, an increase in wealth is equivalent to a reduction in risk aversion when absolute risk aversion is decreasing.
- As usual, a change in λ has an ambiguous effect because of the presence of a wealth effect: an increase in λ makes self-insurance more desirable, but it also makes policyholders poorer. Under decreasing absolute risk aversion, this has a positive impact on insurance demand, which implies that the global effect is ambiguous.
- The analysis of the effect of a change in the distribution of the loss is more complex. The best result has been obtained by Jang and Hadar (1995), who have shown that an increase in the probability of an accident of a deterministic severity has a positive effect on D .¹⁰ Finally, Eeckhoudt et al. (1991) obtain results for the effect of an increase in risk of the distribution of damage severity.

⁸For the definition of the order of risk aversion, see Segal and Spivak (1990).

⁹Machina (1995) extends this result to non-expected utility models with Frechet differentiability.

¹⁰Eeckhoudt and Gollier (1999) extend this result to non-expected utility models with second-order risk aversion.

Observe that when the change in distribution is an MPC that is concentrated in loss states x above the optimal deductible, the effect is obviously null. Indeed, the risk-neutral insurer absorbs 100% of the increase in risk without changing the premium. The policyholder is not affected by the change.

4.4 Nonlinear Transaction Costs

To our knowledge, no econometric analysis has been performed to test for the linearity of transaction costs on insurance markets. In this section, we examine the case of nonlinear transaction costs.

4.4.1 Stochastic Indemnity Schedule

In the previous section, we have shown that the indemnity must be a deterministic function of the loss in the case of linear costs. When the transaction cost is a concave function of the indemnity, this may not be true. Indeed, randomizing indemnities generates a reduction in the expected transaction cost. If risk aversion is not too large, a random indemnity schedule may be optimal.

An interesting particular case of concave cost functions is due to the presence of a fixed cost per claim: when there is no claim at all the cost is zero, but even a small claim generates fixed costs for the insurer, as an audit cost, or processing the payment of the indemnity. There is an upward jump in cost at zero, which introduces a concavity to the cost function. Gollier (1987b) characterizes the best deterministic contract in that case. It exhibits a straight deductible, but with a clause that no indemnity would be paid if the loss is just slightly over the deductible. That clause eliminates “nuisance claims,” i.e., claims that are too small with respect to the fixed auditing costs. More recent works in the literature on optimal audits show that stochastic audits and indemnities are optimal.¹¹

4.4.2 No Overinsurance

In most models on optimal insurance, constraint $I(x) \leq x$ is imposed: no overinsurance is allowed. We know from Propositions 1 and 3 that this constraint is never binding in the case of linear costs. Huberman et al. (1983) claim that this constraint may be binding in the case of nonlinear costs. This is not true, as long as the policyholder is risk-averse.

Proposition 5. *Suppose that V satisfies the FSD property and the MPC property. Then, constraint $I(x) \leq x$ is never binding.*

Proof. Suppose by contradiction that $0 < \max_x I(x) - x$. Let y be the argument of the maximum and $\pi = \text{Prob}[\tilde{x} = y]$. It implies that this is in loss state y that the final wealth is the largest. Let also define $\hat{I}(\cdot)$ such that $\hat{I}(x) = I(x)$ if $x \neq y$ and $\hat{I}(y) = I(y) - \epsilon$, $\epsilon > 0$. Suppose first that the new premium is $\hat{P}_1 = P - \pi\epsilon$. Purchasing this new contract generates an MPC to the distribution of final wealth. Indeed, we reduce the largest potential wealth level, whereas we translate the distribution to the right to preserve the mean.

¹¹See Mookherjee and Png (1989) for a first result on this topic. The literature on optimal auditing is not covered in this survey. This is because our basic assumption is symmetric information, ex ante and ex post.

But, in fact, the premium to pay for the new contract is not \hat{P}_1 , but $\hat{P} = \hat{P}_1 - \pi(c(I(y)) - c(I(y) - \epsilon))$. This is smaller than \hat{P}_1 . Taking into account this additional reduction in premium yields an additional increase in V if it satisfies FSD. Thus, the initial contract is not efficient. ■

The intuition is that overinsurance generates two effects that are detrimental to the welfare of the policyholder. First, a marginal increase of indemnity over the size of the loss yields an additional cost of insurance, which is detrimental to any V satisfying FSD. Second, this marginal change in indemnity generates an MPC to final wealth. Indeed, we know from Proposition 1 that there exists a $x \leq 0$ for which $I(x) = 0$. In consequence, the marginal change increases the wealth level at the right of the distribution of w_f . The net effect is thus an MPC.

Notice that the combination of Propositions 1 and 5 implies that $I(0) = 0$.

4.4.3 Optimal Design of the Indemnity Schedule

An interesting problem is to characterize the optimal policy when transaction costs are not linear. Under the EU model, Raviv (1979) showed that if $c(\cdot)$ is increasing and convex, then

$$I'(x) = \left[1 + \frac{c''(I(x))}{1 + c'(I(x))} T(w_0 - x + I(x) - P) \right]^{-1} \quad (4.5)$$

when $I(x) > 0$. $T(z)$ is the absolute risk tolerance measured at z , i.e., $T(z) = -u'(z)/u''(z)$. When $c'' > 0$, the marginal indemnity is less than unity. The intuition is that large indemnities are relatively more costly. One can use the above formula when c is concave, provided the second-order condition of the decision problem is satisfied. In this case, the marginal indemnity is larger than 1. The extreme case is the presence of a fixed cost per claim, which generates an upward discontinuity to the indemnity function.

4.5 Other Reasons for Partial Insurance

This chapter focussed on the existence of transaction costs to explain why partial insurance may be an equilibrium. Several other reasons can justify different forms of risk retention by the policyholder. The presence of asymmetric information between the two parties is a well-known argument which is examined at length in the literature. In the case of an adverse selection problem, accepting a positive risk retention ($I' < 1$ or $D > 0$) is a way for the policyholder to signal a low risk. When there is a moral hazard problem, imposing a retention of risk gives an incentive to policyholder to invest in prevention. Holmstrom (1978) characterizes the optimal insurance design under a moral hazard problem. We now discuss three other arguments: the existence of a random error in observing losses, the risk aversion of the insurer, and the heterogeneity of beliefs.

4.5.1 Errors in Observation

Insurers often face the difficulty to estimate the size of damages. Gollier (1996) assumes that the insurer can indemnify the policyholder only on the basis of a proxy $\tilde{y} \mid x$ of the actual loss x . If the actual loss x equals the estimated loss y plus an independent white noise, then the optimal contract contains a straight deductible. The optimal deductible is negatively affected by the error if u

is “risk vulnerable,” a condition introduced by [Gollier and Pratt \(1996\)](#).¹² The existence of an error in estimating the loss reduces the quality of an insurance contract to cover the basic risk. Indeed, the insurance adds an additional indemnity risk to the wealth of the policyholder. Under risk vulnerability, this reduction in the quality of insurance *reduces* the demand for it. Only when u is not risk vulnerable, errors in estimating the loss generate an increase in risk retention at equilibrium. Indeed, in this case, the deterioration in the quality of the insurance product will be compensated for by an increase in its purchase.

A more realistic assumption is that the risk of error is increasing with the estimated loss. [Gollier \(1996\)](#) shows that under prudence ($u''' > 0$), the optimal insurance contains a disappearing deductible in that case: $I(y) = \max(0, J(y))$, with $J'(y) > 1$. The increase in expected wealth as the loss increases is used to forearm against the increased risk of error in the indemnity paid by the insurer.

4.5.2 Risk Aversion of the Insurer

We assumed in this chapter that insurers are risk-neutral. This means that the minimum premium that is acceptable to them equals the expected indemnity plus the expected cost of insurance. This is a realistic assumption when individual risks are not correlated with the “market risk.” It implies that individual risks are fully diversifiable by shareholders of insurance companies. Therefore, at equilibrium, they will not get any extra risk premium to bear individual risks. On the contrary, when risks are correlated with the market risk, the equilibrium insurance tariff must contain a risk premium for shareholders to accept to bear these risks. This is a relevant problem for catastrophic risks and some risks that are economic in nature (e.g., unemployment).

The general problem is to determine efficient risk-sharing arrangements in an economy of risk-averse agents. In fact, this problem is not different from the problem of the characterization of an equilibrium on financial markets. The link with the literature of finance is here very strong. The main difference between the theory of finance and the economics of insurance is the existence of much larger transaction costs ($\cong 30\%$) in insurance than in finance ($\cong 2\%$).¹³

[Arrow \(1953\)](#) provides the general framework for the analysis of the allocation of risks in an economy with no transaction costs. [Borch \(1960, 1962\)](#) examines optimal risk-sharing rules in a general EU framework. [Wilson \(1968\)](#), [Buhlmann and Jewell \(1979\)](#), [Raviv \(1979\)](#), [Eliashberg and Winkler \(1981\)](#), and [Blazenko \(1985\)](#) considered the specific problem of a risk-averse insurer with utility function v who can insure a risk initially borne by a policyholder with utility function u . They obtain that

$$I'(x) = \frac{T_v(R - I(x) + P)}{T_v(R - I(x) + P) + T_u(w_0 - x + I(x) - P)}, \quad (4.6)$$

where R is the wealth of the insurer. The marginal indemnity equals absolute risk tolerance of the insurer expressed as a percentage of the group’s absolute risk tolerance. The smaller the insurer’s risk tolerance, the larger the risk transfer and the larger the risk retention by the policyholder. It is interesting to observe that there is a simple way to obtain this rule in the case of a small risk with

¹²Risk vulnerability is linked to the third and the fourth derivative of the utility function. All familiar utility (exponential, power, logarithmic) functions satisfy this property.

¹³The analogies are numerous. For example, the fact that $\lambda = 0$ implies that $D = 0$ is equivalent in finance to the fact that risk-averse investors will not invest in the risky asset if its expected return does not exceed the risk-free rate.

variance σ^2 . If the risk is small, the use of the Arrow–Pratt approximation yields that the sum of the risk premiums supported by the policyholder and the insurer is written as

$$\Pi = \frac{1}{2} \frac{(1 - I')^2 \sigma^2}{T_u} + \frac{1}{2} \frac{I'^2 \sigma^2}{T_v},$$

where $I' = I'(0)$ and $T_u = T_u(w_0)$ and $T_v = T_v(R)$. We look for the risk-sharing arrangement which minimizes the sum of risk premiums in the economy: $\min_{I'} \Pi$. Solving the first-order condition of this problem directly yields $I' = T_v / (T_v + T_u)$.

Leland (1980) examined the sign of I'' . In our context, the convexity of I would mean a contract similar to a deductible policy, whereas the concavity of I would correspond to a contract with a cap on indemnities. Leland shows that the sign of I'' depends upon which of the two functions u and v decrease at the fastest rate.

4.5.3 Heterogeneity and Ambiguity of Beliefs

In this chapter, we have assumed that the policyholder and the insurer share the same beliefs about the distribution of losses. In the real world, people disagree in general on the evaluation of risks, even in situations without asymmetric information. They just disagree on their prior beliefs, or on the way to interpret signals to update these beliefs. These disagreements can also be due to ambiguous scientific knowledge. Following Savage (1954), we first assume that, in the absence of an objective probability distribution for losses, agents select a subjective probability distribution to compute their expected utility. The distribution considered by the policyholder need not be the same than the distribution used by the insurer. Let F and G denote, respectively, the cumulative distribution function of the loss for the policyholder and for the insurer. The decision problem of the policyholder can be written as follows:

$$\max_{I(\cdot) \geq 0, P} \int u(w_0 - x + I(x) - P) dF(x) \quad (4.7)$$

subject to

$$P = (1 + \lambda) \int I(x) dG(x). \quad (4.8)$$

The first-order condition for this problem can be written as

$$u'(w_0 - x + I(x) - P) \leq \psi(1 + \lambda) \frac{dG(x)}{dF(x)}$$

for all x , with an equality when $I(x)$ is positive. Let us focus our analysis in the neighborhood of a loss x such that $I(x)$ is positive and where F and G are differentiable. When the likelihood ratio $G'(x)/F'(x)$ is constant, as is the case under common beliefs, the above first-order condition implies that $I'(x) = 1$, which is the standard straight deductible result. Suppose alternatively that $G'(x)/F'(x)$ is increasing. If it is monotonically increasing, this corresponds to the classical assumption of monotone likelihood ratio (MLR) order which plays a crucial role in information theory and in the modern theory of contract. It is a strong form of optimism on the side of the policyholder. Indeed, the increasing nature of the likelihood ratio G'/F' means that the insurer's G puts more probability weight on the larger losses than the policyholder's F . By fully differentiating the above first-order condition with respect to x implies that $I'(x)$ is less than unity. Optimism on the side of

the policyholder is another plausible explanation of the optimality of partial insurance. [Wilson \(1968\)](#), [Leland \(1980\)](#), and [Gollier \(2007\)](#) characterize optimal risk-sharing contracts with heterogeneous beliefs.

We have justified the difference between F and G by the existence of heterogeneous beliefs in the EU model. Recent non-EU models consider the possibility for agents to have preferences under uncertainty in which probabilities are distorted. So are the dual theory ([Yaari 1987](#)) or the rank-dependent EU model (RDEU, [Quiggin 1993](#)). In these models, states are ranked according to the level of the corresponding final wealth. State probabilities are distorted as a function of the rank of the corresponding state. Because the state rank depends upon the insurance policy that has been selected by the agent, the distortion of probabilities is endogenous. Suppose first that, given the insurance contract selected by the agent, final wealth is a decreasing function of the loss. Then, the RDEU version of the above problem can be rewritten as follows:

$$\max_{I(\cdot) \geq 0, P} \int u(w_0 - x + I(x) - P)w'(G(x))dG(x), \quad (4.9)$$

where G is interpreted as the objective probability distribution, w is the increasing probability distortion function with $w(0) = 0$ and $w(1) = 1$, and $G(x)$ is the rank of states with loss x . This is equivalent to the above model by defining the implicit distribution function F used by the policyholder in such a way that $dF(x) = w'(G(x))dG(x) = dw(G(x))$, or $F(x) = w(G(x))$. Optimism is obtained in the RDEU model if the weighting function w is concave, so that larger final wealth is perceived as relatively more likely under F than under G . This is equivalent to $G'(x)/F'(x) = 1/w'(G(x))$ being increasing, i.e., to the optimistic MLR condition. This implies coinsurance above the optimal deductible. Other distortion functions are usually considered in this literature. Pessimism is obtained with convex distortion functions w . This tends to generate disappearing deductible ($I'(x) > 1$), but this would yield a reversion in the rank of states. [Sung et al. \(2011\)](#) characterize the optimal insurance contract when it is constrained by $0 \leq I(x) \leq x$, so that final wealth is constrained to be decreasing in x . It is also often suggested that agents overweight the probability of extreme events, which correspond to a function w being first concave and then convex. Intuitively, this tends to raise the willingness to insure the very small and very large losses.

We assumed earlier in this section that agents behave according to the subjective expected utility model when they face ambiguous probabilities. Since the seminal work by [Ellsberg \(1961\)](#), we know that a large fraction of human beings violates this hypothesis. Facing a risk of losing 100 with probability 1/2 is not equivalent to facing a risk of losing 100 with an unknown probability of mean 1/2. Contrary to what is obtained under the Savagian subjective expected utility model, ambiguity aversion means that introducing a mean-preserving spread in probabilities reduces welfare. Formal decision models of ambiguity aversion include [Gilboa and Schmeidler \(1989\)](#) and [Klibanoff et al. \(2005\)](#). Ambiguity aversion undoubtedly raises the willingness to pay for insurance. However, there is no general result about how ambiguity aversion affects the optimal design of insurance. Interesting examples in that vein can be found in [Carlier and Dana \(2005, 2008\)](#) and [Chateauneuf et al. \(2000\)](#). [Alary et al. \(2012\)](#) show that the optimal insurance design has a straight deductible when the ambiguity is concentrated on the no-loss probability, i.e., when the loss distribution conditional to the occurrence of a loss is unambiguous.

4.6 Conclusion

Most breakthroughs in the theory of optimal insurance have been made before the development of decision models alternative to expected utility. We are now realizing that many of these results can be extended at no cost to non-expected utility models. Arrow's result is the most striking example of this

phenomenon. Arrow (1971) proved that a deductible insurance is optimal for a risk-averse expected utility maximizer if transaction costs are linear. The complexity of the proofs of this result by Arrow and others has obscured our understanding of the optimality of deductibles in insurance for a long time. In fact, the literature has only recently recognized that this result is a direct consequence of the very general notions of strong risk aversion and of an increase in risk. Thus Arrow's result is robust to any decision model that satisfies this property. This conclusion is useful not only because it extends the initial proposition, but also because it provides a simple intuition for the optimality of a deductible policy.

However, various other results in insurance economics require a more precise modeling of risk preferences. And there, the expected utility model is still unbeatable to produce simple useful and testable properties of the optimal behavior under risk. The insurance market is likely to be a good candidate for testing those models.¹⁴

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Chapter 5

The Effects of Changes in Risk on Risk Taking: A Survey

Louis Eeckhoudt and Christian Gollier

Abstract We examine an important class of decision problems under uncertainty that entails the standard portfolio problem and the demand for coinsurance. The agent faces a controllable risk—his demand for a risky asset, for example—and a background risk. We determine how a change in the distribution in one of these two risks affects the optimal exposure to the controllable risk. Restrictions on first-order and second-order stochastic dominance orders are in general necessary to yield an unambiguous comparative statics property. We also review another line of research in which restrictions are made on preferences rather than on stochastic dominance orders.

Keywords Comparative statics under uncertainty • Increase in risk • Background risk • Portfolio decision • Insurance demand

5.1 Introduction

To start this survey, we present two problems that look very different at first glance. Consider an investor who has to allocate a given amount of money (w_0) between a safe asset paying a return (i) and a risky one paying a random return (\tilde{x}). If the mathematical expectation of \tilde{x} exceeds i , it is optimal for an investor who obeys the axioms of expected utility to invest a strictly positive amount in the risky asset. Assume now that because of some good news, the prospects of the risky asset become “better” in the sense of improving the welfare of its holder. Intuition suggests that a rational investor should invest more in the risky asset because it has become relatively more attractive.

We now turn to the second problem. We consider the case of an insured whose wealth w_0 may be reduced by a random damage \tilde{y} . To protect himself against this damage he can buy insurance that is sold with a positive and proportional loading by an insurance company. The company and the insured have identical information about the initial risk \tilde{y} . It is well known that in this case, expected-utility maximizers should buy less than full insurance. Now assume that the insured receives a private information indicating that his risk deteriorates. Intuition suggests again that the insured should now demand more coverage to compensate for the deterioration in risk.

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The examples of portfolio and insurance decisions illustrate a more general problem that is the topics of this survey: how do changes in risk affect risk taking (e.g., portfolio) or risk avoidance (e.g., insurance) by a decision-maker? We basically show that unless specific restrictions are made on the change in risk and/or on the shape of the utility function, a risk-averse decision-maker may very well decide to increase his exposure to a risk whose distribution deteriorates.

While they have the same formal structure, the two examples just described share another important feature: the decision-maker faces only one risk and by his single decision about this risk, he optimally controls the total risk he will assume. An important part of this survey will be devoted to a more realistic case developed in the literature under the general heading of “background risk.” In this problem two risks are involved: one is exogenous and is not subject to transformations by the decision-maker while the other one is endogenous and can be controlled in the way described in each of the two examples. The exogenous risk can be, for example, a risk related to labor income that is traditionally not insurable through standard insurance markets. The question raised in this new framework can be described as follows: how does the background risk affect the optimal decisions about the endogenous one? Is it true that, e.g., a deterioration in the background risk will always reduce risk taking vis-a-vis the other risk?

Before turning to this question, we present our basic model in Sect. 5.2 and we state some first results about it. Section 5.3 is devoted to a presentation of the standard stochastic orders. In Sect. 5.4, we survey results about the impact of a change in the distribution of the endogenous/controllable risk. As indicated earlier, the role and impact of background risk are examined in Sect. 5.5. Some extensions and a concluding remark are provided, respectively, in Sects. 5.6 and 5.7.

5.2 A Simple Model

The two problems presented in the introduction can be written in the following compact manner¹:

$$\max_{\alpha} Eu(w_0 + \alpha\tilde{x} + \tilde{\epsilon}), \quad (5.1)$$

where α is the decision variable, the value of which measures the extent of risk taking. The random variable $\tilde{\epsilon}$ stands for the background risk. The utility function u is assumed to be increasing and concave. By assumption $\tilde{\epsilon}$ is independent of \tilde{x} , the endogenous/controllable risk.²

Notice finally that for the problem to make sense the random variable \tilde{x} must take negative and positive values; otherwise, the optimal α would be either $-\infty$ or $+\infty$. The absolute value of α expresses the exposure to risk \tilde{x} . Its optimal level—denoted α^* —has two properties that can be stated as follows:

- If the mathematical expectation of \tilde{x} is strictly positive, so will be α^* . This property which was shown to be true in the absence of background risk remains valid in its presence (for a proof in an insurance context, see [Doherty-Schlesinger 1983](#)).
- In the absence of background risk an increase in risk aversion decreases α^* (see [Pratt 1964](#)). However, as shown by [Kihlstrom et al. \(1981\)](#), this relationship does not extend when an

¹For more details, see [Dionne et al. \(1993\)](#) and more especially pages 315–317. See also [Eeckhoudt-Gollier \(1995\)](#) and more specifically page 183, Exercise 10.1. The reader who is interested in an insurance interpretation of some results in this survey may also refer to [Alarie et al. \(1992\)](#).

²Gollier and Schlee (2006) examine the more general problem with a correlated background risk. More recent developments around these topics are also mentioned at the end of Sect. 5.6. Notice also that many results reviewed in this chapter also hold when final wealth is a concave function of α and \tilde{x} .

independent background risk is added to initial wealth. This result illustrates the importance of background risk, the presence of which may invalidate results that hold true in its absence.

5.3 Detrimental Changes in Risk

Suppose that random variable \tilde{x} undergoes an exogenous change in distribution. The initial cumulative distribution function is denoted F , whereas the final one is denoted G . Economists usually consider two specific subsets of changes in risk: first-order or second-order stochastic dominance (respectively, FSD and SSD). In order to define these stochastic dominance orders, one looks at the effect of a change in risk on a specific class of agents.

5.3.1 First-Order Stochastic Dominance

F dominates G in the sense of FSD if the expected utility under F is larger than under G for any increasing utility function:

$$\int u(x)dF(x) \geq \int u(x)dG(x) \quad \forall u \text{ increasing.} \quad (5.2)$$

Observe that among the set of increasing functions, we have the standard “step” (or indicator) function, which takes value 0 if x is less than a given y ; otherwise, it takes value 1. Thus, applying the above definition to this function yields the necessary condition $1 - F(y) \geq 1 - G(y)$ or $F(y) \leq G(y)$. Notice also that any increasing function can be obtained by a convex combination of step functions, i.e., the set of step functions is a basis of the set of increasing functions. Observe finally that the expectation operator is linear, i.e., if u_1 and u_2 satisfy condition (5.2), then $\lambda u_1 + (1 - \lambda)u_2$ also satisfies (5.2). All this implies that requiring $F(y) \leq G(y)$ for all y is not only necessary but also sufficient to guarantee that (5.2) holds. In conclusion, F dominates G in the sense of FSD if and only if

$$F(x) \leq G(x) \quad \forall x. \quad (5.3)$$

Among other properties,³ it is worth remembering that after an FSD deterioration the mathematical expectation of a random variable necessarily decreases while the converse is not necessarily true.

5.3.2 Second-Order Stochastic Dominance

Whereas this notion was already known in the statistical literature for a long time,⁴ it became popular in the economics and finance literature after the publication of Hadar and Russell’s article (1969). Distribution F dominates distribution G in the sense of SSD if all risk-averse agents prefer F to G . This is less demanding than FSD, since SSD requires F to be preferred to G just for increasing and concave utility functions, not for all increasing functions.

³For an excellent survey on stochastic dominance, see H. Levy (1992).

⁴See Hardy et al. (1929).

Observe that the set of “min” functions— $u(x) = \min(x, y)$ —are increasing and concave. Thus a necessary condition for SSD is obtained by requiring condition (5.2) to hold for such functions. It yields

$$\int^y x dF(x) + y(1 - F(y)) \geq \int^y x dG(x) + y(1 - G(y)),$$

or, integrating by parts,

$$\int^y F(x) dx \leq \int^y G(x) dx. \quad (5.4)$$

Notice that any increasing and concave function can be obtained by a convex combination of “min” functions. Thus, using the same argument as before, it is true that condition (5.4) is not only necessary but is also sufficient for F to dominate G in the sense of SSD.

If F dominates G in the sense of SSD and if F and G have the same mean, then G is said to be an increase in risk (IR). Rothschild and Stiglitz (1970) showed that any increase in risk can be obtained either by adding noise to the initial random variable or by a sequence of mean-preserving spreads (MPS) of probabilities. A noise is obtained by adding a zero-mean lottery to any outcome of the initial random variable. A MPS is obtained by taking some probability mass from the initial density and by transferring it to the tails in a way that preserves the mean.

Finally, notice that any SSD deterioration in risk can be obtained by the combination of an FSD deterioration combined with an increase in risk.

5.4 The Comparative Statics of Changes in the Controllable Risk

In this section, we assume that some information is obtained that allows agents to revise the distribution of \tilde{x} , but $\tilde{\epsilon}$ remains unaffected. The literature devoted to this topic was mostly developed under the assumption that there is no background risk. Most often, this is without loss of generality. Indeed, for every increasing and concave u , define the indirect utility function v as follows:

$$v(z) = Eu(z + \tilde{\epsilon}). \quad (5.5)$$

This allows us to rewrite the initial problem (5.1) as

$$\max_{\alpha} Ev(w_0 + \alpha \tilde{x}). \quad (5.6)$$

Observe now that $u^{[n]}$, i.e., the n th derivative of u , and $v^{[n]}$ have the same sign, for any integer n . In particular v is increasing and concave. As long as no restriction on the utility function other than those on the sign of some of its derivatives is imposed, (5.1) and (5.6) are qualitatively the same problems.

As mentioned above, stochastic orders have been defined on the basis of how changes in distribution affect the welfare of some well-defined set of agents in the economy. In this section, we examine the effect of a disliked change in the distribution of \tilde{x} on the optimal exposure α^* to this risk. For a while many researchers naturally extended the results about the agent’s welfare to his optimal degree of risk taking. It turns out, however, that such an extension may not be correct.

The first-order condition on α^* under distribution F is written as

$$\int xu'(w_0 + \alpha^*x)dF(x) = 0. \quad (5.7)$$

Given the concavity of the objective function with respect to the decision variable, the change in risk from F to G reduces the optimal exposure to risk if

$$\int xu'(w_0 + \alpha^*x)dG(x) \leq 0. \quad (5.8)$$

It happens that F dominating G in the sense of FSD or SSD is neither necessary nor sufficient for α^* to be reduced, i.e., for condition (5.8) to be satisfied whenever (5.7) is satisfied. It is striking that an FSD deterioration in risk \tilde{x} or an increase in risk \tilde{x} can induce some risk-averse agents to increase the size α^* of their exposure to it! As counterexamples, let us examine the standard utility function $u(z) = z^{1-\gamma}/(1-\gamma)$. Consider in particular the case of a constant relative risk aversion $\gamma = 3$, which is within the range of degrees of risk aversion observed in the real world. Finally, take $w_0 = 2$ and an initial distribution of $\tilde{x} = (-1, 0.1; +4, 0.9)$. In this case, one can compute $\alpha^* = 0.6305$.

Suppose now that \tilde{x} undergoes an FSD deterioration with a new distribution $(-1, 0.1; +2, 0.9)$. Contrary to the intuition, the agent reacts by increasing his exposure to $\alpha^* = 0.7015$! Alternatively, suppose that \tilde{x} undergoes an increase in risk to the new distribution $(-1, 0.1; +3, 0.45, +5, 0.45)$. Again, it is a puzzle that the agent reacts to this increase in risk by increasing his exposure to $\alpha^* = 0.6328$.

From examples such as these, researchers tried to restrict the model in order to exclude the possibility of such puzzles. Two directions of research have been followed. One can either restrict preference functionals, or one can restrict the set of changes in risk. We hereafter examine these two lines of research separately.

5.4.1 Restrictions on the Utility Function

This line of research has been explored by [Rothschild and Stiglitz \(1971\)](#), [Fishburn and Porter \(1976\)](#), [Cheng et al. \(1987\)](#), and [Hadar and Seo \(1990\)](#). All their findings rely on the following observation. Define the function $\phi(x; w_0) = xu'(w_0 + \alpha^*x)$, where α^* is the optimal exposure under F . We hereafter normalize it to unity. Combining conditions (5.7) and (5.8), the change in risk reduces the optimal exposure α^* if

$$\int \phi(x; w_0)dF(x) \geq \int \phi(x; w_0)dG(x). \quad (5.9)$$

5.4.1.1 Conditions for FSD Shifts

Suppose first that F dominates G in the sense of FSD. Which condition is required on ϕ to guarantee that (5.9) holds? Comparing this condition to condition (5.2) directly provides the answer to this question: ϕ must be an increasing function. Because

$$\frac{\partial \phi}{\partial x}(x; w_0) = u'(w_0 + x) + xu''(w_0 + x),$$

ϕ is increasing if

$$A^r(w_0 + x) - w_0 A(w_0 + x) \leq 1 \quad \forall x, \quad (5.10)$$

where $A(z) = -u''(z)/u'(z)$ and $A^r(z) = zA(z)$ are, respectively, the absolute and the relative degree of risk aversion measured at z . In conclusion, an FSD deterioration in \tilde{x} always reduces the optimal exposure to it if relative risk aversion is uniformly less than unity. If condition (5.10) is not satisfied for some x , it is always possible to build a counterexample, as we have done above.

5.4.1.2 Conditions for Increases in Risk

The same argument can be used for increases in risk, which require ϕ to be concave in x . After some computations, we get that the second derivative of ϕ with respect to x is negative if and only if

$$P^r(w_0 + x) - w_0 P(w_0 + x) \leq 2 \quad \forall x, \quad (5.11)$$

where $P(z) = -u'''(z)/u''(z)$ and $P^r(z) = zP(z)$ are, respectively, the absolute and the relative degree of prudence measured at z . In conclusion, an increase in risk \tilde{x} always reduces the optimal exposure to it if relative prudence is positive and less than 2. Notice that we built the counterexample above on the basis of $P^r(z) = \gamma + 1 = 4$.

5.4.2 Restrictions on the Change in Risk

5.4.2.1 First-Order Stochastically Dominated Shifts

In this section, we present some restrictions on FSD in order to guarantee that all risk-averse agents reduce their exposure after the shift in distribution.

A first step in this direction was made in a slightly different context by [Milgrom \(1981\)](#) and later on by [Landsberger and Meilijson \(1990\)](#) and [Ormiston and Schlee \(1993\)](#). We say that F dominates G in the sense of the monotone likelihood ratio order (MLR) if, crudely said, $\psi(x) = G'(x)/F'(x)$ is decreasing. It is easy to verify that MLR is a particular case of FSD. If F dominates G in the sense of MLR, we obtain that

$$\begin{aligned} \int x u'(w_0 + x) dG(x) &= \int x u'(w_0 + x) \psi(x) dF(x) \\ &\leq \psi(0) \int x u'(w_0 + x) dF(x) = 0. \end{aligned} \quad (5.12)$$

The inequality is due to the fact that $x\psi(x)$ is always less than $x\psi(0)$. The last equality is the first-order condition on $\alpha^* = 1$ under F . In consequence, a MLR deterioration in risk reduces the optimal exposure to it for all risk-averse agents.

Since the FSD condition is already rather restrictive, the MLR property is even more so. Hence it is worth trying to extend the result we have just stated. First, observe that one can replace the monotonicity of ψ by a weaker single-crossing condition: $\psi(x)$ must single-cross the horizontal line at $\psi(0)$ from above. This is indeed the only thing that has been used in the proof (5.12). This single-crossing condition is much weaker than MLR.

Second, Eeckhoudt and Gollier (1995) considered the ratio of the cumulative distributions, that is $\frac{G(x)}{F(x)}$, and coined the term “monotone probability ratio” (MPR) when this expression is nondecreasing in x . As one can guess:

$$\text{MLR} \Rightarrow \text{MPR} \Rightarrow \text{FSD}.$$

MPR is weaker than MLR but is still a subset of FSD. It can be shown that the same comparative statics property holds under MPR. Hence the MPR condition is clearly an improvement on the MLR one.

5.4.2.2 Increases in Risk

Eeckhoudt and Hansen (1980) obtained a restriction on an increase in risk that yields the desired comparative statics property. They defined the notion of a “squeeze” of a density. This notion has been extended by Meyer and Ormiston (1985) who defined a strong increase in risk (SIR). A SIR is obtained when some probability weight is taken from the initial density of \tilde{x} and sent either at its boundaries or outside the initial support. Meyer and Ormiston showed that all risk-averse agents reduce their exposure to a risk that undergoes a SIR.

In two subsequent articles, Black and Bulkley (1989) and Dionne et al. (1993) weakened the notion of a SIR. Contrary to a SIR, these restrictions allow for transferring probability masses inside the initial support of the distribution of \tilde{x} . However, to maintain the desired comparative statics result, they had to make assumptions about the behavior of the likelihood ratio between the initial and the final densities. Another sufficient condition for an increase in risk to have an unambiguous effect on α^* is the notion of a simple increase in risk, introduced by Dionne and Gollier (1992). A simple increase in risk is an IR such that F single-crosses G at $x = 0$.

To conclude this quick review, let us mention that much of this research resulted from A. Sandmo’s discussion (1971) of the impact of the “stretching” of a random variable. A stretching of \tilde{x} results from its linear transformation into \tilde{y} with $\tilde{y} = t\tilde{x} + (1-t)E(\tilde{x})$ and $t > 1$. This transformation is mean preserving since $E\tilde{y} = E(\tilde{x})$. This intuitive notion was later on generalized by Meyer and Ormiston (1989) under the terminology of the “deterministic transformation” of a random variable. However to obtain intuitive comparative statics results with such transformation the assumption of decreasing absolute risk aversion (DARA) is required.

All the contributions dealing with special cases of either FSD or IR that we have surveyed so far share a common trend: one starts with rather restrictive sufficient conditions to yield the desired comparative statics result and then one progressively relaxes them. The endpoint of these successive improvements is given by a set of necessary and sufficient conditions that we now present.

5.4.2.3 The Necessary and Sufficient Condition

Gollier (1995, 1997) proposed a reversal in the agenda of research. Rather than trying to restrict the existing stochastic orders in order to obtain an unambiguous comparative statics property, one should solve the following problem: what is the stochastic order such that all risk-averse agents reduce their exposure to the risk that undergoes such a change in distribution? He coined the term “central dominance” (CR) for it.

Rothschild and Stiglitz (1971) already tried to solve this question, but their solution was wrong. Their argument went as follows: under which condition can we guarantee that

$$\int xu'(w_0 + x)dG(x) \leq \int xu'(w_0 + x)dF(x) \quad (5.13)$$

for all increasing and concave utility functions? Using the basis approach developed earlier in this chapter, the condition is that (replace u by any “min” function)

$$\int^y x dG(x) \leq \int^y x dF(x)$$

for all y . Contrary to the claim of [Rothschild and Stiglitz \(1971\)](#), this condition is sufficient, but not necessary for CR. Indeed, condition (5.13) is sufficient but not necessary for the comparative statics property. The correct necessary and sufficient condition is that the LHS of (5.13) be negative whenever the RHS is zero. Basing the analysis on this observation, [Gollier \(1995\)](#) obtained a correct characterization of CR, which is

$$\exists m \in R : \forall y : \int^y x dG(x) \leq m \int^y x dF(x). \quad (5.14)$$

All sufficient conditions mentioned above are particular cases of CR. Interestingly enough, strong and simple increases in risk satisfy condition (5.14) with $m = 1$, which was the condition proposed by [Rothschild and Stiglitz \(1971\)](#). But conditions like MLR and MPR and the weakenings of SIR by [Black and Buckley \(1989\)](#) and others satisfy the condition with $m \neq 1$. Observe also, whereas we already know that SSD is not sufficient for CR (see the numerical counter examples), it also appears that SSD is not necessary. That is, it can be the case that all risk-averse agents reduce their α^* after a change which is *not* a SSD.

5.5 The Comparative Statics of Background Risk

In the previous section, we explained why the presence of a background risk is unimportant to determine the *sign* of the impact of a change in the distribution of the controllable risk. However, the background risk has an impact on the optimal *value* of the exposure to \tilde{x} .

In this section, we do the comparative statics analysis that is symmetric to the one performed in the previous section. We take the distribution of \tilde{x} as given and we perturbate the distribution of background risk $\tilde{\epsilon}$. Up to now, the literature focused mostly on the effect of *introducing* a background risk in the analysis. One compares the solution to program (5.6) to the solution of

$$\max_{\alpha} Eu(w_0 + \alpha \tilde{x}).$$

Remember that, as shown by [Pratt \(1964\)](#), the necessary and sufficient condition for an unambiguous comparison, independent of w_0 and the distribution of \tilde{x} , is that v be more risk averse than u . In this case, the introduction of a background risk reduces the optimal exposure to \tilde{x} . Thus, the problem simplifies to determining whether

$$-\frac{Eu''(z + \tilde{\epsilon})}{Eu'(z + \tilde{\epsilon})} \geq -\frac{u''(z)}{u'(z)} \quad (5.15)$$

for all z . If $\tilde{\epsilon}$ is degenerated at a negative value, this condition is just DARA. But it is logical to concentrate the analysis on the introduction of a *pure* background risk, viz., $E\tilde{\epsilon} = 0$.

The intuition that the introduction of a pure background risk should reduce the optimal exposure to other independent risks corresponds to the common wisdom that independent risks are substitutes. This intuition requires additional restrictions to the model, as shown by the following counterexample. Take $u(z) = \min(z, 50 + 0.5z)$, $w_0 = 101$, and $\tilde{x} = (-1, 0.5; +1.9, 0.5)$. Without background risk, one can compute $\alpha^* = 1$. But if pure background risk $\tilde{\epsilon} = (-20, 0.5; +20, 0.5)$ is added to wealth w_0 , the agent increases his optimal exposure to $\alpha^* = 10.53!$

Several authors tried to find conditions on u that implies that a pure background risk reduces α^* . If $\tilde{\epsilon}$ is small, one can use second-order Taylor expansions of the numerator and denominator of the LHS of (5.15) to check that

$$-\frac{Eu''(z + \tilde{\epsilon})}{Eu'(z + \tilde{\epsilon})} \cong A(z) + 0.5\sigma_{\tilde{\epsilon}}^2 [A''(z) - 2A'(z)A(z)]. \quad (5.16)$$

Thus, a necessary and sufficient condition for any pure small background risk to reduce the optimal exposure to other risks is

$$A''(z) \geq 2A'(z)A(z) \quad \forall z. \quad (5.17)$$

Absolute risk aversion may not be too concave. But what is necessary and sufficient for small risk is just necessary if one wants the comparative statics property to hold for any risk. [Gollier and Scarmure \(1994\)](#) proved that a sufficient condition is that absolute risk aversion be decreasing and convex. The proof of this result is immediate. Indeed, let us define $h(t) = u'(z + t)/Eu'(z + \tilde{\epsilon})$. It yields

$$\begin{aligned} -\frac{Eu''(z + \tilde{\epsilon})}{Eu'(z + \tilde{\epsilon})} &= Eh(\tilde{\epsilon})A(z + \tilde{\epsilon}) \\ &= EA(z + \tilde{\epsilon}) + E(h(\tilde{\epsilon}) - 1)A(z + \tilde{\epsilon}) \\ &\geq A(z + E\tilde{\epsilon}) + \text{cov}(h(\tilde{\epsilon}), A(z + \tilde{\epsilon})) \\ &\geq A(z). \end{aligned} \quad (5.18)$$

The first inequality is a direct application of Jensen's inequality, and $A'' > 0$. The second inequality comes from the fact that h and A are two decreasing functions of ϵ . This concludes the proof.

The convexity of absolute risk aversion is compatible with its positivity and its decrease. It is also an intuitive assumption as it means that the risk premium to any (small) risk decreases with wealth in a decreasing way. Observe that the familiar utility functions with constant relative risk aversion γ are such that $A(z) = \gamma/z$, so $A' < 0$ and $A'' > 0$. Thus, there is no ambiguity of the effect of background risk for this set of utility functions.

[Eeckhoudt and Kimball \(1992\)](#) and [Kimball \(1993\)](#) obtained an alternative sufficient condition that they called "standard risk aversion." Risk aversion is standard if absolute risk aversion A and absolute prudence P are both decreasing in wealth. Decreasing prudence means that the effect on savings of a risk on future incomes is decreasing with wealth.

[Gollier and Pratt \(1996\)](#) obtained the necessary and sufficient condition for a background risk with a non-positive mean to increase the aversion to other independent risks. They coined the term (background) "risk vulnerability." They used a technique of proof that has been systematized in [Gollier and Kimball \(1997\)](#) to solve other problems dealing with multiple risks.

Up to now, we examined the effect of introducing a background risk. [Eeckhoudt, Gollier, and Schlesinger \(1996\)](#) considered the more general problem of the effect of increasing the background risk, in the sense of a FSD or IR shift in distribution. In the case of an increase in background risk, they showed that the restrictions to impose on u to obtain an unambiguous effect on α^* are much

more demanding than risk vulnerability. Meyer and Meyer (1998) relaxed these conditions on u at the cost of restricting the changes in risk. For example, standard risk aversion is sufficient when limiting the analysis to the effect of a strong increase in background risk.

5.6 Extensions

Let us go back to the problem analyzed in Sect. 5.4. Indeed, the effect of a change in the distribution of \tilde{x} and the effect of introducing a pure background risk are not without any link. Suppose that there is no background risk, but rather that the increase in risk in \tilde{x} takes the form of adding an *independent* pure white noise $\tilde{\epsilon}$ to it. The derivative of the objective function with the new risk $\tilde{x} + \tilde{\epsilon}$ evaluated at the initial optimal exposure (normalized to 1) is written as

$$\begin{aligned} E(\tilde{x} + \tilde{\epsilon})u'(w_0 + \tilde{x} + \tilde{\epsilon}) &= E\tilde{x}u'(w_0 + \tilde{x} + \tilde{\epsilon}) + E\tilde{\epsilon}u'(w_0 + \tilde{x} + \tilde{\epsilon}) \\ &= E\tilde{x}v'(w_0 + \tilde{x}) + E\tilde{\epsilon}u'(w_0 + \tilde{x} + \tilde{\epsilon}) \\ &\leq E\tilde{\epsilon}u'(w_0 + \tilde{x} + \tilde{\epsilon}) \\ &\leq 0. \end{aligned} \tag{5.19}$$

The first inequality is obtained by using the fact that $\alpha^* = 1$ under the initial risk \tilde{x} , together with the fact that v is more concave than u under risk vulnerability. The second inequality is a direct consequence of the fact that $E\tilde{\epsilon} = 0$. We conclude that risk-vulnerable agents reduce their exposure to a risk that has been increased in the sense of adding a zero-mean independent white noise to it. This result is in Gollier and Schlesinger (1996).

Other developments of this field of research have been made to extend the basic model (5.1) to more than one source of endogenous risk. Landsberger and Meilijon (1990), Meyer and Ormiston (1985) and Dionne and Gollier (1996) considered the two-risky-asset problem, which is written as

$$\max_{\alpha} Eu(w_0 + \alpha\tilde{x}_1 + (1 - \alpha)\tilde{x}_2).$$

These authors determined whether imposing MLR, SIR, or other restrictions on the change in the conditional distribution of \tilde{x}_1 generates the same conclusion in this more general context. Notice that rewriting final wealth as $w_0 + \alpha(\tilde{x}_1 - \tilde{x}_2) + \tilde{x}_2$ suggests that this problem is similar to the initial one, with a controllable risk ($\tilde{x}_1 - \tilde{x}_2$) and a “background” risk \tilde{x}_2 . But the two risks are here correlated.

Another line of research is related to the management of multiple endogenous risks, a problem which can be formulated as follows:

$$\max_{\alpha_1, \dots, \alpha_n} Eu\left(w_0 + \sum_{i=1}^n \alpha_i \tilde{x}_i\right).$$

Eeckhoudt et al. (1994) examined the case where the \tilde{x}_i are i.i.d., in which case all α_i^* are the same. They addressed the question of how α^* is affected by an increase in n . As an application, we have the optimal strategy of an agent who has to insure a fleet of vehicles. Gollier et al. (1997) showed that an increase in n reduces α^* if relative risk aversion is constant and less than unity.

While the extension presented so far was made in the 1990s to deal essentially with endogenous risks, it is worth mentioning that after 2000 there was a renewal of interest for the impact of background risks on the management of controllable ones. The first article in this direction was

published by [Arrondel–Calvo \(2003\)](#). These authors considered the case of correlated small risks and obtained a first interesting result: an additive and negatively correlated background risk may increase the demand for the endogenous risky asset because the decision-maker will wish to benefit from the hedging effect induced by the increased holding of such an asset.

This line of research was much developed a few years later in two almost simultaneous articles by [Tsetlin–Winkler \(2005\)](#) and [Franke et al. \(2006\)](#) who extended the Arrondel–Calvo’s contributions in two directions. They considered “large” risks and they also analyzed the (realistic) case of multiplicative background risks. Many examples of such a situation can be found in both articles and they give rise in Franke et al. (2006) to the notion of “multiplicative risk vulnerability” (see their (5.3) and its discussion) which complements that of additive risk vulnerability discussed in Sect. 5.5.

Finally attention was recently paid to the case where the background risk is not expressed in the same units as the endogenous one. Building upon a previous articles by [Rey \(2003\)](#), [Li \(2011\)](#) analyzed the behavior of an investor jointly facing an endogenous financial risk and an exogenous nonfinancial one that are not independent. Interestingly the analysis is developed using different notions of dependence, beyond the traditional one of correlation.

5.7 Conclusion

Stochastic dominance orders have been defined to determine the effect of a change in risk on the welfare of some category of economic agents. It is now apparent that these concepts are not well suited to perform comparative statics analyses. As an example, an increase in risk à la Rothschild–Stiglitz on the return of a risky asset may induce some risk-averse agents to increase their demand for it. Also, an increase in background risk à la Rothschild–Stiglitz may induce some risk-averse agents to raise their demand for another independent risk. In this chapter, we summarize the main findings that allow to solve these paradoxes. We tried to convince the reader that most restrictions to preferences or to stochastic orders make sense even if some are rather technical.

We examined a simple model with a single source of endogenous risk, plus a background risk. We separately considered the case of a change in the distribution of the endogenous risk and the case of a change in background risk. The current trends in this field are for the analysis of multiple risk taking situations, in which these two analyses are often combined to produce new results. Much progress must be still done on our understanding of the interaction between risks, but we now have the relevant tools and concepts to perform this work efficiently.

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Chapter 6

Risk Measures and Dependence Modeling

Paul Embrechts and Marius Hofert

Abstract This chapter provides an introduction and overview about modeling risks in insurance and finance. Besides the problem of adequately modeling individual risks, modeling their possibly complicated interactions and dependencies is challenging from both a theoretical point of view and from practice. Well-known concepts to model risks are presented and their strengths and weaknesses discussed.

6.1 Risk Measures

In a world of increasing quantification, the handling of risk, through either measurement or management, plays a fundamental role. As a consequence, we notice the increase in importance and visibility of risk management (RM) as an interdisciplinary field of research with considerable potential for wide-ranging applications. Often, RM obtains several different prefixes, as there are Q (quantitative), E (enterprise), G (global), T (total), I (integrated), etc., resulting in a range of disciplines spanning the breadth of quantitative to qualitative. As much as behind the word “risk” hides a multitude of concepts and interpretation, the same can be said for “risk measure.” For this chapter we make a choice for QRM and borrow the context, as well as examples, from the realm of banking and insurance. Consequently, a key reference is [McNeil et al. \(2005\)](#) and the references therein. It should be stressed however that the techniques and tools introduced can be (and are) applied across a much wider range of applications. The key prominence of (Q)RM within the financial industry is the regulatory environment which demands from banks (Basel Committee guidelines, Basel III, say) as well as from insurance companies (Solvency 2, Swiss Solvency Test) to come up with minimal capital (solvency) buffers to protect the various stakeholders from possible adverse financial consequences, ultimately default. Though we concentrate on the Q-prefix standing for “quantitative”, we want to stress the other Q-interpretation, “qualitative”. Any well-functioning risk management system needs a balance between the two Qs. In the context of Basel II, Basel III, and Solvency 2, this is achieved through the so-called three-pillar concept; see [McNeil et al. \(2005, Chap. 1\)](#).

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6.1.1 The Risk Mapping and the P&L

Throughout this chapter, we assume all random variables and random vectors to be defined on some probability space $(\Omega, \mathcal{F}, \mathbb{P})$. They are denoted by uppercase letters and their realizations by lowercase letters.

A crucial start to any RM exercise is the understanding (awareness) of the underlying risk drivers, also referred to as *risk factors*. We explain the main issues for a simplified, one-period portfolio model of financial/insurance instruments and use the following notation (see also [McNeil et al. 2005](#), Chap. 2):

V_t = value of a portfolio \mathcal{P} at time t (here “value” can be interpreted as “market value” when available);

$(t = 0)$ = today, v_0 is known

$(t > 0)$ = future time period, V_t is unknown

$P\&L_t = -(V_t - v_0)$, the *Profit and Loss (P&L)* at time t , denoted by L_t , the *loss* hence the minus sign;

$V_t = f(Z_t)$, Z_t a d -dimensional random vector of *risk factors* (d is typically large); f denotes the *structure function* of the portfolio \mathcal{P} ; this expression is referred to as *mapping*.

Often f is highly nonlinear

$X_t = Z_t - Z_{t-1}$ are the *risk factor changes* for one period in time.

With the above notation, we obtain for the loss random variable

$$L_t = -(V_t - v_0) = -[f(z_0 + X_t) - f(z_0)] =: l(X_t) \quad (6.1)$$

where l is the loss operator of the portfolio \mathcal{P} , equivalently of the portfolio structure function f .

Remark 6.1. We could (and indeed should) have included an explicit time parameter in the definition $V_t = f(t, Z_t)$ as well as $L_t = l(t, X_t)$. We refrain from doing so at this very basic level; see [McNeil et al. \(2005, Chap. 2\)](#) for further details and examples.

A key question within QRM now concerns finding “the” distribution function (df) of L_t . We write “the” as indeed at this point one can opt for a conditional versus unconditional approach. Though for illustrative purposes we choose to follow the latter (stationary models), the former more readily leads to dynamic risk measurement; see Sect. 6.1.5. Note however that in practice the separation is not so clean-cut.

In order to find $F_{L_t}(x) = \mathbb{P}(L_t \leq x)$, we need first a stochastic model for the risk factor changes X_t . Clearly, only for very few of such models and given f can we hope to find F_{L_t} . At this point, several options are open to the quantitative risk manager:

Option 1 (The lucky one): for a given model for X_t and portfolio structure f , F_{L_t} can be calculated analytically.

Option 2 (A widely used one): assuming sufficient smoothness of f , linearize (6.1) via a Taylor expansion to obtain

$$L_t^\Delta = - \sum_{j=1}^d D_j f(z_0) X_{t,j},$$

where $D_j f(z_0)$ denotes the partial derivative of f with respect to the j th component evaluated at z_0 ; here of course we use that the increments X_t are “small”, an assumption which may or may not hold in practice. For financial portfolios, here the so-called “Greeks” enter, delta hedging and higher-order convexity corrections leading to delta-gamma approximations.

Option 3 (The general one): keep L_t , choose a model for X_t , and use Monte Carlo simulation.

Option 4 (The practical one): given that Options 1–3 are either too crude or too difficult in order to come up with a full reporting of dfs $(F_{L_t})_{t \geq 0}$, RM in finance and insurance settled for the calculation and reporting of certain risk measures (i.e., real numbers) $(R(L_t))_{t \geq 0}$ associated to the P&Ls.

In the next sections, we will look more closely at certain aspects of the above options and start with Option 4, risk measures.

6.1.2 Coherent Risk Measures

In the language of the previous sections (Option 4), a risk measure R should map a loss random variable L_t (or simply L) to a real number indicating how safe it is to hold the underlying financial position over the period $[0, t]$. Also, R needs to satisfy certain axioms reflecting desirable properties.

Definition 6.1 (Coherent Risk Measure). Suppose \mathcal{U} is a cone of almost surely finite random variables, and define $R : \mathcal{U} \rightarrow \mathbb{R}$ so that:

- (1) $\forall L \in \mathcal{U}, a \in \mathbb{R}: R(L + a) = R(L) + a$ (translation invariance)
- (2) $\forall L_1, L_2 \in \mathcal{U}: R(L_1 + L_2) \leq R(L_1) + R(L_2)$ (subadditivity)
- (3) $\forall L \in \mathcal{U}, \lambda > 0: R(\lambda L) = \lambda R(L)$ (positive homogeneity)
- (4) $\forall L_1 \leq L_2$ almost surely: $R(L_1) \leq R(L_2)$ (monotonicity)

A risk measure satisfying (1)–(4) is called *coherent*.

Remark 6.2. (1) Though the economic and actuarial literature contains numerous contributions offering an axiomatization of risk measures, the contribution of [Artzner et al. \(1999\)](#) had a considerable impact on the research in this field. See also [McNeil et al. \(2005, Chap. 6\)](#) for further details and references.

- (2) Given our sign convention (losses are in the right tail, i.e., positive) $R(L)$ should be interpreted as the amount of regulatory capital to hold for having the position L (in case $R(L) \geq 0$). Also, $R(L)$ is the capital to hold at time 0, whereas L (or indeed L_t) corresponds to the end-of-one-period- $[0, t]$ position.
- (3) An extensive literature exists on the (non-) appropriateness of the axioms (1)–(4). We will come back to some of the issues in the following sections.

Given the definition of a coherent risk measure and besides [Remark 6.2](#) (3), the following questions pose themselves naturally:

- (Q1) Do coherent risk measures exist?
- (Q2) Can they be characterized?
- (Q3) Are widely used risk measures coherent?

The third question will be answered in Sect. 6.3.1. The first two questions can be answered directly and ideally via answering (Q2):

Proposition 6.1 (Characterization of Coherent Risk Measures). *Suppose Ω is finite and let $\mathcal{U} = \mathbb{R}^\Omega$. Then, for any coherent risk measure R on \mathcal{U} , there is a set \mathcal{Q} of probability measures on Ω so that for $L \in \mathcal{U}$:*

$$R(L) = \sup\{\mathbb{E}^{\mathbb{Q}}[L] : \mathbb{Q} \in \mathcal{Q}\} =: R_{\mathcal{Q}}(L). \quad (6.2)$$

Remark 6.3. For a proof of this result, see McNeil et al. (2005, Proposition 6.11). For a more general discussion, see Delbaen (2000). Risk measures of the type (6.2) are called *generalized scenarios*.

Returning to the risk mapping setting (6.1), we have a clear roadmap ahead of us:

- Find statistically well-fitting models for the vector X_t of risk factor changes.
- Estimate the risk measure chosen for a given portfolio structure function f .
- Discuss properties like aggregation and time scaling within the above.

A relatively easy and historically important example concerns the (d -dimensional) multivariate normal distribution $N_d(\mu, \Sigma)$.

Proposition 6.2. *The following are equivalent:*

- (1) $X \sim N_d(\mu, \Sigma)$
- (2) $\forall a \in \mathbb{R}^d \setminus \{0\}: a^\top X \sim N_1(a^\top \mu, a^\top \Sigma a)$

Property (2) above yields a fairly straightforward way ahead for linear or linearized portfolios. Clearly, it would be useful to find a class of multivariate dfs with similar properties: this is found in the class of so-called *elliptical dfs*; see Sect. 6.2.1.4 and McNeil et al. (2005, Sect. 3.3 and Definition 1.3). In those models, QRM is rather trivial; see McNeil et al. (2005, Theorem 6.8, Proposition 6.13). In all such and more general models, key features such models should exhibit are (at least) heavy-tailedness (even power tails) and special dependence, for instance, allowing for sufficiently many joint extreme events. The former can partly be achieved by “randomization” like in the elliptical case; a typical example is the family of multivariate Student’s t -distributions; see Sect. 6.2.1.4 or McNeil et al. (2005, Example 3.7). Special dependencies can typically be achieved by the copula toolbox (see Sect. 6.2.1) and mathematically better understood using extreme value theory (EVT, see Sect. 6.3.3). Before discussing these and related issues, we will revisit the theory of risk measures.

6.1.3 Alternative Approaches

Without being able to go into any detail, below we list some approaches to risk measurement, beyond the class of coherent risk measures. The axiom (2) of subadditivity in Definition 6.1 of a coherent risk measure and (3) of positive homogeneity have often been criticized. The former in relation to aggregation and diversification and the latter concerning liquidity, that is, (3), may fail for λ large. This has led to the notion of *convex risk measures*, where besides (1) and (4) in Definition 6.1, the following axiom holds:

$$\forall L_1, L_2 \in \mathcal{U}, \lambda \in [0, 1] : R(\lambda L_1 + (1-\lambda)L_2) \leq \lambda R(L_1) + (1-\lambda)R(L_2). \quad (6.3)$$

A risk measure satisfying (1) and (4) in Definition 6.1 is often referred to as a *monetary risk measure*. Hence a monetary risk measure satisfying (6.3) is a convex risk measure. A positively homogeneous convex risk measure is coherent. Through this weakening of the coherence axioms (2) and (3) a more general class of risk measures is obtained. Besides an ever-expanding research literature on the subject, one can find a very readable introduction to convex risk measures in [Föllmer and Schied (2011, Chap. 4)].

A mathematically equivalent way for introducing and studying risk measures is through the notion of *acceptance sets*

$$\mathcal{A}_R = \{L \in \mathcal{U} : R(L) \leq 0\},$$

hence those positions L for which no regulatory capital is needed; see, for instance, Föllmer and Schied (2011, Sect. 4.1). An excellent review on the subject is Föllmer and Schied (2010). We strongly advise the interested reader to consult the above references in order to find related work by:

- P. Huber on Robust Statistics
- A. Ben-Tal on convex risk measures and the optimized certainty equivalent
- I. Gilboa and D. Schmeidler on an axiomatic theory of risk measures from the realm of mathematical economics
- A fundamental theorem on law invariant coherent risk measures by S. Kusuoka; see also the next section

6.1.4 An Actuarial View

From (Denuit et al. 2005, p. 59) we quote:

Numerous risk measures have been proposed in insurance and finance, ranging from the most elementary to the most elaborate. As long as risk measurement is based on an axiomatic approach, it is senseless to look for the “right” risk measure (...). Different classes of risk measures represent different schools of thought. ... The functional form and fundamental properties of risk measures have been extensively studied in the actuarial literature since 1970, in the guise of premium calculation principles (see Kaas et al. 2001, Chap. 5).

We shall not enter the discussion on similarities between premium calculation principles (in insurance) and risk measures (in finance). It suffices to say that there are obvious mathematical similarities, a nontrivial amount of similar results, but, at the same time, sufficient complementarities which make a comparison between the two fields relevant.

Definition 6.2 (Comonotonicity). A sequence of random variables L_1, \dots, L_d is *comonotonic* if there exists a random variable Z and increasing functions ψ_1, \dots, ψ_d , so that $L_j = \psi_j(Z)$, almost surely, $j \in \{1, \dots, d\}$.

Kusuoka’s Theorem (referred to in the previous section) concerns the notion of comonotonicity; see Kusuoka (2001). For its formulation we need three further notions:

- A risk measure is *law invariant* if for $L_1 \stackrel{(d)}{=} L_2$, $R(L_1) = R(L_2)$.
- A risk measure R is *comonotonic additive* if for L_1, L_2 comonotonic,

$$R(L_1 + L_2) = R(L_1) + R(L_2).$$

- A risk measure R on L^2 is *regular* if it is law invariant and comonotonic additive.

Theorem 6.1 (Kusuoka 2001). *A coherent risk measure R is regular if and only if there exists $\phi : [0, 1] \rightarrow [0, \infty)$, increasing, so that*

$$R(L) = \int_0^1 \phi(t) F_L^-(t) dt, \quad (6.4)$$

where F_L^- is the generalized inverse of F_L defined in Definition 6.3.

Remark 6.4. In Sect. 6.3 we shall reinterpret this important result in terms of the Value-at-Risk concept. For the moment it suffices to say that any regular, coherent risk measure on L^2 is a weighted average of quantiles (note however that ϕ needs to be increasing!). Risk measures of the type (6.4) are referred to as *spectral risk measures*; see Acerbi (2002). The function ϕ can be interpreted as a risk aversion function and hence opens the way for a link between the concept of coherence and investors' preferences. The latter point is particularly stressed in Dowd et al. (2008). For an application to futures clearinghouse margin requirements, see Cotter and Dowd (2006). Spectral risk measures are further related to the notions of distorted risk measures and Choquet integrals; see Pflug and Römisch (2007), Föllmer and Schied (2011), and Gzyl and Mayoral (2007). For the relevant theory of Choquet integrals, a topic in the realm of nonadditive probability, see Denneberg (1994). Finally, more recently, the above concepts have entered the world of behavioral finance and prospect theory; see, for instance, He and Zhou (2011).

The notion of comonotonicity plays a fundamental role in actuarial risk theory; it also corresponds to the dependence structure (comonotonic copula, see Sect. 6.2.1.2) yielding a maximal linear correlation between two risks; see Höfding's identity in Lemma 6.1.

The actuarial literature now abounds in premium principles and their risk measure counterparts, as there are:

- The Esscher premium principle
- The Wang distortion measures
- The zero-utility principle and distorted expectation method
- The ruin-theory-based risk measure
- Indeed many others

See the references above. For a more mathematical discussion, see the early Goovaerts et al. (1984).

6.1.5 Multi-period Risk Measurement

Whereas for the previous sections (essentially a one-period approach) by now standard textbooks exist and a fairly consolidated body of theory can be given, this is by no means true for multi-period or dynamic risk measurement. The latter field constitutes a strongly growing field of intensive research. From a regulatory point of view, RM is essentially one period, for example, quarterly or yearly. At the trading level, RM is of course highly dynamic through the notion of delta hedging (and its generalizations to higher-order Greeks). The area of research highlighted in this section mainly concerns the properties of multi-period RM for regulatory (risk capital adequacy) purposes. We only point here at some basic references from which the interested reader can dig deeper:

- A good place to start the journey is through the already mentioned contribution Föllmer and Schied (2010, Sect. 7) and the references therein; see also Chap. 5 in Pflug and Römisch (2007) and Chap. 11 in Föllmer and Schied (2011).
- A very readable overview (updated to early 2010) is Acciaio and Penner (2010).
- For an application of dynamic risk measurement to pension funds, see van Bilsen (2010).

6.2 Dependence Modeling

6.2.1 Copulas

The investigation of multivariate dfs with standardized univariate marginal dfs dates back to the work of Fréchet (1935) and Höffding (1940). In the seminal work of Sklar (1959), it is stated that any multivariate df can be decomposed into its univariate marginal dfs and a function called “copula” (Latin for “link”). Conversely, any univariate dfs combined with a copula gives a proper multivariate df. These results are the two parts of *Sklar’s Theorem*; see Sklar (1959).

While studying certain measures of association, Schweizer and Wolff (1981) discovered the usefulness of copulas in analyzing the dependence between random variables. They show that copulas are invariant under strictly increasing transformations. In combination with Sklar’s Theorem, this result implies that copulas precisely capture the information about the dependence structure between random variables.

By the middle of the 1990s of the last century, copulas entered the world of financial and insurance mathematics and are used to model dependencies of various kinds. Since then, this young and active field of research has developed quite fast; see Genest et al. (2009). The recent subprime mortgage crisis, for example, has shown that dependence structures have to be modeled adequately and cannot be neglected.

6.2.1.1 Definition and Basic Properties

Recall that a multivariate *distribution function (df)* $H : \mathbb{R}^d \rightarrow [0, 1]$ is defined by $H(x) = \mathbb{P}(X \leq x)$, where $X = (X_1, \dots, X_d)^\top$ and $x = (x_1, \dots, x_d)^\top \in \mathbb{R}^d$. A function evaluated at the symbols $-\infty$ or ∞ is understood as the corresponding limit (possibly $\pm\infty$ itself). The j th *margin (al df)* $F_j : \mathbb{R} \rightarrow [0, 1]$ of H is defined as $F_j(x_j) = H(\infty, \dots, \infty, x_j, \infty, \dots, \infty)$, $x_j \in \mathbb{R}$. By an *increasing (decreasing)* function we understand a nondecreasing (nonincreasing) function.

Although we are mainly interested in multivariate dfs, we also need some concepts from univariate functions in general.

Definition 6.3. For an increasing function $T : \mathbb{R} \rightarrow \mathbb{R}$ with $T(-\infty) = \lim_{x \downarrow -\infty} T(x)$ and $T(\infty) = \lim_{x \uparrow \infty} T(x)$, the *generalized inverse* $T^- : \mathbb{R} \rightarrow \bar{\mathbb{R}} = [-\infty, \infty]$ of T is defined by

$$T^-(y) = \inf\{x \in \mathbb{R} : T(x) \geq y\}, \quad y \in \mathbb{R}, \quad (6.5)$$

with the convention that $\inf \emptyset = \infty$. If $T : \mathbb{R} \rightarrow [0, 1]$ is a df, $T^- : [0, 1] \rightarrow \bar{\mathbb{R}}$ is also called the *quantile function* of T .

Note that if T is continuous and strictly increasing, T^- coincides with T^{-1} , the ordinary inverse of T on $\text{ran } T = \{T(x) : x \in \mathbb{R}\}$, the range of T . Generalized inverses of increasing functions in general and quantile functions in particular appear quite frequently when working with copulas. For a summary of important properties of generalized inverses see Embrechts and Hofert (2013). With these properties, one can directly show the following (pedagogically important) results; see also Embrechts and Hofert (2013). Here and in the following, $U[0, 1]$ denotes the (standard) uniform distribution on $[0, 1]$.

Proposition 6.3. Let F be a df and $X \sim F$.

- (1) If F is continuous, then $F(X) \sim U[0, 1]$.
- (2) If $U \sim U[0, 1]$, then $F^-(U) \sim F$.

Let $X \sim F$. The transform $F(X)$ addressed in Proposition 6.3 (6.3) is also referred to as *distributional transform*. Note that Proposition 6.3 (6.3) is not correct if F is not continuous since not all values in $(0, 1)$ are attained. A generalization of the notion of distributional transforms to allow for this property to hold even if F is not continuous can be given as follows. A *modified df* $F : \mathbb{R} \times [0, 1] \rightarrow [0, 1]$ is defined by

$$F(x, \lambda) = \mathbb{P}(X < x) + \lambda \mathbb{P}(X = x), \quad x \in \mathbb{R}, \lambda \in [0, 1].$$

The *generalized distributional transform* of X is then defined by $F(X, \Lambda)$ where $\Lambda \sim U[0, 1]$ is independent of X . An analogous result to Proposition 6.3 can then be given as follows; see Nešlehová (2007) for a proof.

Proposition 6.4. *Let $X \sim F$ and $\Lambda \sim U[0, 1]$ be independent.*

- (1) $F(X, \Lambda) \sim U[0, 1]$.
- (2) If $U = F(X, \Lambda)$, then $F^{-}(U) = X$ almost surely.

With these tools at hand, we are now able to introduce and study the notion of copulas.

Definition 6.4. A d -dimensional *copula* is a d -dimensional multivariate df with standard uniform univariate margins.

The following proposition characterizes copulas. Indeed, it is sometimes given as definition.

Proposition 6.5. *A function $C : [0, 1]^d \rightarrow [0, 1]$ is a d -dimensional copula if and only if the following properties hold:*

- (1) C is grounded, that is, $C(u) = 0$ if $u_j = 0$ for at least one $j \in \{1, \dots, d\}$.
- (2) C has standard uniform univariate margins, that is, $C(u) = u_j$, $u_j \in [0, 1]$, if $u_k = 1$ for all $k \in \{1, \dots, d\} \setminus \{j\}$.
- (3) C is d -increasing, that is, the C -volume

$$\Delta_{(a,b]} C = \sum_{j \in \{0,1\}^d} (-1)^{\sum_{k=1}^d j_k} C(a_1^{j_1} b_1^{1-j_1}, \dots, a_d^{j_d} b_d^{1-j_d})$$

is nonnegative for all $a, b \in [0, 1]^d$ with $a \leq b$.

Remark 6.5. (1) The d -increasingness property of copulas means that C assigns nonnegative (probability) mass to all nonempty rectangles $\emptyset \neq (a, b] \subseteq [0, 1]^d$. For a random vector $U \sim C$, this means that $\mathbb{P}(U \in (a, b]) = \Delta_{(a,b]} C \geq 0$; thus d -increasingness is indeed a required property.

(2) When constructing copulas, the d -increasingness property is typically the most complicated part to obtain. If the copula under consideration admits continuous partial derivatives, then d -increasingness is equivalent to showing that the density candidate

$$c(u) = D_{1\dots d} C(u) = \frac{\partial^d}{\partial x_d \dots \partial x_1} C(x) \Big|_{x=u}$$

is indeed nonnegative on $(0, 1)^d$.

(3) By Proposition 6.5, the convex combination $\lambda C_1 + (1 - \lambda) C_2$ of two copulas C_1 and C_2 is a copula as well. By linearity, also the *convex sum* of a family $(C_\theta)_{\theta \in \mathbb{R}^p}$ of copulas with respect to the *mixing distribution* F is a copula, given by $C(u) = \int_{\mathbb{R}^p} C_\theta(u) dF(\theta)$. Both results can also be obtained in a probabilistic way from Definition 6.4.

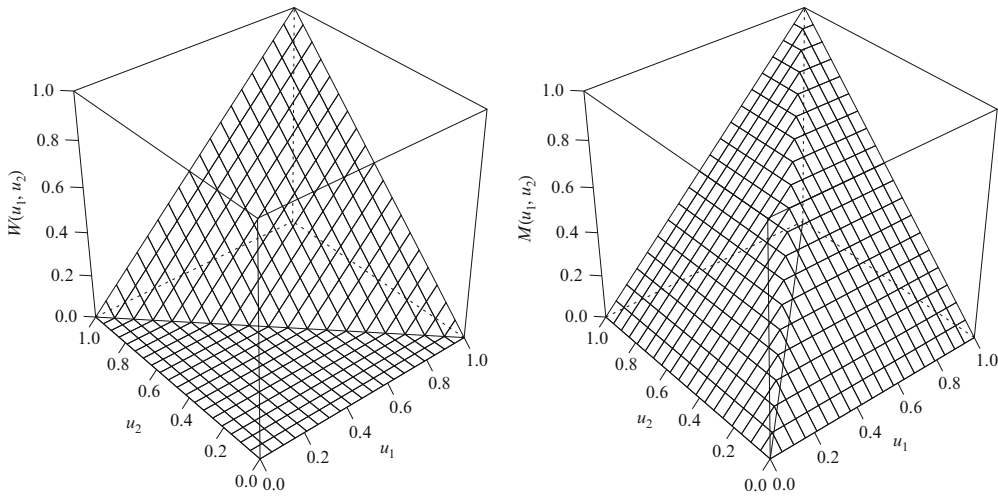


Fig. 6.1 The lower Fréchet–Höfding bound W (left) and the upper Fréchet–Höfding bound M (right)

The following theorem is known as the *Fréchet –Höfding bounds theorem*, attributed to [Fréchet \(1935\)](#) and the work of [Höfding \(1940\)](#). It states important functional bounds on copulas; for a proof, see [Nelsen \(2007, p. 47\)](#). As we will see in Sect. 6.2.1.2, these bounds relate to extremal dependencies among components of a random vector. They are also of interest and widely used for computing bounds for risk measures. For more refined versions of the bounds using (multivariate) margins of C , see [Joe \(1997, p. 57\)](#).

Theorem 6.2 (Fréchet–Höfding Bounds Theorem). Let $W(u) = \max\{\sum_{j=1}^d u_j - d + 1, 0\}$ and $M(u) = \min_{1 \leq j \leq d}\{u_j\}$.

(1) Any d -dimensional copula satisfies

$$W(u) \leq C(u) \leq M(u), \quad u \in [0, 1]^d.$$

(2) W is a copula if and only if $d = 2$. For $d \geq 3$ and any $v \in [0, 1]^d$ there exists a copula C such that $C(v) = W(v)$.

(3) M is a copula for all dimensions $d \geq 2$.

It is a basic exercise to show that $\Delta_{(1/2,1]}W = 1 - d/2$, which is negative for $d \geq 3$. Hence, for $d \geq 3$, W is not a copula (only a pointwise lower bound to any given copula). This is only one of many examples illustrating the fact that results obtained for two dimensions do not necessarily carry over to higher dimensions. Until recently, most of the copula theory was presented mainly for the bivariate case. The general multivariate case is both theoretically and empirically more challenging.

Figure 6.1 shows the bivariate lower and upper Fréchet–Höfding bounds W (left) and M (right), respectively.

6.2.1.2 Sklar’s Theorem and Random Vectors

One of the most important theorems in copula theory and its applications is *Sklar’s Theorem*. It is attributed to [Sklar \(1959\)](#). The classical proof based on a multilinear extension is given in [Sklar \(1996\)](#); a probabilistic, more modern proof can be found in [Rüschendorf \(2009\)](#) based on generalized distributional transforms.

Theorem 6.3 (Sklar's Theorem).

(1) For any df H with margins F_j , $j \in \{1, \dots, d\}$, there exists a copula C such that

$$H(x) = C(F_1(x_1), \dots, F_d(x_d)), \quad x \in \mathbb{R}^d. \quad (6.6)$$

C is uniquely determined on $\prod_{j=1}^d \text{ran } F_j$, that is, the product of the ranges of the margins, and given by

$$C(u) = H(F_1^-(u_1), \dots, F_d^-(u_d)), \quad u \in \prod_{j=1}^d \text{ran } F_j.$$

(2) Conversely, given any copula C and univariate dfs F_j , $j \in \{1, \dots, d\}$, H defined by (6.6) is a df with margins F_j , $j \in \{1, \dots, d\}$.

Part (1) of Sklar's Theorem allows us to decompose any multivariate df into its univariate margins and a copula. It allows us to study multivariate dfs independently of their margins. This is often used in statistical applications, such as estimation and goodness-of-fit testing. Part (2) allows to construct new multivariate dfs and is often used for model building and sampling purposes. Sklar's Theorem thus reflects the two main areas of application of copulas.

Before we continue, let us stress that C in (6.6) is only unique if all univariate margins are continuous. We will focus on this case in what follows. Many natural interpretations do not hold anymore if some margins are discontinuous; see [Genest and Nešlehová \(2007\)](#) for more details.

Since Sklar's Theorem is formulated in terms of dfs, let us now study its implications on the corresponding random vectors. For this, let X be a d -dimensional random vector with df H , continuous margins F_j , $j \in \{1, \dots, d\}$, and copula C . As an example, X could be a random vector of risks, losses, or liabilities. If we apply the margins to X , that is, if we consider $U = (F_1(X_1), \dots, F_d(X_d))^T$, we know by Proposition 6.3 (1) that U has standard uniform margins. Its df is thus some copula \tilde{C} . How is this copula \tilde{C} related to the copula of X , that is, the copula C that corresponds to H via (6.6) in Sklar's Theorem? As one can show, both copulas are precisely the same so that

$$U = (F_1(X_1), \dots, F_d(X_d))^T \sim C. \quad (6.7)$$

This property is also known as *invariance principle*.

Theorem 6.4 (Invariance Principle). Let $X = (X_1, \dots, X_d)^T \sim H$ with continuous margins F_j , $j \in \{1, \dots, d\}$, and copula C . If T_j is strictly increasing on $\text{ran } X_j$, $j \in \{1, \dots, d\}$, then the copula of $(T_1(X_1), \dots, T_d(X_d))^T$ is (again) C , that is, copulas are invariant under strictly increasing transformations on the product of the ranges of the underlying random variables.

Going back to [Schweizer and Wolff \(1981\)](#), the invariance principle allows us to study U in (6.7) when investigating the dependence between the random variables X_j , $j \in \{1, \dots, d\}$. Therefore, dependence properties can be studied independently of the marginal distributions as has been mentioned before. This is one of the reasons why copulas are important.

The copula corresponding to independent components X_j , $j \in \{1, \dots, d\}$, is given by $\Pi(u) = \prod_{j=1}^d u_j$, the so-called *independence copula*. It puts (probability) mass uniformly on $[0, 1]^d$. Note that the bivariate lower Fréchet–Höfding bound W puts mass uniformly on the secondary diagonal of the unit square. Since this is, as a subset of $[0, 1]^2$, a set of (Lebesgue) measure zero, W is a *singular copula*. Note that a bivariate random vector $U \sim W$ can be written as $U = (U, 1 - U)^T$ almost

surely, where $U \sim U[0, 1]$. Similarly, the upper Fréchet–Höfding bound M is also a singular copula. It puts mass on the main diagonal and thus allows for the stochastic representation $U = (U, \dots, U)^\top$. Due to the fact that W and M correspond to “perfect negative” and “perfect positive” dependence, they are also referred to as *countermonotonic* and *comonotonic copula*, respectively.

6.2.1.3 Measures of Association

Practitioners often prefer to work with numbers rather than functions. A number that describes the association between random variables is referred to as a *measure of association*. Many such measures exist; they typically summarize different aspects of association. In the following, we will concentrate on three such notions: the linear correlation coefficient, measures of concordance (in particular, Kendall’s tau), and the coefficients of tail dependence. Although some of these measures of association extend to more than two dimensions, we only consider the (still) more popular bivariate case.

The Linear Correlation Coefficient

The well-known (*Pearson’s*) (*linear*) *correlation coefficient* of two random variables X_1 and X_2 with $\mathbb{E}[X_j^2] < \infty$, $j \in \{1, 2\}$, is defined by

$$\rho = \rho(X_1, X_2) = \frac{\text{Cov}[X_1, X_2]}{\sqrt{\text{Var}[X_1]}\sqrt{\text{Var}[X_2]}}.$$

It is one of the most widely used measures of association. The following identity turns out to be quite useful from a theoretical point of view but also in calculations; see [Embrechts et al. \(2002\)](#).

Lemma 6.1 (Höfding’s Identity) Let $(X_1, X_2)^\top \sim H$ with corresponding margins F_1 and F_2 and $\mathbb{E}[X_j^2] < \infty$, $j \in \{1, 2\}$. Then

$$\text{Cov}[X_1, X_2] = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} (H(x_1, x_2) - F_1(x_1)F_2(x_2)) dx_1 dx_2.$$

Some well-known properties of the correlation coefficient are summarized in the following proposition:

Proposition 6.6. Let X_1 and X_2 be two random variables with $\mathbb{E}[X_j^2] < \infty$, $j \in \{1, 2\}$. Then:

- (1) $-1 \leq \rho \leq 1$.
- (2) $|\rho| = 1$ if and only if there exist real numbers $a \neq 0$ and b such that $X_2 = aX_1 + b$ almost surely, that is, X_1 and X_2 are perfectly linearly dependent. If $\rho = -1$, then $a < 0$ and if $\rho = 1$ then $a > 0$.
- (3) If X_1 and X_2 are independent, then $\rho = 0$. However, the converse statement is false in general.
- (4) Correlation is invariant under strictly increasing linear transformations on the ranges of the underlying random variables. However, it is in general not invariant under nonlinear such transformations.

Parts (1) and (2) of Proposition 6.6 follow from the Cauchy–Schwarz inequality. A counterexample for Part (3) is constructed in Sect. 6.2.2 based on Höfding’s identity. With Höfding’s identity, it is also easy to see that if $(X_{i1}, X_{i2})^\top$ has copula C_i and $\mathbb{E}[X_{ij}^2] < \infty$, $i, j \in \{1, 2\}$, then $C_1(u) \leq C_2(u)$ for all $u \in [0, 1]^2$ implies that the correlation coefficient ρ_1 corresponding to $(X_{11}, X_{12})^\top$ is less than or equal to the correlation coefficient ρ_2 corresponding to $(X_{21}, X_{22})^\top$. Concerning (4) of Proposition 6.6, let

us note that nonlinear transformations may even affect the existence of the correlation coefficient: taking X_1 and X_2 to be independent and identically distributed (i.i.d.) according to a Par(3) distribution (i.e., a Pareto distribution with df $F(x) = 1 - x^{-\alpha}$, $x \geq 1$, $\alpha = 3$) implies that $\rho(X_1, X_2) = 0$, but $\rho(X_1^2, X_2)$ is not even defined since X_1^2 is Par(3/2) distributed and thus does not have finite variance.

The popularity of correlation is due to the fact that the correlation coefficient is often straightforward to calculate and easy to manipulate under linear operations. Furthermore, it is a natural measure in the context of elliptical distributions; see Embrechts et al. (2002). In the non-elliptical world, however, it can be quite misleading to use the correlation coefficient as a measure of association; see Sect. 6.2.2.

The main problem with correlation as a measure of association is that it also depends on the margins of the random variables under consideration. As a consequence, the range of attainable correlations depends on the marginal distributions; see Sect. 6.2.2. Correlation is thus not a copula property (alone), hence also not invariant under strictly increasing transformations in general. It is not possible with the correlation coefficient to study the underlying dependence structure independently of the margins. This is also undesirable from a statistical point of view, since transforming the given data with the margins may change the correlation coefficient. Moreover, as we have seen above, the margins even have an influence on the existence of correlation since it is only defined if the second moments of the underlying random variables are finite.

Kendall's Tau: A Rank Correlation Measure

Concerning the deficiencies of the correlation coefficient ρ , a desirable property of a measure of association for two continuously distributed random variables $X_j \sim F_j$, $j \in \{1, 2\}$, is that it should only depend on their copula. According to the invariance principle, it suffices to study such measures of association in terms of *ranks*, that is, to study the random variables $F_j(X_j)$, $j \in \{1, 2\}$, instead of X_j , $j \in \{1, 2\}$. These measures are thus called *rank correlation measures* (the word “correlation” actually means “dependence” here). They are also known as *measures of concordance*. As functionals of the underlying copula, they have many desirable properties and can be used to fit copulas to empirical data.

In the following, we restrict ourselves to the case where X_1 and X_2 are continuous. For generalizations to not necessarily continuously distributed random variables, we refer the interested reader to Nešlehová (2004, 2007).

Definition 6.5. A measure of association $\kappa = \kappa(X_1, X_2) = \kappa(C)$ between two continuously distributed random variables X_1 and X_2 with copula C is a *rank correlation coefficient* if the following properties hold:

- (1) κ is defined for every pair X_1, X_2 of continuously distributed random variables.
- (2) $-1 \leq \kappa \leq 1$, $\kappa(W) = -1$, and $\kappa(M) = 1$.
- (3) $\kappa(X_1, X_2) = \kappa(X_2, X_1)$.
- (4) If X_1 and X_2 are independent, then $\kappa(X_1, X_2) = \kappa(I) = 0$.
- (5) $\kappa(-X_1, X_2) = -\kappa(X_1, X_2)$.
- (6) If C_1 and C_2 are bivariate copulas such that $C_1(u) \leq C_2(u)$ for all $u \in [0, 1]^2$, then $\kappa(C_1) \leq \kappa(C_2)$.
- (7) If $(C_n)_{n \in \mathbb{N}}$ is a sequence of bivariate copulas which converges pointwise to C , then $\lim_{n \rightarrow \infty} \kappa(C_n) = \kappa(C)$.

As a consequence of Definition 6.5 and the invariance principle, rank correlation coefficients share the following properties; see Scarsini (1984).

Proposition 6.7. Let κ be a measure of concordance for two continuously distributed random variables X_1 and X_2 .

- (1) If X_2 is almost surely a strictly decreasing function in X_1 , then $\kappa(X_1, X_2) = \kappa(W) = -1$.
 (2) If X_2 is almost surely a strictly increasing function in X_1 , then $\kappa(X_1, X_2) = \kappa(M) = 1$.
 (3) If T_j is a strictly increasing function on $\text{ran } X_j$, $j \in \{1, 2\}$, then $\kappa(T_1(X_1), T_2(X_2)) = \kappa(X_1, X_2)$.

In practical applications, several rank correlation coefficients are used, for example, Spearman's rho, Kendall's tau, Blomqvist's beta, or Gini's gamma. We only briefly present some results about Kendall's tau here. For other rank correlation measures or measures of association in more than two dimensions, we refer to [Nelsen \(2007, p. 180\)](#) and [Jaworski et al. \(2010, p. 209\)](#).

Let $X_j \sim F_j$, $j \in \{1, 2\}$, be continuously distributed random variables and let $(X'_1, X'_2)^\top$ be an i.i.d. copy of $(X_1, X_2)^\top$. Then Kendall's tau is defined by

$$\tau = \mathbb{E}[\text{sign}((X_1 - X'_1)(X_2 - X'_2))],$$

where $\text{sign}(x) = \mathbb{1}_{(0, \infty)}(x) - \mathbb{1}_{(-\infty, 0)}(x)$ denotes the *signum function*. For a random sample $(x_{1i}, x_{2i})^\top$, $i \in \{1, \dots, n\}$, of $(X_1, X_2)^\top$ (i.e., realizations of independent copies of $(X_1, X_2)^\top$), Kendall's rank correlation coefficient has an obvious estimator, also called *sample version of Kendall's tau*, given by

$$\hat{\tau} = \frac{1}{\binom{n}{2}} \sum_{1 \leq i_1 < i_2 \leq n} \text{sign}((x_{1i_1} - x_{1i_2})(x_{2i_1} - x_{2i_2})).$$

The sample version of Kendall's tau is a U -statistic, for which many asymptotic properties are known; see [Serfling \(1980, p. 171\)](#) or [Lee \(1990\)](#) for more details.

A simple calculation (see [Nelsen 2007, p. 159](#)) shows that Kendall's tau can be written as

$$\tau = 4 \int_{[0,1]^2} C(u) dC(u) - 1$$

so, indeed, Kendall's tau only depends on the underlying copula C and does not involve the marginal dfs. From this representation one can also check that Kendall's tau satisfies all defining properties of a rank correlation coefficient. Furthermore, it additionally satisfies that $\tau = -1$ ($\tau = 1$) implies that $C = W$ ($C = M$, respectively); see [Embrechts et al. \(2002\)](#).

Finally, note that the computation of τ is often simplified by the identity

$$\int_{[0,1]^2} C(u) dC'(u) = \frac{1}{2} - \int_{[0,1]^2} D_1 C(u) D_2 C'(u) du,$$

where C and C' are two copulas and $D_j C$ denotes the partial derivative of C with respect to the j th coordinate; see [Li et al. \(2002\)](#).

The Tail-Dependence Coefficients

Tail dependence measures the extremal dependence between two random variables, that is, the strength of dependence in the tails of their bivariate distribution.

Definition 6.6. Let $X_j \sim F_j$, $j \in \{1, 2\}$, be continuously distributed random variables. Provided the limits to exist, the *lower tail-dependence coefficient* λ_L and the *upper tail-dependence coefficient* λ_U of X_1 and X_2 are defined by

$$\lambda_L = \lim_{t \downarrow 0} \mathbb{P}(X_2 \leq F_2^-(t) \mid X_1 \leq F_1^-(t)),$$

$$\lambda_U = \lim_{t \uparrow 1} \mathbb{P}(X_2 > F_2^-(t) \mid X_1 > F_1^-(t)).$$

If $\lambda_L \in (0, 1]$ ($\lambda_U \in (0, 1]$), then X_1 and X_2 are *lower (upper) tail dependent*. If $\lambda_L = 0$ ($\lambda_U = 0$), then X_1 and X_2 are *lower (upper) tail independent*.

Intuitively, the lower tail-dependence coefficient measures the probability that one random variable is “small” given the other one is “small” (“small” is meant with respect to their quantiles and as a limit). Similarly, the upper tail-dependence coefficient measures the probability that one random variable is “large” given the other one is “large.” This kind of dependence plays an important role in certain applications (also linked to the recent subprime crisis) such as intensity-based credit default models for pricing collateralized debt obligations (CDOs); see [Donnelly and Embrechts \(2010\)](#) or [Hofert and Scherer \(2011\)](#) for more details.

There are similar ways to generalize Definition 6.6 to the general multivariate case involving more than two random variables; for an excellent overview, we refer to [Jaworski et al. \(2010, p. 228\)](#).

The limits in Definition 6.6 (and thus the tail-dependence coefficients) do not necessarily exist; see [Kortschak and Albrecher \(2009\)](#) for a counterexample. Although interesting from a theoretical point of view, note that the tail-dependence coefficients exist for all well-known copula classes.

The following results are often useful in computing the tail-dependence coefficients. They also show that the notion of tail dependence is a copula property. The proof of the first part is straightforward using the results of [Embrechts and Hofert \(2013\)](#), Proposition 6.3(1) and Eq. (6.7). The second and third parts follow with l’Hôpital’s rule and the chain rule.

Theorem 6.5. *Let $X_j \sim F_j$, $j \in \{1, 2\}$, be continuously distributed random variables with copula C . Then:*

- (1) $\mathbb{P}(X_2 \leq F_2^-(t) \mid X_1 \leq F_1^-(t)) = C(t, t)/t$ for all $t \in (0, 1]$. Thus, λ_L exists if and only if $\lim_{t \downarrow 0} C(t, t)/t$ exists, in which case both are equal.
- (2) If $t \mapsto C(t, t)$ is differentiable in a neighborhood of 0 and $\lim_{t \downarrow 0} \frac{d}{dt} C(t, t)$ exists, then λ_L exists and equals this limit.
- (3) If C is totally differentiable in a neighborhood of 0 and $\lim_{t \downarrow 0} (D_1 C(t, t) + D_2 C(t, t))$ exists, then λ_L exists and equals this limit.

Similarly for λ_U :

- (1) $\mathbb{P}(X_2 > F_2^-(t) \mid X_1 > F_1^-(t)) = (1 - 2t + C(t, t))/(1 - t) = \hat{C}(1 - t, 1 - t)/(1 - t)$ for all $t \in [0, 1)$ (\hat{C} denotes the survival copula corresponding to C ; see [Nelsen 2007, p. 32](#)). Thus, λ_U exists if and only if $\lim_{t \uparrow 1} (1 - 2t + C(t, t))/(1 - t) = \lim_{t \downarrow 0} \hat{C}(t, t)/t$ exists, in which case both are equal.
- (2) If $t \mapsto C(t, t)$ is differentiable in a neighborhood of 1 and $2 - \lim_{t \uparrow 1} \frac{d}{dt} C(t, t)$ exists, then λ_U exists and equals this limit.
- (3) If C is totally differentiable in a neighborhood of 1 and $2 - \lim_{t \uparrow 1} (D_1 C(t, t) + D_2 C(t, t))$ exists, then λ_U exists and equals this limit.

Finally, let us mention that it was recently shown by [Beare \(2010\)](#) that when C is absolutely continuous with square-integrable density then both tail-dependence coefficients are zero.

6.2.1.4 Copula Classes

Joe (1997, p. 84) presents desirable properties of families of multivariate distributions. He mentions:

- (1) Interpretability (e.g., through a stochastic or mixture representation).
- (2) Closure under the taking of margins, in particular, the bivariate margins should belong to the same parametric family (important, e.g., when one first thinks about appropriate bivariate distributions during the model building process).
- (3) Flexible and wide range of dependencies.
- (4) Closed-form representation of the df and density or at least computationally feasible.

There is no multivariate model known that adequately fulfills all of these properties. By Sklar's Theorem it is clear that the main work is to construct appropriate copulas. The construction of new copulas and copula classes (parametric families of copulas) is one of the most active research fields in copula theory. The construction principles differ substantially and it is not possible to list all of them in this introduction. Rather, we focus on two important classes of copulas that highlight the theoretical concepts but also their limitations.

Elliptical Copulas

Simply put, *elliptical copulas* are copulas that arise from elliptical distributions via Sklar's Theorem. In other words, if X is a d -dimensional random vector following an elliptical distribution with marginal dfs F_j , $j \in \{1, \dots, d\}$, then $U = (F_1(X_1), \dots, F_d(X_d))^T$ is a random vector with an elliptical copula as df.

Elliptical distributions can be defined in different ways. The following definition is intuitive in that it provides a stochastic representation of an elliptically distributed random vector. Note that a *Cholesky factor* of a symmetric, positive definite matrix Σ is a lower triangular matrix A with positive diagonal elements such that $AA^T = \Sigma$. Furthermore, we denote with $U(\mathbb{S}_d)$ the uniform distribution on the unit sphere $\mathbb{S}_d = \{x \in \mathbb{R}^d : \|x\|_2 = 1\}$, where $\|x\|_2 = \sqrt{x_1 + \dots + x_d}$ denotes the Euclidean norm in \mathbb{R}^d .

Definition 6.7 (Elliptical Distributions). A d -dimensional random vector X follows an *elliptical distribution* with mean $\mu \in \mathbb{R}^d$, symmetric, positive definite *dispersion matrix* $\Sigma \in \mathbb{R}^{d \times d}$, and *radial part* $R \geq 0$ (a nonnegative random variable) if X allows for the stochastic representation

$$X = \mu + RAU,$$

where A is the Cholesky factor of Σ and $U \sim U(\mathbb{S}_d)$ is independent of R .

By conditioning on the radial part $R \sim F_R$ and writing $\Omega_d(t^T t)$ for the characteristic function of $U(\mathbb{S}_d)$, one can compute the characteristic function of X by $\phi(t) = e^{it^T \mu} h(t^T \Sigma t)$, $t \in \mathbb{R}^d$, where $h(t) = \int_0^\infty \Omega_d(r^2 t) dF_R(r)$. One can show that an elliptically distributed random vector X has a density f_X if and only if R has a density f_R . In this case, one has $f_X(x) = g((x - \mu)^T \Sigma^{-1}(x - \mu)) / \sqrt{\det \Sigma}$ for some function $g : [0, \infty) \rightarrow [0, \infty)$ also known as *density generator*. The level sets of the density of X are thus ellipses, hence the name *elliptical distributions*. Furthermore, the marginal dfs F_j , $j \in \{1, \dots, d\}$, can be expressed in terms of g via

$$F_j(\mu_j + \sqrt{\sigma_{jj}}x) = \frac{1}{2} + \frac{\pi^{(d-1)/2}}{\Gamma((d-1)/2)} \int_0^x \int_{y^2}^\infty (t - y^2)^{(d-1)/2-1} g(t) dt dy. \quad (6.8)$$

The density of R can also be expressed in terms of the density generator g , via $f_R(r) = 2\pi^{d/2}r^{d-1}g(r^2)/\Gamma(d/2)$, $r > 0$. Another important property of X is that $(\|X\|, X/\|X\|)^\top$ is in distribution equal to $(R, U)^\top$. With this result one can show that if $\mathbb{E}[R^2] < \infty$ then $\text{Cov}(X) = \mathbb{E}[R^2]\Sigma/d$. The covariance matrix is thus not necessarily equal to the dispersion matrix Σ . The ij th entry of the correlation matrix P of X is equal to $\rho_{ij} = \sigma_{ij}/\sqrt{\sigma_{ii}\sigma_{jj}}$, where σ_{ij} denotes the ij th entry of Σ . For more details about these and other results, see [Cambanis et al. \(1981\)](#), [Fang et al. \(1989, p. 31\)](#), [Fang et al. \(2002\)](#), or [Embrechts et al. \(2003\)](#).

Concerning measures of association, let $(X_1, X_2)^\top$ follow an elliptical distribution with mean vector 0 and correlation matrix P with off-diagonal entry ρ , and assume that $\mathbb{P}(X = 0) = 0$. Then Kendall's tau is given by

$$\tau = \frac{2}{\pi} \arcsin \rho;$$

see [Lindskog et al. \(2002\)](#) including an even slightly more general formula. Concerning tail dependence, there is no formula known for elliptical distributions in general. If the radial part R is regularly varying, see [Hult and Lindskog \(2002\)](#) for a formula. Note that elliptical distributions are *radially symmetric*, that is, $X - \mu$ is in distribution equal to $\mu - X$. This is equivalent to saying that U following an elliptical copula is in distribution equal to $1 - U$, where 1 denotes the d -dimensional vector of ones. It therefore follows that the lower and upper tail-dependence coefficients are necessarily equal. This is considered as one of the major drawbacks of elliptical distributions since joint large losses, for example, are typically observed with larger probability than joint large gains.

Sklar's Theorem provides a straightforward general sampling algorithm for elliptical copulas. Note that it suffices to specify a distribution for the radial part R and a correlation matrix P corresponding to Σ .

Algorithm 1 (Elliptical Copulas).

- (1) Sample $R \sim F_R$.
- (2) Generate $U \sim U(\mathbb{S}_d)$ (this can be done by sampling i.i.d. $Z_j \sim N(0, 1)$, $j \in \{1, \dots, d\}$, and taking $U = Z/\|Z\|$).
- (3) Compute the Cholesky factor A of P .
- (4) Set $X = RAU$ and return $(F(X_1), \dots, F(X_d))^\top$ where F is the df of X_j , $j \in \{1, \dots, d\}$.

Well-known examples of elliptical copulas include *Gaussian* and *t copulas*. As their names indicate, these are dfs of $U = (F_1(X_1), \dots, F_d(X_d))^\top$ for X following a multivariate normal and a multivariate t distribution, respectively. Both Gaussian and t copulas are implemented in the R package `copula`.

The radial part R of a d -dimensional multivariate normal distribution follows a *chi distribution* χ_d with d degrees of freedom (equivalently, $R^2 \sim \chi_d^2$). The corresponding density generator is $g(t) = \exp(-t/2)/(2\pi)^{d/2}$, $t \geq 0$. It follows from Formula (6.8) that the df F in Algorithm 6.6 (4) is the standard normal df. Sampling Gaussian copulas thus boils down to sampling $X \sim N(0, P)$ and returning $U = (\Phi(X_1), \dots, \Phi(X_d))^\top$, where Φ denotes the df of the standard normal distribution. Figure 6.2 (left) shows a sample of size 500 from a bivariate Gaussian copula with correlation coefficient chosen such that Kendall's tau equals 0.5. Concerning tail dependence, it follows from Theorem 6.5 (3) and by symmetry that $\lambda_L = 2 \lim_{t \downarrow 0} D_1 C(t, t) = 2 \lim_{t \downarrow 0} \mathbb{P}(U_2 \leq t | U_1 = t) = 2 \lim_{x \downarrow -\infty} \mathbb{P}(X_2 \leq x | X_1 = x)$. Since X_2 given $X_1 = x$ is $N(\rho x, 1 - \rho^2)$ -distributed, $\lambda_L = 2 \lim_{x \downarrow -\infty} \Phi((x(1 - \rho))/\sqrt{1 - \rho^2}) = \mathbb{1}_{\{\rho=1\}}$. Recall that $\lambda_U = \lambda_L$ for elliptical copulas so that Gaussian copulas are tail independent as long as $\rho \neq 1$. This implies that Gaussian copulas, in the limit, do not assign a positive probability to jointly large realizations of X_1 and X_2 (unless $\rho = 1$) which is considered as one of the major drawbacks of these copulas.

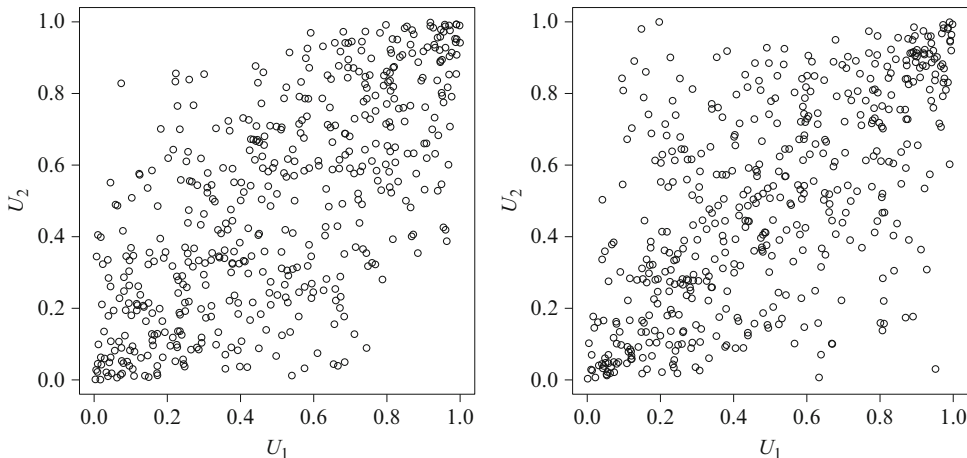


Fig. 6.2 Scatter plots of bivariate samples of size 500 for a Gaussian copula (left) and a t copula with four degrees of freedom with correlation coefficient chosen such that Kendall's tau equals 0.5

A d -dimensional Gaussian copula with correlation matrix P can be written as

$$\begin{aligned} C(u) &= \Phi_P(\Phi^{-1}(u_1), \dots, \Phi^{-1}(u_d)) \\ &= \int_{-\infty}^{\Phi^{-1}(u_d)} \dots \int_{-\infty}^{\Phi^{-1}(u_1)} \frac{\exp(-x^\top P^{-1}x/2)}{(2\pi)^{d/2} \sqrt{\det P}} dx_1 \dots dx_d \end{aligned}$$

where Φ_P denotes the df of $N(0, P)$. The evaluation of a Gaussian copula thus cannot be done explicitly and typically involves Monte Carlo simulation in higher dimensions. The density of C , however, is explicit, given by

$$c(u) = \frac{1}{\sqrt{\det P}} \exp(-x^\top (P^{-1} - I_d)x/2), \quad x = (\Phi^{-1}(u_1), \dots, \Phi^{-1}(u_d))^\top,$$

where I_d denotes the identity matrix in dimension d . The $d(d-1)/2$ parameters of a Gaussian copula appearing as entries of P are typically estimated by maximum-likelihood estimation (in small dimensions) or by pairwise inverting Kendall's tau, possibly followed by a maximization of the likelihood (in larger dimensions).

For a d -dimensional multivariate t distribution with ν degrees of freedom, the radial part allows for the stochastic representation $R^2/d \sim F(d, \nu)$, where $F(a, b)$ denotes an F -distribution with degrees of freedom $a > 0$ and $b > 0$. The corresponding density generator is $g(t) = \frac{\Gamma((d+\nu)/2)}{(\pi\nu)^{d/2} \Gamma(\nu/2)} (1 + t/\nu)^{-(d+\nu)/2}$, $t \geq 0$. By (6.8), the df of F in Algorithm 6.6 (4) corresponds to a (univariate) t distribution with ν degrees of freedom (short t_ν). Sampling t copulas thus boils down to sampling $X \sim t_{\nu, P}$ (a multivariate t distribution with ν degrees of freedom and correlation matrix P ; see Demarta and McNeil 2005) and returning $U = (t_\nu(X_1), \dots, t_\nu(X_d))^\top$. Figure 6.2 (right) shows a sample of size 500 from a bivariate t copula with four degrees of freedom and correlation coefficient chosen such that Kendall's tau equals 0.5. A similar calculation as before using the fact that the conditional distribution function of X_2 given $X_1 = x_1$ is given by

$$F_{X_2|X_1}(x_2 | x_1) = t_{\nu+1} \left(\frac{x_2 - \rho x_1}{\sqrt{(1-\rho^2)(\nu + x_1^2)/(\nu+1)}} \right)$$

allows one to derive that

$$\lambda_L = \lambda_U = \begin{cases} 0, & \rho = -1, \\ 2t_{v+1}\left(-\sqrt{\frac{(v+1)(1-\rho)}{1+\rho}}\right), & \rho \in (-1, 1), \\ 1, & \rho = 1, \end{cases}$$

so that, in contrast to Gaussian copulas, t copulas allow for tail dependence. Although a limit cannot be detected from finitely many points, this difference in the tail behavior is also visible in Fig. 6.2.

A d -dimensional t_ν copula with correlation matrix P can be written as

$$\begin{aligned} C(u) &= t_{\nu,P}(t_\nu^{-1}(u_1), \dots, t_\nu^{-1}(u_d)) \\ &= \int_{-\infty}^{t_\nu^{-1}(u_d)} \cdots \int_{-\infty}^{t_\nu^{-1}(u_1)} \frac{\Gamma((d + \nu)/2)(1 + x^\top P^{-1}x/\nu)^{-\frac{d+\nu}{2}}}{\Gamma(\nu/2)(\pi\nu)^{d/2}\sqrt{\det P}} dx_1 \dots dx_d. \end{aligned}$$

As for Gaussian copulas, the evaluation of t copulas in larger dimensions is typically done via Monte Carlo simulation. The density of C is explicitly given by

$$c(u) = \frac{\Gamma((\nu + d)/2)}{\Gamma(\nu/2)\sqrt{\det P}} \left(\frac{\Gamma(\nu/2)}{\Gamma((\nu + 1)/2)} \right)^d \frac{(1 + x^\top P^{-1}x/\nu)^{-(\nu+d)/2}}{\prod_{j=1}^d (1 + x_j^2/\nu)^{-(\nu+1)/2}}.$$

Besides the $d(d - 1)/2$ entries of the correlation matrix P , t copulas have the degrees of freedom parameter ν . These copulas are typically estimated by maximum-likelihood estimation in small dimensions and pairwise inverting Kendall’s tau followed by maximum-likelihood estimation for ν in larger dimensions; see McNeil et al. (2005, p. 235).

Archimedean Copulas

An (Archimedean) generator is a continuous, decreasing function $\psi : [0, \infty) \rightarrow [0, 1]$ which satisfies $\psi(0) = 1$, $\psi(\infty) = \lim_{t \uparrow \infty} \psi(t) = 0$, and which is strictly decreasing on $[0, \inf\{t : \psi(t) = 0\})$. A d -dimensional copula C is called Archimedean if it permits the representation

$$C(u) = \psi(\psi^{-1}(u_1) + \cdots + \psi^{-1}(u_d)), \quad u \in [0, 1]^d, \tag{6.9}$$

for some generator ψ with inverse $\psi^{-1} : (0, 1] \rightarrow [0, \infty)$ and $\psi^{-1}(0) = \inf\{t : \psi(t) = 0\}$.

Many known copula families are Archimedean, including the families of Ali-Mikhail-Haq, Clayton, Frank, Gumbel, and Joe; see below for more details. In contrast to elliptical copulas, Archimedean copulas are given explicitly in terms of their generators. All relevant properties can be expressed in terms of this one-place real function. Furthermore, as they are not restricted to radial symmetry, Archimedean copulas are able to capture different kinds of tail dependence, a desired feature shared by many applications. As a drawback, Archimedean copulas are *exchangeable*, that is, symmetric in their arguments; see (6.9). This implies, for example, that all bivariate marginal copulas are the same. More flexible, asymmetric extensions of Archimedean copulas were recently introduced; see Hofert (2012) and references therein. Many others exist, but are not discussed here.

Malov (2001) and McNeil and Nešlehová (2009) (2009) show that a generator defines an Archimedean copula if and only if ψ is *d-monotone*, meaning that ψ is continuous on $[0, \infty)$, admits

derivatives up to the order $d - 2$ satisfying $(-1)^k \frac{d^k}{dt^k} \psi(t) \geq 0$ for all $k \in \{0, \dots, d - 2\}$, $t \in (0, \infty)$, and $(-1)^{d-2} \frac{d^{d-2}}{dt^{d-2}} \psi(t)$ is decreasing and convex on $(0, \infty)$. According to [McNeil and Nešlehová \(2009\)](#), an Archimedean copula C admits a density c if and only if $\psi^{(d-1)}$ exists and is absolutely continuous on $(0, \infty)$. In this case, c is given by

$$c(u) = \psi^{(d)}(t(u)) \prod_{j=1}^d (\psi^{-1})'(u_j), \quad u \in (0, 1)^d, \quad (6.10)$$

where $t(u) = \sum_{j=1}^d \psi(u_j)$.

In practical applications, one mainly Assumes ψ to be *completely monotone*, meaning that ψ is continuous on $[0, \infty)$ and $(-1)^k \frac{d^k}{dt^k} \psi(t) \geq 0$ for all $k \in \mathbb{N}_0$, $t \in (0, \infty)$, so that ψ is the Laplace–Stieltjes transform (\mathcal{LS}) of a df F on the positive real line, that is, $\psi = \mathcal{LS}[F]$; see Bernstein’s Theorem in [Feller \(1971, p. 439\)](#). The class of all such generators is denoted by Ψ_∞ and it is obvious that a $\psi \in \Psi_\infty$ generates an Archimedean copula in any dimension and that its density exists. In what follows we assume $\psi \in \Psi_\infty$. Note that completely monotone generators are *strict* meaning that $\psi(t) > 0$ for all $t \in [0, \infty)$. Furthermore, $\tau \geq 0$ for the Archimedean copulas generated by such generators.

The explicit functional form of Archimedean copulas turns out to be useful in computations. One can show that Kendall’s tau can be represented in semi-closed form as

$$\tau = 4 \int_0^1 \frac{\psi^{-1}(t)}{(\psi^{-1}(t))'} dt + 1 = 1 - 4 \int_0^\infty t (\psi'(t))^2 dt;$$

see [Genest and Rivest \(1993\)](#) and [Joe \(1997, p. 91\)](#). Concerning tail dependence, if the lower and upper tail-dependence coefficients of an Archimedean copula exist, Theorem 6.5, a simple substitution, and an application of l’Hôpital’s rule lead to the formulas

$$\begin{aligned} \lambda_L &= \lim_{t \rightarrow \infty} \frac{\psi(2t)}{\psi(t)} = 2 \lim_{t \rightarrow \infty} \frac{\psi'(2t)}{\psi'(t)}, \\ \lambda_U &= 2 - \lim_{t \downarrow 0} \frac{1 - \psi(2t)}{1 - \psi(t)} = 2 - 2 \lim_{t \downarrow 0} \frac{\psi'(2t)}{\psi'(t)}; \end{aligned}$$

see [Joe and Hu \(1996\)](#).

A random vector U following an Archimedean copula with generator $\psi \in \Psi_\infty$ allows for a simple stochastic representation, given by

$$U = (\psi(R_1/V), \dots, \psi(R_d/V))^\top,$$

where $R_j \sim \text{Exp}(1)$, $j \in \{1, \dots, d\}$, and $V \sim F = \mathcal{LS}^{-1}[\psi]$ are independent. This provides a straightforward sampling algorithm, known as *Marshall–Olkin algorithm*, and is also the basis for several nonsymmetric extensions of Archimedean copulas; see [Hofert \(2012\)](#).

There are several well-known parametric Archimedean families; see [Nelsen \(2007, p. 116\)](#). Among the most widely used in applications are those of Ali–Mikhail–Haq (“A”), Clayton (“C”), Frank (“F”), Gumbel (“G”), and Joe (“J”). These families are implemented in the R package `nacopula`. The corresponding densities (6.10) were found recently; see [Hofert et al. \(2013\)](#) for these and other, more general results. Table 6.1 shows their generators and corresponding distributions $F = \mathcal{LS}^{-1}[\psi]$; detailed information about the latter is given in [Hofert \(2012\)](#) and references therein. Note that these one-parameter families can be extended to allow for more parameters, for example, via outer power

Table 6.1 Well-known one-parameter Archimedean generators ψ with corresponding distributions $F = \mathcal{L}S^{-1}[\psi]$

| Family | Parameter | $\psi(t)$ | $V \sim F = \mathcal{L}S^{-1}[\psi]$ |
|--------|--------------------------|--|--|
| A | $\theta \in [0, 1)$ | $(1 - \theta)/(\exp(t) - \theta)$ | Geo($1 - \theta$) |
| C | $\theta \in (0, \infty)$ | $(1 + t)^{-1/\theta}$ | $\Gamma(1/\theta, 1)$ |
| F | $\theta \in (0, \infty)$ | $-\log(1 - (1 - e^{-\theta}) \exp(-t))/\theta$ | Log($1 - e^{-\theta}$) |
| G | $\theta \in [1, \infty)$ | $\exp(-t^{1/\theta})$ | S($1/\theta, 1, \cos^\theta(\pi/(2\theta)), \mathbb{1}_{\{\theta=1\}}; 1$) |
| J | $\theta \in [1, \infty)$ | $1 - (1 - \exp(-t))^{1/\theta}$ | Sibuya($1/\theta$) |

Table 6.2 Kendall's tau and tail-dependence coefficients

| Family | τ | λ_L | λ_U |
|--------|--|-----------------|--------------------|
| A | $1 - 2(\theta + (1 - \theta)^2 \log(1 - \theta))/(3\theta^2)$ | 0 | 0 |
| C | $\theta/(\theta + 2)$ | $2^{-1/\theta}$ | 0 |
| F | $1 + 4(D_1(\theta) - 1)/\theta$ | 0 | 0 |
| G | $(\theta - 1)/\theta$ | 0 | $2 - 2^{1/\theta}$ |
| J | $1 - 4 \sum_{k=1}^{\infty} 1/(k(\theta k + 2)(\theta(k - 1) + 2))$ | 0 | $2 - 2^{1/\theta}$ |

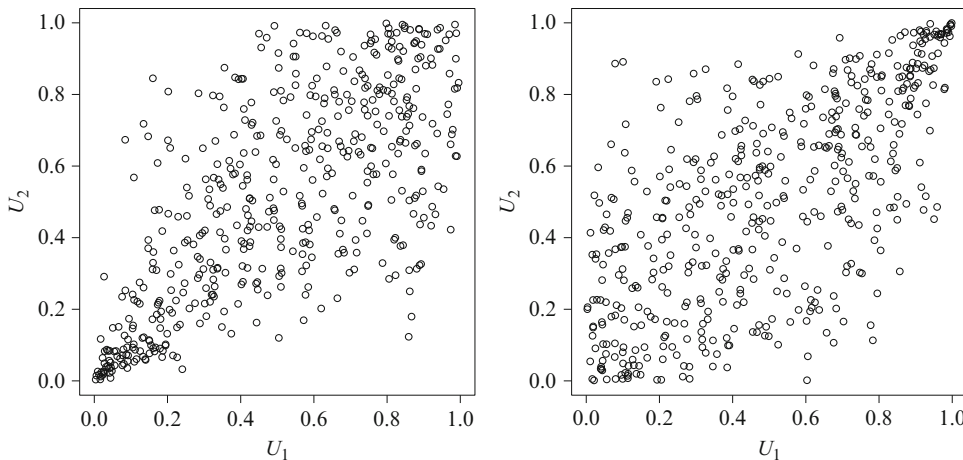


Fig. 6.3 Scatter plots of bivariate samples of size 500 for a Clayton copula (left) and a Gumbel copula (right) with parameter θ chosen such that Kendall's tau equals 0.5

transformations. Furthermore, there are Archimedean families which are naturally given by more than a single parameter.

Table 6.2 summarizes properties concerning Kendall's tau and the tail-dependence coefficients. Here, $D_1(\theta) = \int_0^\theta t/(\exp(t) - 1) dt/\theta$ denotes the *Debye function of order one*.

Figure 6.3 shows a sample of size 500 from a bivariate Clayton copula (left) and a bivariate Gumbel copula (right), where the parameter is chosen such that Kendall's tau equals 0.5. The asymmetries in the tails are clearly visible, but also the exchangeability of $(U_1, U_2)^\top$, that is, $(U_1, U_2)^\top$ and $(U_2, U_1)^\top$ have the same distribution.

6.2.2 Correlation Pitfalls

In this section, we address some pitfalls in the thinking about dependencies. These fallacies involve not only correlation in the narrow sense of the correlation coefficient ρ but also correlation in the broader sense of dependence. As we have seen in Sect. 6.2.1, dependence properties are linked to the underlying copula. However, in practice, dependence is often thought of in terms of certain measures of association (mainly the linear correlation coefficient ρ). In this section we will see concrete counterexamples when this way of thinking may be misleading.

The following copula family proves to be useful in the construction of such counterexamples; see [Long and Krzysztofowicz \(1995\)](#) or [Mari and Kotz \(2001, p. 90\)](#) (and [de la Peña et al. 2006](#) for an extension to higher dimensions). It is given by

$$C(u_1, u_2) = u_1 u_2 + f_1(u_1) f_2(u_2), \quad (6.11)$$

where f_1, f_2 are continuous functions on $[0, 1]$ and continuously differentiable on $(0, 1)$ with $f_j(0) = f_j(1) = 0$, $j \in \{1, 2\}$, and $f_1'(u_1) f_2'(u_2) + 1 \geq 0$, $u_1, u_2 \in (0, 1)$. By construction, C is grounded and has uniform margins. To see that C is indeed a copula, one can compute its density and check that it is nonnegative under the given assumptions. Hence, C is a copula. Note that as a special case for $f_1(x) = \theta x(1-x)$ with $\theta \in [-1, 1]$ and $f_2(x) = x(1-x)$, one obtains the *Farlie–Gumbel–Morgenstern* family of copulas.

Fallacy 1: Marginal distributions and correlation determine the joint distribution

The multivariate normal distribution is fully determined by its marginal distributions and the correlation matrix P . In general, however, a joint distribution function H is not necessarily determined by its marginal distribution functions F_j , $j \in \{1, \dots, d\}$, and the correlation matrix P .

Although numerous examples of varying complexity and practical relevance can be stated, we give a broad class of examples following a construction interesting in its own right. Consider the bivariate case. Assume we have given standard uniform univariate margins and the correlation coefficient ρ to be zero. We will show that these fixed margins together with the fixed correlation coefficient do not uniquely determine the joint distribution H . Note that H here is in fact equal to its copula C since we assume standard uniform univariate margins. In other words, we will construct two different copulas that both have correlation coefficient zero. To be more precise, we construct an uncountable set of copulas of the form (6.11) with correlation coefficient zero.

Since we assume standard uniform univariate margins, $\text{Var}[X_j] = 1/12$, $j \in \{1, 2\}$. By Höfdding's identity, it follows that for H of the form (6.11), we have

$$\begin{aligned} \rho &= 12 \text{Cov}[X_1, X_2] = 12 \int_0^1 \int_0^1 (C(u_1, u_2) - u_1 u_2) du_1 du_2 \\ &= 12 \int_0^1 f_1(u_1) du_1 \int_0^1 f_2(u_2) du_2. \end{aligned}$$

We see that ρ is necessarily zero if one of the integrals is zero. To guarantee that, take an admissible f_1 which is point symmetric about $1/2$. It is a simple exercise to construct a polynomial, for example, that has this property. One such polynomial is $f_1(x) = 2x(x-1/2)(x-1)$, $x \in [0, 1]$, which satisfies $f_1(0) = f_1(1/2) = f_1(1) = 0$, $f_1'(x) \in [-1/2, 1]$, $x \in [0, 1]$, and which is point symmetric about $1/2$. For f_2 we then may simply take $f_2(x) = \theta x(1-x)$ for $\theta \in [-1, 1]$. These choices for f_1 and f_2 satisfy all required assumptions for (6.11) to be a proper copula, which is then given by

$$C(u_1, u_2) = u_1 u_2 (1 - 2\theta(u_1 - 1/2)(u_1 - 1)(u_2 - 1)). \quad (6.12)$$

Clearly, this gives an uncountable number of joint dfs with given (standard uniform univariate) margins and correlation coefficient zero. Moreover, we see that only for $\theta = 0$ we obtain the independence copula; hence this construction also serves as a counterexample for Proposition 6.6 (3). Figure 6.4 shows the density of copula (6.12) for $\theta = 1$, which clearly does not correspond to independence.

The same example is readily seen to extend to nonuniform margins, assuming the margins to have finite second moments and F_1 to be symmetric about zero; for example, one may take standard normal margins. More examples are given in Embrechts et al. (2002) or follow from Sharakhmetov and Ibragimov (2002).

Note that specifying the marginal distributions and the rank correlation measure Kendall's tau also does not uniquely determine the joint distribution. A counterexample can be constructed easily by considering a Clayton and a Gumbel copula with parameter $\theta = 2$. Both copulas have the same (standard uniform univariate) margins and Kendall's tau equal to 0.5. Since rank correlation measures such as Kendall's tau do not depend on the margins, any bivariate model with either of these two copulas has Kendall's tau equal to 0.5.

Fallacy 2: Given margins F_1 and F_2 , all $\rho \in [-1, 1]$ can be attained by a suitably chosen bivariate model

In the early nineties, one of the questions raised by the industry that came up at RiskLab, ETH Zurich, was how to simulate from a bivariate model with log-normal margins $\text{LN}(0, 1)$ and $\text{LN}(0, 16)$ and correlation 0.5. The answer is: there is no such model.

To see this, let us consider two random variables $X_j \sim \text{LN}(0, \sigma_j^2)$, $j \in \{1, 2\}$. It is readily seen from Höfding's identity that minimal and maximal correlation coefficients are obtained by taking the copulas to be the lower and upper Fréchet–Höfding bound, respectively. In case of the former, note that $(X_1, X_2)^\top$ allows for the stochastic representation $(\exp(\sigma_1 Z), \exp(-\sigma_2 Z))^\top$, where $Z \sim \text{N}(0, 1)$. Since $\mathbb{E}[\exp(tZ)] = \exp(t^2/2)$ and $\text{Var}[X_j] = (\exp(\sigma_j^2) - 1) \exp(\sigma_j^2)$, $j \in \{1, 2\}$, one can compute the minimal attainable correlation coefficient explicitly. Similarly for the maximal attainable correlation coefficient (using that $(X_1, X_2)^\top = (\exp(\sigma_1 Z), \exp(\sigma_2 Z))^\top$ in distribution). One thus obtains $\rho \in [\rho_{\min}, \rho_{\max}] = [\tilde{\rho}(\sigma_1, -\sigma_2), \tilde{\rho}(\sigma_1, \sigma_2)]$, where

$$\tilde{\rho}(\sigma_1, \sigma_2) = \frac{\exp((\sigma_1 + \sigma_2)^2/2) - \exp((\sigma_1^2 + \sigma_2^2)/2)}{\sqrt{(\exp(\sigma_1^2) - 1) \exp(\sigma_1^2)} \sqrt{(\exp(\sigma_2^2) - 1) \exp(\sigma_2^2)}}.$$

Figure 6.5 shows ρ_{\min} and ρ_{\max} as functions in σ_1, σ_2 . These plots show the narrow corridor of attainable correlations. For the original question with $\sigma_1^2 = 1$ and $\sigma_2^2 = 16$, one obtains the range (rounded to four digits) $\rho \in [-0.0003, 0.0137]$ which is far below 0.5.

6.3 Specific Risk Measures: Value-at-Risk and Expected Shortfall

Recall 6.1.2 from Sect. 6.1.2: “Are widely used risk measures coherent?” Once more, when no extra references are given explicitly, McNeil et al. (2005) is a basic source. Recall the setup from Sect. 6.1: consider the one-period (P&)L random variable L with df F_L .

Fig. 6.4 Density c of the copula C in (6.12) for $\theta = 1$

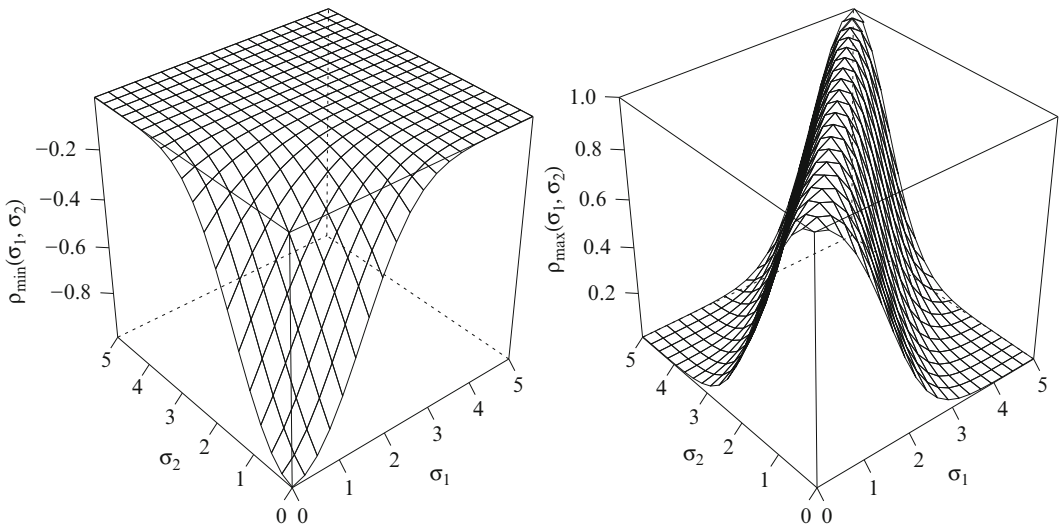
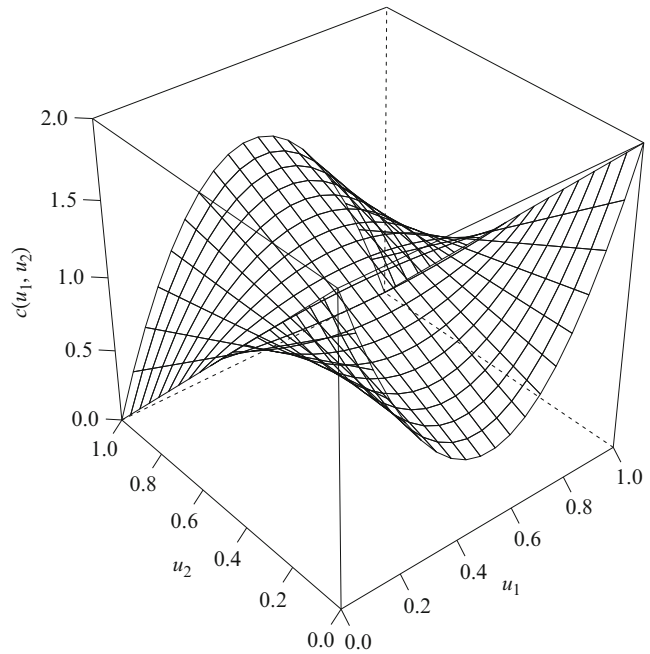


Fig. 6.5 Minimal (left) and maximal (right) attainable linear correlation for a bivariate model with margins $\text{LN}(0, \sigma_1^2)$ and $\text{LN}(0, \sigma_2^2)$, respectively

Definition 6.8 (Value-at-Risk and Expected Shortfall).

(1) For $0 < \alpha < 1$, the *Value-at-Risk (VaR)* of L at confidence level α is given by

$$\text{VaR}_\alpha(L) = F_L^-(\alpha),$$

so that $\mathbb{P}(L > \text{VaR}_\alpha) = 1 - \alpha$, typically small.

(2) For $0 < \alpha < 1$, the *Expected Shortfall (ES)* of L at confidence level α is given by

$$ES_\alpha(L) = \frac{1}{1-\alpha} \int_\alpha^1 VaR_\beta(L) d\beta. \quad (6.13)$$

- Remark 6.6.* (1) VaR was introduced at J.P. Morgan in the early 1990s and quickly gained industry-wide acceptance and legal status through the Basel Accords. It is to be stressed that $VaR_\alpha(L)$ (as well as $ES_\alpha(L)$) very much depends on the construction of the P&L of the bank (trading book). In particular, their calculations involve a holding period which is ten days for market risk ($\alpha = 0.99$) and one year for credit and operational risk ($\alpha = 0.999$). A basic textbook on the more practical aspects of VaR is [Jorion \(2007\)](#). A measure of the growth of success of VaR-based RM can be deduced from the publication intensity and growth in volume of the editions: 332 in 1997, 543 in 2001, and 602 in 2007. On the other hand, numerous contributions discuss the dangers lurking in the RM usage of VaR and related metrics. Of course, one number will never be sufficient in handling the risks embedded in a trading book; see [Rootzén and Klüppelberg \(1999\)](#). Much more important is the full understanding of the risk mapping as discussed in Sect. 6.1.1. Below we will come back to some of the weaker methodological properties of a quantile risk measure like VaR.
- (2) If F_L is continuous, then the “average-VaR” definition of $ES_\alpha(L)$ reduces to the more familiar conditional expectation:

$$ES_\alpha(L) = \mathbb{E}[L \mid L > VaR_\alpha(L)].$$

- (3) The difference between VaR and ES, does it matter? The following lemma yields an answer.

Lemma 6.2 (VaR and ES for Normal and Student’s t Random Variables)

- (i) Suppose $L \sim N(\mu, \sigma^2)$, then

$$\lim_{\alpha \uparrow 1} \frac{ES_\alpha(L)}{VaR_\alpha(L)} = 1.$$

- (ii) Suppose $L \sim t_\nu$ (Student’s t with ν degrees of freedom, $\nu > 1$), then

$$\lim_{\alpha \uparrow 1} \frac{ES_\alpha(L)}{VaR_\alpha(L)} = \frac{\nu}{\nu - 1} > 1.$$

So answering the above question “whether it matters” would be: for normal random variables, no; for Student’s t random variables with ν close to 1, yes!

A “nice” property for normal-based RM is given in the next lemma.

Lemma 6.3 (VaR and ES for Normal Random Variables) Suppose $L \sim N(\mu, \sigma^2)$ and $1/2 < \alpha < 1$, then:

- (i) $VaR_\alpha(L) = \mu + \sigma \Phi^{-1}(\alpha)$, where Φ is the standard normal df.
- (ii) $ES_\alpha(L) = \mu + \sigma \frac{\phi(\Phi^{-1}(\alpha))}{1-\alpha}$, where $\phi = \Phi'$, the standard normal density function.
- (4) It is presumably correct to say that VaR-based RM has lulled the financial industry into a false belief of safety in the run-up to the 2007 subprime crisis; see also [Donnelly and Embrechts \(2010\)](#).
- (5) From VaR to regulatory capital: denote $VaR_{\alpha,t}^d$ the Value-at-Risk of a trading book, say, at confidence α and holding period d , calculated at time (day) t . A fundamental component of the regulatory capital charge for time t , today, say, is

$$\max \left\{ VaR_{99\%,t}^{10}, \frac{\delta}{60} \sum_{k=1}^{60} VaR_{99\%,t-k+1}^{10} \right\},$$

where:

- The 60-day averaging reflects risk capital smoothing
- The 10-day period corresponds to two trading weeks
- The max-operator switches to the first VaR component in times of extreme stress
- $\delta \in [3, 5]$ is a model-stress factor also depending on the backtesting properties of the underlying VaR models (typically tested for 1-day data)

6.3.1 Aggregation and Diversification

For risk measures as discussed in Sect. 6.1, aggregation and diversification properties very much depend on the axiom(s) of (sub-)additivity; see Sects. 6.1.2 and 6.1.3. As already stressed before, in the world of multivariate normality and more generally ellipticity (Definition 6.7), VaR-based RM is fairly straightforward.

Theorem 6.7 (VaR Is Coherent for $N_d(\mu, \Sigma)$). For $\alpha > 1/2$, $\text{VaR}_\alpha(\cdot)$ is coherent on the space of risks $L \sim N_d(\mu, \Sigma)$.

We give the main argument for $d = 2$. Suppose $(L_1, L_2)^\top \sim N_2(\mu; \sigma_1^2, \sigma_2^2, \rho)$, then $L_1 + L_2 \sim N_1(\mu_{L_1+L_2}, \sigma_{L_1+L_2}^2)$, where

$$\begin{aligned}\mu_{L_1+L_2} &= \mu_1 + \mu_2, \\ \sigma_{L_1+L_2}^2 &= \sigma_1^2 + \sigma_2^2 + 2\rho\sigma_1\sigma_2 \leq (\sigma_1 + \sigma_2)^2.\end{aligned}$$

Hence, because of Lemma 6.3, for $\alpha > 1/2$,

$$\begin{aligned}\text{VaR}_\alpha(L_1 + L_2) &= \mu_{L_1+L_2} + \sigma_{L_1+L_2}\Phi^{-1}(\alpha) \\ &\leq \mu_1 + \mu_2 + (\sigma_1 + \sigma_2)\Phi^{-1}(\alpha) \\ &= \text{VaR}_\alpha(L_1) + \text{VaR}_\alpha(L_2).\end{aligned}$$

It is essentially the Cauchy–Schwarz inequality for standard deviations (reflected in $\rho \leq 1$) that leads to the above conclusion. A similar proof holds for the more general class of elliptical dfs; see McNeil et al. (2005, Theorem 6.8).

An interesting question now concerns the loss of sub-additivity for VaR; this typically happens in the following three cases:

Case 1 (Extreme heavy-tailedness). For instance, for $L_i \sim \text{Par}(1/2)$, $i \in \{1, 2\}$, independent, where

$$\mathbb{P}(L_i > x) = x^{-1/2}, \quad x \geq 1,$$

we have that for all $\alpha \in (0, 1)$,

$$\text{VaR}_\alpha(L_1 + L_2) > \text{VaR}_\alpha(L_1) + \text{VaR}_\alpha(L_2). \quad (6.14)$$

The key point here is that $\mathbb{E}[L_i] = \infty$ and similar conclusions can be made for losses L_i satisfying $\mathbb{P}(L_i > x) = x^{-\delta}L(x)$ for $0 \leq \delta < 1$ and L a slowly varying function in Karamata's sense; see Embrechts et al. (1997, Appendix A3.1). In this case, however, as a function of the interdependence of the underlying risk factors and higher-order properties

of L , (6.14) will typically not hold for all α values. The notion of multivariate regular variation becomes relevant for a full understanding of the aggregation properties of VaR; see, for instance, Embrechts et al. (2009) and the references therein. Examples of models with infinite mean one encounters in the modeling of internet traffic data, catastrophes (i.e., nuclear risk, earthquakes, pyroclastic flows). Super-additivity of VaR for such models/data has considerable implications for insurability, for instance; for examples of this, see Ibragimov et al. (2009, 2011). An early example in the realm of operational risk is to be found in Nešlehová et al. (2006). Further empirical results on heavy-tailed distributions in economics and finance, including, in particular, infinite mean models, are to be found in Gabaix (2008) and Ibragimov (2009).

Case 2 (Very skewed dfs). Especially in the context of credit risk management, one often encounters dfs which are very skewed. In such cases, VaR may indeed be super-additive; see, for instance, McNeil et al. (2005, Example 6.7).

Case 3 (Special dependence). In Cases 1 and 2 above, one can criticize that the marginal dfs are somewhat special. The third class of examples allows for any marginal dfs but then constructs a special dependence structure, that is, copula. For an example involving $L_i \sim N(0, 1)$, $i \in \{1, 2\}$, see McNeil et al. (2005, Example 6.22).

Remark 6.7. In view of Proposition 6.1, Theorem 6.7, and Case 1 above, some extra comments are in order. Very heavy-tailed risks (in particular infinite mean risks) typically offer examples where VaR_α is super-additive for certain α values. On the other hand, for elliptical models, VaR_α is always coherent, that is, sub-additive. This occasionally confuses users when confronted with the (elliptical) Student's distribution on $\nu < 1$ (infinite mean) degrees of freedom. For an explanation of this issue, see Mainik and Embrechts (2011). The problem of defining risk measures on the space of infinite mean risk factors is mathematically discussed in Delbaen (2009).

Theorem 6.8 (VaR and Comonotonicity). *Let $0 < \alpha < 1$ and L_1, \dots, L_d be comonotonic (see Sect. 6.2.1.2) with dfs F_1, \dots, F_d , respectively, which are continuous and strictly increasing; then*

$$\text{VaR}_\alpha(L_1 + \dots + L_d) = \text{VaR}_\alpha(L_1) + \dots + \text{VaR}_\alpha(L_d).$$

For a proof of this result, see McNeil et al. (2005, Proposition 6.15). One can draw an interesting conclusion from this result and Fallacy 2 in Sect. 6.2.2: recall that the linear correlation upper bound is achieved for comonotonicity; hence super-additive examples for VaR must correspond to linear correlation coefficients less than the maximal one. This once more shows that linear correlation is not the right tool for measuring worst dependence situations in a VaR controlled world! On top of the issues above, VaR suffers from the so-called “spike the firm” syndrome, that is, one can hide losses well above the VaR cutoff point without the RM system being able to notice this. From that point of view, Expected Shortfall as defined in (6.13) is always coherent.

Remark 6.8. The additivity property of VaR_α can also hold for special models, for instance, in the case of two i.i.d. standard Cauchy distributed risks; see Nešlehová et al. (2006, Example 3.2).

6.3.2 Statistical Estimation

Returning to our discussion on risk measures for the trading book of a bank, there are essentially three methods for estimating the VaR (and also the ES) of a P&L.

Method 1: The Variance–Covariance Method

Recall that $L_t^\Delta = -\sum_{j=1}^d D_j f(z_0) X_{t,j}$ and assume that $X_t \sim N_d(u, \Sigma)$. If we denote the weights $w_j = -D_j f(z_0)$, then $L_t^\Delta = w^\top X_t \sim N_d(w^\top \mu, w^\top \Sigma w)$ so that (see Lemma 6.3) for $\alpha > 1/2$,

$$\begin{aligned}\widehat{\text{VaR}}_\alpha(L_t^\Delta) &= w^\top \hat{\mu} + (w^\top \hat{\Sigma} w)^{1/2} \Phi^{-1}(\alpha), \\ \widehat{\text{ES}}_\alpha(L_t^\Delta) &= w^\top \hat{\mu} + (w^\top \hat{\Sigma} w)^{1/2} \frac{\phi(\Phi^{-1}(\alpha))}{1 - \alpha}.\end{aligned}$$

In these formulae, the hat notation ($\hat{\theta}$) denotes a statistical estimation of the parameter θ . Hence, such estimates need to be available. An obvious pro of the method is its analytic tractability; clear cons are the fact that linearization (L^Δ) may not be a good approximation to the real P&L (L); normality definitely underestimates tail risk both marginally as well as jointly. Extensions to the class of elliptical dfs are possible, though extra parameters may enter. The variance–covariance method was the one originally introduced through J.P. Morgan’s RiskMetrics around 1994.

Method 2: Historical Simulation

In this approach, we work with the original P&L, make no model assumptions on X_t , but base estimation on historical values (at least one year of daily data) on each of the risk factors, that is, we receive historical daily P&L data calculated with today’s portfolio structure:

$$\{\tilde{l}_s = l(x_s) : s = t - n + 1, \dots, t\}.$$

From the histogram of these historical P&L values we determine VaR and ES using an empirical estimator. The latter estimation step can be further refined by smoothing the histogram in the tail, for instance, using EVT; see Sect. 6.3.3. Here the pros are that we use L and make no explicit model assumption on the underlying model or dependence. A disadvantage clearly is the heavy reliance on historical data. For that reason, care has to be taken to include sufficient and relevant stress scenarios in the data base. The historical simulation method, with its obvious variants, is mainly used throughout the industry; [Pérignon and Smith \(2010\)](#) note that 73% of the banks who report their VaR methodologies use historical simulation.

Method 3: Monte Carlo Simulation

Also here, we stay with L but now come up with a better fitting model for X_t from which we simulate risk factor changes as in Method 2. Clearly positive is the more realistic risk factor modeling as compared to the normal in Method 1; a disadvantage is the considerable technical difficulty in setting up such a full Monte Carlo approach. As a consequence, only very few banks (the biggest) take this road; again see [Pérignon and Smith \(2010\)](#) for more information.

Remark 6.9. We refer the reader to [McNeil et al. \(2005\)](#) for numerous extensions to the above fitting procedures.

6.3.3 Link to Extreme Value Theory

It is clear that, given the space, there is no way in which we can give any reasonable introduction to EVT; a good start is [Embrechts et al. \(1997\)](#), the numerous references therein, and the very huge literature published on extremes in finance and insurance (a Google search will quickly convince the interested reader of this). We will just make a couple of comments on EVT and QRM; [McNeil et al. \(2005, Chap. 7\)](#) contains further relevant material.

Suppose $X, X_1, \dots, X_n \sim F$ i.i.d., F continuous and denote $M_n = \max\{X_1, \dots, X_n\}$; then classical EVT concerns the convergence in distribution of $(M_n - d_n)/c_n$ to some nondegenerate limit H . The famous Fisher–Tippett Theorem [Embrechts et al. \(1997, Theorem 3.2.3\)](#) yields only three types for such H : Fréchet, Gumbel, and Weibull. Based on this result, already interesting estimation can be made on tail events like high quantiles; the method used is the so-called block-maxima method. For details and some examples, see [McNeil et al. \(2005, Sect. 7.3.4\)](#). The method most relevant for RM applications, however, not only estimates $\bar{F}(x) = \mathbb{P}(X > x)$ for large x (or its quantile function close to 1) but also considers the conditional tail above a high threshold u :

$$\bar{F}_u(x) = \mathbb{P}(X - u > x \mid X > u), \quad x > 0. \quad (6.15)$$

One typically takes $u = \text{VaR}_\alpha$ with α close to 1. The famous Pickands–Balkema–de Haan Theorem [McNeil et al. \(2005, Theorem 7.20\)](#) yields the generalized Pareto dfs as an appropriate limit for (6.15) for u large. This result yields an estimate of $\bar{F}_u(x)$ for u large and through inversion an estimate for the corresponding risk measure. The method goes under the name POT, standing for “peaks over threshold” and is fully discussed in [McNeil et al. \(2005, Sect. 7.4.2\)](#). We end this very brief introduction to EVT with some comments:

- EVT is based on very precise model assumptions which need to be Checked.
- Standard fitting software is widely available.
- Convergence results for extremes typically yield slow rates.
- As EVT-based estimation uses a precise stochastic model, confidence intervals for the various risk measures can be calculated; they typically are wide far in the tail.
- Simulation and bootstrapping extremes are possible but need to be handled with care; see, for instance, [Asmussen and Glynn \(2007\)](#).
- Numerous extensions of classical one-dimensional EVT exist: multivariate EVT, non-i.i.d. cases, and stochastic processes. Beware, however, that EVT in higher dimensions (even higher than 3, say), from a practical point of view, is still somewhat in its infancy.

6.4 Conclusion and Outlook

Whereas risk measures and their statistical estimation have been used for a very long time in such fields as actuarial science, reliability, medical statistics, and engineering, the establishment of an international regulatory framework for financial institutions has led to a surge in interest in the topic. At the same time and this often due to a malfunctioning of available RM technology during crises, critical voices have been (are being) raised on their usefulness. Besides giving a review of some of the theory behind risk measures, we also stressed the wider quantitative problems facing any risk management system: the modeling of extremes (EVT) and interdependence (copulas). Whatever RM environment one plans to establish, these techniques will no doubt be crucial building blocks. Their understanding will certainly be helpful in coming up with resilient systems and also be instrumental in avoiding many of the RM-traps and fallacies that one encounters in practice.

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Chapter 7

The Theory of Insurance Demand

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Abstract This chapter presents the basic theoretical model of insurance demand in a one-period expected-utility setting. Models of coinsurance and of deductible insurance are examined along with their comparative statics with respect to changes in wealth, prices and attitudes towards risk. The single risk model is then extended to account for multiple risks such as insolvency risk and background risk. It is shown how only a subset of the basic results of the single-risk model is robust enough to extend to models with multiple risks.

7.1 Introduction

The theory of insurance demand is often regarded as the purest example of economic behavior under uncertainty. Interestingly, whereas 20 years ago most upper-level textbooks on micro-economics barely touched on the topic of uncertainty, much less insurance demand, textbooks today at all levels often devote substantial space to the topic. The purpose of this chapter is to present the basic model of insurance demand that imbeds itself not only into the other chapters in this volume and in the insurance literature but also in many other settings within the finance and economics literatures. Since models that deal with non-expected-utility analysis are dealt with elsewhere in this Handbook, I focus only on the expected-utility framework.

Many models look at markets for trading risk, but typically such risks are designed for trades. Insurance, on the other hand, deals with a personal risk. In treating such a risk, the consumer can try to modify the risk itself through methods such as prevention, which is another topic in this book. Alternatively, the consumer could try to pool risks with a large group of other consumers, but organizing such a group would pose some problems of its own. We can view insurance as an intermediary that in a certain sense organizes such risk pooling. Such an approach is generically referred to as “risk financing.”

The device offered by the insurer is one in which, for a fixed premium, the insurer promises an indemnity for incurred losses. Of course, there are many variations on this theme, as one can see from gleaning the pages of this Handbook. From a purely theoretical viewpoint, the model presented in Sect. 7.1 of this chapter should be viewed as a base model, from which all other models deviate.

In some ways, insurance is simply a financial asset. However, whereas most financial assets are readily tradable and have a risk that relates to the marketplace, insurance is a contract contingent on

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an individual's own personal wealth changes. This personal nature of insurance is what distinguishes it from other financial assets. It also exacerbates problems of informational asymmetry, such as moral hazard and adverse selection, which also are dealt with elsewhere in this Handbook.

The preponderance of insurance models isolates the insurance-purchasing decision. The consumer decides how much insurance to buy for a well-defined risk. And indeed, this chapter starts out the same way in Sect. 7.2. However, when multiple risks face the consumer, it is not likely to be optimal to decide how to handle each risk separately. Rather, some type of overall risk-management strategy is called for. Simultaneous decisions over multiple risk-management instruments are beyond the scope of this chapter. However, even if we make an insurance decision in isolation, the presence of these other risks is most likely going to affect our choice. The second part of this chapter shows how the presence of other risks—so-called “background risk”—impacts the consumer's insurance-purchasing decision.

7.2 The Single Risk Model

Insurance contracts themselves can be quite complicated, but the basic idea is fairly simple. For a fixed premium P the insurer will pay the insured a contingent amount of money that depends upon the value of a well-defined loss. This insurance payment is referred to as the *indemnity*.¹

To make the model concrete, consider an individual with initial wealth $W > 0$. Let the random variable \tilde{x} denote the amount of the loss, where we assume that $0 \leq x \leq W$ to avoid bankruptcy issues. The insurance indemnity is contingent only on x and will be written as $I(x)$. We often assume that $I(x)$ is nondecreasing in x and that $0 \leq I(x) \leq x$, though neither of these assumptions is necessary to develop a theory of insurance demand. We do, however, assume that the realization of \tilde{x} is costlessly observable by all parties and that both parties agree on the distribution of the random variable \tilde{x} . Models that do not make these last two assumptions are dealt with elsewhere in this Handbook.

The insurer, for our purpose, can be considered as a risk-neutral firm that charges a market-determined price for its product. The individual is considered to be risk averse with von Neumann–Morgenstern utility of final wealth given by the function $u(\cdot)$, where u is assumed to be everywhere twice differentiable with $u' > 0$ and $u'' < 0$. The assumption of differentiability is not innocuous. It is tantamount in our model to assuming that risk aversion is everywhere of order 2.²

7.3 Proportional Coinsurance

The simplest type of indemnity payment is one in which the insurer pays a fixed proportion, say α , of the loss. Thus, $I(x) = \alpha x$. This type of insurance indemnity is often referred to as *coinsurance*, since the individual retains (or “coinsures”) a fraction $1 - \alpha$ of the loss. If $\alpha = 1$, the insurer pays an indemnity equal to the full value of the loss, and the individual is said to have *full insurance*.

An assumption that $0 \leq I(x) \leq x$ here is equivalent to assuming that $0 \leq \alpha \leq 1$. The case where $\alpha > 1$ is often referred to as *over insurance*. The case where $\alpha < 0$ is referred to by some as “selling

¹Technically an “indemnity” reimburses an individual for out-of-pocket losses. I will use this terminology to represent generically any payment from the insurance company. For some types of losses, most notably life insurance, the payment is not actually indemnifying out-of-pocket losses, but rather is a specified fixed payment.

²See Segal and Spivak (1990). Although extensions to the case where u is not everywhere differentiable are not difficult, they are not examined here. See Schlesinger (1997) for some basic results.

insurance,” but this description is incorrect. If $\alpha < 0$, the individual is taking a short position in his or her *own* loss; whereas selling insurance is taking a short position in someone else’s loss.

To consider the insurance-purchasing decision, we need to specify the insurance premium as a function of the indemnity. The most general form of the premium is

$$P[I(\cdot)] = E[I(\tilde{x}) + c[I(\tilde{x})]]. \quad (7.1)$$

Here E denotes the expectation operator and $c(\cdot)$ is a cost function, where $c[I(x)]$ denotes the cost of paying indemnity $I(x)$, including any market-based charges for assuming the risk $I(\tilde{x})$. Note that P itself is a so-called *functional*, since it depends upon the function $I(\cdot)$.

As a base case, we often consider $c[I(x)] = 0 \forall x$. This case is often referred to as the case of “*perfect competition*” in the insurance market, since it implies that insurers receive an expected profit of zero, and the premium is referred to as a *fair premium*.³

The premium, as defined in (7.1), is a bit too general to suit our purpose here. See [Gollier \(2013\)](#) for more discussion of this general premium form. We consider here the simplest case of (7.1) in which the expected cost is proportional to the expected indemnity; in particular

$$P(\alpha) = E(\alpha\tilde{x} + \lambda\alpha\tilde{x}) = \alpha(1 + \lambda)E\tilde{x}, \quad (7.2)$$

where λ is called the *loading factor*, $\lambda \geq 0$. Thus, for example, if λ equals 0.10, the insurer would charge a premium equal to the expected indemnity plus an additional 10% to cover the insurer’s expenses and profit margin. The consumer’s final wealth can then be expressed as a random variable, dependent upon the choice of the level of coverage α ,

$$\tilde{Y}(\alpha) \equiv W - \alpha(1 + \lambda)E\tilde{x} - \tilde{x} + \alpha\tilde{x}. \quad (7.3)$$

The individual’s objective is to choose α so as to maximize his or her expected utility

$$\underset{\alpha}{\text{maximize}} E[u(\tilde{Y}(\alpha))], \quad (7.4)$$

where we might or might not wish to impose the constraint that $0 \leq \alpha \leq 1$.

Solving (7.4) is relatively straightforward, yielding a first-order condition for the unconstrained objective

$$\frac{dEu}{d\alpha} = E[u'(\tilde{Y}(\alpha)) \cdot (\tilde{x} - (1 + \lambda)E\tilde{x})] = 0. \quad (7.5)$$

The second-order condition for a maximum holds trivially from our assumption that $u'' < 0$. Indeed, $d^2Eu/d\alpha^2$ is negative *everywhere*, indicating that any α^* satisfying (7.5) will be a global maximum. The fact that $E[u(\tilde{Y}(\alpha))]$ is globally concave in α also turns out to be quite important in later examining various comparative statics.

Evaluating $dEu/d\alpha$ at $\alpha = 1$ shows that

$$\left. \frac{dEu}{d\alpha} \right|_{\alpha=1} = Eu'(W - \alpha(1 + \lambda)E\tilde{x})(\tilde{x} - (1 + \lambda)E\tilde{x}) = -\lambda(E\tilde{x})u'(W - \alpha(1 + \lambda)E\tilde{x}). \quad (7.6)$$

³Obviously real-world costs include more than just the indemnity itself, plus even competitive insurers earn a “normal return” on their risk. Thus, we do not really expect $c[I(x)] = 0$. That the zero-profit case is labeled “perfect competition” is likely due to the seminal article by [Rothschild and Stiglitz \(1976\)](#). We also note, however, that real-world markets allow for the insurer to invest premium income, which is omitted here. Thus, zero-costs might not be a bad approximation for our purpose of developing a simple model. The terminology “fair premium” is taken from the game-theory literature, since such a premium in return for the random payoff $I(\tilde{x})$ represents a “fair bet” for the insurer.

Since $u' > 0$, the sign of (7.6) will be zero if $\lambda = 0$ and will be negative if $\lambda > 0$. Together with the concavity of $Eu(\tilde{Y}(\alpha))$ in α , this implies the following result, usually referred to as *Mossin's Theorem*⁴:

Mossin's Theorem: If proportional insurance is available at a fair price ($\lambda = 0$), then full coverage ($\alpha^* = 1$) is optimal. If the price of insurance includes a positive premium loading ($\lambda > 0$), then partial insurance ($\alpha^* < 1$) is optimal.

Note that Mossin's Theorem does not preclude a possibility that $\alpha^* < 0$ in the unconstrained case. Indeed, evaluating $dEu/d\alpha$ at $\alpha = 0$ when $\lambda > 0$ yields

$$\left. \frac{dEu}{d\alpha} \right|_{\alpha=0} = -\lambda Eu'(\tilde{Y}(0)) \cdot E\tilde{x} + \text{Cov}(u'(\tilde{Y}(0)), \tilde{x}). \quad (7.7)$$

Since the covariance term in (7.7) is positive and does not depend on λ , we note that there will exist a unique value of λ such that the derivative in (7.7) equals zero. At this value of λ , zero coverage is optimal, $\alpha^* = 0$. For higher values of λ , $\alpha^* < 0$. Since $Eu(\tilde{Y}(\alpha))$ is concave in α , $\alpha = 0$ will be a constrained optimum whenever the unconstrained optimum is negative. In other words, if the price of insurance is too high, the individual will not purchase any insurance.

As long as the premium loading is nonnegative, $\lambda \geq 0$, the optimal level of insurance will be no more than full coverage, $\alpha^* \leq 1$. If, however, we allow for a negative premium loading, $\lambda < 0$, such as might be the case when the government subsidizes a particular insurance market, then over insurance, $\alpha^* > 1$, will indeed be optimal in the case where α is unconstrained. Strict concavity of $Eu(\tilde{Y}(\alpha))$ in α once again implies that full insurance, $\alpha = 1$, will be a constrained optimum for this case, when over insurance is not allowed.

It may be instructive for some readers to compare the above results with the so-called *portfolio problem* in financial economics. The standard portfolio problem has an investor allocate her wealth between a risky and a riskless asset. If we let A denote final wealth when all funds are invested in a riskless asset, and let \tilde{z} denote the random excess payoff above the payoff on the riskless asset, the individual must choose a weight β , such that final wealth is

$$Y(\beta) = (1 - \beta)A + \beta(A + \tilde{z}) = A + \beta\tilde{z}. \quad (7.8)$$

A basic result in the portfolio problem is that $\text{sgn}\beta^* = \text{sgn}E\tilde{z}$. If we set $A \equiv W - (1 + \lambda)E\tilde{x}$, $\tilde{z} \equiv (1 + \lambda)E\tilde{x} - \tilde{x}$, and $\beta = (1 - \alpha)$, then (7.8) is equivalent to (7.3). Noting that $\text{sgn}E\tilde{z} = \text{sgn}\lambda$ in this setting, our basic portfolio result is exactly equivalent to Mossin's Theorem. Using (7.8), we can think of the individual starting from a position of full insurance ($\beta = 0$) and then deciding upon the optimal level to coinsure, β^* . If $\lambda > 0$, then coinsurance has a positive expected return, so that any risk averter would choose to accept some of the risk $\beta^* > 0$ (i.e. $\alpha^* < 1$).

7.3.1 Effects of Changes in Wealth and Price

Except in the special case of a binary risk, it is often difficult to define what is meant by the *price* and the *quantity* of insurance. Since the indemnity is a function of a random variable and since the premium is a functional of this indemnity function, both price and quantity—the two fundamental building blocks of economic theory—have no direct counterparts for insurance. However, for the case

⁴The result is often attributed to Mossin (1968), with a similar analysis also appearing in Smith (1968).

of coinsurance, we have the level of coinsurance α and the premium loading factor λ , which fill in nicely as proxy measures of quantity and price, respectively.

If the individual’s initial wealth changes, but the loss exposure remains the same, will more or less insurance be purchased? In other words, is insurance a “normal” or an “inferior” good? Clearly, if $\lambda = 0$, then Mossin’s Theorem implies that full insurance remains optimal. So let us consider the case where $\lambda > 0$, but assume that λ is not too large, so that $0 < \alpha^* < 1$. Since $Eu(\tilde{Y}(\alpha))$ is concave in α , we can determine the effect of a higher W by differentiating the first-order condition (7.5) with respect to W . Before doing this however, let us recall a few items from the theory of risk aversion.

If the Arrow–Pratt measure of local risk aversion, $r(y) = -u''(y)/u'(y)$, is decreasing in wealth level y , then preferences are said to exhibit decreasing absolute risk aversion (DARA). Similarly, we can define constant absolute risk aversion (CARA) and increasing absolute risk aversion (IARA). We are now ready to state the following result.

Proposition 1. *Let the insurance loading λ be positive. Then for an increase in the initial wealth level W ,*

1. *The optimal insurance level α^* will decrease under DARA*
2. *The optimal insurance level α^* will be invariant under CARA*
3. *The optimal insurance level α^* will increase under IARA*

Proof. Let F denote the distribution of \tilde{x} . By assumption, the support of F lies in the interval $[0, W]$. Define $x_0 \equiv (1 + \lambda)E\tilde{x}$. Assume DARA. Then we note that $r(y_1) < r(y_0) < r(y_2)$ for any $y_1 > y_0 > y_2$, and, in particular for $y_0 = W - \alpha^*(1 + \lambda)E\tilde{x} - x_0 + \alpha x_0$. Differentiating (7.5) with respect to W , we obtain

$$\begin{aligned} \left. \frac{\partial^2 Eu}{\partial \alpha \partial W} \right|_{\alpha^*} &= \int_0^W u''(Y(\alpha^*)) (x - (1 + \lambda)E\tilde{x}) dF \\ &= - \int_0^{x_0} r(Y(\alpha^*)) u'(Y(\alpha^*)) (x - (1 + \lambda)E\tilde{x}) dF \\ &\quad - \int_{x_0}^W r(Y(\alpha^*)) u'(Y(\alpha^*)) (x - (1 + \lambda)E\tilde{x}) dF \\ &< -r(y_0) \left[\int_0^W u'(Y(\alpha^*)) (x - (1 + \lambda)E\tilde{x}) dF \right] = 0. \end{aligned} \tag{7.9}$$

Thus, increasing wealth causes α^* to fall.

The cases where preferences exhibit CARA or IARA can be proved in a similar manner. ■

We should caution the reader that DARA, CARA and IARA do not partition the set of risk-averse preferences. Indeed each of these conditions is shown to be sufficient for the comparative-static effects in Proposition 1, though none is necessary.⁵

The case of CARA is often used as a base case, since such preferences eliminate any income effect. However, a more common and, by most standards, realistic assumption is DARA, which implies that insurance is an inferior good. One must use caution in using this terminology, however. It is valid only

⁵If we wish to strengthen the claims in Proposition 1 to hold for every possible starting wealth level and every possible random loss distribution, then DARA, CARA and IARA would also be necessary.

for the case of a fixed loss exposure \tilde{x} . Since real-world loss exposures typically increase as wealth increases, we do not necessarily expect to see richer individuals spending less on their insurance purchases, *ceteris paribus*.⁶ We do, however, expect that they would spend less on the same loss exposure.

In a similar manner, we can examine the effect of an increase in the loading factor λ on the optimal level of insurance coverage. Differentiating the first-order condition (7.5) with respect to λ obtains

$$\left. \frac{\partial^2 Eu}{\partial \alpha \partial \lambda} \right|_{\alpha^*} = -[E \tilde{x} Eu'(\tilde{Y}(\alpha^*))] - \alpha E \tilde{x} \frac{\partial^2 Eu}{\partial \alpha \partial W}. \quad (7.10)$$

The first term on the right-hand side of (7.10) captures the substitution effect of an increase in λ . This effect is negative due to the higher price of insurance. A higher λ implies that other goods (not insurance) are now relatively cheaper, so that the individual should save some of the premium and use it to buy other items. The second term on the right-hand side of (7.10) captures an income effect, since a higher premium would lower overall wealth, *ceteris paribus*. For a positive level of α , which we are assuming, this effect will be the opposite sign of $\partial^2 Eu / \partial \alpha \partial W$. For example, under DARA, this income effect is positive: the price increase lowers the average wealth of the individual, rendering him or her more risk averse. This higher level of risk aversion, as we shall soon see, implies that the individual will purchase more insurance. If this second (positive) effect outweighs the negative substitution effect, insurance can be considered a Giffen good.⁷ More comprehensively, the following result is a direct consequence of (7.10) and Proposition 1.

Proposition 2. *Let the insurance loading be positive, with $0 < \alpha^* < 1$. Then, insurance cannot be a Giffen good if preferences exhibit CARA or IARA, but may be Giffen if preferences exhibit DARA.*

7.3.2 Changes in Risk and in Risk Aversion

If the loss distribution F changes, it is sometimes possible to predict the change in optimal insurance coverage α^* . Conditions on changes to F that are both necessary and sufficient for α^* to increase are not trivial, but can be found by applying a Theorem of [Gollier \(1995\)](#) to the portfolio problem, and then using the equivalence of the portfolio problem and the insurance problem. Although this condition is very complex, there are several sufficient conditions for α^* to rise due to a change in risk that are relatively straightforward. Since this topic is dealt with elsewhere in this Handbook ([Eeckhoudt and Gollier 2014](#)), I do not detour to discuss it any further here.

A change in risk aversion, on the other hand, has a well-defined effect upon the choice of insurance coverage. First of all, we note that for an insurance premium that is fair, $\lambda = 0$, any risk-averse individual will choose an insurance policy with full coverage, $\alpha^* = 1$. If, however, the insurance premium includes a positive premium loading, $\lambda > 0$, then an increase in risk aversion will always increase the level of insurance. More formally, it is given as follows:

Proposition 3. *Let the insurance loading be positive, with $0 < \alpha^* < 1$. An increase in the individual's degree of risk aversion at all levels of wealth will lead to an increase in the optimal level of coverage, *ceteris paribus*.*

⁶If the support of \tilde{x} is $[0, L]$, it may be useful to define $W \equiv W_0 + L$. If the loss exposure is unchanged, an increase in W can be viewed as an increase in W_0 . More realistically, an increase in W will consist of increases in both W_0 and L .

⁷A necessary and sufficient condition for insurance not to be Giffen is given by [Briys et al. \(1989\)](#).

Proof: Let α_u^* denote the optimal level of coverage under the original utility function u . Let v denote a uniformly more risk-averse utility function. We know from Pratt (1964) that there exists a function $g : \mathbb{R} \rightarrow \mathbb{R}$ such that $v(y) = g[u(y)]$, where $g' > 0$ and $g'' < 0$.

Since v is a risk-averse utility function, we note that $E v(\tilde{Y}(\alpha))$ is concave in α . Thus, consider the following:

$$\begin{aligned} \left. \frac{dE v}{d\alpha} \right|_{\alpha_u^*} &= \left. \frac{dE g[u]}{d\alpha} \right|_{\alpha_u^*} = \int_0^W g'[u(Y(\alpha_u^*))] u'(Y(\alpha_u^*)) (x - (1 + \lambda) E \tilde{x}) dF \\ &> g'[u(y_0)] \left\{ \int_0^{x_0} u'(Y(\alpha_u^*)) (x - (1 + \lambda) E \tilde{x}) dF + \int_{x_0}^W u'(Y(\alpha_u^*)) (x - (1 + \lambda) E \tilde{x}) dF \right\} = 0 \end{aligned} \tag{7.11}$$

where x_0 and y_0 are as defined in the proof of Proposition 1, and where the inequality follows from the concavity of g . This last expression equals zero by the first-order condition for α_u^* .

Since $E v(\tilde{Y}(\alpha))$ is concave in α , the inequality in (7.11) implies that $\alpha_v^* > \alpha_u^*$. ■

7.3.3 Deductible Insurance

Although proportional coinsurance is the simplest case of insurance demand to model, real-world insurance contracts often include fixed co-payments per loss called “deductibles.” Indeed, optimal contracts include deductibles under fairly broad assumptions. Under fairly simple but realistic pricing assumptions, straight deductible policies can be shown to be optimal.⁸ In this section, we examine a few aspects of insurance demand when insurance is of the deductible type.

For deductible insurance, the indemnity is set equal to the excess of the loss over some predetermined level. Let L denote the supremum of the support of the loss distribution, so that L denotes the maximum possible loss. By assumption, we have $L \leq W$. Define the deductible level $D \in [0, L]$ such that $I(x) \equiv \max(0, x - D)$. If $D = 0$, the individual once again has full coverage, whereas $D = L$ now represents zero coverage. One complication that arises is that the general premium, as given by (7.1), can no longer be written as a function of only the mean of the loss distribution, as in (7.2). Also, it is difficult to find a standard proxy for the *quantity* of insurance in the case of deductibles.⁹

In order to keep the model from becoming overly complex, we assume here that the distribution F is continuous, with density function f , so that $dF(x) = f(x)dx$. We will once again assume that the insurance costs are proportional to the expected indemnity, so that the premium for deductible level D is given by

$$\begin{aligned} P(D) &= (1 + \lambda) E[I(\tilde{x})] = (1 + \lambda) \int_D^L (x - D) dF(x) \\ &= (1 + \lambda) \int_D^L [1 - F(x)] dx, \end{aligned} \tag{7.12}$$

where the last equality is obtained via integration by parts.

⁸See the essay by Gollier (2013) in this Handbook for a detailed analysis of the optimality of deductibles.

⁹Meyer and Ormiston (1999) make a strong case for using $E[I(\tilde{x})]$, although its often much simpler to use D as an inverse proxy for insurance demand.

Using Leibniz Rule, one can calculate the marginal premium reduction for increasing the deductible level,¹⁰

$$P'(D) = -(1 + \lambda)(1 - F(D)). \quad (7.13)$$

By increasing the deductible level, say by an amount ΔD , the individual receives a lower payout in all states of the world for which the loss exceeds the deductible. The likelihood of these states is $1 - F(D)$. While it is true that the likelihood will also change as D changes, this effect is of secondary importance and, due to our assumption of a continuous loss distribution, disappears in the limit.

Following the choice of a deductible level D and using the premium as specified in (7.12), final wealth can be written as

$$\tilde{Y}(D) = W - P(D) - \min(\tilde{x}, D). \quad (7.14)$$

The individual's objective is now to choose the best deductible D to

$$\text{maximize } E[u(\tilde{Y}(D))], \text{ where } 0 \leq D \leq L. \quad (7.15)$$

Assume that the premium loading is nonnegative, $\lambda \geq 0$, but not so large that we obtain zero coverage as a corner solution, $D^* = L$. The first-order condition for the maximization in (7.15), again using Leibniz rule, is

$$\begin{aligned} \frac{dEu}{dD} &= -P' \int_0^D u'(W - P - x) dF + (-P' - 1) \int_D^L u'(W - P - D) dF \\ &= -P' \int_0^D u'(W - P - x) dF + (-P' - 1)(1 - F(D))u'(W - P - D) = 0. \end{aligned} \quad (7.16)$$

The first term in either of the center expressions in (7.16) represents the marginal net utility benefit of premium savings from increasing D , conditional on the loss not exceeding the deductible level. The second term is minus the net marginal utility cost of a higher deductible, given that the loss exceeds the deductible. Thus, (7.16) has a standard economic interpretation of choosing D^* such that marginal benefit equals marginal cost.

The second-order condition for the maximization in (7.16) can be shown to hold as follows.

$$\begin{aligned} \frac{d^2Eu}{dD^2} &= (1 + \lambda)(-f(D)) \int_0^D u'(W - P - x) dF + (-P')u'(W - P - D)f(D) \\ &\quad + (-P')^2 \int_0^D u''(W - P - x) dF + (1 + \lambda)(-f(D))(1 - F(D))u'(W - P - D) \\ &\quad + (-P' - 1)(-f(D))u'(W - P - D) + (-P' - 1)^2(1 - F(D))''(W - P - D). \end{aligned} \quad (7.17)$$

Multiplying all terms containing $f(D)$ in (7.17) above by $(1 - F(D))/(1 - F(D))$ and simplifying yields

¹⁰Leibniz rule states that $\frac{d}{dt} \int_{a(t)}^{b(t)} H(x, t) dx = H(b, t) b'(t) - H(a, t) a'(t) + \int_{a(t)}^{b(t)} \frac{\partial H}{\partial t} dx$.

$$\begin{aligned} \frac{d^2Eu}{dD^2} &= \frac{-f(D)}{1-F(D)} \left[-P' \int_0^D u'(W-P-x)dF + (-P'-1)(1-F(D))u'(W-P-D) \right] \\ &+ \left[(-P')^2 \int_0^D u''(W-P-x)dF + (-P'-1)^2(1-F(D))u''(W-P-D) \right] < 0 \end{aligned} \quad (7.18)$$

The first term in (7.18) is zero by the first-order condition, while the second term is negative from the concavity of u , thus yielding the inequality as stated in (7.18).

To see that Mossin's Theorem can be extended to the case of deductibles, rewrite the derivative in (7.16) as

$$\frac{dEu}{dD} = (1-F(D)) \left[(1+\lambda) \int_0^L u'(W-P-\min(x,D))dF - u'(W-P-D) \right]. \quad (7.19)$$

If $\lambda = 0$, then (7.19) will be negative for any $D > 0$, and is easily seen to equal zero when $D = 0$. For $\lambda > 0$, (7.19) will be positive at $D = 0$, so that the deductible should be increased. Therefore, Mossin's Theorem also holds for a choice of deductible. It is also straightforward to extend the comparative-static results of Propositions 1–3 to the case of deductibles as well, although we do not provide the details here.

Another type of insurance indemnity is for so-called “upper-limit insurance.” Under this type of insurance, the insurer pays for full coverage, but only up to some prespecified limit θ . For losses above this limit the indemnity is simply $I(x) = \theta$. Unlike a deductible policy, which requires the individual to bear small losses on his or her own, an upper-limit policy requires the individual to bear the cost of losses over size θ on his or her own. Whereas deductible insurance is the most preferred indemnity structure for a risk averter, as shown in this Handbook by [Gollier \(2013\)](#) using stochastic dominance arguments, it turns out that upper-limit policies are the least preferred type of indemnity structure.¹¹

Mossin's Theorem also can be extended to the case of upper-limit insurance policies as well, although the mathematical details are a bit messy and are not presented here.¹²

7.4 The Model with Multiple Risks

Although much is to be learned from the basic single-risk model, rarely is the insurance decision made with no other uncertainty in the background. This so-called background risk might be exogenous or endogenous. In the latter case decisions on how to best handle risk cannot usually be decided in isolation on a risk-by-risk basis. Rather, some type of comprehensive risk management policy must

¹¹[Gollier \(2013\)](#) uses the stochastic-dominance methodology proposed by [Gollier and Schlesinger \(1996\)](#) to show the optimality of deductibles for a risk averter. A similar type of argument can be constructed to show that upper-limit policies are least preferred.

¹²The problematic issue deals with differentiability of the objective function. The details can be found in [Schlesinger \(2006\)](#).

be applied.¹³ However, even in the case where the background risk is exogenous and independent of the insurable risk, we will see that the mere presence of background risk affects the individual's insurance choice.

The existence of uninsurable background risk is often considered a consequence of incomplete markets for risk sharing. For example, some types of catastrophic risk might contain too substantial an element of non-diversifiable risk, including a risk of incorrectly estimating the parameters of the loss distribution, to be insurable. Likewise, non-marketable assets, such as one's own human capital, might not find ready markets for sharing the risk. Similarly, problems with asymmetry of information between the insurer and the insured, such as moral hazard and/or adverse selection, might preclude the existence of insurance markets for certain risks.

We begin the next section by examining a type of secondary risk that is always present for an insurable risk, but almost universally ignored in insurance theory; namely the risk that the insurer does not pay the promised indemnity following a covered loss. The most obvious reason for non-payment is that the insurer may be insolvent and not financially capable of paying its claims in full. However, other scenarios are possible. For instance, there might be some events that void insurance coverage, such as a probationary period for certain perils, or exclusion of coverage in situations of civil unrest or war.¹⁴ Even if the insurer pays the loss in full, it may decide to randomly investigate a claim thereby substantially delaying payment. In such an instance, the delay reduces the present value of the indemnity, which has the same effect as paying something less than the promised indemnity.

7.4.1 *The Model with Default Risk*

We consider here an insurance model in which the insurer might not pay its claims in full. To keep the model simple, we consider only the case of a full default on an insured's claim in which a loss of a fixed size either occurs or does not occur. Let the support of the loss distribution be $\{0, L\}$, where a loss of size L occurs with probability p , $0 < p < 1$. Let α once again denote the share of the loss paid as an indemnity by the insurer, but we now assume that there is only a probability q , $0 < q < 1$, that insurer can pay its claim, and that with probability $1 - q$ the claim goes unpaid.¹⁵ As a base case, we consider a fair premium, which we calculate taking the default risk into account as $P(\alpha) = \alpha pqL$.

Obviously such a premium is not realistic, since for $q < 1$ it implies that the insurer will default almost surely. More realistically the insurance will contain a premium loading of $\lambda > 0$. Thus, $P(\alpha) = \alpha p[(1 + \lambda)q]L$. Since P , α , p , and L are known or observable, the consumer observes only $q(1 + \lambda)$, rather than q and λ separately. It is the consumer's *perception* of q and λ that will cause a deviation in insurance purchasing from the no-default-risk case. Since we only concern ourselves with how default risk affects insurance demand, the base case of a "fair premium" with $\lambda = 0$ seems like a good place to start.

Given our model, states of the world can be partitioned into three disjoint sets: states in which no loss occurs, states in which a loss occurs and the insurer pays its promised indemnity, and states in which a loss occurs but the insurer pays no indemnity. We assume that the individual's loss distribution is independent of the insurer's insolvency. Thus, the individual's objective can be written as

¹³This question was first addressed by [Mayers and Smith \(1983\)](#) and [Doherty and Schlesinger \(1983a\)](#). The special case of default risk was developed by [Doherty and Schlesinger \(1990\)](#).

¹⁴Although not modeled in this manner, the possibility of a probationary period is examined by [Eeckhoudt et al. \(1988\)](#), who endogenize the length of probation.

¹⁵In a two-state (loss vs. no loss) model, there is no distinction between coinsurance and deductibles. A coinsurance rate α is identical to a deductible level of $D = (1 - \alpha)L$.

$$\underset{\alpha}{\text{maximize}} \quad Eu = (1 - p)u(Y_1) + pq u(Y_2) + p(1 - q)u(Y_3) \quad (7.20)$$

where

$$\begin{aligned} Y_1 &\equiv W - \alpha pqL \\ Y_2 &\equiv W - \alpha pqL - L + \alpha L \\ Y_3 &\equiv W - \alpha pqL - L \end{aligned}$$

The first-order condition for maximizing (7.20) is

$$\frac{dEu}{d\alpha} = -(1 - p)pqLu'(Y_1) + pq(1 - pq)Lu'(Y_2) - p(1 - q)pqLu'(Y_3) = 0. \quad (7.21)$$

If we evaluate the derivative in (7.21) when $\alpha = 1$ and $q < 1$, we have $Y_1 = Y_2 > Y_3$ so that

$$\left. \frac{dEu}{d\alpha} \right|_{\alpha=1} = p^2qL(1 - q)[u'(Y_1) - u'(Y_3)] < 0. \quad (7.22)$$

Given the concavity of $u(\cdot)$, (7.22) implies that $\alpha^* < 1$ and clearly Mossin's Theorem does not hold in the presence of default risk. Consequently, we have

$$Y_1 > Y_2 > Y_3. \quad (7.23)$$

In the presence of default risk, although we can purchase “nominally full insurance,” with $\alpha^* = 1$, this does not fully insure the individual, since the insurer might not be able to pay a valid claim. Indeed, in the case where the insurer does not pay a filed claim, the individual is actually worse off than with no insurance, since the individual also loses his or her premium. The higher the level of insurance, the higher the potential loss of premium. Thus, it is not surprising that $\alpha^* = 1$ is not optimal.¹⁶

It also is not difficult to show that, in contrast to the case with no default risk, an increase in risk aversion will not necessarily lead to an increase in the level of insurance coverage. Although a more risk-averse individual would value the additional insurance coverage absent any default risk, higher risk aversion also makes the individual fear the worst-case outcome (a loss and an insolvent insurer) even more. More formally, let $v(\cdot)$ be a more risk-averse utility function than $u(\cdot)$. As in Sect. 7.3.3, we know there exists an increasing concave function g , such that $v(y) = g[u(y)]$ for all y .

Without losing generality, assume that $g'[u(Y_2)] = 1$, so that $g'[u(Y_1)] < 1 < g'[u(Y_3)]$. Now, we can calculate the following:

$$\begin{aligned} \left. \frac{dEv}{d\alpha} \right|_{\alpha^*} &= -g'[u(Y_1)](1 - p)pqLu'(Y_1) + pq(1 - pq)Lu'(Y_2) \\ &\quad - g'[u(Y_3)]p(1 - q)pqLu'(Y_3). \end{aligned} \quad (7.24)$$

Comparing (7.24) with (7.21), we see that one of the negative terms on the right-hand side in (7.24) is increased in absolute magnitude while the other is reduced. However, it is not possible to predetermine

¹⁶Note that if there is no default risk with $q = 1$, then $u'(Y_1) = u'(Y_2)$ implying that $\alpha^* = 1$, as we already know from Mossin's Theorem. Also, if insurance in default pays for most of the claim (as opposed to none of the claim), it is possible for full coverage or even more-than-full coverage to be optimal. See [Doherty and Schlesinger \(1990\)](#) and [Mahul and Wright \(2007\)](#).

which of these two changes will dominate, a priori. Thus, we cannot predict whether α^* will increase or decrease.

Using similar arguments, it is easy to show that insurance is not necessarily an inferior good under DARA, as was the case without default risk. A somewhat more surprising result is that, under actuarially fair pricing, an increase in the probability of insolvency does not necessarily lead to a higher level of coverage. To see this, use the concavity of $Eu(Y(\alpha))$ in α , which is easy to check, and calculate

$$\left. \frac{\partial^2 Eu}{\partial \alpha \partial q} \right|_{\alpha^*} = p\alpha L[H(\alpha^*)] + p^2 q L[u'(Y_3) - u'(Y_2)], \tag{7.25}$$

where $H(\alpha)$ is defined as the derivative in the first-order condition (7.21), with $u(Y)$ replaced by the utility function $-u'(Y)$. The level of insurance coverage will increase, due to an increase in q , if and only if (7.25) is positive. Although the second term on the right-hand side of (7.25) is positive, the first term can be either positive or negative. For example, if u exhibits DARA, it is straightforward to show that $-u'$ is a more risk averse utility than u . Therefore, by our results on increases in risk aversion, $H(\alpha^*)$ might be either positive or negative.

There are two, and only two, circumstances in which the form of the utility function u will yield $d\alpha^*/dq > 0$, regardless of the other parameters of the model (assuming fair prices). The first is where u is quadratic, so that $H(\alpha) = 0$ for all α . The second is where u satisfies CARA, and which case $-u'$ and u represent the same risk-averse preferences.¹⁷ Hence, $H(\alpha^*) = 0$. We also know that for any risk-averse utility u , $d\alpha^*/dq > 0$ for q sufficiently close to $q = 1$. This follows since $\alpha^* = 1$ for $q = 1$, but $\alpha^* < 1$ for $q < 1$.

7.4.2 An Independent Background Risk

As opposed to a default risk, we now suppose that the insurer pays all of its claims, but that the individual's uninsured wealth prospect is $W + \tilde{\varepsilon} - \tilde{x}$, where \tilde{x} once again represents the insurable loss and where $\tilde{\varepsilon}$ represents a zero-mean background risk that is independent of \tilde{x} . We assume that the support of the distribution of $\tilde{\varepsilon}$ is not the singleton $\{0\}$ and that $W + \tilde{\varepsilon} - \tilde{x} > 0$ almost surely. It is assumed that $\tilde{\varepsilon}$ cannot be insured directly. We wish to examine the effect of $\tilde{\varepsilon}$ on the choice of insurance level α^* .

The case of an independent background risk is easily handled by introducing the so-called *derived utility function* which we define as follows:

$$v(y) \equiv Eu(y + \tilde{\varepsilon}) = \int_{-\infty}^{\infty} u(y + \varepsilon) dG(\varepsilon), \tag{7.26}$$

where $G(\cdot)$ is the distribution function for $\tilde{\varepsilon}$. The signs of the derivatives of v are easily seen to be identical to those of u . Note that we can now write

¹⁷This is easiest to see by noting that $-u'$ is an affine transformation of u .

$$\begin{aligned} \max_{\alpha} Eu(\tilde{Y}(\alpha) + \tilde{\varepsilon}) &= \int_0^L \int_{-\infty}^{\infty} u(Y(\alpha) + \varepsilon) dG(\varepsilon) dF(x) \equiv \int_0^L v(Y(\alpha)) dF(x) \\ &= Ev(\tilde{Y}(\alpha)). \end{aligned} \tag{7.27}$$

In other words, $v(Y(\alpha))$ is simply the “inner part” of the iterated integral in (7.27). Finding the optimal insurance level for utility u in the presence of background risk $\tilde{\varepsilon}$ is identical to finding the optimal insurance level for utility v , absent any background risk.

For example, suppose u exhibits CARA or that u is quadratic. Then it is easy to show in each case that v is an affine transformation of u , so that background risk has no effect on the optimal choice of insurance.¹⁸

More generally, we know from Proposition 3 that more insurance will be purchased whenever the derived utility function $v(\cdot)$ is more risk averse than $u(\cdot)$. A sufficient condition for this to hold is *standard risk aversion* as defined by Kimball (1993). A utility function exhibits standard risk aversion “if every risk that has a negative interaction with a small reduction in wealth also has a negative interaction with any undesirable, independent risk.” (Kimball 1993, p. 589). Here “negative interaction” means that risk magnifies the reduction in expected utility. Kimball shows that standard risk aversion is characterized by decreasing absolute risk aversion and decreasing absolute prudence, where absolute risk aversion is $r(y) = -u''(y)/u'(y)$ and absolute prudence is $\eta(y) = -u'''(y)/u''(y)$.

It is easy to show that DARA is equivalent to $\eta(y) > r(y) \forall y$. Since DARA implies prudence (i.e., $u'''(y) > 0$), then under DARA the function $-u'(y)$ represents a risk-averse utility of its own. The condition $\eta(y) > r(y)$ thus implies that $-u'(\cdot)$ is a more risk-averse utility than $u(\cdot)$. Similarly, it follows that decreasing absolute prudence or “DAP” implies that $u'''(y) < 0$ and that $u''(\cdot)$ is a more risk-averse utility function than $-u'(\cdot)$.

Let $\pi(y)$ denote the risk premium, as defined by Pratt (1964), for utility $u(\cdot)$, given base wealth y and fixed zero-mean risk $\tilde{\varepsilon}$. Similarly, let $\pi_1(y)$ and $\pi_2(y)$ denote the corresponding risk premia for utilities $-u'(\cdot)$ and $u''(\cdot)$, respectively. That is,

$$\begin{aligned} Eu(y + \tilde{\varepsilon}) &\equiv u(y - \pi(y)) \\ -Eu'(y + \tilde{\varepsilon}) &\equiv -u'(y - \pi_1(y)) \\ Eu''(y + \tilde{\varepsilon}) &\equiv u''(y - \pi_2(y)). \end{aligned} \tag{7.28}$$

Standard risk aversion thus implies that $\pi_2(y) > \pi_1(y) > \pi(y) > 0 \forall y$. Thus, we have the following set of inequalities

$$-\frac{v''(y)}{v'(y)} = \frac{-Eu''(y + \tilde{\varepsilon})}{Eu'(y + \tilde{\varepsilon})} = \frac{-u''(y - \pi_2)}{u'(y - \pi_1)} > \frac{-u''(y - \pi_1)}{u'(y - \pi_1)} > \frac{-u''(y)}{u'(y)}. \tag{7.29}$$

The first inequality follows from DAP while the second inequality follows from DARA. Consequently $v(\cdot)$ is more risk-averse than $u(\cdot)$.¹⁹

¹⁸For CARA, $v(y) = ku(y)$ and for quadratic utility $v(y) = u(y) + c$, where $k = E[\exp(r\tilde{\varepsilon})] > 0$, r denotes the level of risk aversion, and $c = -t\text{var}(\tilde{\varepsilon})$ for some $t > 0$. Gollier and Schlesinger (2003) show that these are the only two forms of utility for which v represents preferences identical to u .

¹⁹Another simple proof that standard risk aversion is sufficient for the derived utility function to be more risk averse appears in Eeckhoudt and Kimball (1992). Standard risk aversion is stronger than necessary, however. See Gollier and Pratt (1996).

The above result taken together with our previous result on increases in risk aversion implies the following:

- Proposition 4.** (a) *If insurance has a zero premium loading, $\lambda = 0$, then full coverage is optimal in the presence of an independent background risk.*
 (b) *If insurance premia include a positive loading, $\lambda > 0$, then partial coverage is optimal in the presence of an independent background risk.*
 (c) *If insurance premia include a positive loading, $\lambda > 0$, and utility exhibits standard risk aversion, then more coverage is purchased in the presence of an independent zero-mean background risk.*

Remark 1. Parts (a) and (b) above do not require $E\tilde{\varepsilon} = 0$. They are direct applications of Mossin's Theorem to utility $v(\cdot)$. Although the discussion above is for proportional coinsurance, part (c) of Proposition 4 also applies to deductibles, since it only relies upon $v(\cdot)$ being more risk-averse than $u(\cdot)$.

7.4.3 Nonindependent Background Risk

Obviously the background risk need not always be statistically independent of the loss distribution. For example, if $\tilde{\varepsilon} = \tilde{x}$ then final wealth is risk free without insurance.²⁰ Buying insurance on \tilde{x} would only introduce risk into the individual's final wealth prospect. Consequently, zero coverage is optimal, even at a fair price, $\lambda = 0$. For example, suppose the individual's employer provides full insurance coverage against loss \tilde{x} . We can represent this protection by $\tilde{\varepsilon}$ as described here, and thus no further insurance coverage would be purchased.

Similarly, if $\tilde{\varepsilon} = -\tilde{x}$ then final wealth can be written as $\tilde{Y} = W - 2\tilde{x}$ with no insurance. Treating $2\tilde{x}$ as the loss variable, Mossin's Theorem implies that full insurance on $2\tilde{x}$ will be optimal at a fair price. This can be achieved by purchasing insurance with a coinsurance level of $\alpha^* = 2$. Although this is nominally "200% coverage," it is defacto merely full coverage of $2\tilde{x}$. If insurance is constrained to exclude over-insurance, then $\alpha = 1$ will be the constrained optimum. For insurance markets with a premium loading $\lambda > 0$, Mossin's Theorem implies that $\alpha^* < 2$. In this case, a constraint of no over-insurance might or might not be binding.

For more general cases of nonindependent background risk, it becomes difficult to predict the effects on insurance purchasing. Part of the problem is that there is no general measure of dependency that will lead to unambiguous effects on insurance demand. Correlation is not sufficient since other aspects of the distributions of \tilde{x} and $\tilde{\varepsilon}$, such as higher moments, also are important in consumer choice.²¹ Alternatives measures of dependence, many based on stochastic dominance, do not lead to definitive qualitative effects on the level of insurance demand.

For example, suppose we define the random variable $\tilde{\varepsilon}'$ to have the same marginal distribution as $\tilde{\varepsilon}$, but with $\tilde{\varepsilon}'$ statistically independent of \tilde{x} . We can define a partial stochastic ordering for $W + \tilde{\varepsilon} - \tilde{x}$ versus $W + \tilde{\varepsilon}' - \tilde{x}$. If, for example, we use second-degree stochastic dominance, we will be able to say whether or not the risk-averse consumer is better off or worse off with $\tilde{\varepsilon}$ or $\tilde{\varepsilon}'$ as the source of background risk, but we will not be able to say whether the level of insurance demanded will be higher or lower in the presence of background risk $\tilde{\varepsilon}$ versus background risk $\tilde{\varepsilon}'$.

²⁰In stating that two random variables are equal, we mean that they each yield the same value in every state of nature, not simply that they have equal distributions.

²¹Doherty and Schlesinger (1983b) use correlation, but restrict the joint distribution of \tilde{x} and $\tilde{\varepsilon}$ to be bivariate normal. For other joint distributions, correlation is not sufficient. A good discussion of this insufficiency can be found in Hong et al. (2011).

Some research has used more sophisticated partial orderings to examine the behavior of insurance demand in the presence of a background risk that is not statistically independent from the loss distribution. For the most part, this work has focused on comparing insurance demands both with and without the background risk. [Aboudi and Thon \(1995\)](#) did an excellent and thorough job of characterizing many of the potential partial orderings, albeit in a discrete probability space, but they only whet our appetite for applying these orderings to insurance demand. [Hong et al. \(2011\)](#) also characterize some of these orderings, and they show that one of these orderings in particular, namely positive (or negative) expectation dependence, is both necessary and sufficient to claim a variant of Mossin's Theorem for coinsurance²²:

Generalized Mossin's Theorem: *In the presence of a background risk $\tilde{\varepsilon}$, less than (more than) full coverage is always demanded by a risk averter at a fair price if and only if losses are positively (negatively) expectation dependent on $\tilde{\varepsilon}$*

Other types of dependencies are of course possible. [Eeckhoudt and Kimball \(1992\)](#), for example, use one particular partial ordering, assuming that the conditional distribution of $\tilde{\varepsilon}$ given x_1 dominates the conditional distribution of $\tilde{\varepsilon}$ given x_2 via third-degree stochastic dominance, for every $x_1 < x_2$. One example of such a relationship would be that the conditional distributions of $\tilde{\varepsilon}$ all have the same mean and variance, but the conditional distributions of $\tilde{\varepsilon}$ become more negatively skewed as losses increase. Eeckhoudt and Kimball go on to show that such a negative dependency between $\tilde{\varepsilon}$ and \tilde{x} leads to an increase in insurance demand in the presence of background risk, whenever preferences exhibit standard risk aversion. Important to note here is that even with the strong third-degree stochastic dominance assumption, risk aversion alone is not strong enough to yield deterministic comparative statics.

In an interesting article, [Tibiletti \(1995\)](#) compares the demand for insurance for a change in background risk from $\tilde{\varepsilon}'$ to $\tilde{\varepsilon}$, where $\tilde{\varepsilon}'$ is statistically independent from \tilde{x} and has the same marginal distribution as $\tilde{\varepsilon}$. She uses the concept of concordance as her partial ordering. In particular, if $H(\varepsilon, x)$ is the joint distribution of the random vector $(\tilde{\varepsilon}, \tilde{x})$ and $G(\varepsilon, x)$ the distribution of $(\tilde{\varepsilon}', \tilde{x})$, then H is *less concordant* than G if $H(\varepsilon, x) \geq G(\varepsilon, x) \quad \forall \varepsilon, x$. In other words, G dominates H by joint first-degree stochastic dominance.²³

However, even using concordance, we need to make fairly restrictive assumptions on preferences to yield deterministic comparisons between optimal levels of insurance purchases. In particular, suppose that we restrict the degree of relative prudence, $y\eta(y) = -yu'''(y)/u''(y)$, to be no greater than one. Then for H less concordant than G , more insurance will be purchased under H ; i.e., more insurance is purchased in the presence of background risk $\tilde{\varepsilon}$ than in the presence of the independent background risk $\tilde{\varepsilon}'$. While this result seems intuitively appealing, just as the result of [Eeckhoudt and Kimball \(1992\)](#), neither follows automatically if we assume only risk aversion for consumer preferences.²⁴

²²Losses \tilde{x} are positively expectation dependent on $\tilde{\varepsilon}$ if $E(\tilde{x}|\tilde{\varepsilon} \leq k) \leq E(\tilde{x}) \quad \forall k$. In a certain sense, a smaller value of $\tilde{\varepsilon}$ implies that expected losses will be smaller. Negative expectation dependence simply reverses the second inequality in the definition. It should be noted that [Hong et al. \(2011\)](#) do not consider the case of a positive premium loading. Thus, their theorem only extends one part of Mossin's Theorem. See also the article by [Dana and Scarsini \(2007\)](#), which uses similar dependence structures to examine the optimal contractual form of insurance.

²³To the best of my knowledge, [Tibiletti \(1995\)](#) also introduces the use of *copulas* into insurance models. Copulas allow one to describe the joint distribution of $(\tilde{\varepsilon}, \tilde{x})$ as a joint distribution function of the marginal distributions of $\tilde{\varepsilon}$ and \tilde{x} , which is a type of normalization procedure. This allows one to both simplify and generalize the relationship between H and G . The use of particular functional forms for the *copula* allows one to parameterize the degree of statistical association between \tilde{x} and $\tilde{\varepsilon}$. See [Frees and Valdez \(1998\)](#) for a survey of the use of *copulas*.

²⁴The fact that detrimental changes in the background risk $\tilde{\varepsilon}$ do not necessarily lead to higher insurance purchases under simple risk aversion is examined by [Eeckhoudt et al. \(1996\)](#), for the case where the deterioration can be measured by

As a final case consider a background risk that changes size as the state of nature changes. In particular, consider a model with two loss states, but with a possibly different zero-mean background risk in each potential state. The consumer chooses α to maximize

$$Eu = (1 - p)Eu(W + \tilde{\varepsilon}_1 - \alpha(1 + \lambda)pL) + pEu(W + \tilde{\varepsilon}_2 - \alpha(1 + \lambda)pL - L + \alpha L). \quad (7.30)$$

The first-order condition for maximizing (7.30) can be written as

$$-c_1Eu'(W + \tilde{\varepsilon}_1 - \alpha(1 + \lambda)pL) + c_2Eu'(W + \tilde{\varepsilon}_2 - \alpha(1 + \lambda)pL - L + \alpha L) = 0, \quad (7.31)$$

where c_1 and c_2 are positive constants. The first term (negative) is the marginal utility cost of higher coverage if no loss occurs, which stems from the higher premium. The second term (positive) is the marginal utility benefit of the higher indemnity if a loss occurs.

If the consumer is prudent, $u''' > 0$, the presence of $\tilde{\varepsilon}_i$ will increase the marginal utility in both states.²⁵ If marginal utility is increased by the same proportion in each state, then simultaneously eliminating both $\tilde{\varepsilon}_i$ will not have any effect on the optimal insurance demand. The same coinsurance level α would be optimal both with and without the background risks.

On the other hand, if we only eliminate $\tilde{\varepsilon}_1$, then there would be background risk only in the loss state. In this case, the marginal utility cost of insurance would fall, and more insurance would be purchased due to prudence. In other words, insurance would be higher if there was only a background risk in the loss state. The reason for this is a precautionary motive. Although the risk $\tilde{\varepsilon}_2$ cannot be hedged, having more wealth in the loss state makes this $\tilde{\varepsilon}_2$ -risk more bearable under prudence. Thus, the consumer has a precautionary motive to buy more insurance. If we eliminated only the $\tilde{\varepsilon}_2$ -risk, but kept the $\tilde{\varepsilon}_1$ -risk, the same precautionary motive would be used to reduce the demand for insurance in order to save some of the premium dollars in the no-loss state.²⁶

7.5 Concluding Remarks

Mossin's Theorem is often considered to be the cornerstone result of modern insurance economics. Indeed this result depends only on risk aversion for smooth preferences, such as those found in the expected-utility model.²⁷ On the other hand, many results depend on stronger assumptions than risk aversion alone, and research has turned in this direction. Stronger measures of risk aversion, such as those of Ross (1981) and of Kimball (1993), have helped in our understanding more about the insurance-purchasing decision.

One common "complaint," that I hear quite often from other academics, is that these restrictions on preferences beyond risk aversion are too limiting. These critics might be correct, if our goal is to guess at reasonable preferences and then see what theory predicts. However, insurance demand is not just a theory. I doubt there is anyone reading this that does not possess several insurance policies. If our goal in setting up simple theoretical models is to capture behavior in a positive sense, then such restrictions

first- or second-degree stochastic dominance. Keenan et al. (2008) extend the analysis to consider deteriorations via background risks that either reduce expected utility or increase expected marginal utility.

²⁵This follows easily using Jensen's inequality, since marginal utility is convex under prudence.

²⁶The intuition behind this precautionary effect can be found in Eeckhoudt and Schlesinger (2006). Further results on how such differential background risk can affect insurance decisions can be found in Fei and Schlesinger (2008).

²⁷Actually, this result depends on the differentiability of the von Neumann–Morgenstern utility function. "Kinks" in the utility function can lead to violations of Mossin's result. See, for example, Eeckhoudt et al. (1997).

on preferences might be necessary. Of course, one can always argue that more restrictions belong elsewhere in our models, not on preferences. However, we are continually able to better understand the economic implications of higher-order risk attitudes, as set forth by [Eeckhoudt and Gollier \(2014\)](#). Explaining the rationale behind preference assumptions and restrictions should be an integral part of insurance–decision modeling.

The single-risk model in a static setting as presented in this chapter should be viewed as a base case. Simultaneous decisions about multiple risky decisions as well as dynamic decisions are not considered in this chapter. Many extensions of this base-case model already are to be found in this Handbook. Certainly there are enough current variations in the model so that every reader should find something of interest. Of course, just as insurance decisions in the real world are not static, models of insurance demand should not be either. It is interesting for me to reflect on the knowledge gained since the first edition of this Handbook. I look forward to seeing the directions in which the theory of insurance demand is expanded in the years to come, and I am encouraged to know that some of you who are reading this chapter will be playing a role in this development.

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Chapter 8

Prevention and Precaution

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Abstract This chapter surveys the economic literature on prevention and precaution. Prevention refers as either a self-protection activity—i.e. a reduction in the probability of a loss—or a self-insurance activity—i.e. a reduction of the loss. Precaution is defined as a prudent and temporary activity when the risk is imperfectly known. We first present results on prevention, including the effect of risk preferences, wealth and background risks. Second, we discuss how the concept of precaution is strongly linked to the effect of arrival of information over time in sequential models as well as to situations in which there is ambiguity over probability distributions.

8.1 Introduction

The ways to protect against risks are numerous. An obvious way, as largely explained in this handbook, is to transfer risks to a third party via insurance or reinsurance, without modifying the risk itself. Another way to protect against risks is to act directly on the risk by altering either its occurrence or its consequences. This is what prevention is about. The study of prevention started with the earlier work of Ehrlich and Becker (1972). Since then, it has led to a flourishing literature in the field of risk and insurance economics. It seems then appropriate to include an entire new chapter about prevention in this handbook on insurance economics.

In day-to-day language, prevention is very similar to precaution. In economics, however, prevention is usually a static concept while precaution is fundamentally a dynamic one. Indeed, models of precaution generally involve a sequence of decisions with arrival of information over time. Therefore, although the concepts of prevention and precaution are closely connected, we will see that their formal analyses have evolved very differently in the economics literature.

This chapter offers a survey of both the economics of prevention and precaution. We begin by reviewing the early work on prevention in Sect. 8.2. We start first by presenting the basic model of

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prevention with a monetary risk under the Expected Utility (EU) framework. We present the roles of individual preferences in explaining optimal prevention, and more specifically the roles of risk aversion and prudence. We also look at wealth effect and more general distribution of loss than the two-state model. We then consider other contexts such as non-monetary risk, the presence of background risk and a non-expected utility environment. In Sect. 8.3, we address the concept of precaution. We first relate this concept to the Precautionary Principle, then present the early literature on the irreversibility effect and option values and finally discuss the more recent literature, including the one related to climate change policy as well as to ambiguity. Lastly, a short conclusion is provided.

8.2 Prevention

Prevention is a risk-reducing activity that takes place *ex ante*, i.e. before the loss occurs. As risk is defined through the size and probability of the potential loss, prevention can either impact the size of the potential loss, its probability or both. When it modifies the size of the loss, it is referred to as self-insurance or loss reduction. When it modifies the probability of the loss, it is referred to as self-protection or also loss prevention. An activity reducing both the size and the probability of loss is referred to as self-insurance-cum-protection (SICP) (Lee 1998). For example, sprinkler systems reduce the loss from fires, and car seat belts reduce the degree of injury from car crash; stronger doors, locks or bars on windows reduce the probability of illegal entry. Naturally, as observed in practice, many actions individuals take modify both the size and the probability of the potential loss. For instance, high quality brakes reduce both the probability of an automobile accident and the magnitude of a loss if an accident occurs.

The academic literature on prevention dates back to the earlier work of Ehrlich and Becker (1972). In their seminal paper they examined, within the EU framework, the interaction between market insurance, self-insurance and self-protection. In line with intuition based on the moral hazard problem, they showed that market insurance and self-insurance are substitutes. Yet, surprisingly, the analysis of self-protection led to different results since they derived that market insurance and self-protection could be complements depending on the level of the probability of loss. Thus, the presence of market insurance may, in fact, increase self-protection activities relative to a situation where market insurance is unavailable. This work has led to many discussions and extensions on the optimal individual behaviour with respect to self-insurance and self-protection.

In order to avoid any confusion in terminology, it is important to stress the similarity between prevention and the concept of willingness-to-pay (WTP). WTP is the amount an individual is willing to pay to reduce either the size of the loss or the probability of the loss. Indeed as stressed by Chiu (2000), the concept of WTP to reduce the probability of loss is equivalent to investigating the optimal choice of self-protection given an assumed relationship between self-protection spending and the loss probability. Dachraoui et al. (2004) confirmed this equivalence by showing that self-protection and WTP to reduce the probability share the same properties. In the same vein, the WTP to reduce the size of a loss is equivalent to investigating the optimal choice of self-insurance given an assumed relationship between self-insurance spending and the loss size. Throughout this chapter, when using the term WTP, we will make reference to the WTP to reduce the probability, unless otherwise specified.

8.2.1 Expected Utility Model with a Monetary Risk

8.2.1.1 Self-Insurance and Self-Protection

Consider an individual with initial wealth w_0 subject to a risk of loss of size L_0 with $0 \leq L_0 \leq w_0$. The loss occurs with probability p_0 ($0 < p_0 < 1$). This individual has an increasing vNM utility function, u ($u' > 0$). The individual can engage in self-insurance activities to reduce the size of the loss, should it occur. Let y denote the level of self-insurance. Its effect is described by the differentiable function $L(y)$, which relates the size of the loss to the level of self-insurance activity, with $L(0) = L_0$, $L'(y) < 0$ and $L''(y) > 0$ for all $y \geq 0$, i.e. reduction in the size of loss becomes more difficult as self-insurance activities increase. The cost of self-insurance, $c(y)$, is represented by a monotonic and convex function with the usual assumption that $c(0) = 0$, $c' > 0 \forall y > 0$ and $c'' > 0 \forall y \geq 0$. The objective of the individual is to maximise his expected utility given by:

$$V(y) = p_0 u(w_0 - c(y) - L(y)) + (1 - p_0) u(w_0 - c(y)) \quad (8.1)$$

The first-order condition (FOC) for a maximum is

$$\frac{dV(y)}{dy} = -p_0(c'(y) + L'(y))u'(B(y)) - (1 - p_0)c'(y)u'(G(y)) = 0 \quad (8.2)$$

where $B(y) = w_0 - c(y) - L(y)$ and $G(y) = w_0 - c(y)$.

The FOC implies that $-L'(y)$ must be greater than $c'(y)$ which means that the magnitude of the potential marginal benefit of self-insurance must be at least as high as the cost of the increase in y . Assumptions made on $L(y)$ and $c(y)$ guarantee that the second-order condition is satisfied for all risk-averse individuals ($u'' < 0$).

Let us denote y^* the optimal level of self-insurance. From (8.2), it is such that:

$$-c'(y^*)[p_0 u'(B(y^*)) + (1 - p_0)u'(G(y^*))] = p_0 L'(y^*)u'(B(y^*)) \quad (8.3)$$

The left-hand term of (8.3) represents the marginal cost of self-insurance while the right-hand term represents its marginal benefit. It can be seen that an investment in self-insurance increases wealth in the bad states of nature at a cost of reduced wealth in the good state. Self-insurance is very close to market insurance and results on market insurance usually apply to self-insurance.

Suppose now that the individual can invest in self-protection activities x that reduce the probability of loss, but do not affect the size of the loss L_0 should it occur. The probability of loss is a decreasing function of the level of self-protection whose marginal productivity is increasing, i.e. $p(0) = p_0$, $p'(x) < 0$ and $p''(x) > 0$ for all $x \geq 0$. In this case, the individual's expected utility is:

$$V(x) = p(x)u(w_0 - c(x) - L_0) + (1 - p(x))u(w_0 - c(x)) \quad (8.4)$$

The first-order condition for a maximum is

$$\frac{dV(x)}{dx} - c'(x)[p(x)u'(B(x)) + (1 - p(x))u'(G(x))] - p'(x)[u(G(x)) - u(B(x))] = 0 \quad (8.5)$$

where $B(x) = w_0 - c(x) - L_0$ and $G(x) = w_0 - c(x)$.

Assumptions made on $c(x)$ and $p(x)$ are not sufficient to guarantee that the second-order condition for a maximum is satisfied (i.e. $V''(x) < 0 \forall x$). For sake of simplicity, it is assumed that the functions u , c , p and the parameters w_0 and L_0 are such that $V'''(x) < 0 \forall x$ (see for instance Jullien et al. 1999). This ensures a unique solution to the individual maximisation problem x^* such that $V'(x^*) = 0$ that can be also written as:

$$-c'(x^*)[p(x^*)u'(B(x^*)) + (1 - p(x^*))u'(G(x^*))] = p'(x^*)[u(G(x^*)) - u(B(x^*))] \quad (8.6)$$

The left-hand term in (8.6) is the expected marginal cost (in terms of utility) of self-protection activities. The right-hand term is the expected marginal benefit (in terms of utility) from the resulting decrease in the loss probability.

An investment in self-protection modifies probabilities so that the good state of nature becomes more likely, but it also reduces final wealth in every state of nature. This trade-off between reducing the probability of loss and reducing final wealth may not necessarily be appreciated by all individuals as explained in the next section. We will see that restrictions are needed on the utility function, on the distribution function or on the loss function for an individual to pursue self-protection.

Before doing so, let us stress that self-protection and self-insurance can be analysed using the concept of WTP. WTP makes it possible to evaluate the monetary value one is ready to forgo to benefit from a reduction in either the loss or the probability of loss (Jones-Lee 1974). This concept is often used to measure the benefit of prevention.

Let us denote t the maximum amount of money the individual is willing to pay to benefit from a reduction of the loss from L_0 to L_1 with $L_1 < L_0$. t verifies the following equation:

$$p_0u(w_0 - L_0) + (1 - p_0)u(w_0) = p_0u(w_0 - t - L_1) + (1 - p_0)u(w_0 - t) \quad (8.7)$$

Let us denote d the maximum amount of money the individual is willing to pay to benefit from a reduction of the probability of loss from p_0 to p_1 with $p_1 < p_0$. d verifies the following equation:

$$p_0u(w_0 - L_0) + (1 - p_0)u(w_0) = p_1u(w_0 - d - L_0) + (1 - p_1)u(w_0 - d) \quad (8.8)$$

Note that the WTPs t and d can also be expressed in terms of marginal rate of substitution in the case of infinitesimal change in risk. This is especially true for mortality risk or in studies on the value of statistical life (VSL) (see Sect. 8.2.2.1).

Various authors (e.g. Chiu 2005 and Dachraoui et al. 2004) showed that the optimal level of self-insurance y^* and t and the optimal level of self-protection x^* and d share similar properties.

8.2.1.2 Optimal Prevention and Risk Aversion

Dionne and Eeckhoudt (1985) investigated how self-insurance and self-protection decisions reacted to an increase in risk aversion defined through an increasing and concave transformation of the utility function. They considered a simple two-state model in which the severity of the possible loss is fixed as detailed in the previous section. They showed that self-insurance increases with risk aversion, while an increase in risk aversion does not always induce a higher level of self-protection.

Following Pratt (1964), a more risk-averse individual whose utility function v ($v'(w) > 0 \forall w$ and $v''(w) < 0 \forall w$) can be represented by a concave transformation, k , of u such as $v(w) = k(u(w))$ with $k'(w) > 0$ and $k''(w) < 0$ for all w .

The first-order condition of agent with a utility function v evaluated at y^* is:

$$-p_0(c'(y^*) + L'(y^*))k'(u(B(y^*)))u'(B(y^*)) - (1 - p_0)c'(y^*)k'(u(G(y^*)))u'(G(y^*)) \quad (8.9)$$

Equation (8.9) is positive because $k'(u(B(y^*))) > k'(u(G(y^*)))$ under the concavity of k .

Hence, an increase in risk aversion always induces an increase in self-insurance activity since it increases its marginal benefit and decreases its marginal cost.

In the case of self-protection, the first-order condition for an agent with a utility function v evaluated at x^* is:

$$\begin{aligned} & -c'(x^*)[p(x^*)k'(u(B(x^*)))u'(B(x^*)) + (1 - p(x^*))k'(u(G(x^*)))u'(G(x^*))] \\ & - p'(x^*)[u(G(x^*)) - u(B(x^*))] \end{aligned} \quad (8.10)$$

Contrary to what is obtained in the preceding case, $k' > 0$ and $k'' < 0$ are not sufficient to compare the two levels of self-protection. However, in the specific case of a quadratic utility function, [Dionne and Eeckhoudt \(1985\)](#) showed that self-protection increases (decreases) with risk aversion for an initial probability of loss strictly inferior (superior) to one-half. An intuition of this result is that variance increases (decreases) with the probability when the probability is strictly inferior to one-half. Even if the variance is not a perfect measure of risk, this provides an intuition of the results. Their work has led to an extensive literature on the role of individual preferences in explaining optimal prevention decision, and in particular on the roles of risk aversion and prudence.

[Hiebert \(1989\)](#) extended [Dionne and Eeckhoudt \(1985\)](#)'s result of self-insurance to the case where either the magnitude of prospective loss or the productivity of self-insurance is uncertain. He showed that an increase in risk aversion always leads to an increase in self-insurance when the potential loss is random, while this is not necessarily the case when the effectiveness of self-insurance is random. This happens since an increase in self-insurance reduces the variance of the (conditional) loss in the case of random loss, while it increases the variance in the case of random effectiveness.

[Briys and Schlesinger \(1990\)](#) went further into the analysis of self-insurance and self-protection as risk-reducing activities. If the cost of self-insurance and self-protection is assumed actuarially fair, i.e. that expected wealth remains constant for all levels of self-insurance or self-protection, they showed that an increase in self-insurance induces a mean-preserving contraction in the sense of [Rothschild and Stiglitz 1970](#)). However, this is not the case for self-protection which is clearly neither a mean-preserving contraction nor a mean preserving spread. As a more risk averse would optimally invest more in risk reducing activities, he will invest more in self-insurance but not necessarily in self-protection as it is not necessarily risk reducing.

[Briys et al. \(1991\)](#) investigated whether these results were robust for the case of non-reliability of prevention, i.e. in the case where the effectiveness of prevention was uncertain. In the case of self-insurance, they showed that the positive relationship between risk aversion and self-insurance no longer holds. This happens since the risky self-insurance helps to control one risk, but creates another one—namely the risk of wasting money on self-insurance activities that do not work. Since the real test of workability comes only during the loss experience, the individual cannot be certain whether or not self-insurance will be effective until a loss is experienced. Thus, a more risk-averse individual may conceivably decide to reduce the investment in self-insurance, so as to improve the worst possible state. They also showed that the relation between risk aversion and self-protection was still ambiguous under non-reliability.

[Lee \(1998\)](#) added to this literature by examining the effect of increased risk aversion on SICP activity, which influences both the probability and the size of the potential loss. He showed that the effect depends in part on the shape of the loss function and that of the probability function. In particular, if the marginal reduction in a loss in the bad state outweighs the marginal increase in the cost of SICP expenditures, more risk-averse individuals invest more in SICP. The intuition for this result is that, under the above condition, an increase in SICP expenditures makes the distribution of utility less risky or induces second-order stochastic dominance in the distribution of utility.

[Eeckhoudt et al. \(1997\)](#) showed that the WTP to reduce the probability of a financial loss is not necessarily increasing in the Arrow–Pratt measure of risk aversion depending on conditions on individual preferences. For instance, a risk-averse individual with CARA utility function can have

a higher WTP than a risk neutral individual. In the same vein, [Jullien et al. \(1999\)](#) showed that self-protection increases with risk aversion if and only if the initial probability is less than a utility-dependent threshold.

[Courbage and Rey \(2008\)](#) addressed the links between risk aversion and WTP in the case of small risks, i.e. risks defined by small losses that can be approximated by second-order Taylor series developments. In this environment, they showed that the WTP increases with risk aversion if the loss probability is inferior to one-half. If this probability is superior to one-half, the higher the initial loss probability, the more efficient prevention activity has to be to increase the WTP of a more risk-averse individual.

8.2.1.3 The Role of Prudence in Self-Protection Activities

As shown by [Dionne and Eeckhoudt \(1985\)](#), in the special case of quadratic utility, the probability threshold under which self-protection increases with risk aversion is exactly one-half. As quadratic utility function is characterised by a third derivative of the utility function being nil, the sign of the third derivative may drive self-protection activities. [Eeckhoudt and Gollier \(2005\)](#) showed that actually both risk aversion and prudence (as defined by the third derivative of the utility function being positive) play a role in explaining self-protection activities. Since risk aversion tends to raise self-protection when the probability is close to zero, and to lower it when this probability is close to unity, [Eeckhoudt and Gollier \(2005\)](#) concentrated on the intermediary case where the probability of loss is around one-half. In such a case, they showed that a prudent agent, either risk averse or risk lover, will exert less self-protection than a risk neutral one (which by definition is prudent neutral). They explained this result by the fact that less effort has no impact on the measure of risk at the margin, whereas it raises the precautionary accumulation of wealth which is helpful to face future risk.

[Chiu \(2000\)](#) using a WTP approach obtained a related result. He showed that a risk-averse individual with a vNM utility function $u(x)$ is willing to pay more than the expected reduction of loss for a reduction in the probability of loss if the initial probability of loss is below a threshold determined by $-u'''(x)/u''(x)$ which is known as the index of absolute prudence.

Building on these works, [Chiu \(2005\)](#) showed that, identifying individuals with their vNM utility function, $-v'''(x)/v''(x) \leq -u'''(x)/u''(x)$ implies that individual v 's optimal choice of self-protection expenditure is larger than individual's u , provided that the marginal expenditure in self-protection is equal to the marginal reduction in the expected loss. [Chiu \(2005\)](#) also stressed that the effect of a mean-preserving increase in self-protection is a special combination of downside risk increase and a mean-preserving contraction satisfying the conditions for $-u'''(x)/u''(x)$ to measure u 's strength of downside risk aversion relative to his own risk aversion. Therefore, an individual whose aversion to downside risk is weaker relative to his preference for a mean-preserving contraction will opt for such an increase in self-protection expenditure.

[Dachraoui et al. \(2004\)](#) defined even more restrictive conditions on the utility function to exhibit an exogenous threshold probability over which a more risk-averse individual invests more in self-protection activities and has a higher WTP. They used the concept of mixed risk aversion (MRA) introduced by [Caballé and Pomansky \(1996\)](#) to define "more risk-averse MRA". An individual is more risk-averse MRA than another if he is more risk averse, more prudent, more temperate, etc. They showed that if an agent is more risk-averse MRA than another then he will select a higher level of self-protection and have a higher WTP than the other individual only if the loss probability is lower than one-half.

In a related article, [Dionne and Li \(2011\)](#) proved that the level of self-protection chosen by a prudent agent is larger than the optimal level of self-protection chosen by a risk neutral agent if absolute prudence is less than a threshold that is utility independent, and stays the same for all agents. This threshold is equal to "the marginal change in probability on variance per third moment of loss

distribution". The intuition is that the level of self-protection chosen by a prudent agent is larger than the optimal level of self-protection chosen by a risk neutral agent when the negative effect of self-protection on the variance is larger than the positive effect on the third moment of the loss distribution.

All these models consider a one-period framework, i.e. they implicitly assume that the decision to engage in self-protection activities and its effect on the loss probability are simultaneous. However, it often happens that the decision to engage in self-protection activities precedes its effect on the probability calling for the use of a two-period framework. Within a two-period framework, [Menegatti \(2009\)](#) showed that the role of prudence in explaining self-protection activities was opposite to the case of a one-period framework as described by [Eeckhoudt and Gollier \(2005\)](#). In particular he showed that for a loss probability equal to one-half, a prudent agent, whatever his risk aversion, chooses a higher level of self-protection than a risk neutral agent (who by definition is prudent neutral). The explanation comes from the [Eeckhoudt and Schlesinger \(2006\)](#) notion of risk apportionment under which a prudent agent desires a larger wealth in the period where he bears the risk. In a two-period framework, more effort reduces wealth in the first period when there is no risk and increases expected wealth in the second period when the agent bears the risk, which is appreciated by a prudent agent.

8.2.1.4 Prevention, Insurance and Wealth Effect

Prevention and Insurance

[Ehrlich and Becker \(1972\)](#) were the first to address the relationship between insurance and, respectively, self-insurance and self-protection. They showed that market insurance and self-insurance are substitutes in the sense that an increase in the price of insurance, the probability of loss being the same, decreases the demand for market insurance and increases the demand for self-insurance. This is the case as insurance and self-insurance both decrease the size of the loss. This does not apply to self-protection which can be either a substitute or complement to insurance. Indeed, market insurance has two opposite effects on self-protection. On the one hand, self-protection is discouraged because its marginal gain is reduced by the reduction of the difference between the incomes and thus the utilities in different states; on the other hand, it is encouraged if the price of market insurance is negatively related to the amount spent on protection through the effect of these expenditures on the probabilities.

[Boyer and Dionne \(1983\)](#) derived some new propositions concerning the choice amongst self-insurance, self-protection and market insurance under alternative market conditions. In particular, they showed that risk-averse individuals prefer self-insurance to market insurance under perfect information about self-protection if market insurance and self-insurance are associated with the same variation in the expected net loss and are equally costly.

[Chang and Ehrlich \(1985\)](#) extended their analysis by showing that if the price of insurance were responsive to self-protection, then the latter would induce a substitution away from self-insurance and towards market insurance, as long as the utility function exhibits constant or decreasing absolute risk aversion (see also [Boyer and Dionne \(1989\)](#) for a related result).

[Briys et al. \(1991\)](#) addressed the links between market insurance and self-insurance in the case where the effects of self-insurance are not perfectly reliable. They implicitly assumed that the potential non-performance of self-insurance is known by the consumer, who assigns a probability distribution to the effectiveness of the tool. In such a case, they showed that market insurance and self-insurance may be complements. As the authors stressed it, the intuition behind this result is not clear and might be best understood by focusing on the worst possible outcome for the consumer. This occurs in the state of nature where both a loss occurs and self-insurance fails. In this case, the consumer not only suffers the higher loss but also loses the investment in self-insurance. At a higher price level of insurance, less insurance is purchased and so more of the loss is borne out of pocket. By decreasing the investment in self-insurance, the consumer can at least improve the worst possible state of the world.

More recently, [Kunreuther and Muermann \(2008\)](#) investigated the optimal investment in self-protection of insured individuals when they face interdependencies in the form of potential contamination from others. They showed that if individuals cannot coordinate their actions, then the positive externality of investing in self-protection implies that, in equilibrium, individuals underinvest in self-protection. They also showed that limiting insurance coverage through deductibles can partially internalise this externality and thereby improve individual and social welfare.¹

Prevention and Wealth Effect

The effect of a change in wealth on self-insurance is the same effect as a change in wealth on insurance. It depends on how risk aversion reacts to a change in wealth. [Lee \(2010\)](#) showed that an increase in initial wealth decreases (increases, does not change) self-insurance against wealth loss if the utility function satisfies DARA (IARA, CARA). The intuition is that with DARA, an increase in initial wealth reduces the marginal utility benefit of an increase in self-insurance more than the marginal utility cost. Therefore, it decreases the incentives to invest in self-insurance. With IARA, the opposite holds, and an increase in initial wealth increases the incentives to invest in self-insurance. With CARA such wealth effects are absent.

Results regarding self-protection are less clear-cut since an increase in initial wealth decreases both the marginal utility benefit and marginal utility cost of self-protection; it may increase or decrease self-protection. [Sweeney and Beard \(1992\)](#) showed that the effect of an initial wealth increase depends on both the probability of loss and the characteristics of the agent's absolute risk-aversion function. In particular, the length of the interval of probability values over which self-protection is a normal good for a person depends in a complex fashion on the shape of that person's risk-aversion function over the entire interval of wealth between the two possible outcomes. The authors also looked at the effect of a change in the size of the potential loss and provided plausible restrictions on risk preferences under which an increase in the size of the potential loss leads to increased self-protection.

8.2.1.5 More General Distributions of Loss

The previous works considered a two-state model, i.e. either a loss (the bad state) or no loss (the good state) occur. However, results in the two-state case do not necessarily carry over to many states and this is especially true for self-insurance. The difficulty is that self-insurance does not necessarily reduce larger losses in the bad states more effectively than smaller losses in the good states. Rather, the effectiveness of a given self-insurance investment across different states depends on its technology and the nature of the losses. Self-insurance may thus not act as insurance, and wealthier individuals may invest less or more in self-insurance. [Lee \(2010\)](#) provided some sufficient conditions under which self-insurance is an inferior good and some conditions under which it is a normal good. This depends on the single-crossing condition in [Diamond and Stiglitz \(1974\)](#) under which more risk-averse individuals increase the level of the control variable.

[Lee \(1998\)](#) also examined the effect of increased risk aversion on SICP activity in the case of a general model with many states of the world. He showed that contrary to the two-state model, the condition that the marginal reduction in a loss in the bad state outweighs the marginal increase in the cost of SICP expenditures is not sufficient to have more risk-averse individuals investing more in SICP. To obtain this result, an additional condition concerning the shape of the distribution function

¹See also [Schlesinger and Venezian \(1986\)](#) for an analysis of consumer welfare in a model considering both insurance and self-protection under various market settings.

is needed. This additional condition ensures that an increase in SICP decreases wealth or utility in all favourable states while increasing wealth or utility in all unfavourable states. In this way, an increase in SCIP contracts the distribution of utility towards the mean.

Recently, [Meyer and Meyer \(2011\)](#) studied the relationship between risk aversion and prudence and the demand for self-protection outside the usual assumption that the loss variable follows a Bernoulli distribution, and that changes in the level of self-protection are mean-preserving. Their analysis replaced these two strong conditions with one which is more general. This modification includes representing a change in the level of self-protection using the procedure developed by [Diamond and Stiglitz \(1974\)](#) to represent changes in the riskiness of a random alternative. The self-protective acts that can be considered are changed from those that are mean-preserving to those that are mean utility preserving for an arbitrary utility function. Their analysis showed that when the risk changes are equal in size, then all that matters is whether the decision-maker's absolute risk aversion measure increases faster or slower than does the absolute risk aversion measure of the reference person. When these risk changes are not equal in size, whether the decision-maker is more or less risk averse than the reference person also enters into the decision.

8.2.2 *Other Contexts*

8.2.2.1 **Non-monetary Risk**

The previous literature focuses on financial risks, i.e. it considers individual preferences as dependent only on wealth. It does not capture situations for which risks are not monetary and in particular health risks. Indeed, one important feature of health as a good is its irreplaceable feature ([Cook and Graham 1977](#)), i.e. a good for which there is no substitute on the market. This calls for using a bivariate utility function to represent individual preferences where arguments of the function are, respectively, wealth and health. The use of bivariate utility functions makes it possible to dissociate satisfaction of wealth in case of illness and of good health.

[Lee \(2005\)](#) investigated how a change in initial wealth modifies the level of prevention against a health loss using bivariate utility function. He showed that the sign of the cross derivative of the utility function plays a crucial role. If this sign is positive, then an increase in initial wealth increases self-insurance against health loss. The reason is simply that under a positive sign of the cross derivative, an increase in initial wealth increases the marginal utility of health giving greater incentives to invest in self-protection. As for self-protection, [Lee \(2005\)](#) also showed that under a positive sign of the cross derivative, an increase in initial wealth increases self-protection against health loss. It is the case because under this condition, an increase in initial wealth increases the marginal benefit of prevention and decreases its marginal cost. These predictions contrast with the result in the standard model with wealth loss only.

[Courbage and Rey \(2006\)](#) looked at the link between self-protection and the concept of fear of sickness (FS). FS measures the "degree of future pain" induced by the occurrence of the illness, where pain is measured via a decrease in utility. They showed that when an individual has a higher FS than another, then lower prudence exhibited by the first individual over the second is a sufficient condition to pursue more prevention, whatever the distribution of the probability of illness. The story behind this result is that FS affects the marginal benefit of prevention while its marginal cost depends on prudence.

There is also an important literature on the value of a statistical life (VSL). The VSL is extensively used in cost-benefit analysis in order to obtain a monetary value of life-savings benefits. The VSL can be seen as a WTP per unit of reduction in a mortality risk. To obtain a formal expression of the VSL, consider a simple static model such as

$$(1 - p)u(w_0) + pv(w_0) \quad (8.11)$$

where $u(\cdot)$ is the utility if alive and $v(\cdot)$ is the utility if dead. This simple model, introduced first by [Dreze \(1962\)](#) and afterwards by [Jones-Lee \(1974\)](#), has been commonly used in the literature (see, e.g. [Viscusi and Aldy 2003](#)). Within this model, it is traditionally assumed that $u(\cdot) > v(\cdot)$, $u' > 0$, $v' \geq 0$, $u' > v'$, $u'' \leq 0$ and $v''(\cdot) \leq 0$. That is, state-dependent utilities are increasing and concave. Moreover, utility if alive is larger than utility if dead and marginal utility if alive is larger than marginal utility if dead. The VSL is formally the marginal rate of substitution between wealth and survival probability, i.e. the slope of the indifference curve at (w_0, p) . It is defined by:

$$\text{VSL} = \frac{dw_0}{dp} = [u(w_0) - v(w_0)] / [(1 - p)u'(w_0) + pv'(w_0)] > 0 \quad (8.12)$$

Note that the VSL may vary across individuals since it depends on w_0 , p and on the shape of the utility function through u and v . In particular, under our assumptions it is easy to see that the VSL increases in wealth. It also increases in the baseline probability of death p , an effect coined the “dead-anyway effect” ([Pratt and Zeckhauser 1996](#)).

8.2.2.2 Prevention and Background Risk

[Briys and Schlesinger \(1990\)](#) addressed the issue of whether the presence of a background risk would modify the relation between risk aversion and self-insurance. Using the stronger measure of risk aversion proposed by [Ross \(1981\)](#), they showed that more risk-averse individuals invest more in self-insurance activities when their initial wealth is also random.

[Courbage and Rey \(2008\)](#) showed in the case of small risks that either DARA or risk vulnerability is required to have an increase in the WTP to reduce the probability of loss in the face of an independent unfair background risk of loss, depending on the support of the background risk and on the level of the probability of loss.

[Bleichrodt et al. \(2003\)](#) used a bivariate utility function depending on wealth and health to address how the willingness to pay to decrease the probability of illness reacts to the presence of co-morbidity. They showed that the willingness to pay for health improvements increases with the severity and probability of occurrence of co-morbidities. This result is obtained under mild restrictions on the shape of the utility function and some additional assumptions of the correlation between the two conditions. In the same vein, [Eeckhoudt and Hammitt \(2001\)](#) examined the effects of background mortality and financial risk on the VSL. They showed that under reasonable assumptions about risk aversion and prudence with respect to wealth in the event of survival and with respect to bequests in the event of death, background mortality and financial risks decrease VSL. In addition, they showed that results depend on the size of the risks. Indeed, the effects of large mortality or financial risks on VSL can be substantial but the effects of small background risks are negligible.

Finally, in two simultaneous and independent contributions, [Courbage and Rey \(2012\)](#) and [Eeckhoudt et al. \(2012\)](#) looked at the impact of both the presence and an increase of a background risk on optimal self-protection activities using a two-period model as introduced by [Menegatti \(2009\)](#). While [Eeckhoudt et al. \(2012\)](#) considered the background risk only in the second period, [Courbage and Rey \(2012\)](#) considered various other configurations of background risk, defined either in the

first or second period, as state-independent or state-dependent, or in both periods simultaneously. The introduction of a first period background risk is shown to reduce self-protection under prudence in this period, while it increases self-protection if the background risk is introduced in the second period under prudence in the second period. In the case of state-dependent background risks, risk aversion only drives the results. The effect of an increase in the background risk, as defined through n th-order stochastic dominance, naturally depends on the configuration of the background risk and is driven by the signs of the successive derivatives of the utility function to any order n .

8.2.2.3 Prevention and Non-expected Utility Models

Many empirical contradictions of the independence axiom (see, e.g. Allais 1953, Ellsberg 1961) have led economists to call into question the global validity of EU models and to develop new theories of choice under risk. The question is then whether existing results are robust to new models of behaviour under risk. An important class is the Rank Dependent Expected Utility's (RDEU) developed by Quiggin (1982) and Yaari (1987). Under RDEU, probabilities are distorted and treated in a nonlinear way. The weight given to an event depends on the ranking with respect to the others allowing individuals to overweight or underweight bad or good events.

Konrad and Skaperdas (1993) studied the properties of self-insurance and self-protection under RDEU. They showed that many of the comparative statics results that hold for expected utility carry over to RDEU. In particular, they showed that more risk-averse individuals (as defined through the shapes of both the utility function and probability transformation function) have a higher demand for self-insurance, even with background risk. Self-insurance demand in case of multiplicative risk increases (decreases) with wealth if the individual has increasing (decreasing) relative risk aversion. The generally ambiguous results on risk aversion and self-protection carry over also for RDEU. However, for risks that occur with very small or very large probabilities, the comparative statics of increases in risk aversion are qualitatively determined.

Courbage (2001) reconsidered the relationships existing between market insurance and, respectively, self-insurance and self-protection in the context of Yaari's Dual Theory (DT). While EU assigns a value to a prospect by taking a transformed expectation that is linear in probabilities but non-linear in wealth, DT provides the counterpoint since it reverses the transformation. The results for EU on self-insurance carry over to DT. Market insurance and self-insurance are substitutes, even with a background risk. They can be complements when reliability of self-insurance activity is not guaranteed. The generally ambiguous link between market insurance and self-protection carries over also to DT. However, this result is easily explainable by the role of the transformation function in under- or overestimating probabilities and their variation. He also considered the situation where the insurance company may not price the premium according to effective self-insurance and self-protection activities. Naturally, in that case market insurance and self-protection are substitutes.

Langlais (2005) looked at the links between risk aversion and the WTP without the EU assumptions. Introducing minimal assumptions on the individual preferences, he showed that the WTP for both a first-order stochastic dominance and second-order stochastic dominance reduction of risk is the sum of a mean effect, a pure risk effect and a wealth effect. Depending on the sign of these three effects, the WTP of a risk-averse decision-maker may be lower than the WTP of a risk-neutral one, for a large class of individual preferences' representation and a large class of risks.

Bleichrodt and Eeckhoudt (2006) considered also self-protection activities in the context of RDEU but in the specific case of WTP for reductions in the probability of health loss using univariate utility function. They compare the WTP under RDEU to the one under EU. They find that the introduction of probability weighting leads to an increase in the WTP for reductions in health risks when the individual underweights the probability of being in good health and is relatively sensitive to changes in loss probability. When the individual overweights the probability of being in good health and is

relatively insensitive to changes in loss probability, probability weighting decreases the WTP for reductions in health risks. Their results show that the effect of probability weighting can be large and may lead to unstable estimates of WTP for the probabilities generally used in empirical elicitation of WTP.

Recently, [Etner and Jeleva \(2013\)](#) as well used the RDEU model to study the impact of risk perception on self-protection in the context of health risks. They highlighted the importance of the shape of the probability transformation in explaining medical prevention decisions.

Finally, note that self-protection and self-insurance activities have also been studied in models of ambiguity preferences under which the decision-maker is assumed to be uncertain about the probability of the loss occurring. We decided to present these works in Sect. 8.3.5. dealing with the concept of precaution since, as it will be explained, precaution refers to models in which today's decision is affected either by the receipt of information in the future or by ambiguity over loss probability distributions.

8.3 Precaution

In this section, we argue that a fundamental difference between prevention and precaution rests on the difference between risk and information. To study precaution, the theoretical literature has traditionally considered a two-decision model and has examined the anticipated effect of receiving more information in the future on the first decision. This effect was first studied in the 1970s, and was initially referred to as the irreversibility effect by [Henry \(1974\)](#). It also relates to the notion of (quasi-)option value as introduced by [Arrow and Fischer \(1974\)](#). It was then generalised in the 1980s, most notably after [Epstein \(1980\)](#) provided a technique for developing the comparative statics of information in a sequential model. More recently this effect was related to the study of climate policy by, for example, [Ulph and Ulph \(1997\)](#) and to the Precautionary Principle by [Gollier et al. \(2000\)](#).

8.3.1 Prevention vs Precaution

The origin of the word prevention relates to the idea of “acting before”. Prevention may be understood as an anticipative measure taken in order to avoid a risk, or at least to attempt to limit its damages. In contrast, the latin root of the word precaution refers to the idea of “watching out”. It thus concerns a more diffuse threat, suggesting that there is only a potential risk. Consistent with this idea, it is often said that the Precautionary Principle (PP) introduced a new standard of risk management when the very existence of a risk is not scientifically established. The principle 15 of the 1992 Rio Declaration defines the PP as follows: “*Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation*”.²

Since [Knight \(1921\)](#), it is usual to make a distinction between a risk, characterised by an objective probability distribution, and uncertainty, which is not related to any precise probability distribution. And it is often said in a colloquial sense that prevention is related to the management of risk while

²Similar definitions have been given in international statements of policy including, e.g. the 1992 Convention on Climate Change, the 1992 Convention on Biological Diversity, the Maastricht Treaty in 1992/93 and the 2000 Cartagena Protocol on Biosafety. The PP has also been enacted in the national law of several countries, especially in Europe. In France for instance, the PP was included in 2005 in the French Constitution, that is at the highest juridical national level.

precaution is related to the management of uncertainty. Yet, without a clear definition of risk and uncertainty, this distinction is hardly operational. In fact, in the classical Savagian expected utility framework, there is essentially no difference between risk and uncertainty (Savage 1954; De Finetti 1974). Agents make decisions based on their subjective beliefs, but the decision-making framework remains the same independent of agents' beliefs.

The key point, however, is that one can propose a formal distinction between risk and uncertainty within the Savagian framework. This distinction relates to the possibility of acquiring information over time. A situation of uncertainty can be thought of as a situation in which more information is expected to arrive in the future. Formally, the subjective probability distribution that the decision-maker holds in the initial period is expected to be updated over time. This is the *lack of full scientific certainty* advocated by the PP, suggesting that there will be scientific progress in the future. With the accumulation of knowledge, uncertainty resolves, at least partially, allowing for a revision of beliefs. This leads us to recognise that precaution is not a static concept.

To sum it up, prevention can be viewed as a static concept that refers to the management of a risk at a given time and given a stable probability distribution, as we have seen in the previous section. In contrast, precaution is a dynamic concept that recognises that there is scientific progress over time. Precaution thus could be interpreted as a cautious and temporary decision that aims at managing the current lack of definitive scientific evidence. The theoretical question underlying the literature on precaution is therefore how the prospect to receive information in the future affects today's decisions. This question was initially addressed in a model where decisions can be irreversible.

8.3.2 The "Irreversibility Effect"

The development of an irreversible project is considered. The project is irreversible in the sense that once it is developed it cannot be stopped, or at an infinite cost. If the project is developed immediately, the current net benefit is equal to $b > 0$. But the project is risky in the long run, and its future net benefit is represented by the random variable $\tilde{\theta}$. Under risk-neutrality and no discounting, the traditional cost-benefit rule is that the project should be adopted now if and only if the sum of expected net benefits is positive, that is $b + E_{\tilde{\theta}}\tilde{\theta} \geq 0$, where $E_{\tilde{\theta}}$ denotes the expectation operator over $\tilde{\theta}$, and 0 represents the return of the best alternative if the project is not developed.

Suppose that arrival of information about the future returns of the project is expected over time. Namely, at a future date, the realisation $\tilde{\theta}$ of will be known, $\tilde{\theta} = \theta$, and if the project had not been adopted yet, the project should be adopted if it is profitable, i.e. if $\theta \geq 0$. Under this scenario, viewed from today the return of the project becomes $E \max(0, \tilde{\theta})$. This implies that the optimal strategy may *not* be to adopt the project immediately despite its positive expected value.³ The optimal strategy can be instead to wait before deciding to adopt or not the project until arrival of information and thus giving up the immediate benefit of the project b .

This shows that the prospect of receiving information in the future may lead not to developing an irreversible project even when it has a positive net present value. This is because such a project

³As an illustration, assume for instance $b = 1$, and that $\tilde{\theta}$ takes values $+3$ or -3 with equal probability. In that case, the project has a positive expected value $b + E_{\tilde{\theta}}\tilde{\theta} = 1$. But the point is that we have $E \max(0, \tilde{\theta}) = 1.5$ which is greater than 1.

“kills” the option of taking advantage of the forthcoming information. In other words, the prospect of receiving information in the future gives a premium to the decision of not developing an irreversible project. This effect is known as the “irreversibility effect” (Henry 1974).

Notice, however, that the example above is very specific. It involves perfect information, complete irreversibility, all-or-nothing decisions and risk neutrality. In the following, we will discuss conditions under which the “irreversibility effect” can be generalised. To do so, we consider from now a two-decision model represented by the following optimisation programme

$$\max_{x_1 \in D} E_{\tilde{s}} \max_{x_2 \in D(x_1)} E_{\tilde{\theta}/\tilde{s}} v(x_1, x_2, \tilde{\theta}) \tag{8.13}$$

The timing of the model is the following. At date 1, the decision-maker chooses x_1 in a set D . Between date 1 and date 2, he observes the realisation of a random variable, i.e. a signal, \tilde{s} , which is potentially correlated with $\tilde{\theta}$. At date 2, before the realisation of $\tilde{\theta}$, he chooses x_2 in a set $D(x_1)$. Finally $\tilde{\theta}$ is realised and the decision-maker has payoff $v(x_1, x_2, \theta)$. The question becomes: what is the effect of a “better information” \tilde{s} on the optimal decision at date 1?⁴

Let us first answer this question using the previous example. We have $v(x_1, x_2, \theta) = x_1 b + x_2 \theta$ with $D = \{0, 1\}$ and $D(x_1) = \{x_1, 1\}$. Note that the decision of developing the project, $x_1 = 1$, is irreversible in the sense that it reduces the decision set at date 2 to a singleton $D(x_1) = \{1\}$. We now compare what happens with and without information. The situation without information is equivalent to \tilde{s} independent from $\tilde{\theta}$: the observation of signal \tilde{s} does not give any information on the realisation of $\tilde{\theta}$. In this case, programme (8.13) becomes

$$\max_{x_1 \in \{0,1\}, x_2 \in \{x_1,1\}} E_{\tilde{\theta}}(x_1 b + x_2 \tilde{\theta}) = \max(b + E_{\tilde{\theta}} \tilde{\theta}, 0) \tag{8.14}$$

Consider alternatively the case with (perfect) information before date 2. This is equivalent to assuming perfect correlation between \tilde{s} and $\tilde{\theta}$. In this case, programme (8.13) becomes

$$\max_{x_1 \in \{0,1\}} E_{\tilde{\theta}} \max_{x_2 \in \{x_1,1\}}(x_1 b + x_2 \tilde{\theta}) = \max(b + E_{\tilde{\theta}} \tilde{\theta}, E_{\tilde{\theta}} \max(0, \tilde{\theta})) \tag{8.15}$$

Note that the difference between (8.14) and (8.15) corresponds to the value of perfect information. This comparison of (8.14) and (8.15) also shows that the returns of the best alternative have been re-evaluated from 0 to $V \equiv E \max(0, \tilde{\theta})$. This term V has been coined the (quasi-)option value in the literature (Arrow and Fischer 1974). It represents the welfare-equivalent cost of investing in the irreversible project.

8.3.3 The Effect of More Information

The comparison above between (8.14) and (8.15) rests on two extreme information structures: one structure gives no information and the other gives perfect information. We now introduce the notion of “better information”. This notion dates back to the mathematicians Bohnenblust et al. (1949), and especially to Blackwell (1951). A convenient definition is introduced by Marschak and Miyasawa (1968). Let \tilde{s} (resp. \tilde{s}') an information structure potentially correlated with $\tilde{\theta}$ and $\pi_{\tilde{s}}$ (res. $\pi_{\tilde{s}'}$) the vector of posterior probabilities of $\tilde{\theta}$ after observing signals s (resp. s'). Let also define S the set of probability distributions. Then \tilde{s} is a better information structure than \tilde{s}' if and only if:

⁴We note that the economic literature has used different terms to define the notion of a better information. These terms include an earlier resolution of uncertainty (Epstein 1980), an increase in uncertainty (Jones and Ostroy 1984), arrival of information over time (Demers 1991), learning (Ulph and Ulph 1997) and a better information structure (Gollier et al. 2000).

$$\text{for any convex function } \rho \text{ on } S, E_{\tilde{s}}\rho(\pi_{\tilde{s}}) \geq E_{\tilde{s}'}\rho(\pi_{\tilde{s}'}) \quad (8.16)$$

Thus a better information structure induces a mean-preserving spread in posterior beliefs.

We are now in a position to study the initial question about the effect of a better information structure on the optimal decision at date 1. Let us first define the value function of the second period problem as

$$j(\pi_s, x_1) = \max_{x_2 \in D(x_1)} E_{\tilde{\theta}/s} v(x_1, x_2, \tilde{\theta}) \quad (8.17)$$

Note that this value function is always convex in posterior beliefs π_s since it is the maximum of linear functions of π_s . Hence from (8.16) any better information structure increases ex ante expected utility. This is a mathematical representation of the idea that more information is always valuable. This is always true under EU. Moreover, the first-order condition of problem (8.13) is now equal to $E_{\tilde{s}} j_1(\pi_{\tilde{s}}, x_1) = 0$ where j_1 represents the derivative of j with respect to x_1 . Using (8.16) and (8.17) it is then easy to understand that better information increases the first decision if and only if $j_1(\pi_s, x_1)$ is convex in π_s . This observation about the convexity of j_1 essentially constitutes the Epstein (1980)'s theorem.

This theorem permits the investigation of the effect of better information on decisions under some regularity and differentiability assumptions,⁵ and it has been extensively used in the literature. Specifically, this theorem by Epstein has been used to generalise the irreversibility effect to partial information, partial irreversibility, continuous decisions and risk aversion. To see this, assume that the second period payoff function is independent of x_1 writing for the moment

$$v(x_1, x_2, \theta) = u(x_1) + V(x_2, \theta) \quad (8.18)$$

Also assume that $D(x_1) = [0, f(x_1)]$ so that an increase in x_1 reduces the future decision set if and only if $f > 0$ is decreasing. We thus can say that the irreversibility effect holds in this model if we can show that more information leads to a less irreversible decision, that is if we can show formally that j_1 is concave in the probability vector π_s whenever f is decreasing. After direct computations, it can be shown indeed that $j_1(\pi_s, x_1) = f'(x_1) \max(0, E_{\tilde{\theta}/s} V_2(f(x_1), \tilde{\theta}))$ where V_2 is the derivative of V with respect to x_2 ; see for instance the related results in Gollier and Treich (2003) or Måler and Fisher (2005). Since $E_{\tilde{\theta}/s} V_2(f(x_1), \tilde{\theta})$ is linear in π_s and the maximum operator is convex, the function $\max(0, E_{\tilde{\theta}/s} V_2(f(x_1), \tilde{\theta}))$ is convex in π_s which implies that the concavity of $j_1(\pi_s, x_1)$ indeed depends on whether f' is negative. This shows that the irreversibility effect holds in general in this model.

8.3.4 The “Precautionary Effect”

In his important article, Epstein observes that the irreversibility effect need not hold for payoff functions $v(x_1, x_2, \theta)$ in which the second period payoff directly depends on x_1 , namely when (8.18) does not hold. Underlying this technical observation, there is a fundamental economic insight. Indeed problems related to the Precautionary Principle are usually such that the actions today affect the risks borne in the future. This implies that condition (8.18) typically fails. In the remainder of this subsection, we thus present (but do not prove) some results about the effect of better information in models in which $v(x_1, x_2, \theta)$ does depend on x_1 . When such an intertemporal dependence is

⁵Jones and Ostroy (1984) generalised Epstein's theorem to non-differentiable problems and to a more general characterisation of adjustment costs.

introduced, there exists a new effect that is coined the “precautionary effect”. The sign of this effect is usually indeterminate and strongly depends on the functional forms considered.

A typical application of the effect of better information has been the timing of climate policy. An influential early contribution is that of [Ulph and Ulph \(1997\)](#) who consider a microeconomic climate change model in which the payoff function is of the form $v(x_1, x_2, \theta) = u_1(x_1) + u_2(x_2) - \theta d(\delta x_1 + x_2)$. They interpret x_t as the emissions of CO2 in period t and $\theta d(\cdot)$ as the risk of climate damage that depends on the sum of emissions up to a decay parameter δ and of the damage function $d(\cdot)$. Observe that in that model the level of emissions today x_1 affects the climate damage borne in the future: $\theta d(\delta x_1 + x_2)$. Ulph and Ulph then show that a better information structure may well lead to increase, and not decrease, emissions at date 1. This negative precautionary effect holds in particular when the utilities and the damage function are quadratic. Similarly, [Kolstad \(1996\)](#) observes that the precautionary effect due to stock pollution may reverse the irreversibility effect due to investment in a pollution abatement technology. Moreover, a basic insight from [Kolstad \(1996\)](#) and [Ulph and Ulph \(1997\)](#) is that better information does have an effect on today’s decisions even without the presence of an irreversibility constraint, for instance even if the set $D(x_1)$ is equal to the real line.

[Gollier et al. \(2000\)](#) analyse a model with stock effects as in [Ulph and Ulph \(1997\)](#) and [Kolstad \(1996\)](#) but with monetary damages $v(x_1, x_2, \theta) = u_1(x_1) + u_2(x_2 - \theta(\delta x_1 + x_2))$. They show that x_1 decreases with better information if and only if $u_2(\cdot)$ has a constant relative risk aversion (CRRA) parameter lower than 1, or a derivative “sufficiently” convex. This latter condition suggests that the coefficient of prudence is instrumental for signing the effect of a better information structure on early decisions, a new insight in this literature on the effect of information. They also show an impossibility result in the sense that if the utility function u_2 does not belong to class of harmonic absolute risk aversion (HARA) utility functions, then it is not possible to sign the comparative statics analysis for all probability distributions of the risk and all information structures.

Finally, and to mention some macroeconomic applications, [Epstein \(1980\)](#) considers a three-period consumption model with known current return of capital R , but uncertain future return, i.e. a model of the form $v(x_1, x_2, \theta) = u_1(x_1) + u_2(x_2) + u_3(1 - R^2 x_1 - \theta x_2)$. A related model is that of [Eeckhoudt et al. \(2005\)](#) where they consider an uncertain lifetime income, namely $v(x_1, x_2, \theta) = u_1(x_1) + u_2(x_2) + u_3(\theta - R^2 x_1 - R x_2)$. These articles show that the optimal x_1 responds differently to better information depending on the curvature of the utility functions. Overall these results suggest that the qualitative effect of better information strongly depends on the functional forms, in particular on the attitude towards risk of the decision-maker.

Most contributions in the last decades investigating the effect of better information have used [Epstein \(1980\)](#)’s theorem. This theorem is useful because the complex effect of better information characterised by all possible Blackwell-ordered information structures amounts to a study on how the properties of the value function in (8.17) translate into properties of the primitive model (8.13). One can view this theorem as a parallel of [Rothschild and Stiglitz \(1970\)](#)’s analysis of a change in risk to study the effect of a change in information.

We conclude this section with three remarks that concern future research. First, we observe that despite the usefulness of Epstein’s theorem, it is not easy technically to translate properties on the value function onto properties on the model’s primitives, and sometimes it may not even be possible to do so as shown in [Gollier et al. \(2000\)](#). Therefore, there is a need to provide a complementary theorem that would directly give conditions on the model’s primitives to sign the effect of better information. Second, it would be interesting to consider the comparative static analysis of better information with a less general notion than that of Blackwell. While alternative notions like monotone likelihood ratios have been used in the static value of information literature, we have not seen yet the use of these

notions in sequential option value models. Third, we notice that virtually all the literature relies on the use of the (Savagian) expected utility framework, and it does not seem obvious to study the effect of better information in broader or different frameworks. One typical difficulty is that alternative frameworks may induce a negative value of information. This last remark relates to the literature on ambiguity and ambiguity aversion that we briefly discuss now.

8.3.5 Ambiguity Aversion

It turns out that there is another approach to precaution. This approach is based on models involving ambiguity (aversion), i.e. models that can accommodate the Ellsberg (1961)'s paradox like for instance the early maxmin model of Gilboa and Schmeidler (1989) or the recent smooth ambiguity aversion model of Klibanoff et al. (2005). As precaution usually refers to situations in which there is ambiguity over probability distributions, many scholars actually believe that ambiguity (aversion) provides a more natural approach to study issues related to the Precautionary Principle. This approach also proposes a fairly simple distinction between risk and uncertainty. Risk corresponds to a situation in which the decision-maker believes that there is a unique probability distribution while uncertainty (i.e. ambiguity) corresponds to a situation in which he believes that there are multiple coexisting probability distributions.

To illustrate, we use the recent Klibanoff et al. (2005)'s theory of ambiguity (aversion) and apply it to the basic self-insurance model introduced in (8.1). But assume there might be multiple probabilities of loss denoted now by the random variable \tilde{p} . Formally, the objective function then becomes

$$V(y) = \Phi^{-1} [E_{\tilde{p}}\Phi[\tilde{p}u(w_0 - c(y) - L(y)) + (1 - \tilde{p})u(w_0 - c(y))]] \quad (8.19)$$

in which a concave (resp. convex) function $\Phi[\cdot]$ represents ambiguity aversion (resp. ambiguity loving); see Klibanoff et al. (2005) for a representation theorem of this model. The function $\Phi[\cdot]$ captures the gain in utility associated with a mean-preserving contraction in \tilde{p} . At the limit, when \tilde{p} is degenerate and equal to p_0 with probability 1, we are back to the model defined by (8.1). In that case, there is no ambiguity over probabilities, we are in a risk situation and ambiguity aversion naturally plays no role. Observe alternatively that under ambiguity neutrality, i.e. under $\Phi[\cdot]$ linear, we are also back to the EU model of (8.1) under $E_{\tilde{p}}\tilde{p} = p_0$ despite the presence of ambiguity.

Interestingly, Treich (2010) and Snow (2011) studied the effects of the presence of ambiguity and of ambiguity aversion on self-insurance and self-protection choices. Treich (2010) showed that ambiguity aversion increases the VSL as soon as the marginal utility of wealth is higher if alive than dead. Snow (2011) showed that the levels of self-insurance and self-protection activities that are optimal for an ambiguity-averse decision-maker are higher in the presence of ambiguity than in its absence, and always increase with greater ambiguity aversion. See Alary, Gollier and Treich (2013) for more general conditions on the effect of ambiguity aversion on self-insurance and self-protection.

A major concern, however, is that ambiguity (aversion) models have long been criticised for introducing anomalies in dynamic settings. Al-Najjar and Weinstein (2010) recently summarise these criticisms. In particular, they emphasise that it is not clear how to update beliefs in ambiguity (aversion) models. They also show that these models systematically induce time-inconsistent choices. As we initially argued that precaution is fundamentally a dynamic concept, we therefore believe that it is perhaps premature to include a thorough discussion of ambiguity models in this section on precaution. But we also believe this is probably the most promising avenue of research in this area.

8.4 Conclusion

Prevention is one tool amongst others to manage risks. Yet, it differs from others in the sense that it alters the risk itself via a modification either of the loss probability or the consequences of the risk. This chapter has shown that in the last 40 years, the economic literature on prevention has been developed in many directions. Most significantly, these directions include the analysis of: (1) the specificities and complementarities between self-insurance, self-protection and insurance choices, (2) the effect of wealth, risk preferences (e.g. risk aversion, prudence) and different risks (e.g. background risks, non-monetary risks) on these choices and (3) prevention under alternative decision theoretic frameworks to EU known as non-EU models.

All in all, it seems that this research area has undergone significant developments similar to other research areas within the economics of risk, uncertainty and insurance, like for instance the theoretic analysis of portfolio choices and insurance demand. Nevertheless, in comparison to other areas, the empirical literature on prevention is quite thin. For instance, we are not aware of any important empirical “puzzle” in the literature on prevention similar to the “equity premium puzzle” that could have a stimulating effect on the production of empirical articles.

It is worth mentioning that prevention is also studied in other fields of economics than the economics of risk, uncertainty and insurance. For instance, there exists various works on self-protection in the literature of game theory. These works make reference to the concepts of contest and rent seeking (see [Congleton et al. 2010](#)). There also exists a literature on incentives to invest in prevention with respect to liability rules in the analysis of law economics as well as in the literature of the economics of crime (see [Kaplow and Shavell 2002](#)). Lastly, in public economics, prevention is analysed in terms of public goods versus private goods (see [Shogren and Crocker 1991, 1998, Quiggin 1998](#)).

This chapter has also discussed the difference between prevention and precaution. Prevention can be viewed as a static concept that refers to the management of a risk at a given time and given a stable probability distribution. In contrast, precaution is a dynamic concept related to the management of uncertainty that recognises that there is scientific progress over time. In that sense, the crucial question underlying the literature on precaution is how the prospect of receiving information in the future affects today’s decisions. This is why the concept of precaution is strongly linked to the study of sequential models with arrival of information over time. An alternative approach to precaution is to consider situations in which there is ambiguity over probability distributions. Hence, a future research challenge would be to combine both approaches, that is to perform a sequential analysis in models of ambiguity (aversion).

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Chapter 9

Optimal Insurance Contracts Under Moral Hazard

Ralph A. Winter

Abstract This chapter surveys the theory of optimal insurance contracts under moral hazard. Moral hazard leads to insurance contracts that offer less than full coverage of losses. What *form* does the optimal insurance contract take in sharing risk between the insurer and the individual: a deductible or coinsurance of some kind? What are the factors that influence the design of the contract? Posed in the most general way, the problem is identical to the hidden-action principal–agent problem. The insurance context provides structure that allows more specific implications for contract design. This chapter reviews the static models of optimal insurance under ex ante and ex post moral hazard as well as the implications of repeated contracting.

9.1 Introduction

9.1.1 *The Concept of Moral Hazard*

This chapter offers a synthesis of the economic theory of moral hazard in insurance, with a focus on the design of optimal insurance contracts. In this context, moral hazard refers to the impact of insurance coverage in distorting incentives. The topic divides naturally into ex ante moral hazard and ex post moral hazard. Ex ante, an individual facing the risk of an accident, such as a home fire, a car accident, or a theft, can generally take actions to reduce the risk. Without insurance, the costs and benefits of accident avoidance, or precaution, would be internal to the individual. The incentives for avoidance would be optimal. With insurance, however, some of the accident costs are borne by the insurer. The insured individual, bearing all of the costs of accident avoidance but only some of the benefits, will then underinvest in precaution. This is ex ante moral hazard. Ex post, once the event of a need for medical care (for example) has occurred, an individual will spend more resources on care if a portion of those expenses is covered by insurance. Insurance covering the replacement of lost or stolen items is also subject to ex post moral hazard.

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An insurance contract may specify levels of precaution (the number of fire extinguishers, the frequency of inspection of equipment, and so on). And it may constrain expenditures *ex post*. If insurance contracts were complete in the sense of specifying the individual's care in all dimensions and in all future contingencies prior to the accident and expenditures in the event of need, then moral hazard would not be an issue. But insurance contracts are not complete. An automobile insurance policy, for example, does not specify the attention and focus that a driver must dedicate to driving safely. A health insurance policy does not dictate the diet or exercise routine of the individual covered. The precaution decisions taken after an insurance contract is signed are inefficient because of the positive externality on the insurer entailed in greater precautionary effort. The optimal insurance contract must be designed, within the constraints of asymmetric information and enforceability, in anticipation of rational decisions on the part of the insured individual.

The term moral hazard originated in the insurance context that we study here. The domain of the term has expanded, however, to include virtually all contracts, well beyond the traditional context of insurance contracts. Labor contracts, for example, are designed with the knowledge that the effort, diligence, and enthusiasm of the employee cannot be specified completely in the contract and instead must be induced through incentives provided in the contract. The relationships between a homeowner and a contractor, a lawyer and a customer, partners in a joint venture, and the editor of this volume and the author of this chapter are all subject to moral hazard. Even a marriage is subject to moral hazard in that costs are imposed on one marriage partner whenever the other one shirks.¹ Moral hazard in general refers to the distortions resulting from externalities among parties to an incomplete contract, on the decisions taken after the contract.

Moral hazard is distinguished from externalities in general by the existence of a contractual relationship between the decision maker and the party exposed to the externality. An insurance company and the insured individual have a contract; a polluting firm located upstream from a city taking water from a river generally has no contractual relationship with the users. Even this limit on the definition of moral hazard is tenuous, however. Moral hazard can encompass any externality if one adopts the broad theory of social contract (Hobbes 1651). Law and social norms can be interpreted together as a contract specifying the rights and obligations of individuals in a society. All individuals are in the social contract, and externalities are the consequence of incompleteness in the social contract. The ethical adjective *moral* in moral hazard is suggestive of this broader interpretation, but the phrase moral hazard has a much narrower origin in the insurance industry. Moral hazard, as describing the tendency for insurance to create incentives for individuals to be less careful in protecting themselves or property against risks, gained frequent usage in the late nineteenth and early twentieth centuries with the growth of private and social insurance in Europe and the USA (Dembe and Boden 2000).²

¹In an ideal marriage, costs imposed on the spouse are internalized in an individual's own utility function. Love solves the moral hazard problem.

²It has been suggested that the etymology of the term moral hazard may involve a second historical use of the term *moral* (Dembe and Boden 2000). Daniel Bernoulli (1738) in his resolution of the St. Petersburg paradox first posed by Nicholas Bernoulli in 1714 applied a theory that he referred to as "the theory of moral value." *Moral* referred to the subjective or psychological value placed on the gain in an individual's wealth. The *moral expectation* was distinguished from the *mathematical expectation*. Today we call Bernoulli's moral value the Bernoulli utility or Von-Neumann Morgenstern utility of wealth. Bernoulli's use of the term "moral" as meaning subjective or personal value is consistent with the usage of moral in the eighteenth and nineteenth centuries as meaning in accordance with the customs or norms of human conduct, rather than ethical as in current English usage. As Dembe and Boden note at p. 261, "The classical eighteenth-century mathematical analysis of subjective utility in risk-bearing situations can thus be considered as essentially value-neutral, despite being couched in the language of *moral* values and expectations." It is tempting for an economist, who considers maximizing behavior under incomplete contracts simply to be rational behavior, to trace the use of the term moral hazard in economics to the essentially value-neutral language of moral expectation in the eighteenth century. Dembe and Boden place considerable weight on this possibility, although Arrow (1963) is quite explicit in citing the prior insurance literature, in introducing the moral hazard terminology to the economics literature.

Kenneth Arrow (1963) pioneered the economic analysis of moral hazard. Pauly (1968) also offered an important early contribution. A large part of the microeconomics literature over the past 25 years has been devoted to the implications of incomplete contracts and incentives. The literature on the principal–agent theory, beginning with Holmstrom (1977, 1979), Shavell (1979a), and Mirrlees (1975, 1976), is central in this movement. In returning to the original context in reviewing the implications of moral hazard for insurance contracts, we draw on the developments in this literature. In accepted terminology, it is the hidden-action version of the principal–agent model that provides the structure for optimal insurance contracts under moral hazard. Shavell (1979b) is an early link between the general contracting theory and insurance.

Moral hazard is distinguished from adverse selection, another form of asymmetric information, by the timing of the informational asymmetry. In moral hazard problems, the insurer and the insured are symmetrically informed at the time of contracting. The individual’s precaution decisions taken after the contract are not observed by the insurer or at least not by a court enforcing the contract. In asymmetric information models, in contrast, insured individuals have private information at the time of contracting.³ The moral hazard/adverse selection distinction is cast in the contracting literature as the difference between hidden action (private information regarding actions of the insured individual or agent) and hidden information (private information on the characteristics of the insured individual).

9.1.1.1 The Questions

It has been well known since Professor Arrow’s classic 1963 chapter that the contractual response to moral hazard is to leave some of the risk uninsured, i.e., to leave some of the risk with the risk-averse individual rather than transferred entirely to the insurer. Leaving the individual with some share of the consequences of a marginal change in precaution improves the individual’s incentives to take precautions. The optimal contract will balance the risk-sharing benefits of greater insurance with the incentive benefits of less insurance. The central question for the design of optimal insurance contracts is what *form* the risk-sharing takes. Will optimal insurance involve a contract in which the individual bears the cost of all losses, up to some limit? This is a *deductible*. Will the optimal contract involve full insurance of marginal losses up to some coverage limit? Or will it involve some continuous sharing of the marginal accident costs?

I begin with the most general model of an insurance contract in a static setting with ex ante moral hazard. This is essentially the general principal–agent model, applied to insurance. The insurance context imposes a structure on the general principal–agent contract that yields predictions, such as the following (Holmstrom 1979): a pure deductible insurance contract is optimal if precautionary efforts affect the probability of an accident but not the severity of the random losses given the accident.

The application to insurance begins with the simplest theory: individual effort affects the probability of a loss of known size. We then consider the opposite assumption that care affects the (random) severity of a loss, but not the probability of loss. This yields a contract that is in one respect the opposite of a deductible: losses up to some critical value are fully covered. Higher losses are

³Models of insurance markets with asymmetric information are reviewed by Georges Dionne, Neil Doherty, and Nathalie Fombaron in a chapter in this handbook.

partially covered. In a more general formulation, I review conditions under which coinsurance, with a sharing of risk between the insurer and the insured, is optimal. A natural extension to the models in this section is the important case of an accident where the size of the loss from the accident is not observable. Without moral hazard, the optimal insurance coverage is greater than the expected loss in this extension, providing utility satisfies the property of decreasing absolute risk aversion. Introducing moral hazard reduces the optimal amount of insurance coverage.

I then turn to the case of ex post moral hazard, motivated by its most important example, medical care insurance. Zeckhauser (1970) offered the basic model of ex post moral hazard. I review this setting with a more modern revelation-principle approach to optimal contracting. Ma and Riordan (2002) develop a model that captures very clearly the trade-off between incentives to spend efficiently on ex post care and insurance. I review the analysis by Ma and Riordan by both demand-side management (coinsurance or incomplete insurance) and supply-side management through the provision of incentives to physicians.

I then discuss the economics of multiperiod insurance contracts under moral hazard, offering an overview of the literature on the following questions: When is there an incentive to enter a multiperiod insurance contract, as opposed to relying on a sequence of short-term contracts, to balance incentives and insurance? What are the characteristics of an optimal long-term insurance contract? The conclusion offers an outline of additional topics in the economics of moral hazard and insurance.

9.2 Ex Ante Moral Hazard: A General Distribution of Losses

A general formulation of the optimal insurance problem under moral hazard is a simple adaptation of the standard principal-agent model under hidden action (Holmstrom 1979; Bolton and Dewatripont 2005). A risk-averse individual faces a random loss x with a distribution that depends upon the effort, a , that the individual takes ex ante to avoid the loss. Let this distribution be $F(x; a)$ with continuous density $f(x; a)$ on support $[0, \bar{x}]$. Assume that increases in a reduce the random loss in the sense of first-order stochastic dominance: $\partial F(x; a)/\partial a \leq 0$ with the inequality strict for a positive measure of effort levels. The individual's utility over wealth and effort is expressed as $u(w) - v(a)$, with $u' > 0$, $u'' < 0$, $v' > 0$, and $v'' > 0$. The individual's initial wealth is w .

The separability of the utility function in wealth and effort is one of two common formulations of preferences in principal-agent models. The second is the opposite: that costs of precaution are entirely pecuniary, with utility given by $u(w - a)$.⁴

Throughout this chapter we assume that an individual has access to a competitive insurance market that will provide any contract yielding nonnegative expected profit. The essence of moral hazard is that the individual's effort is not contractible. The insurance contract specifies only an up-front premium, r , and the insurance coverage $I(x)$ that will be provided for each realization of the loss x . The insurance contract is exclusive in the sense that the individual enters only one contract. The individual's effort is determined after the contract by the individual acting in her own interest given the contract. We follow the standard approach in contract theory in writing the contract *as if* effort entered the contract, but subject the choice of contract to the *incentive compatibility constraint* that the choice of effort be the

⁴Ma and Riordan (2002) adopt a general assumption on preferences that accommodates both non-pecuniary and pecuniary costs of effort.

level that the individual will actually choose given the rest of the contract. The optimal contract is the solution to the following:

$$\max_{r, I(x), a} \int_0^{\bar{x}} u(w - r - x + I(x)) f(x; a) dx - v(a) \tag{9.1}$$

subject to

$$a \in \arg \max_e \int_0^{\bar{x}} u(w - r - x + I(x)) f(x; e) dx - v(e) \tag{9.2}$$

$$\int_0^{\bar{x}} I(x) f(x; a) dx - r \leq 0 \tag{9.3}$$

The individual chooses the contract to maximize expected utility (9.1) subject to the incentive compatibility constraint (9.2) and the individual rationality or nonnegative expected profit constraint (9.3). The notation “ $a \in \arg$ ” allows for the possibility that there are multiple solutions to the agent’s maximization problem. At this level of generality, not much can be said about the optimal insurance coverage, $I(x)$. Some insight can be gained into the optimality conditions by assuming that the first-order condition for the agent’s incentive compatibility constraint is not only necessary but sufficient for the agent’s optimum—in other words, that the second-order condition holds. While a common step in the analysis of principal–agent problems, the assumption, unfortunately, is ad hoc. The conditions that have been established to guarantee sufficiency of the “first-order approach” to the principal–agent model are strong. Rogerson (1985a,b) showed that the first-order approach to principal–agent problems is valid under two additional assumptions: the *monotone likelihood ratio property* (MLRP) and the concavity of the distribution function in a , for any x .⁵ The MLRP here is the following:

$$\frac{d}{dx} \frac{f_a(x; a)}{f(x; a)} \leq 0 \tag{9.4}$$

The MLRP and the assumption of concavity of F assure that the agent’s objective, $\int_0^{\bar{x}} u(w - r - x + I(x)) f(x; a) dx - v(a)$, is concave. The MLRP is a reasonable assumption, but as Jewitt (1988), Bolton and Dewatripont (2005), and others point out, the concavity condition (which is a convexity condition, in the standard principal–agent formulation) is quite restrictive.⁶

I follow convention in adopting the first-order approach in spite of its restrictiveness. Under this approach, we can replace the incentive compatibility constraint (9.2) with the first-order condition

$$\int_0^{\bar{x}} u(w - r - x + I(x)) f_a(x; a) dx - v'(a) = 0 \tag{9.5}$$

⁵The assumptions of concavity of the distribution function F and the MLRP for the random loss x correspond to the assumptions in a conventional principal–agent model of the *convexity* of the distribution function and an MLRP with the opposite inequality. Here, x is a loss; in the conventional principal–agent problem, x is profit.

⁶Jewitt (1988) provides sufficient conditions for the first-order approach beyond the restrictive convexity condition and including the observation by the principal of multiple relevant statistics.

The optimal insurance problem in the presence of ex ante moral hazard is thus the maximization of (9.1) subject to (9.3) and (9.5).

For a given insurance coverage function $I(x)$, the constraints (9.3) and (9.5) define a system of equations in a and r . We let the solution in (a, r) to this system be represented by the operators $a = A[I(x)]$ and $r = R[I(x)]$. (Appendix contains a proof of the uniqueness of this solution in a neighborhood of the optimum.) We can substitute these operators into the objective function (9.1) to obtain an *indirect utility function* over the coverage function, $I(\cdot)$:

$$EV[I(x)] = \int u(w - R[I(x)] - x + I(x))f(x; A[I(x)])dx - v(A[I(x)]) \quad (9.6)$$

The optimal insurance problem is the choice of the function $I(\cdot)$ to maximize (9.6). We can obtain the optimality condition, using the standard approach to optimization on a space of functions, by considering a small deviation in the optimal coverage function $I^*(\cdot)$. (This is a calculus-of-variations approach.) Let us impose a small variation $\epsilon h(x)$ on top of the coverage policy $I(x)$, so that the new coverage policy is $I(x) + \epsilon h(x)$. Given $I(x)$ and $h(x)$, the indirect utility can be rewritten as the function of this small variation ϵ :

$$E\tilde{V}(\epsilon) = \int u(w - \tilde{r}(\epsilon) - x + I(x) + \epsilon h(x))f(x; \tilde{a}(\epsilon))dx - v(\tilde{a}(\epsilon))$$

with $\tilde{r}(\epsilon)$ and $\tilde{a}(\epsilon)$ defined as the solutions in r and a to the following two equations:

$$\int u(w - r - x + I(x) + \epsilon h(x))f_a(x; a)dx = v'(a) \quad (9.7)$$

$$r = \int (I(x) + \epsilon h(x))f(x, a)dx \quad (9.8)$$

Next we decompose the marginal effect of a small variation ϵ . Taking the derivative respect to ϵ and evaluating at 0, we obtain

$$\begin{aligned} E\tilde{V}'(0) &= \int (u'(w - r - x + I(x))(-r' + h(x))f(x; a) \\ &\quad + u(w - r - x + I(x))f_a(x; a)\tilde{a}')dx - v'(a)\tilde{a}' \end{aligned} \quad (9.9)$$

r' and a' can be solved by differentiating (9.7) and (9.8):

$$\tilde{a}'(0) = \frac{\int u'h(x)f_a dx - \int u'f_a dx * \int h(x)f dx}{v''(a) - \int u f_{aa} dx + \int u'f_a dx * \int I(x)f_a dx} \quad (9.10)$$

$$\tilde{r}'(0) = \int I(x)f_a dx \cdot \tilde{a}' + \int h(x)f dx \quad (9.11)$$

Substituting (9.10) and (9.11) back to (9.9), we have

$$\begin{aligned} EV' &= \int u f_a dx * \tilde{a}' \\ &\quad - v'(a)\tilde{a}' \\ &\quad - \int I(x)f_a dx * \tilde{a}' * \int u'f dx \end{aligned}$$

$$\begin{aligned}
 & - \int h(x) f dx * \int u' f dx \\
 & + \int u' h(x) f dx
 \end{aligned} \tag{9.12}$$

The five terms in this expression reflect the marginal effect of a small variation of coverage, with ex ante moral hazard.⁷ The terms represent:

- (a) A change to the expected utility due to the shift of loss distribution
- (b) The disutility of marginal effort
- (c) The utility cost of the change in the premium due to the shift of loss distribution
- (d) The utility cost of a change of premium due to an increased level of coverage
- (e) The utility impact of a change in the level of coverage

The changes in expected utility due to (a) and (b) are exactly offsetting, from the incentive compatibility first-order condition (9.5)—an envelope-theorem effect. This leaves only the last three terms to represent the marginal impact of a change in coverage on utility. The last two terms would appear in a complete contract, without moral hazard; these represent (at the fixed care level) the utility cost of the premium paid for marginal additional coverage and the benefit of additional coverage. This leaves only the middle term of (9.12), the change in the premium due to the endogenous change in care level, as reflecting the moral hazard problem. This term is not only the utility cost of the change in ex ante premium reflecting the market’s rational forecast of the shift in the lost distribution, it represents the expected value in utility terms of the externality that the individual imposes on the insurance company in choosing the care level once the contract is entered into.

Starting with (9.12), we can establish three propositions in the general ex ante model. First, even in the presence of moral hazard, an insurance contract offers positive coverage. Starting from zero coverage, $I(x) = 0$, and letting $h(x) = x$, i.e., full coverage, the right-hand side of (9.12) represents the marginal gain from moving ε towards full coverage starting at $\varepsilon = 0$. With these values for $I(x)$ and $h(x)$, the term (c) drops out. The first two terms continue to sum to zero, so that the right-hand side of (9.12) equals $-\int x f dx * \int u' f dx + \int x u' f dx = \text{cov}(u', x) > 0$. (The covariance is positive since a higher x leads to a lower wealth level, and u' is decreasing in wealth because of the concavity of u .) Zero coverage is therefore dominated by a marginal amount in coverage at all values of loss. Moral hazard never eliminates the value of insurance. Hence our first general principle:

In the general model, some insurance is optimal even in the presence of moral hazard.

The second proposition is that moral hazard will always lead to partial coverage. Full coverage is never optimal. To see this, evaluate the right-hand side of (9.12) with $I(x) = x$ and any $h(x) < 0$, that is, consider a marginal *reduction* in coverage, starting from full coverage. With a reduction, rather than an increase, in coverage, the right-hand side of (9.12) changes sign. And with the *marginal* reduction in coverage, the last two terms drop out because at full coverage wealth is invariant to x and therefore u' is constant in this two equations. This leaves only the negative of term (c): $\int x f_a dx * \tilde{a}' * \int u' f dx = \partial[\int x f(x, a) dx] / \partial a * \tilde{a}' * \int u' f dx < 0$.⁸ Thus, a marginal reduction in coverage starting from full

⁷This decomposition parallels (7) in [Shavell \(1979a\)](#), which considers the simpler insurance problem with only one possible value for the loss if an accident does occur.

⁸To elaborate on the proof of this inequality, note that $\int f dx = 1 \Rightarrow \int f_a dx = 0 \Rightarrow E(f_a/f) = \int (f_a/f) f dx = 0$ so that $\int x f_a dx = \int x (f_a/f) f dx = E[x * (f_a/f)] = \text{cov}(x, f_a/f) < 0$, by MLRP. Turning to the second term, $\tilde{a}' > 0$ since less coverage leads to more effort. The third term is positive since u' is positive.

coverage will yield a positive expected utility gain equal to the expected utility value of the gain in efficiency from reducing moral hazard. Full coverage is always dominated:

In the general model, full insurance is never optimal in the presence of moral hazard.

Define the coinsurance in an insurance policy $I(x)$ as $x - I(x)$, i.e., as the share of the loss that the individual must bear. The third proposition in the general ex ante moral hazard problem is about the monotonicity of coinsurance in the size of the loss. Intuitively, one might expect that coinsurance is increasing in x since this would give the individual incentive to avoid high losses, which involve the highest cost to the insurer. In general, however, coinsurance is not monotonic in an optimal insurance policy. Suppose, for example, that there are four possible realizations of the loss: 1, 2, 3, and 4. Suppose that with zero care, the distribution of the loss on the support $\{1, 2, 3, 4\}$ is $(0.1, 0.4, 0.1, 0.4)$. An increase in care, we suppose, would move the distribution closer to $(0.4, 0.1, 0.4, 0.1)$. This is a first-order stochastic dominant shift downwards in the random loss, with greater care, so it is not unreasonable.⁹ But it is easy to verify that the optimal insurance policy leaves the individual with more loss at the realizations 2 and 4 than it does at the realizations 1 and 3.

The key condition sufficient for monotonicity of coinsurance, and violated by this example, is the MLRP (9.4), which we have been assuming in our derivation. The third proposition on the general ex ante moral hazard problem, following from a standard result in the principal-agent model, is that optimal coinsurance is nondecreasing in the size of the loss under the MLRP.

The first-order condition for the optimal $I(x)$ can be found by solving the maximization of (9.1) subject to (9.5) and (9.3) via a pointwise Lagrangian. This yields first-order conditions that can be reduced to the following:

$$u'(w - r - x + I(x)) \left[1 + \mu \frac{f_a(x; a)}{f(x, a)} \right] - \lambda = 0 \quad (9.13)$$

Without the incentive compatibility constraint, i.e., if $\mu = 0$, we would get the Arrow–Borch condition for first-best optimal insurance, that u' be constant across states (Borch 1962). This implies full insurance minus a constant: $I(x) = x - k$. With the incentive compatibility constraint, insurance is less than first best. By the MLRP, $f_a(x; a)/f(x; a)$ is nonincreasing in x . Since u' is strictly decreasing, (9.13) then implies that $x - I(x)$ is nondecreasing in x :

In the general model, under MLRP, the individual's share of the loss is nondecreasing in the size of the loss.

The likelihood ratio enters because the optimal contract rewards to the extent that individual incentives matter ($\mu > 0$); the individual is “punished” more severely via reduced coverage in states for which a reduction likelihood is sensitive to increased effort. This encourages effort by deviating from full insurance in the most efficient way.

9.3 Ex Ante Moral Hazard in Special Cases

More specific predictions about the form of an optimal insurance policy follow from additional assumptions on the distribution of losses. A natural structure on insurance losses is a *two-stage compound lottery*: an accident occurs or not, and then conditional upon an accident nature draws from a random distribution of losses. Care can affect either stage of the lottery. I follow Ehrlich and

⁹This type of distribution can easily result from an exogenous uncertainty that has a bimodal distribution.

Becker (1972) in distinguishing between care taken to reduce the probability of an accident and care to reduce the (random) size of the loss contingent upon an accident. In Ehrlich and Becker’s terminology, the former is *self-protection*. These authors call the latter “self-insurance”, but I will use the term *loss reduction*, because self-insurance has a different meaning in the insurance literature. Both types of care are important in various settings. Expenditures on fire sprinklers reduce the size of a loss, but not the probability of a fire. Expenditures on burglar alarms or security systems reduce the probability of a theft, whereas the decision not to buy expensive silverware reduces the loss if there is a theft. In the important case of earthquake insurance, *all* precaution is loss reducing. Driving an automobile more slowly and carefully reduces both the probability of an accident and the costs of an accident should it occur.

I consider, in turn, the implications of moral hazard on these two types of care, reviewing first Holmstrom’s key result on the form of optimal insurance contracts under self-protection. I then exploit the two-stage structure for an additional question: the optimal insurance contract when an insurer can observe the event of an accident but cannot observe the size of the loss.

9.3.1 Self-protection and Moral Hazard: The Optimality of Deductibles

Self-protection refers to the case where an individual can take effort, a , to affect the probability, $p(a)$, of an accident, but not $F(x)$, the distribution of losses conditional upon there being an accident. Many risk situations fit this description. A driver may be constrained to drive at a particular speed on the freeway but be careless to some degree in his driving or in how long he drives while tired. In this situation, the probability of an accident is affected by care, but the random severity of the accident if it does occur may depend very little if at all on care.

Holmstrom (1979) shows that under self-protection, the optimal insurance policy is a deductible, d , with full coverage above the deductible. In other words, the optimal $I^*(x)$ satisfies $I^*(x) = \max(0, x - d)$ for some deductible, d . Holmstrom takes a first-order approach to this problem, without assuming explicitly a set of assumptions under which the first-order approach is valid. A basis for the first-order approach is relatively straightforward in this special case, however. We can *define* the level of care as the extent to which the probability of an accident is reduced below the probability, p_0 , that the accident would occur with zero care. (There is no loss in generality in adopting this definition.) The probability of an accident is then linear in a , $p = p_0 - a$. Assume that the disutility of care, $v(a)$, is convex with Inada conditions $v'(0) = 0$ and $v'(a) \rightarrow \infty$ as $a \rightarrow \bar{a}$ for some \bar{a} . This is enough to ensure that the agent’s problem, $\max_a [1 - (p_0 - a)]u(w - r) + (p_0 - a) \int_0^{\bar{x}} u(w - r - x + I(x))f(x)dx - v(a)$, is concave and that the agent’s first-order condition is both necessary and sufficient for the incentive compatibility condition.¹⁰

The optimal insurance contract under these conditions solves the following problem:

$$\max_{r, I(x), a} [1 - (p_0 - a)]u(w - r) + (p_0 - a) \int_0^{\bar{x}} u(w - r - x + I(x))f(x)dx - v(a)$$

¹⁰The same set of assumptions can be used to justify the first-order approach in Shavell (1979a). Shavell adopts an assumption that the costs of care are pecuniary (i.e., a reduction in wealth) rather than purely non-pecuniary, as we assume here.

subject to the IC and zero-profit conditions

$$u(w - r) - \int_0^{\bar{x}} u(w - r - x + I(x))f(x)dx - v'(a) = 0$$

$$r - (p_0 - a) \int_0^{\bar{x}} I(x)f(x)dx = 0$$

as well as a nonnegativity constraint

$$I(x) \geq 0$$

reflecting the assumption that an individual cannot be compelled to report an accident.

Ignoring, for the moment, the nonnegativity constraint, the first-order condition on the choice of $I(x)$ implies that

$$u'(w - r - x + I(x)) = \lambda / \left[1 - \frac{\mu}{(p_0 - a)} \right]$$

which is independent of x . This can be achieved only if the individual bears the same net loss, $x - I(x)$, in all realizations of x . Care does not affect the distribution of losses conditional upon the event of an accident, so there is no reason to have the individual bear risk on the individual conditional upon that event. With moral hazard on the probability, $x - I(x)$ is positive in order to elicit care. Incorporating the nonnegativity constraint then leads directly to the optimality of a pure deductible policy, $I(x) = \max(x - d, 0)$, for some deductible d :

Where care affects the probability of an accident but not the distribution of losses conditional upon an accident, the optimal insurance policy is a deductible with full coverage of marginal losses above the deductible.

Holmstrom shows that an insurance contract more general than a pure deductible is optimal when the effort affects not only the probability of an accident but the losses conditional upon an accident as well. All that is required for a deductible is that there be an atom at 0 in the distribution of losses. The coinsurance of losses above 0 provides incentives for an individual to exert effort, as in the principal-agent model that we outlined.¹¹

9.3.2 Loss Reduction and Moral Hazard

An alternative assumption isolates the impact of optimal contracting of effort that affects the distribution of losses conditional upon an accident, but not the probability of the accident itself. Insurance to replace household furnishings in the event of an earthquake illustrates this case. A homeowner cannot

¹¹An alternative theory supporting the optimality of deductibles in insurance contracts is costly state verification (Townsend 1979 and Gale and Hellwig 1985). This is a theory that endogenizes the extent of asymmetry in information, rather than taking it as given as in the basic principal-agent approach. Insurers cannot always costlessly observe the loss that an individual has incurred. If the loss (the “state”) can be verified only at a cost, then the optimal insurance policy will call for coverage only when the claimed loss exceeds a specific level. In other words, a deductible is optimal when the state can be verified only at a cost. The theory involves essentially a reinterpretation of the Townsend and Gale-Hellwig corporate-finance models in terms of insurance contracts.

affect the chance of an earthquake, but can take measures to reduce the contingent losses. Investing in earthquake protection reduces losses and even purchasing less expensive home furnishings reduces losses.

Let us take the first-order approach to this incentive contract design problem. Assume that an individual faces with exogenous probability p a loss that is distributed with distribution $F(x; a)$. An increase in effort shifts $F(x; a)$ downwards in the sense of first-order stochastic dominance. The individual in this case maximizes $[1 - p]u(w - r) + p \int_0^{\bar{x}} u(w - r - x + I(x))f(x; a)dx - v(a)$ subject to ICC and zero-profit constraints that are the obvious modifications of (9.2) and (9.3). (We ignore, for the moment, any bounds on $I(x)$.) It is straightforward to verify that the first-order condition on $I(x)$ solving the optimal contracting problem yields (9.13) as in the general model. Using this plus the first-order condition on r yields

$$u'(w - r) = \int u'(w - r - x + I(x))f(x; a)dx \quad (9.14)$$

The deviation from perfect insurance in any moral hazard problem serves only to generate incentives in the most efficient way. Equation (9.14) reveals that in this case the Arrow–Borch condition holds across the event of a loss: the marginal utility of wealth conditional upon no accident equals the conditional expectation of marginal utility given an accident. This must be an optimality condition because if the condition were violated there would be an insurance benefit to transferring a dollar between the event of an accident and the event of no accident and the transfer would involve no cost in terms of incentive distortion because p is exogenous. The condition (9.13) implies that the amount of risk borne by the individual, $x - I(x)$, is nondecreasing in x , so as to give the individual incentive to reduce the stochastic size of the loss by exerting more care. The monotonicity of $I(x)$ plus the equality of the expected marginal utility of wealth in the events of accident and no accident implies that $I(x) > x$ for low x . If we then add a constraint $I(x) \leq x$ on the contract (insurance payout cannot exceed loss because the individual has the ability to cause a loss), the optimal coverage is $I(x) \leq x$, full coverage, for all losses below a critical value \hat{x} (Rees and Wambach 2008). The condition that care affects the size of the loss but not the probability is the opposite of the set of assumptions giving rise to a deductible, and the nature of the optimal contract is the opposite. Low losses are fully covered, instead of not covered at all.

We do not in reality observe insurance contracts with full coverage of low losses. The implication that should be drawn from the model of loss reduction and moral hazard, however, is not the stark prediction of full coverage of low losses but rather the relative inefficiency of deductibles, the opposite kind of contract, in the presence of moral hazard on the size of damages. Providing zero coverage in the event of a small loss, via deductibles, distorts the incentive to mitigate losses.

9.3.3 Optimal Insurance with Unobservable Loss

The conventional approach to the moral hazard problem, as outlined to this point, assumes that the care decision, a , on the part of the insured individual cannot be observed, but that the size of the loss, x , is observed perfectly. The theory allows for hidden action, but not hidden information. The analysis of the ex post moral hazard problem in a later section of this chapter is a problem in which the actual loss of the insured individual is not observed perfectly. The need for medical care in the event of a disease or accident, for example, is largely left up to the individual rather than prescribed by the insurance company. In this case, the cost of the prescribed medical care ex post provides a signal of the actual

loss. But the extreme case of imperfect observation of the loss, when no signal at all is available as to its size, fits well within the ex ante moral hazard model. Consider, for example, insurance offered in all major premium credit cards against delay of baggage arrival during air travel.¹² The provider of baggage insurance has no information on the cost to the individual of the baggage delay. This cost may be zero or, for the business traveler who has to replace a suit for a meeting, substantial. The only feasible insurance policy when x is unobservable is a fixed payment, I , in the event of a loss.

No Moral Hazard: If the individual cannot affect the distribution of loss then there is no moral hazard problem, apart from the constraint that an individual would not report the true loss, x . The individual facing a random loss x with exogenous probability p chooses an optimal insurance contract (r^*, I^*) to solve the following problem:

$$\max_{r, I} (1 - p)u(w - r) + pEu(w - r - x + I) \quad (9.15)$$

subject to

$$r = pI$$

The first-order condition for this problem is the familiar Arrow–Borch condition that the expected marginal utility in the event of an accident must equal the marginal utility in the event of no accident:

$$Eu'(w - r - x + I) - u'(w - r) = 0 \quad (9.16)$$

If the utility function satisfies decreasing absolute risk aversion, $d[-u''(w)/u'(w)]/dw < 0$, then $u''' > 0$, i.e., u' is convex. The first-order condition evaluated at $I = Ex$ is then positive:

$$Eu'(w - r - x + Ex) - u'(w - r) > u'(w - r - Ex + Ex) - u'(w - r) = 0$$

where the inequality follows from Jensen's and the convexity of u' . This implies that the optimal insurance coverage is greater than the expected loss.

Moral Hazard on Probability of an Accident: Suppose that the probability of an accident equals $p_0 - a$, where a is the individual's effort in avoiding an accident. The individual disutility of effort is, as earlier, a convex function, $v(a)$, satisfying Inada conditions. In this case, the optimal insurance policy solves the following problem:

$$\max_{r, I, a} [1 - (p - a)]u(w - r) + (p - a)Eu(w - r - x + I) - v(a) \quad (9.17)$$

subject to

$$a \in \arg \max_e [1 - (p - e)]u(w - r) + (p - e)Eu(w - r - x + I) - v(e)$$

$$r = (p - a)I$$

¹²The standard insurance policy against baggage delay (as of 2012) allows the insured individual to claim up to 500 dollars to purchase clothing if baggages are delayed by more than 4 hours.

Substituting the individual's first-order condition for the incentive compatibility constraint into (9.17) and solving for the first-order condition for this maximization problem yield the following equation ¹³:

$$Eu'(w-r-x+I) - u'(w-r) \\ = \lambda [Eu'(w-r-x+I)[1-(p-a)] + u'(w-r)(p-a)] \frac{1}{(p-a)[1-(p-a)]}$$

Comparing this first-order condition with the non-moral hazard optimal insurance condition (9.16), we see that the expected marginal utility with accident is higher than the one without accident, which implies the coverage I with moral hazard is lower than the coverage when there is no moral hazard. The partial insurance coverage again enhances the incentive for the individual to take care.

Moral Hazard on the Size of the Loss: In situations such as our example of baggage delay insurance, it is reasonable to assume that the probability of an accident is exogenous. The traveler does not cause the baggage delay. The care that an individual would take to avoid a high cost of delay, however, is the outcome of a decision on the part of the individual. The individual would take into account the need for specific items in baggage and would carry the essential items on the flight.

If the loss on the part of the individual were observable, the inability of the insurer to observe care would create a moral hazard problem, as we saw in the previous subsection of this chapter. The insurance policy would cover higher losses with greater insurance payout, and because the insured individual exerts a positive externality on the insurer when he takes the care decision, the decision is distorted.

Where the size of the loss is not observed, however, the moral hazard problem disappears. The insurance policy is limited to paying a lump sum in the event of an accident, as we have discussed, leaving the individual with the full share of loss at the margin and therefore the full benefit of care. The optimal policy would be identical to (9.15) with the distribution of losses given by $F(x; a^*)$ where a^* is the first-best level of care. The non-observability of care by the insurer is costly to the individual, of course, in that it constrains the class of insurance contracts that can be written. Ironically, the extra limitation on what the insurer can observe eliminates the incentive distortion.

9.4 Ex Post Moral Hazard

The ex post moral hazard problem arises when an individual's expenditures on reducing the damages from an accident are covered by insurance, and the insurer cannot identify exactly the efficient expenditure ex post. The most important example of ex post moral hazard problem is in medical insurance, which has from the beginning been a focus of the literature on moral hazard (Arrow 1963; Pauly 1968; Zeckhauser 1970; Ma and McGuire 1997; and Ma and Riordan 2002). Insurers cannot identify the exact state of health of an individual and must instead rely on the decision by the individual and her doctor as to the level of care and expenditure.

¹³With the substitution of the agent's first-order condition for the ICC, the Lagrangian is

$$\begin{aligned} \mathcal{L} = & [1-(p-a)]u(w-(p-a)I) \\ & + (p-a)E_x u(w-(p-a)I-x+I) \\ & - v(a) + \lambda[u(w-(p-a)I) \\ & - E_x u(w-(p-a)I-x+I) - v'(a)] \end{aligned}$$

The conventional view is that the insured individual, capturing the full benefit of marginal expenditure on medical care but bearing less than the full cost, will spend excessively relative to the first best. I begin by outlining a simplest model supporting this intuition. This model draws on [Zeckhauser \(1970\)](#). Zeckhauser’s approach is prescient in recognizing the ex post moral hazard problem as one of hidden information rather than hidden action. I reformulate the Zeckhauser model with a continuum of states rather than a finite number and make use of the revelation principle in the reformulation. The revelation principle ([Myerson 1979](#)) implies in this context that in designing an insurance contract in a model with hidden information, one cannot do better than adopting a direct mechanism (a mechanism in which the individual reports her type) that is incentive compatible (subject to the constraint that individuals have the incentive to report the truth). The revelation principle had not been developed at the time of Zeckhauser’s contribution. See [Myerson \(1979\)](#) as well as [Dasgupta, Hammond, and Maskin \(1979\)](#) and [Gibbard \(1973\)](#).

The moral hazard problem in medicare is more complex than the simple model suggests in at least two respects. Additional medical care at one point in time, especially preventative care, may reduce expenditures to be made later and thus benefitting the insurer. The individual bears only part of the benefits as well as part of the costs of preventative medical care. That is, medical care has some elements of ex post moral hazard and some elements of ex ante moral hazard, in that preventative care lessens ex post damages. Second, as analyzed in [Ma and Riordan \(2002\)](#), managed care systems such as HMOs can mitigate the potentially severe incentive problem in medical care. I offer below a brief outline of the Ma and Riordan model.¹⁴

9.4.1 Basic Model of Ex Post Moral Hazard in Medical Care

Consider an individual with an uncertain need for medical care, i.e., uncertain preferences over medical care and all other commodities. Let x be the individual’s expenditure on medical care, y the expenditure on all other commodities, and θ be the uncertain state of the world. State $\theta = 0$ refers to perfect health, and an increase in θ is interpreted as worsening health. The distribution of θ is smooth. The patient’s utility function is $u(x, y; \theta)$, which satisfies $u_x \geq 0, u_{xx} \leq 0, u_y \geq 0, u_{yy} \leq 0, u_x(x, y, \theta) = 0$ for all x exceeding some finite $\hat{x}(\theta)$ for every θ , and

$$\frac{\partial}{\partial \theta} \left(\frac{u_x}{u_y} \right) > 0 \tag{9.18}$$

The condition (9.18) states that marginal rate of substitution between health care and expenditure on all other goods is increasing due to increased severity of illness. The fact that u_x reaches 0 at finite x means that there is a limit to the marginal value of health care even at a zero price. The extra month spent in hospital for a stubbed toe carries negative utility. The individual’s initial wealth is w .

The individual has the opportunity to purchase insurance prior to the realization of θ . The insurance policy $[r, I(x)]$ has a premium r and provides coverage $I(x)$ when expenditure on health is x . Ex post, having entered an insurance policy $[r, I(x)]$, the individual chooses health care expenditure x and other expenditure y to maximize $u(x, y; \theta)$ subject to the budget constraint $x + y - I(x) \leq w - r$. This maximization problem forms the incentive compatibility constraint, in the choice of an optimal insurance contract. The optimal contract solves

$$\max_{r, I(\cdot)} \int u(x(\theta), y(\theta), \theta) f(\theta) d\theta$$

¹⁴An alternative model is offered in [Blomqvist \(1977\)](#).

subject to the incentive compatibility and zero-expected-profit conditions:

$$\forall \theta \quad (x(\theta), y(\theta)) = \arg \max_{\tilde{x}, \tilde{y}} u(\tilde{x}, \tilde{y}; \theta) \quad \text{subject to} \quad \tilde{x} + \tilde{y} - I(x) \leq w - r \quad (9.19)$$

$$r - \int I(x) f(\theta) d\theta = 0$$

The revelation principle allows us to reformulate the problem as the choice of an expenditure plan contingent on health:

$$\max_{x(\theta), y(\theta)} \int u(x(\theta), y(\theta); \theta) f(\theta) d\theta \quad (9.20)$$

subject to

$$\forall \theta \quad \theta \in \arg \max_{\hat{\theta}} u(x(\hat{\theta}), y(\hat{\theta}); \theta) \quad (9.21)$$

$$\int (x(\theta) + y(\theta)) f(\theta) d\theta \leq w \quad (9.22)$$

Taking a first-order approach, we assume that the incentive compatibility constraint (9.21) can be replaced by first-order condition of agent's maximization problem. Under the assumption that the optimal solution $x(\theta), y(\theta)$ varies smoothly with θ , the first-order condition is

$$u_x(x(\theta), y(\theta); \theta)x'(\theta) + u_y(x(\theta), y(\theta); \theta)y'(\theta) = 0 \quad (9.23)$$

That is, the marginal rate of substitution equals the ratio of the rates of change of x and y with θ : $u_x/u_y = -y'(\theta)/x'(\theta)$.

First-Best Benchmark: When the state of health is observable to the insurance company, the incentive compatibility constraint can be dropped. In this case, the maximization of (9.20) subject to (9.22) yields

$$u_x = u_y = \lambda \quad \forall \theta$$

This condition means that the patient is fully insured under the first-best contract: the marginal utility of income is equal across states and, from the patient's ex post maximization problem, equal to the marginal utility on each class of expenditures.

At this level of generality, the pattern of first-best insurance can be almost anything. Consider, for example, an individual with a preference for only two activities: helicopter skiing and reading library books.¹⁵ The individual should purchase *negative* insurance against the event of a broken ankle that would preclude skiing: this event carries a much lower marginal utility of wealth so that transferring wealth out of the event ex ante raises expected utility. Optimal insurance at a fair premium involves equating the expected *marginal* utility across events, not compensating the individual for lost utility.

Optimal Contract: Adopting a first-order approach yields a Lagrangian for the optimal contracting problem given by

$$\mathcal{L} = \int [u - \mu(\theta)(u_x x' + u_y y') + \lambda(w - x - y)] f(\theta) d\theta$$

¹⁵This is a close approximation to the author's preferences.

Let $G(x, y, x', y') = [u - \mu(\theta)(u_x x' + u_y y') + \lambda(w - x - y)]f(\theta)$. Adopting a calculus-of-variations approach, we have that the optimal expenditure plan satisfies

$$\frac{\partial G}{\partial x} = \frac{d}{d\theta} \left(\frac{\partial G}{\partial x'} \right)$$

$$\frac{\partial G}{\partial y} = \frac{d}{d\theta} \left(\frac{\partial G}{\partial y'} \right)$$

The first-order conditions are then

$$(u_x - \lambda + \mu u_{x\theta})f = u_x(\mu f)' \quad (9.24)$$

$$(u_y - \lambda + \mu u_{y\theta})f = u_y(\mu f)' \quad (9.25)$$

Taking the ratio of these first-order conditions, we have

$$\frac{u_x - \lambda + \mu u_{x\theta}}{u_y - \lambda + \mu u_{y\theta}} = \frac{u_x}{u_y}$$

which implies

$$\lambda(u_y - u_x) = \mu u_y^2 \frac{\partial}{\partial \theta} \left(\frac{u_x}{u_y} \right) \geq 0 \quad (9.26)$$

if the multiplier is positive.

To generate predictions, we must impose enough structure to set aside unusual preferences such as those of the helicopter skier. We can do this by imposing a structure of additive utility in x and y : $u(x, y, \theta) = v(x, \theta) + b(y)$, with v and b satisfying conditions that yield our assumed restrictions on derivatives of u . (In particular, for every θ , there is some $\hat{x}(\theta)$ where $v(x, \theta)$ reaches a maximum.) With the additive utility function (which implies a positive multiplier), we have from (9.26)

$$\lambda(b_y - v_x) = \mu b_y v_{x\theta} \geq 0$$

which implies that $b_y \geq v_x$

This gives us the first property of the optimal contract: it involves greater than first-best expenditure on y relative to x . This is possible only if the slope of the optimal insurance coverage, $I'(x)$, is positive because of the incentive compatibility condition (9.19) in the first formulation of the problem. As in the ex ante moral hazard problem, ex post moral hazard does not eliminate the gains from trade in insurance markets. The optimal contract provides a positive amount of insurance.

The second property, however, is that the optimal insurance policy provides less than full coverage of medical expenditures: $I'(x) < 1$. Just as in the ex ante moral hazard problem, some exposure to risk of needing medical expenditures is left with the individual. This follows simply from the requirement at the optimum that $v_x(x(\theta); \theta) > 0$. A positive marginal utility of medical care means that at each θ the individual is spending less than $\hat{x}(\theta)$, which is the expenditure under full insurance. From (9.19) this is possible only if $I'(x) < 1$, showing that insurance, as in [Zeckhauser \(1970\)](#), is incomplete.

9.4.2 Ma–Riordan (2002)

The design of optimal insurance contracts in an environment with ex post moral hazard must balance the benefits of greater insurance in terms of superior allocation of risk-bearing, against the incentive

distortion that greater insurance unavoidably brings. This is the same trade-off that must be struck in any principal–agent model with a risk-averse agent. [Ma and Riordan \(2002\)](#) provide a particularly elegant formulation of this trade-off in the context of ex post moral hazard. In their model, an individual faces a probability λ of becoming ill, with $0 < \lambda < 1$. The illness varies by its severity l with a density $f(l)$ and distribution $F(l)$. The insured individual learns of the benefits of treatment, i.e., the severity of the disease, after the realization of the illness and severity, but neither the illness nor the severity can be contracted upon by the insurer. The consumer’s preferences are presented (in the “utility loss” version of the Ma–Riordan model) by $U(y) - bl$, where y is the income available for expenditure on goods other than medical care. The treatment of the illness is a fixed amount C and eliminates the disease with certainty.¹⁶

A first-best contract, in the Ma–Riordan model, has the consumer paying a fixed premium, P , and receiving treatment whenever the benefits of treatment l are above a particular threshold L . The first-best contract maximizes expected utility subject to a zero-profit constraint:

$$\max_{P,L} (1 - \lambda)U(Y - P) + \lambda \left[\int_0^L [U(Y - P) - bl]f(l)dl + [(1 - F(L))U(Y - P)] \right]$$

subject to

$$P \geq \lambda[1 - F(L)]C$$

The solution involves a threshold L^* that equates the benefits of treatment of a disease of severity L^* with the cost of treatment: $bL^* = U'(Y - P)C$.

When the insurer cannot observe l , the first-best contract cannot be struck. Instead, the contract calls for a copayment, D , on the part of the patient, and leaves the treatment decision up to the patient. The optimal contract (P, D) maximizes expected utility subject to an incentive compatibility constraint that the patient chooses treatment when the severity of illness exceeds a threshold L that is chosen rationally given the contract, as well as a nonnegative profit constraint:

$$\max_{P,D,L} (1 - \lambda)U(Y - P) + \lambda \left[\int_0^L [U(Y - P) - bl]f(l)dl + [1 - F(L)]U(Y - P - D) \right]$$

subject to

$$U(Y - P) - bL = U(Y - P - D)$$

$$P \geq \lambda[1 - F(L)](C - D)$$

Ma and Riordan characterize the optimal copayment D^* as balancing the expected utility cost of a marginally higher copayment against the corresponding benefits of a lower premium. In the case where probability of an illness is small (i.e., letting λ approach zero) the trade-off yields a relatively simple expression:

$$\frac{C - D}{D} = \left[\frac{U'(Y - P - D)}{U'(Y - P)} - 1 \right] / \left\{ \frac{f(L)}{[1 - F(L)]} \frac{DU'(Y - D)}{b} \right\}$$

¹⁶The full model in Ma and Riordan allows for a pecuniary loss al as well as the utility loss.

The term in the numerator of the right-hand side is the insurance benefit of a marginally lower copayment, as given by the “Arrow–Borch distortion” of the given copayment. This distortion depends on the concavity of the utility function on the domain between $Y - D$ and Y . The incentive distortion of a marginally higher copayment depends on the consumer’s elasticity of expected demand for treatment with respect to the copayment (at a constant premium). This elasticity is the expression in the denominator of the right-hand side. This expression illustrates the trade-off between providing insurance and controlling moral hazard. If the consumer is highly averse to income risk and therefore has a high Arrow–Borch distortion, then the insurance company bears a high fraction of the treatment cost in order to better insure the patient. On the other hand, if the demand for treatment is highly price elastic, then the potential incentive distortion is high and the consumer bears a substantial copayment in order to curtail excessive demand. Optimal cost sharing balances these two considerations.

9.4.3 *Ex Post Moral Hazard with Managed Care*

The health-care insurance market has responded to the ex post moral hazard problem with supply-side managed care, especially Health Maintenance Organizations (HMOs). An HMO is an organization that provides managed care for health insurance contracts in the United States. The HMO serves as a liaison between insurers and health-care providers (hospitals, doctors, etc.). Unlike traditional indemnity insurance, an HMO covers only care rendered by those doctors and other professionals who have agreed to treat patients in accordance with the HMO’s guidelines and restrictions in exchange for a steady stream of customers.

The HMO strengthens the role of a health-care provider as a gatekeeper for treatment. Even prior to HMOs physicians played this role.¹⁷ Ma and Riordan (2002) and Ellis and McGuire (1990) develop models of treatment decision as a collective decision that maximizes a weighted sum of the benefits of treatment to the physician and the patient, in which physicians are induced by contracts with insurers to be sensitive to costs. In the Ma–Riordan model, a physician’s payment involves not only a fee, S , for a diagnosis but also a bonus, B , if the diagnosed patient does not receive treatment. The collective decision as to treatment between the doctor and the patient provides a threshold L that maximizes the physician’s expected payment minus the patient’s loss from illness (multiplied by a weight representing patient bargaining power). The constraints on the solution are that the expected costs to the insurance company are covered and the physician must find the relationship profitable. The managed care relationship, when the patient’s bargaining power is high, expands the set of feasible treatments relative to the Ma–Riordan model outlined above. The optimal contract contains both a positive copayment by the consumer and a positive bonus for not treating on the part of the physician. As Ma and Riordan express it, the optimal arrangement involves both demand-side and supply-side management. In some cases in the Ma–Riordan model, the first-best treatment is possible. The point is not that first-best efficiency is possible in the real world but rather that supply-side management is vital in contractual responses to ex post moral hazard.

¹⁷As Arrow (1963, p. 960) explained:

By certifying to the necessity of given treatment or the lack thereof, the physician acts as a controlling agent on behalf of the insurance companies. Needless to say, it is a far from perfect check; the physicians themselves are not under any control and it may be convenient for them or pleasing to their patients to prescribe more expensive medication, private nurses, more frequent treatments, and other marginal variations of care.

9.5 Dynamics of Insurance Contracts Under Moral Hazard

9.5.1 Introduction

We have, to this point, analyzed moral hazard within static models. In reality, insurance contracts can be long term. Long-term insurance contracts often involve experience-based premiums, i.e., premiums that depend on an individual's accident history. Even where insurance contracts are short term, market dynamics may matter because experience in past insurance contracts can affect the optimal contracting. Automobile insurance policies, for example, often involve discounts for drivers with safe driving records.

Introducing dynamics into the theory of moral hazard raises a number of important questions. Perhaps the most basic of these for our purposes is whether multiperiod contracts have any role at all in responding to moral hazard. In a setting where care is noncontractible, is there an advantage to multiperiod term contracts over the plan of entering a sequence of one-period contracts? In other words, can the reality of long-term contracts be explained as an optimal contracting response to moral hazard?

The dynamics of contracting under moral hazard are complex. Optimal insurance coverage in long-term contracting under moral hazard cannot be divorced from an individual's decisions on saving or borrowing. At a general level, this is not surprising. Consumption smoothing over states of the world through insurance is clearly linked to consumption smoothing over time, through savings and borrowing. If an individual had to consume earnings each period, income smoothing over time would be eliminated. The optimal sequence of short-term contracts would be unaffected by dynamics in the sense that finite repetition of the problem would have no impact on the optimal contract. On the other hand, if an insurer has better access to capital markets than individuals, long-term contracts play a role of smoothing consumption over states and over time simultaneously. The optimal long-term contracting problem then confounds optimal insurance with optimal savings through the insurance company.

In order to focus on the pure insurance motives for contracting, as opposed to savings through insurance, I initially set aside the differential access to capital markets by assuming that the individual and the insurer can borrow or invest at the same interest rate. Even from a pure insurance perspective, however, long-term contracts might appear to offer greater contractual flexibility in responding to moral hazard. Experience-based premiums, for example, might appear to be an additional instrument that the contract can rely upon to elicit stronger incentives. If the event of an accident leads not only to losses to the individual because of partial coverage or coinsurance but also to higher future premiums, then the incentives to avoid accidents would seem to be stronger. The flexibility offered by long-term contracts in responding to moral hazard with a richer set of contractual parameters would seem to be of value.

This intuition is false. In the simplest setting, the benchmark setting outlined below, long-term contracts contribute nothing to the resolution of moral hazard. The ability to raise future premiums in response to accident occurrence adds nothing to incentives in the optimal contract that cannot be achieved with partial insurance. More precisely, any allocation of wealth across states that can be achieved by long-term contracts in an a competitive market can also be achieved by a sequence of short-term contracts. Long-term contacts and experience-based premiums must be explained by other features of insurance markets such as hidden information. Such contracts cannot be explained by moral hazard alone.

9.5.2 Benchmark Setting

The benchmark in a moral hazard setting is one in which long-term contracts offer no advantage over a sequence of short-term insurance contracts. This setting requires that individual savings (or consumption) decisions be observed by insurers. If savings were not observed, then the individual's future wealth would not be directly observed by an insurer and, as we shall discuss, savings decisions would possibly be random (a mixed strategy). Because risk aversion depends on wealth, the result would be that a hidden information problem is generated endogenously in the second period. The exception to this would be preferences satisfying constant absolute risk aversion, since under these preferences, changes in wealth do not affect the preferences over insurance contracts (Chiappori et al. 1994; Park 2004). I set aside this problem by assuming that savings are observable. I continue to assume, however, that savings are not contractible—focussing attention on conventional insurance contracts that specify simply premiums and payouts.

I set out the equivalence of a long-term contract and a sequence of short-term contracts in a two-period model within the simple setting. Consider an individual facing the risk of a loss L (an “accident”) in each of the two periods. The probability of the loss in either period if no care is taken is p_0 , and we can measure the care that the individual takes to avoid the accident in either period as the reduction in this probability. Denoting care in period t by a_t , the probability of an accident in period t is $p_t = p_0 - a_t$. The individual's initial wealth at the beginning of period 1 is w . (To save on notation, the individual receives no income in either period.) I treat care as involving a pecuniary cost, for simplicity, although nothing depends upon this assumption: the cost of care a in any period is function $g(a)$ that is increasing and convex with $g'(0) = 0$ and $g'(a)$ unbounded on the interval $[0, p_0]$. The individual can save or borrow at an interest rate r . Finally, the individual faces a competitive insurance market that is willing to offer any insurance policy (we consider one-period contracts and then two-period contracts) that returns zero expected present value of profit, with second-period profits discounted at the same rate r . That is, in the benchmark case, the individual has access to the same capital market as the insurance market.

Short-Term Contracts: When the individual has access only to short-term insurance contracts, the timing of the game is as follows: In each period t , the individual first chooses an insurance contract $[R_t, I_t]$, which requires an immediate payment of R_t in return for insurance coverage of I_t in the event of an accident. The individual then chooses care a_t ; nature chooses between an accident or no accident with probabilities $(p_0 - a_t)$ and $1 - (p_0 - a_t)$, and the individual's net loss in the period is then $-R_t - g(a_t) - L + I_t$. The initial wealth minus the first-period loss can be saved at an interest rate r for consumption in the second period.

In this simple model, the individual's choice over insurance contracts will give rise to a consumption allocation, which is a vector of consumption in the six time-events: $\mathbf{c} = \{c_n^1, c_a^1; c_{nn}^2, c_{an}^2, c_{na}^2, c_{aa}^2\} \in R_+^6$. (The superscript on each element of this vector denotes the time period; the subscript denotes the history of accidents.) The individual's preferences over consumption are represented by the utility $u(c^1) + \delta u(c^2)$, where δ is a discount factor.

A consumption allocation \mathbf{c} is *feasible under short-term contracting* if there exists a contracting plan, $\{(R_1, I_1, a_1), (R_a, I_a, a_a), (R_n, I_n, a_n)\}$ (here subscripts a and n denote plans for second-period contracts given the history of loss realization in period 1) and a savings plan (s_a, s_n) satisfying four sets of constraints:

1. The plan implements \mathbf{c} in the sense that if the plan is followed, the resulting consumption allocation is \mathbf{c} .
2. Participation constraints or nonnegative expected profit constraints.
3. Incentive compatibility constraints on a_n and a_a and sequential rationality of a_1, s_a , and s_n .
4. Sequential rationality in the choice of the second-period contracts in the plan.

Long-Term Contract: Under a long-term contract $[(R_1, I_1, a_1), (R_a, I_a, a_a), (R_n, I_n, a_n)]$, all of the contractual payments (premiums and payouts) are committed to at the beginning of the first period. A consumption plan c is feasible under a long-term contract if an analogous set of constraints is satisfied—but now the nonnegative profit constraint is on the present value of payments and receipts embedded in the long-run contract.

Since the long-term contract involves a weaker set of constraints than the short-term contract, it follows that any consumption allocation feasible under short-term contracts is feasible under a long-term contract. The long-term contract can simply duplicate a plan of short-term insurance contracts. The converse is also true in this setting: It is straightforward to show that the optimal consumption pattern under a long-term contract can be implemented with a sequence of short-term contracts and a sequentially optimal savings plan.¹⁸ Intuitively, a long-term contract can offer no additional gains in expected discounted utility because insurers cannot offer a transfer of wealth across time that at better terms than those available to the individual. The result of irrelevance of multiperiod contracts in the simplest insurance context, in which wealth is observed at the beginning of the second period, is an example of the more general irrelevance of long-term contracts in principal–agent models under particular conditions. (See, for example, [Malcomson and Spinnewyn 1988](#); [Salanié 2005](#) reviews these conditions.)

9.5.3 Departures from the Benchmark

Against this benchmark, we can set out several factors—departures from the assumptions of the benchmark—that give rise to gains from long-term contracting. The first departure is to allow for a difference between the interest rate available to consumers and the interest rate available to insurers. If insurers have superior access to capital markets, then a long-term contract is of course preferred, since the contract can provide both gains from insurance and gains from the better interest rate. [Rogerson \(1985a,b\)](#) analyzes the repeated moral hazard problem under the assumption that the principal has access to capital markets and the agent has no access to capital markets. The optimal contract, in this case, involves spreading the impact of a shock to wealth across future periods. The outcome for the agent thus depends on the outcomes in past periods, a property referred to by Rogerson as the *memory effect*. In our context of insurance, the memory effect would be manifest in higher premiums as a consequence of losses in past periods. That is, the prediction is a long-term contract with experience-based premiums. But the role of experience-based premiums is solely to spread the impact of a loss (which must be borne partly by the insured individual in a model with moral hazard) across time. The experience-based premium is not motivated by the enhancement of incentives. [Rey and Salanié \(1990\)](#) show that the long-term contract with full commitment can be implemented with a series of two-period contracts.

Moving from theory to reality, the superior access to capital markets by insurers is an important basis for long-term contracts in life insurance. Whole life insurance, commonly described as combining insurance and savings, exists in part because of a tax arbitrage: individual savings or

¹⁸For brevity, I omit the detailed development of the model and the proof of this statement. The intuition is clear: the optimality conditions for a long-term contract can be reduced to two sets of conditions: (1) a Borch condition on the optimal smoothing of consumption across states in each time period and (2) an optimal smoothing condition over time on the realized consumption in period 1 and the conditionally expected consumption in period 2. A sequence of short-run insurance contracts meets the first condition. The second condition is met by the individual's optimal savings decision when the individual faces the same interest rate as the insurer.

investment is taxed whereas the tax rate on life insurance companies is very low. Life insurance is recognized as a legitimate tax shelter.¹⁹

The second departure from our benchmark is to allow for hidden information at the outset of the multiperiod game. We have, throughout this chapter, assumed away hidden information about individuals' risk types in order to focus on hidden action. That is, we have focussed on moral hazard issues rather than adverse selection. A substantial literature, reviewed in the chapter by Dionne, Doherty, and Fombaron in this handbook, analyzes the contractual response to hidden information on risk types. Dynamics are a key part of hidden information insurance models. An individual's choice of insurance in a sequence of short-term contracts, for example, will be influenced by the inference that future insurers draw from the contract choice about the individuals' risk type. Commitments made in long-term contracts can mitigate the resulting distortions.

The third departure from the benchmark model concerns again the interaction of savings and insurance. We assumed in our benchmark model that under the strategy of short-term contracting, the insurers had full information in every period on the agent's wealth. Only the agent's effort in each period was not observable. If, however, the individual's savings decision is not observable by the insurance company then we have to consider two possibilities: (1) the agent's savings under the optimal long-term contract is nonrandom (i.e., a pure strategy) or (2) the agent's savings and therefore second-period wealth is random, even conditioning upon the first-period accident outcome. Chiappori et al. (1994) offer a surprising result: *Any optimal contract associated with nonrandom savings decisions cannot implement any effort level above the minimum effort level.* Any higher effort level in the second period requires that a second-period incentive compatibility constraint on a_i^2 (in the notation of our model above) be binding. This means that the agent's utility from the second-period effort level implemented by the contract must be the same as the utility level that the agent could achieve under the contract with another effort level a' . But with savings unobservable, an ex ante incentive compatibility constraint imposes a constraint on the agent's savings decision, s_i , at the end of the first period. An optimal savings decision conditional upon an effort level a' planned for the second period would increase utility for the agent beyond what is determined by the contract. In other words, the ex post incentive compatibility constraint on a_i^2 is incompatible with the ex ante incentive compatibility constraint on s_i . This result requires only that optimal savings depend upon the effort planned for the second period. If the costs of effort are pecuniary (as in our model) and the agent's utility exhibits constant absolute risk aversion this condition will fail. Apart from the case of CARA utility, in short, the optimal contract will involve random savings when savings cannot be observed. Hidden information arises endogenously in the second-period choice of insurance coverage.

9.6 Conclusion: Additional Topics in Insurance Contracts Under Moral Hazard

9.6.1 Summary

This chapter outlines the theory of optimal insurance contracts under the condition that the individual's effort to avoid accidents cannot be contracted (ex ante moral hazard) as well as the case when an individual's expenditures on insured items such as medical care cannot be contracted (ex post

¹⁹Note that the tax-shelter aspects of life insurance are somewhat constrained, at least in the USA, to prevent the avoidance of inheritance tax. In flexible-premium policies, large deposits of premium could cause the contract to be considered a "modified endowment contract" by the Internal Revenue Service (IRS), which would involve a tax liability, negating many of the tax advantages associated with life insurance.

moral hazard). At a general level, the design of an optimal insurance contract is an exercise in solving the principal–agent problem. But the context of insurance provides enough structure to allow predictions on the form of optimal insurance contracts. The main predictions of the ex ante model are easily summarized. Moral hazard reduces the insurance coverage that an optimal contract offers, although moral hazard does not eliminate the gains from insurance altogether. Some coverage remains optimal. The reduction in coverage can take the form of a deductible or coinsurance, and under standard assumptions the amount of losses left uninsured is nondecreasing in the size of the loss.

The same general principles extend to the characterization of optimal coverage under ex post moral hazard. The greater the level of risk aversion, the greater the insurance coverage of marginal expenditures in the ex post moral hazard model. And the higher the elasticity of demand for items covered by insurance, the lower the extent of insurance coverage.

The introduction of dynamics to the moral hazard model highlights the interplay of the spreading of risks across states via insurance with the spreading of income over time with capital markets. Where individual savings are observable (and therefore wealth levels are observable at the time that insurance contracts are struck)—and if insurers have no better access to capital markets (a higher interest rate) than do consumers—long term contracts offer no gains compared to the adoption of short-term insurance contracts. Moral hazard alone is not associated with the efficiency of long-term contracts with experience-based premiums. Long-term contracts are more efficient than a sequence of short-term insurance contracts if the insurer has superior access to credit. Such long-term contracts allow the spreading of losses over time, not just across states. Hidden information, set aside in this chapter, is another basis for long-term contracts, as well as for experience-based premiums. Contracts in which savings decisions are not observable generate endogenous hidden information, even when the characteristics of individuals are common knowledge at the outset of the contract: individual savings decisions are a mixed strategy in equilibrium with the consequence of uncertain preferences in later periods. Constant absolute risk-aversion utility is the exception, since wealth does not affect preferences over risk for these preferences.

9.6.2 *Additional Issues in Optimal Insurance Under Moral Hazard*

Multidimensional Effort: A number of important extensions to the theory of moral hazard have not been covered here. Investment in care to avoid accidents is in reality multidimensional. An individual insuring household belongings against theft can take care in locking the doors and windows, in leaving lights on when she is away, in buying deadbolt locks for the doors, in purchasing an alarm system, and so on. Some dimensions of care can be observed and contracted for more easily than others. The implications for optimal insurance contracts of this fact are worth exploring in depth, as an application of the Holmstrom–Milgrom (1991) model of multitask agency.

Nonexclusive Insurance: Arnott and Stiglitz (1988a; 1988b), Bisin and Guaitoli (2004), and Attar and Chassagnon (2009) have examined moral hazard under the assumption that the price of insurance is uniform in the amount of insurance obtained from a competitive market. That is, each supplier of insurance has no control over the amount of coverage an individual purchases from other insurers. Since in reality insurers can and do contractually restrict payments when coverage is obtained through other policies, this is better interpreted as fraud rather than conventional moral hazard. Optimal insurance under a nonexclusivity restraint and insurance fraud more generally are important areas beyond the treatment of moral hazard that we have offered.

Third-Party Externalities, e.g., in Liability Insurance: I have set aside in this review the possibility of externalities to parties outside the insurance contract. The most important example of this type of externality is in the case of liability insurance. If a potential tortfeasor has limited wealth (either limited personal wealth or, in the case of the individual as corporation, limited corporate wealth), the individual's preferences will be distorted by the protection offered by limited liability even prior to insurance against liability. And if the insurance company has some ability to contract for care and monitor care, even if this is imperfect, then insurance can in this case *improve* incentives. And the victim of the tort for which liability is insured then benefits. This is part of the basis for mandatory liability insurance in some situations. On the other hand, if the individual's wealth is not constrained and the optimal insurance contract looks like the contracts examined in this chapter, then insurance will diminish incentives to the detriment of the victim. The interactions of liability rule and insurance are analyzed in the superb book by [Shavell \(2007\)](#).

Moral Hazard on the Supply Side of Insurance Markets: Moral hazard as we have noted is a problem of contracts in general, not just on the demand side of insurance contracts. Indeed, as the events of the financial crisis of 2008 revealed, the more important moral hazard problem in the insurance market has in recent times been on the *supply* side of insurance contracts. An insurance contract is a financial contract under which an insurer accepts the financial liability of future insurance payments in exchange for a premium payment today. When the insurer has limited liability, the insurer may have the incentive to invest excessively in risky activities because the insurer does not bear the full downside risk of those activities: in the event of bankruptcy, insured individuals do not receive payment specified in the insurance contracts, or if they do receive coverage, it may be from a government insurance guaranty fund. In either case, distortionary incentives for the insurer to enter risky activities result from the downside protection of limited liability. This is exactly parallel to the risk-shifting problem in the presence of debt, recognized in finance since [Jensen and Meckling \(1976\)](#) and [Myers \(1977\)](#). Insurance regulation has long recognized the incentive distortion in asset allocation decisions on the part of insurers, in constraints of the amounts that insurers can invest in risky assets. The actions of AIG, the largest insurer in the USA, specifically the issuance of credit default swaps were central to the financial crisis. The decision of AIG to issue large amounts of these risky liabilities shows that the incentive distortion caused by supplier moral hazard is as important in decisions related to the liability side of the balance sheet as in decisions related to the asset side.

Appendix

This appendix establishes uniqueness of a solution in a and r to the two constraints on the optimal insurance contract in the ex ante model, the zero-profit condition (3) and the agent's first-order condition:

$$\int I(x) f(x, a[I(x)]) dx - r[I(x)] = 0 \quad (9.27)$$

$$\int u(w - r[I(x)] - x + I(x)) f_a(x; a[I(x)]) dx = v'(a[I(x)]) \quad (9.28)$$

Proposition. The solutions in a and r , to (9.27) and (9.28), $a[I(x)]$ and $r[I(x)]$, are unique within a neighborhood of the optimal $I^*(x)$.

Proof. We proceed by showing that the solutions are unique at the optimal $I^*(x)$; the proof for a neighborhood about the optimal $I^*(x)$ follows directly. Suppose $I^*(x)$ is the optimal coverage policy.

Given $I^*(x)$, rearrange the two equations and define $M(r, a)$ and $N(r, a)$ as

$$M(r, a) = \int u(w - r - x + I^*(x)) f_a(x; a) dx - v'(a)$$

$$N(r, a) = r - \int I^*(x) f(x, a) dx$$

Each equation, $M(r, a) = 0$ and $N(r, a) = 0$, defines a curve in (r, a) space. Taking total derivative for both $M(r, a)$ and $N(r, a)$, we can get the slope of both curves in (r, a) space:

$$r'_M(a) = \frac{\int u f_{aa} dx - v_{aa}}{\int u' f_a dx}$$

$$r'_N(a) = \int I^*(x) f_a dx$$

Note that r'_N is the marginal change of coverage payment. This term is nonpositive for optimal contract; otherwise, holding other elements of the contract constant, the insurance company could ask the agent to reduce effort by a small amount, which would reduce the expected coverage paid by insurance company. This change would have only a second-order effect on agent's utility since effort is chosen optimally but a first-order positive effect on the insurance company's profit. This contradicts the optimality of $I^*(x)$, showing that r'_M is nonpositive.

The numerator of r'_M , $\int u f_{aa} dx - v_{aa}$, is the second-order condition for the agent's maximization problem and hence is negative. The denominator is negative for optimal contract. We have shown that $x - I(x)$ is a nondecreasing function of x . Therefore, $u'(w - r - x - I(x))$ is a nondecreasing function of x too. Since $\int f_a dx = \int \frac{f_a}{f} f dx = E[\frac{f_a}{f}] = 0$ and $\frac{f_a}{f}$ is nonincreasing by the MLRP we have:

$$\int u'(w - r - d(x)) f_a dx = E \left[u' \frac{f_a}{f} \right] = \text{cov} \left(u', \frac{f_a}{f} \right) < 0$$

Therefore, $r'_N \leq 0$, and $r'_M > 0$. Therefore, at most, one intersection of two curves $M(r, a) = 0$ and $N(r, a) = 0$ exists.

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Chapter 10

Adverse Selection in Insurance Contracting

Georges Dionne, Nathalie Fombaron, and Neil Doherty

Abstract In this chapter we present some of the more significant results in the literature on adverse selection in insurance markets. Sections 10.1 and 10.2 introduce the subject and Sect. 10.3 discusses the monopoly model developed by Stiglitz (Rev Econ Stud 44:407–430, 1977) for the case of single-period contracts extended by many authors to the multi-period case. The introduction of multi-period contracts raises many issues that are discussed in detail: time horizon, discounting, commitment of the parties, contract renegotiation, and accidents underreporting. Section 10.4 covers the literature on competitive contracts. The analysis is more complicated because insurance companies must take into account competitive pressures when they set incentive contracts. As pointed out by Rothschild and Stiglitz (Q J Econ 90:629–650, 1976), there is not necessarily a Cournot–Nash equilibrium in the presence of adverse selection. However, market equilibrium can be sustained when principals anticipate competitive reactions to their behavior or when they adopt strategies that differ from the pure Nash strategy. Multi-period contracting is discussed. We show that different predictions on the evolution of insurer profits over time can be obtained from different assumptions concerning the sharing of information between insurers about individual’s choice of contracts and accident experience. The roles of commitment and renegotiation between the parties to the contract are important. Section 10.5 introduces models that consider moral hazard and adverse selection simultaneously and Sect. 10.6 covers adverse selection when people can choose their risk status. Section 10.7 discusses many extensions to the basic models such as risk categorization, multidimensional adverse selection, symmetric imperfect information, reversed or double-sided adverse selection, principals more informed than agents, uberrima fides, and participating contracts.

Keywords Adverse selection • Insurance markets • Monopoly • Competitive contracts • Self-selection mechanisms • Single-period contracts • Multi-period contracts • Commitment • Contract renegotiation • Accident underreporting • Risk categorization • Participating contracts

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10.1 Introduction

In 1996, the European Group of Risk and Insurance Economists used its annual meeting to celebrate the 20th anniversary of the [Rothschild and Stiglitz \(1976\)](#) article “Equilibrium in Competitive Insurance Markets: An Essay in the Economics of Imperfect Information.” At this meeting, many contributions on adverse selection were presented and a subset of these presentations was published in a 1997 issue of the Geneva Papers on Risk and Insurance Theory.

One of these contributions was written by [Rothschild and Stiglitz \(1997\)](#) themselves. Their main topic was the role of competition in insurance markets, with an emphasis on underwriting in a world with imperfect information. They argue that insurance competition using underwriting on preexisting conditions (such as genetic conditions) can limit the welfare benefits of insurance. In this survey, we concentrate on a subset of situations involving imperfect information in the insured–insurer relationship; we analyze situations of standard adverse selection where the insured has more information about his risk than the insurer. However, we will consider extensions where insurers learn on individual characteristics that are not known by the insureds. We will also consider the assumption that risks are endogenous to individuals.

Adverse selection can be a significant resource allocation problem in many markets. In automobile insurance markets, risk classification is mainly explained by adverse selection. In health insurance, different insurance policies or contracts are offered to obtain self-selection between different groups. In life insurance, the screening of new clients with medical exams is an accepted activity justified by asymmetric information between the insurer and the insured. These three resource allocation mechanisms can be complements or substitutes and adverse selection is not always a necessary condition for their presence. For example, in automobile insurance, we observe that insurers use risk classification and different deductible policies. Risk classification is usually justified by adverse selection, but the presence of different deductibles can also be explained by proportional transaction costs with different observable risks and by moral hazard. It is very difficult to verify whether the presence of different deductibles is justified by residual adverse selection or not. Another empirical test would be to verify whether bonus–malus schemes or multi-period contracts with memory are explained in various markets by the presence of moral hazard, by that of adverse selection, or both. We shall not discuss these tests or these mechanisms in detail here; other chapters of this book are concerned with these issues ([Chiappori and Salanié 2014](#); [Dionne 2014](#)). Instead, we will review the major allocation mechanisms that can be justified by the presence of adverse selection. Emphasis will be placed on self-selection mechanisms in one-period contracting because a much of the early literature was devoted to this subject (on risk classification, see [Crocker and Snow 2014](#); [Dionne and Rothschild 2011](#)). We will also discuss some extensions of these basic models; particularly, the role of multi-period contracting will be reviewed in detail. Finally, we will discuss the more recent contributions that focus on the effect of modifying the basic assumptions of the standard models. In particular, we will see how introducing moral hazard in the basic [Rothschild and Stiglitz \(1976\)](#) model affects the conclusions about both the nature and the existence of an equilibrium. We will also introduce moral hazard in the monopoly model. Another subject will be insurance coverage when individuals can choose their risk status. Other extensions concern the consideration of multidimensional adverse selection (introduction of different risk-averse individuals or different privately known initial wealth combined with differences in risk, multiple risks), the case where the insurer is more informed than the insured about loss probabilities (reversed adverse selection and even double-sided adverse selection, imprecise information about accident probabilities), adverse selection and *uberrima fides*, and finally the consideration of participating contracts. This survey should be considered as an update of [Dionne et al. \(2000\)](#).

10.2 Basic Assumptions and Some Fundamental Results

Without asymmetric information and under the standard assumptions of insurance models that we shall use in this chapter (same attitude toward risk and same risk aversion for all individuals in all classes of risk, one source of risk, risk neutrality on the supply side, no transaction cost in the supply of insurance, no learning, and no moral hazard), a Pareto optimal solution is characterized by full insurance coverage for all individuals in each class of risk. Each insured sets his optimal consumption level according to his certain wealth. No other financial institution is required to obtain this level of welfare. Both risk categorization and self-selection mechanisms are redundant. There is no need for multi-period insurance contracts because they are not superior to a sequence of one-period contracts. Finally, the two standard theorems of welfare economics hold and market prices of insurance are equal to the corresponding social opportunity costs.

In insurance markets, adverse selection results from asymmetric information between the insured (agent) and the insurer (principal). The insureds are heterogeneous with respect to their expected loss and have more information than the insurance company which is unable to differentiate between risk types. Naturally, the high-risk individual has no incentive to reveal his true risk which is costly for the insurer to observe. Pooling of risks is often observed in insurance markets. “In fact, however, there is a tendency to equalize rather than to differentiate premiums. . . This constitutes, in effect, a redistribution of income from those with a low propensity of illness to those with a high propensity. . .” (Arrow 1963, p. 964). One major difficulty is that a pooling cannot be a Nash equilibrium.

Akerlof (1970) showed that if all insurers have imperfect information on individual risks, an insurance market may not exist, or if it exists, it may not be efficient. He proposed an explanation of why, for example, people over 65 have great difficulty in buying medical insurance, “the result is that the average medical condition of insurance applicants deteriorates as the price level rises—with the result that no insurance sales may take place at any price” (1970; p. 492). The seminal contributions of Akerlof and Arrow have generated a proliferation of models on adverse selection. In this survey, we shall, however, confine our attention to a limited subset. Many authors have proposed mechanisms to reduce the inefficiency associated with adverse selection, the “self-selection mechanism” in one-period contracts that induces policyholders to reveal hidden information by selection from a menu of contracts (Rothschild and Stiglitz 1976; Stiglitz 1977; Wilson 1977; Miyazaki 1977; Spence 1978; Hellwig 1986), the “categorization of risks” (Hoy 1982; Crocker and Snow 1985; Crocker and Snow 1986, 2014), and “multi-period contracting” (Dionne 1983; Dionne and Lasserre 1985; Dionne and Lasserre 1987; Kunreuther and Pauly 1985; Cooper and Hayes 1987; Hosios and Peters 1989; Nilssen 2000; Dionne and Doherty 1994; Lund and Nilssen 2004). All of them address private market mechanisms. In the first case, insurers offer a menu of policies with different prices and quantity levels so that different risk types choose different insurance policies. Pareto improvements for resource allocation with respect to the single-contract solution with an average premium to all clients can be obtained. In the second case, insurers use imperfect information to categorize risks and, under certain conditions, it is also possible to obtain Pareto improvements for resource allocation. In the third case, insurers use the information related to the past experience of the insured as a sorting device (i.e., to motivate high-risk individuals to reveal their true risk *ex ante*).

Before proceeding with the different models, let us comment briefly on some standard assumptions. We assume that all individuals maximize expected utility. The utility functions of the individuals in each risk group are identical, strictly concave, and satisfy the von Neumann–Morgenstern axioms. Utility is time independent, time additive, and state independent. In many models there is no discounting, but this is not a crucial issue. Individuals start each period with a given wealth, W , which is nonrandom. To avoid problems of bankruptcy, the value of the risky asset is lower than W .

All risks in the individual's portfolio are assumed to be insurable. Income received in a given period is consumed in that period; in other words, there is no saving and no banking or lending. Insurers are risk neutral and maximize the value of their cash flows or profits. Insurers write exclusive insurance contracts and there are no transaction costs in the supply of insurance. Finally, the insureds are assumed to be unable to influence either the probabilities of accident or the damages due to accidents; this rules out any problem of moral hazard [Arnott \(1992\)](#), [Eeckhoudt and Kimball \(1992\)](#).

To simplify the presentation we explicitly assume that insurers are risk neutral. An equivalent assumption is that insurers are well diversified in the sense that much of their total risk is diversified by their own equity holders in the management of their personal portfolios. The presence of transaction costs would not affect the qualitative conclusions concerning the effects of adverse selection on resource allocation in insurance markets (see [Dionne et al. 1999](#), for more details). However, proportional transaction costs (or proportional loadings) are sufficient to explain partial insurance coverage and their explicit introduction in the analysis would modify some conclusions in the reference models. For example, each individual in each class of risk would buy less than full insurance in the presence of full information and the introduction of adverse selection will further decrease the optimal coverage for the low-risk individuals. Consequently the presence of adverse selection is not a necessary condition to obtain different deductibles in insurance markets.

The presence of many sources of non-insurable risks or of many risky assets in individual portfolios is another empirical fact that is not considered in the models. As long as these risks are independent, the conclusions should not be affected significantly. However, the optimal portfolio and insurance decisions in the presence of many correlated risks and asymmetric information in one or in many markets are still open questions in the literature.

In reality, we observe that banks coexist with insurers that offer multi-period insurance contracts. The presence of saving and banking may change the conclusions obtained for multi-period contracts under asymmetric information. Particularly, it may modify accident reporting strategies and commitment to the contracts. However, with few exceptions ([Allen 1985](#), moral hazard; [Dionne and Lasserre 1987](#), adverse selection; [Fudenberg et al. 1986](#), moral hazard; [Caillaud et al. 2000](#), insurance and debt with moral hazard), research on principal–agent relationships has not envisaged the simultaneous presence of several alternative types of assets and institutions (see [Chiappori et al. 1994](#), for detailed discussion of different issues related to the effect of savings on the optimality of multi-period contracts).

The assumption of exclusive insurance contracting is discussed in Sect. 10.4 and some aspects of the discounting issues are discussed in Sect. 10.3. There remain the assumptions on the utility function. Although the theory of decision making under uncertainty has been challenged since its formal introduction by von Neumann and Morgenstern ([Machina 1987, 2014](#)), it has produced very useful analytical tools for the study of optimal contracts, such as optimal insurance coverage and the associated comparative statics, and the design of optimal contracts under moral hazard or the characterization of optimal insurance policies under adverse selection. In fact, few contributions use nonlinear models in insurance literature (see however [Karni 1992](#); [Gollier 2014](#); [Machina 2014](#); [Doherty and Eeckhoudt 1995](#)) and very few of these have addressed the adverse selection problem. In this survey we thus limit the discussion to the linear expected utility model. We also assume that utility functions are not function of the states of the world and that all individuals in all classes of risks have the same level of risk aversion. As we will see, some of these assumptions are not necessary to get the desired results but permit the discussion to focus on differences in the risk types.

10.3 Monopoly

10.3.1 Public Information

There are two possible states of the world ($x \in \{n, a\}$): state (n), “no accident” having the probability $(1 - p_i)$, and state (a), “accident” having the probability $0 < p_i < 1$. Consumers differ only by their probability of accident. For simplicity, there are two types of risk in the economy ($i \in \{H, L\}$ for high and low risk) with $p_H > p_L$. Each consumer owns a risky asset with monetary value $D(x)$; $D(a) = 0$ in state (a) and $D(n) = D$ in state (n). Therefore the expected loss for a consumer of type i ($E_i D(x)$) is $p_i D$.

Under public information and without transaction cost, a risk neutral private monopoly¹ would offer insurance coverage (net of premium) (β_i) for an insurance premium (α_i) such that a consumer will be indifferent between purchasing the policy and having no insurance (Stiglitz 1977). In other words, the private monopolist maximizes his total profit over α_i , β_i , and λ_i :

Problem 1.

$$\text{Max}_{\alpha_i, \beta_i, \lambda_i} \sum q_i ((1 - p_i) \alpha_i - p_i \beta_i) \quad (10.1)$$

under the individual rationality (or participating) constraints²

$$V(C_i | p_i) - V(C^0 | p_i) \geq 0 \quad i = H, L \quad (10.2)$$

where $V(C_i | p_i)$ is the expected utility under the contract $C_i = \{\alpha_i, \beta_i\}$;

$$V(C_i | p_i) = p_i U(W - D + \beta_i) + (1 - p_i) U(W - \alpha_i)$$

$U(\cdot)$ is a twice differentiable, strictly increasing, and strictly concave function of final wealth ($U'(\cdot) > 0, U''(\cdot) < 0$)

W is nonrandom initial wealth

C^0 denotes no insurance; $C^0 = \{0, 0\}$

$V(C^0 | p_i) \equiv p_i U(W - D) + (1 - p_i) U(W)$; $V(C^0 | p_i)$ is the reservation utility

q_i is the number of policies sold to consumers of type i

λ_i is a Lagrangian multiplier for constraint (10.2)

It is well known that full insurance, $\beta_i^* = D - \alpha_i^*$ (for $i = H, L$), is the solution to the above problem and that (10.2) is binding for both classes of risk, which means that

$$V(C_i^* | p_i) = V(C^0 | p_i) \quad i = H, L$$

or

$$\alpha_i^* = p_i D + z_i^*,$$

¹For an analysis of several reasons why a monopoly behavior in insurance markets should be considered, see Dahlby (1987). For examples of markets with a monopoly insurer see D'Arcy and Doherty (1990) and Dionne and Vanasse (1992).

²For a detailed analysis of participation constraints, see Jullien (2000).

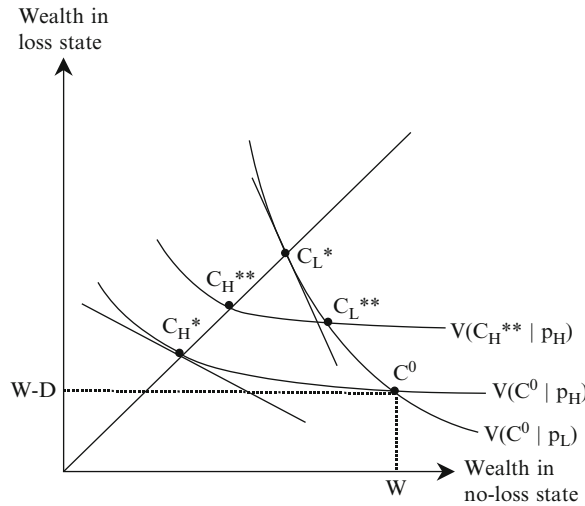


Fig. 10.1 Monopoly model

where z_i^* is the maximum unit profit (or the Arrow–Pratt risk premium) on each policy. In other words z_i^* solves $U(W - p_i D - z_i^*) = p_i U(W - D) + (1 - p_i)U(W)$.

The private monopoly extracts the entire consumer surplus. However, there is no efficiency cost associated with the presence of a monopoly because each individual buys full insurance as under perfect competition.³ This is the classical result that Pareto-efficient risk sharing between a risk-averse agent and a risk-neutral principal shifts all the risk to the principal. To sum up we can write:

Proposition 1. *In the presence of public information about insureds’ underlying risk, an optimal contract between a private monopolist and any individual of type i is characterized by:*

- a) Full insurance coverage, $\beta_i^* = D - \alpha_i^*$
- b) No consumer surplus, $V(C_i^* | p_i) = V(C^0 | p_i)$

Both solutions are shown at C_H^* and C_L^* in Fig. 10.1 where C^0 is the “initial endowment” situation and where the vertical axis is wealth in the accident or loss state and the horizontal axis is wealth in the no-loss state.

Any point to the northwest of C^0 and below or on the 45° line represents the wealth of the insured with any contract where $\alpha_i \geq 0$ and $\beta_i \geq 0$. Because the monopoly solution implies no consumer surplus, it must lie on each risk-type indifference curve passing through C^0 . These indifference curves are strictly convex because $U(\cdot)$ is strictly concave by assumption.⁴

³As in the perfect discrimination case, the monopolist charges a price of insurance to each consumer equal to marginal cost. All potential consumer surplus is collected as monopoly profits, so there is no dead weight loss. This result would not be obtained with a proportional loading.

⁴Since individuals of different types have the same degree of risk aversion, at each point in the figure, the absolute value of the slope of the high-risk indifference curve is lower than that of the low-risk individual. For example, at point C^0 , $U'(W)(1 - p_H)/U'(W - D)p_H < U'(W)(1 - p_L)/U'(W - D)p_L$. At equilibrium points C_H^* and C_L^* , the respective slopes (in absolute values) are $(1 - p_H)/p_H$ and $(1 - p_L)/p_L$. This is true because under full insurance, the insured of type i has $W - p_i D - z_i^*$ in each state.

10.3.2 Private Information and Single-Period Contracts

Under private information the insurer does not observe the individual's risk types⁵ and must introduce mechanisms to ensure that agents will reveal this characteristic. Stiglitz (1977) extended the Rothschild–Stiglitz (1976) model to the monopoly case. In both contributions, price–quantity contracts⁶ permit the separation of risks by introducing incentives for individuals to reveal their type. Low-risk individuals reveal their identity by purchasing a policy that offers limited coverage at a low unit price. Thus they trade off insurance protection to signal their identity. Formally, risk revelation is obtained by adding two self-selection constraints to Problem 1:

$$V(C_i | p_i) - V(C_j | p_i) \geq 0 \quad \begin{array}{l} i, j = H, L \\ i \neq j \end{array} \quad (10.3)$$

Equation (10.3) guarantees that individual i prefers C_i to C_j . Let us use λ_{HL} and λ_{LH} for the corresponding Lagrangian multipliers where λ_{HL} is for the self-selection constraint of the H -type risk and λ_{LH} is that for the L type. λ_{HL} and λ_{LH} cannot both be positive.⁷ From Fig. 10.1 it is easy to observe that if the high-risk individuals are indifferent between both contracts ($\lambda_{HL} > 0$), the low-risk individuals will strictly prefer their own contracts ($\lambda_{LH} = 0$). Moreover, λ_{LH} cannot be positive when λ_{HL} is zero because this leads to a violation of (10.2). Therefore, a feasible solution can be obtained only when $\lambda_{HL} > 0$ and $\lambda_{LH} = 0$.

Figure 10.1 shows the solution to the maximization of (10.1) subject to (10.2) and (10.3) where low-risk individuals choose a positive quantity of insurance⁸ $\beta_L^{**} > 0$ and high-risk individuals buy full insurance coverage ($\beta_H^{**} = \beta_H^*$). Separation of risks and profit maximization imply that $V(C_H^{**} | p_H) = V(C_L^{**} | p_H)$. As discussed above, it is clear that (10.2) and (10.3) cannot both be binding for the high-risk individuals when it is possible for the low risks to buy insurance. In fact, Fig. 10.1 indicates that C_H^{**} is strictly preferred to C_H^* which means that high-risk individuals get some consumer surplus when the monopolist sells insurance to the low-risk individuals. In other words, the participation constraint (10.2) is not binding for the H individuals ($\lambda_H = 0$).

Another property of the solution is that good-risk individuals do not receive any consumer surplus ($\lambda_L > 0$). However, as discussed above, they strictly prefer their contract to the contract offered to the bad-risk individuals. In other words

$$V(C_L^{**} | p_L) = V(C^0 | p_L) \quad \text{and} \quad V(C_L^{**} | p_L) > V(C_H^{**} | p_L),$$

which means that the self-selection constraint is not binding for the low-risk individuals unlike the participation constraint.

⁵For models where neither the insurer nor the insured knows the individuals' probabilities of accident, see Boyer et al. (1989); De Garidel (2005); Malueg (1988); Palfrey and Spatt (1985).

⁶We limit our discussion to private market mechanisms. On public provision of insurance and adverse selection, see Pauly (1974) and Dahlby (1981).

⁷Technically the preference structure of the model implies that indifference curves of individuals with different risks cross only once. This single-crossing property has been used often in the sorting literature (Cooper 1984).

⁸There is always a separating equilibrium in the monopoly case. However, the good-risk individuals may not have any insurance coverage at the equilibrium. Property 4 in Stiglitz (1977) establishes that $C_L^{**} = \{0, 0\}$ when q_H/q_L exceeds a critical ratio of high- to low-risk individuals where q_i is the proportion of individuals i in the economy. The magnitude of the critical ratio is function of the difference in accident probabilities and of the size of the damage. Here, to have $C_L^{**} \neq \{0, 0\}$, we assume that q_H/q_L is below the critical ratio.

In conclusion, one-period contracts with a self-selection mechanism increase the monopoly profits under private information compared with a single contract without any revelation mechanism, but do not necessarily correspond to the best risk allocation arrangement under asymmetric information. In particular, good-risk individuals may not be able to buy any insurance coverage, or, if they can, they are restricted to partial insurance. As we shall see in the next section, multi-period contracts can be used to relax the binding constraints and to improve resource allocation under asymmetric information. In summary

Proposition 2. *In the presence of private information, an optimal one-period contract menu between a private monopoly and individuals of types H and L has the following characteristics:*

- a) $\beta_H^{**} = D - \alpha_H^{**}; \beta_L^{**} < D - \alpha_L^{**}$
- b) $V(C_H^{**} | p_H) > V(C^0 | p_H); V(C_L^{**} | p_L) = V(C^0 | p_L)$
- c) $V(C_H^{**} | p_H) = V(C_L^{**} | p_H); V(C_L^{**} | p_L) > V(C_H^{**} | p_L)$

Proof. See [Stiglitz \(1977\)](#). ■

[Stiglitz \(1977\)](#) also considered a continuum of agent types and showed that some of the above results can be obtained under additional conditions. However, in general, the presence of a continuum of agent types affects the results.⁹

10.3.3 Multi-period Insurance Contracts

Multi-period contracts are often observed in different markets. For example, in many countries, drivers buy automobile insurance with the same insurer for many years and insurers use bonus–malus systems (or experience rating) to relate insurance premiums to the individual’s past experience ([Lemaire 1985](#); [Henriet and Rochet 1986](#); [Hey 1985](#); [Dionne and Vanasse 1989](#); [1992](#); [Dionne et al. 2013](#)). Long-term contracting is also observed in labor markets, workers’ compensation insurance, service contracts, unemployment insurance, and many other markets. The introduction of multi-period contracts in the analysis gives rise to many issues such as time horizon, discounting, commitment of the parties, myopic behavior, accident underreporting, and contract renegotiation. These issues are discussed in the following paragraphs.

Multi-period contracts are set not only to adjust ex post insurance premiums or insurance coverage to past experience but also as a sorting device. They can be a complement or a substitute to standard self-selection mechanisms. However, in the presence of full commitment, ex ante risk announcement or risk revelation remains necessary to obtain optimal contracts under adverse selection.

In [Cooper and Hayes \(1987\)](#), multi-period contracts are presented as a complement to one-period self-selection constraints. Because imperfect information reduces the monopolist’s profits, the latter has an incentive to relax the remaining binding constraints by introducing contracts based on anticipated experience over time. By using price–quantity contracts and full commitment in long-term contracts, Cooper and Hayes introduce a second instrument to induce self-selection and increase monopoly profits: experience rating increases the cost to high risks from masquerading as low risks by exposing them to second-period contingent coverages and premia.

Cooper and Hayes’ model opens with a direct extension of the standard one-period contract presented above to a two-period world with full commitment on the terms of the contract. There is no discounting and all agents are able to anticipate the values of the relevant future variables. To increase

⁹In another context, [Riley \(1979a\)](#) shows that a competitive Nash equilibrium never exists in the continuum case (see also [Riley 1985](#)).

profits, the monopolist offers contracts in which premiums and coverages in the second period are function of accident history in the first period. Accidents are public information in their model. The two-period contract C_i^2 is defined by

$$C_i^2 = \{\alpha_i, \beta_i, \alpha_{ia}, \beta_{ia}, \alpha_{in}, \beta_{in}\}$$

where a and n mean “accident” and “no accident” in the first period and where α_{il} and β_{il} ($l = a, n$) are “contingent” choice variables. Conditional on accident experience, the formal problem consists of maximizing two-period expected profits by choosing C_L^2 and C_H^2 under the following constraints:

$$V(C_i^2 | p_i) \geq 2V(C^0 | p_i) \quad (10.4)$$

$$V(C_i^2 | p_i) \geq V(C_j^2 | p_i) \quad i, j = H, L \\ i \neq j \quad (10.5)$$

where

$$V(C_i^2 | p_k) \equiv p_k U(W - D + \beta_i) + (1 - p_k) U(W - \alpha_i) \\ + p_k [p_k U(W - D + \beta_{ia}) + (1 - p_k) U(W - \alpha_{ia})] \\ + (1 - p_k) [p_k U(W - D + \beta_{in}) + (1 - p_k) U(W - \alpha_{in})] \\ k = i, j \quad i, j = H, L \quad i \neq j.$$

The above constraints show that agents are committed to the contracts for the two periods. In other words, the model does not allow the parties to renegotiate the contract at the end of the first period. Moreover, the principal is committed to a loss-related adjustment of the insurance contract in the second period negotiated at the beginning of the first period. The insured is committed, for the second period, to buy the coverage and to pay the premium chosen at the beginning of the first period. It is also interesting to observe from (10.4) and (10.5) that the decisions concerning insurance coverage in each period depend on the anticipated variations in the premiums over time. In other words, (10.4) and (10.5) establish that variations in both premia and coverages in the second period are function of experience in the first period. Using the above model, Cooper and Hayes proved the following result:

Proposition 3. *In the presence of private information and full commitment, the monopoly increases its profits by offering an optimal two-period contract having the following characteristics:*

- 1) *High-risk individuals obtain full insurance coverage in each period and are not experience rated*
 $\widehat{\alpha}_H = \widehat{\alpha}_{Hn} = \widehat{\alpha}_{Ha}, \widehat{\beta}_H = \widehat{\beta}_{Ha} = \widehat{\beta}_{Hn}$
where $\widehat{\beta}_H = D - \widehat{\alpha}_H$
- 2) *Low-risk individuals obtain partial insurance with experience rating*
 $\widehat{\alpha}_{Ln} < \widehat{\alpha}_L < \widehat{\alpha}_{La}, \widehat{\beta}_{La} < \widehat{\beta}_L < \widehat{\beta}_{Ln}$
- 3) *Low-risk individuals do not obtain any consumer surplus, and high-risk individuals are indifferent between the two contracts*

$$V(\widehat{C}_L^2 | p_L) = 2V(C^0 | p_L), \\ V(\widehat{C}_H^2 | p_H) = V(\widehat{C}_L^2 | p_H).$$

Proof. See Cooper and Hayes (1987). ■

The authors also discuss an extension of their two-period model to the case where the length of the contract may be extended to many periods. They show that the same qualitative results as those in Proposition 3 hold with many periods.

Dionne (1983) and Dionne and Lasserre (1985, 1987) also investigated multi-period contracts in the presence of both adverse selection¹⁰ and full commitment by the insurer. Their models differ from that of Cooper and Hayes in many respects. The main differences concern the revelation mechanism, the sorting device, commitment assumptions, and the consideration of statistical information. Moreover, accidents are private information in their models. Unlike Cooper and Hayes, Dionne (1983) did not introduce self-selection constraints to obtain risk revelation. Instead risk revelation results from a Stackelberg game where the insurer offers a contract in which the individual has to select an initial premium by making a risk announcement in the first period. Any agent who claims to be a low risk pays a corresponding low premium as long as his average loss is less than the expected loss given his declaration (plus a statistical margin of error to which we shall return). If that condition is not met, he is offered a penalty premium. Over time, the insurer records the agent’s claims and offers to reinstate the policy at the low premium whenever the claims frequency becomes reasonable again.¹¹

Following Dionne (1983) and Dionne and Lasserre (1985), the no-claims discount strategy consists in offering two full insurance premiums¹² ($F^1 = \{\alpha_H, \alpha_L\}$) in the first period and for $t = 1, 2, \dots$

$$F^{t+1} \begin{cases} = \alpha_d \text{ if } \sum_{s=1}^{N(t)} \theta^s / N(t) < E_d D(x) + \delta_d^{N(t)} \\ = \alpha_k \text{ otherwise} \end{cases}$$

where

α_d is the full information premium corresponding to the declaration (d), $d \in \{H, L\}$

θ^s is the amount of loss in contract period s , $\theta^s \in \{0, D\}$

α_k is a penalty premium. α_k is such that $U(W - \alpha_k) < V(C_0 | p_H)$

$E_d D(x)$ is the expected loss corresponding to the announcement (d)

$\delta_d^{N(t)}$ is the statistical margin of error

$N(t)$ is the total number of periods with insurance; $N(t) \leq t$

Therefore, from the construction of the model, $\sum_{s=1}^{N(t)} \theta^s / N(t)$ is the average loss claimed by the insured in the first $N(t)$ periods. If this number is strictly less than the declared expected loss plus some margin of error, the insurer offers α_d . Otherwise he offers α_k . The statistical margin of error is used to avoid penalizing honest insureds too often. Yet it has to be small enough to detect those who try to increase their utility by announcing a risk class inferior to their true risk. From the Law of the

¹⁰Townsend (1982) discussed multi-period borrowing–lending schemes. However, his mechanism implies a constant transfer in the last period that is incompatible with insurance in the presence of private information.

¹¹This type of “no-claims discount” strategy was first proposed by Radner (1981) and Rubinstein and Yaari (1983) for the problem of moral hazard (see also Malueg 1986 where the “good faith” strategy is employed). However, because the two problems of information differ significantly, the models are not identical. First the information here does not concern the action of the agent (moral hazard) but the type of risk which he represents (adverse selection). Second, because the action of the insured does not affect the random events, the sequence of damage levels is not controlled by the insured. The damage function depends only on the risk type. Third, in the adverse selection model, the insured cannot change his declaration and therefore cannot depart from his initial risk announcement although he can always cancel his contract. Therefore, the stronger conditions used by Radner (1981) (robust epsilon equilibrium) and Rubinstein and Yaari (1983) (“long proof”) are not needed to obtain the desired results in the presence of adverse selection only. The Law of the Iterated logarithm is sufficient.

¹²In fact their formal analysis is with a continuum of risk types.

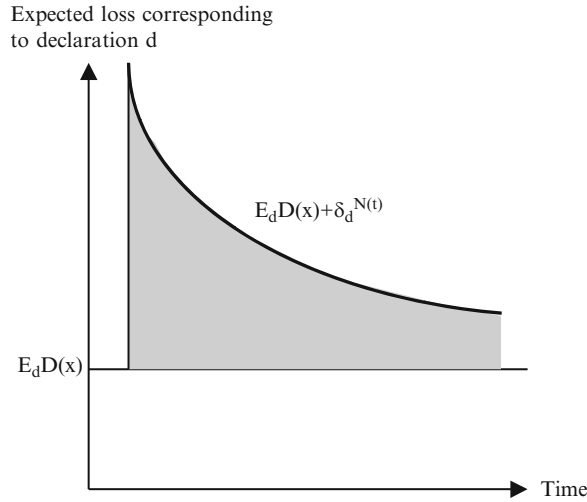


Fig. 10.2 Graphical representation of $E_d D(x) + \delta_d^{N(t)}$

Iterated Logarithm, one can show that

$$\delta_d^{N(t)} = \sqrt{2\gamma\sigma_d^2 \log \log N(t)/N(t)}, \quad \gamma > 1$$

where σ_d^2 is the variance of the individual’s loss corresponding to the declaration (d) and $\delta_d^{N(t)}$ converges to zero over time (with arbitrary large values for $N(t)$).

Graphically, we can represent $E_d D(x) + \delta_d^{N(t)}$ in the following way (Fig. 10.2):

As $N(t) \rightarrow \infty, E_d D(x) + \delta_d^{N(t)} \rightarrow E_d D(x)$.

Over time, only a finite number of points representing $(\Sigma\theta^s/N(t))$ will have a value outside the shaded area.

Proposition 4 below shows that the full information allocation of risks is obtainable using the no-claims discount strategy as $T \rightarrow \infty$ and as long as the agents do not discount the future.¹³

Proposition 4. *Let i be such that*

$$\alpha_i - E_i D(x) \geq 0 \text{ and } U(W - \alpha_i) \geq V(C^0 | p_i).$$

Then, when $T \rightarrow \infty$, there exists a pair of optimal strategies for the individual of type i and the private monopoly having the following properties:

- 1) *The strategy of the monopoly is a “no-claims discount strategy”; the strategy of insured i is to tell the truth about his type in period 1 and to buy insurance in each period.*
- 2) *The optimal corresponding payoffs are $\alpha_i^* - E_i D(x) = z_i^*$ and $U(W - \alpha_i^*) = V(C^0 | p_i)$, $i = H, L$.*
- 3) *Both strategies are enforceable.*

Proof. See [Dionne and Lasserre \(1985\)](#). ■

¹³In general, introducing discounting in repeated games reduces the incentives of telling the truth and introduces inefficiency because players do not care for the future as they care for the current period. In other words, with discounting, players become less patient and cooperation becomes more difficult to obtain. See [Sabourian \(1989\)](#) and [Abreu et al. \(1990\)](#) for detailed discussions of the discount factor issues in repeated contracts.

It is also possible to obtain a solution close to the public information allocation of risks in finite horizon insurance contracts. [Dionne and Lasserre \(1987\)](#) show how a trigger strategy with revisions¹⁴ may establish the existence of an ε equilibrium. This concept of ε equilibrium is due to [Radner \(1981\)](#) and was also developed in the moral hazard context. Extending the definition to the adverse selection problem, [Dionne and Lasserre \(1987\)](#) defined an ε equilibrium as a triplet of strategies (principal, low-risk individual, high-risk individual) such that, under these strategies, the expected utility of any one agent is at least equal to his expected utility under public information less epsilon. In fact, the expected utility of the high-risk individual is that of the full information equilibrium.

As for the case of an infinite number of periods,¹⁵ [Dionne and Lasserre \(1987\)](#) showed that it is in the interest of the monopolist (which obtains higher profits) to seek risk revelation by the insured rather than simply use the ex post statistical instrument to discriminate between low-risk and high-risk agents. In other words, their second main result shows that it is optimal to use statistical tools not only to adjust, ex post, insurance premiums according to past experience but also to provide an incentive for the insured to announce, ex ante, the true class of risk he represents. Finally, they conclude that a multi-period contract with announcement dominates a repetition of one-period self-selection mechanisms ([Stiglitz 1977](#)) when the number of periods is sufficiently large and there is no discounting. This result contrasts with those in the economic literature where it is shown that the welfare under full commitment is equal to that corresponding to a repetition of one-period contracts. Here, a multi-period contract introduces a supplementary instrument (experience rating) that increases efficiency ([Dionne and Doherty 1994](#); [Dionne and Fluet 2000](#)).

Another characteristic of [Dionne and Lasserre's \(1987\)](#) model is that low-risk agents do not have complete insurance coverage when the number of periods is finite; they chose not to insure if they are unlucky enough to be considered as high-risk individuals. However, they always choose to be insured in the first period and most of them obtain full insurance in each period. Finally, it must be pointed out that the introduction of a continuum of agent types does not create any difficulty in the sense that full separation of risks is obtained without any additional condition.

In [Dionne \(1983\)](#) and [Dionne and Lasserre \(1985\)](#) there is no incentive for accident underreporting at equilibrium because there is no benefit associated with underreporting. When the true classes of risk are announced, insureds cannot obtain any premium reduction by underreporting accidents. When the number of periods is finite, matters are less simple because each period matters. In some circumstances, the insured has to evaluate the trade-off between increased premiums in the future and no coverage in the present. This is true even when the contract involves full commitment as in [Dionne and Lasserre \(1987\)](#). For example, the unlucky good risk may prefer to receive no insurance coverage during a particular period to pass a trigger date and have the opportunity to pay the full information premium as long as his average loss is less than the reasonable average loss corresponding to his class of risk.

We now address the incentive for policyholders to underreport accidents. The benefits of underreporting can be shown to be nil in a two-period model with full commitment and no statistical

¹⁴Radner's (1981) contribution does not allow for revisions after the initial trigger. However, revisions were always present in infinite horizon models ([Rubinstein and Yaari 1983](#); [Dionne 1983](#); [Radner 1985](#); [Dionne and Lasserre 1985](#)). A trigger strategy without revision consists in offering a premium corresponding to a risk declaration as long as the average loss is less than the reasonable average loss corresponding to the declaration. If that condition is not met, a penalty premium is offered for the remaining number of periods. With revisions, the initial policy can be reinstated.

¹⁵See also [Gal and Landsberger \(1988\)](#) on small sample properties of experience rating insurance contracts in the presence of adverse selection. In their model, all insureds buy the same contracts, and experience is considered in the premium structure only. They show that the monopoly's expected profits are higher if based on contracts that take advantage of longer experience. [Fluet \(1999\)](#) shows how a result similar to [Dionne and Lasserre \(1985\)](#) can be obtained in a one-period contract with fleet of vehicles.

instrument when the contract cannot be renegotiated over time. To see this, let us go back to the two-period model presented earlier (Cooper and Hayes 1987) and assume that accidents are now private information. When there is *ex ante* full commitment by the two parties to the contract one can write a contract where the net benefit to any type of agent from underreporting is zero. High-risk individuals have full insurance and no experience rating at equilibrium and low-risk individuals have the same level of expected utility whatever the accident reporting at the end of the second period. However, private information about accidents reduces insurers' profits compared with the situation where accidents are public information.

In all the preceding discussions it was assumed that the insurer can precommit to the contract over time. It was shown that an optimal contract under full commitment can be interpreted as a single transaction where the incentive constraints are modified to improve insurance possibilities for the low-risk individuals and to increase profits. Because there is full commitment and no renegotiation, accident histories are uninformative on the risk type. This form of commitment is optimal in Dionne (1983) and Dionne and Lasserre (1985): as in the Arrow–Debreu world, neither party to the contract can gain from renegotiation. However, in a finite horizon world, the role of renegotiation becomes important because self-selection in the first period implies that future contracts might be inefficient given the public information available after the initial period. When the good risks have completely revealed their type, it becomes advantageous to both parties—the insurer and the low-risk individuals—to renegotiate a full insurance contract for the second period. Although the possibilities of renegotiation improve welfare in the second period, they violate the *ex ante* self-selection constraints and reduce *ex ante* welfare. In other words, renegotiation limits the commitment possibilities and reduces parties' welfare *ex ante*. For example, if the high-risk individuals anticipate renegotiation in the second period, they will not necessarily reveal their type in the first period (Dionne and Doherty 1994).

Formally, we can interpret the possibility of renegotiation as adding a new constraint to the set of feasible contracts; unless parties can precommit to not renegotiate then contracts must be incentive compatible and renegotiation proof (Bolton 1990; Dewatripont 1989; Rey and Salanié 1996). To reduce the possibilities of renegotiation in the second period, the insurer that cannot commit not to renegotiate after new information is revealed must set the contracts so that the insured type will not be perfectly known after the first period. This implies that the prospect of renegotiation reduces the speed of information revelation over time. In other words, the prospect of renegotiation can never improve the long-term contract possibilities. In many circumstances, a sequence of one-period contracts will give the same outcome as a renegotiated-proof long-term contract; in other circumstances a renegotiation-proof long-term contract dominates (e.g., when intertemporal and intertype transfers and experience rating are allowed) (Hart and Tirole 1988; Laffont–Tirole 1987, 1990, 1993; Dionne and Doherty 1994; see the next section for more details).

Hosios and Peters (1989) present a formal model that rules out any renegotiation by assuming that only one-period contracts are enforceable.¹⁶ They also discuss the possibility of renegotiation in the second period when this renegotiation is beneficial to both parties. Although they cannot show the nature of the equilibrium under this alternative formally, they obtain interesting qualitative results. For example, when the equilibrium contract corresponds to incomplete risk revelation in the first period, the seller offers, in the second period, a choice of contract that depends on the experience of the first period. Therefore accident underreporting is possible without commitment and renegotiation. This result is similar to that obtained in their formal model where they ruled out any form of commitment

¹⁶On limited commitment see also Dionne et al. (2000); Freixas et al. (1985); Laffont and Tirole (1987).

for contracts that last for more than one period. Only one-period contracts are enforceable. They show the following results.¹⁷

Proposition 5. *In absence of any form of commitment from both parties to the contract:*

- 1) *Without discounting, separating equilibria do not exist; only pooling and semi-separating equilibria are possible.*
- 2) *Accident underreporting can now affect the seller's posterior beliefs about risk types, and insurance buyers may fail to report accidents to avoid premium increases.*

Proof. See [Hosios and Peters \(1989\)](#). ■

This result implies that the insurer does not have full information on the risk types at the end of the first period; therefore, accident reports become informative on the risk type contrary to the Cooper and Hayes model. However, the authors did not discuss the optimality of such two-period contract. It is not clear that a sequence of one-period contracts with separating equilibrium does not dominate their sequence of contracts.

10.4 Competitive Contracts

We now introduce a competitive context. Competition raises many new issues in both static and dynamic environments. The two main issues that will be discussed here are (1) the choice of an adequate equilibrium concept and the study of its existence and efficiency properties and (2) the nature of information between competitive insurers (and consequently the role of government in facilitating the transmission of information between insurance market participants, particularly in long-term relationships).

It will be shown that many well-known and standard results are a function of the assumption on how the insurers share the information about both the individual's choice of contracts and accident experience.

In a first step, the situation where no asymmetric information affects the insurance market is presented as a benchmark. After that, issues raised by adverse selection problem and the remedies to circumvent it are discussed.

10.4.1 Public Information About an Individual's Characteristics

In a competitive market where insurance firms are able to discriminate among the consumers according their riskiness, we would expect insureds to be offered a menu of policies with a complete coverage among which they choose the one that corresponds with their intrinsic risk. Indeed, under competition, firms are now constrained to earn zero expected profits. When information on individual risk characteristics is public, each firm knows the risk type of each individual. The optimal individual contract is the solution to

¹⁷However, separating equilibria are possible with discounting because future considerations are less relevant. In a model with commitment and renegotiation, [Dionne and Doherty \(1994\)](#) obtain a similar result; when the discount factor is very low a separating equilibrium is always optimal in a two-period framework. Intuitively, low discount factors reduce the efficiency of using intertemporal transfers or rents to increase the optimal insurance coverage of the low-risk individuals by pooling in the first period. See [Laffont and Tirole \(1993\)](#) for a general discussion on the effect of discounting on optimal solutions in procurement when there is no uncertainty. See [Dionne and Fluet \(2000\)](#) for a demonstration that full pooling can be an optimal solution when the discount factor is sufficiently high and when there is no commitment. This result is due to the fact that, under no commitment, the possibilities of rent transfers between the periods are limited.

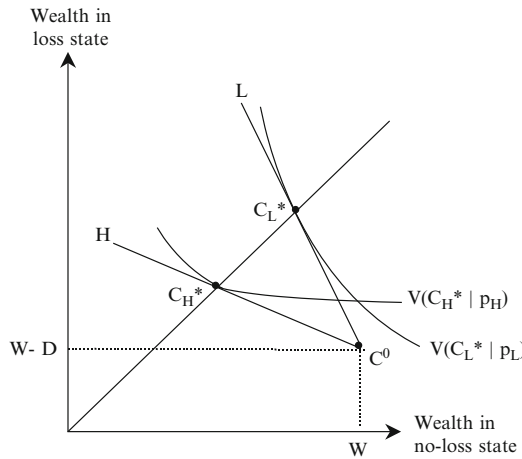


Fig. 10.3 One-period competitive contracts with full information

Problem 2.

$$\text{Max}_{\alpha_i, \beta_i, \lambda_i} p_i U(W - D + \beta_i) + (1 - p_i) U(W - \alpha_i) + \lambda_i [(1 - p_i)\alpha_i - p_i \beta_i], \quad i = H, L$$

where $(1 - p_i)\alpha_i = p_i \beta_i$ is the zero-profit constraint.

As for the monopoly case under public information, the solution to Problem 2 yields full insurance coverage for each type of risk. However, contrary to a monopoly, the optimal solutions C_H^* and C_L^* in Fig. 10.3 correspond to levels of consumer welfare greater than in the no insurance situation (C^0). As already pointed out, the monopoly solution under public information also yields full insurance coverage and does not introduce any distortion in risk allocation. The difference between the monopoly and competitive cases is that in the former, consumer surplus is extracted by the insurer, while in the latter it is retained by both types of policyholder.

Under competition, a zero-profit line passes through C^0 and represents the set of policies for which a type i consumer's expected costs are nil for insurers. The value of its slope is equal to the (absolute) ratio $\frac{1-p_i}{p_i}$. Each point on the segment $[C^0 C_i^*]$ has the same expected wealth for an individual of type i than that corresponding to C^0 . The full information solutions are obtained when the ratio of slopes of indifference curves is just equal to the ratio of the probability of not having an accident to that of having an accident. To sum up,

Proposition 6. *In an insurance world of public information about insureds' riskiness, a one-period optimal contract between any competitive firm on market and any individual of type i ($i = H, L$) is characterized by:*

- a) Full insurance coverage, $\beta_i^* = D - \alpha_i^*$.
- b) No firm makes a surplus, $\pi(C_i^* | p_i) = 0$.
- c) Consumers receive a surplus $V(C_i^* | p_i) > V(C^0 | p_i)$.

Characteristic (b) expresses the fact that premiums are set to marginal costs and characteristic (c) explains why individual participation constraints (10.2) are automatically satisfied in a competitive context. Consequently, introducing competitive actuarial insurance eliminates the wealth variance at the same mean or corresponds to a *mean preserving contraction*.

Under perfect information, competition leads to one-period solutions that are *first-best efficient*. This result does not hold when we introduce asymmetric information.

10.4.2 *Private Information and Single-Period Contracts*

In the presence of adverse selection, the introduction of competition may lead to fundamental problems with the existence and the efficiency of an equilibrium. When insurance firms cannot distinguish among different risk types, they lose money by offering the set of full information contracts (C_H^*, C_L^*) described above, because both types will select C_L^* (the latter contract requires a premium lower than C_H^* and, in counterpart, also fully covers the incurring losses). Each insurer will make losses because the average cost is greater than the premium of C_L^* , which is the expected cost of group L . Under asymmetric information, traditional full information competitive contracts are not adequate to allocate risk optimally. Consequently, many authors have investigated the role of sorting devices in a competitive environment to circumvent this problem of adverse selection. The first contributions on the subject in competitive markets are by [Akerlof \(1970\)](#), [Spence \(1973\)](#), [Pauly \(1974\)](#), [Rothschild and Stiglitz \(1976\)](#), and [Wilson \(1977\)](#). The literature on competitive markets is now very large; it is not our intention here to review all contributions. Our selection of models was based on criteria that will be identified and explained at an appropriate point.¹⁸

A first division that we can make is between models of signaling (informed agents move first) and of screening (uninformed agents move first) ([Stiglitz and Weiss, 1984](#)). [Spence \(1973\)](#) and [Cho and Kreps \(1987\)](#) models are of the first type and are mainly applied to labor markets in which the workers (informed agents) move first by choosing an education level (signal). Then employers bid for the services of the workers and the latter selects the more preferred bids. [Cho and Kreps \(1987\)](#) present conditions under which this three-stage game generates a [Riley \(1979a\)](#) single-period separating equilibrium.¹⁹ Without restrictions (or criteria such as those proposed by [Cho and Kreps 1987](#)) on out-of-equilibrium beliefs, many equilibria arise simultaneously, which limit the explanatory power of the traditional signaling models considerably.²⁰

Although it may be possible to find interpretations of the signaling models in insurance markets, it is generally accepted that the screening interpretation is more natural. [Rothschild and Stiglitz \(1976\)](#) and [Wilson \(1977\)](#) introduced insurance models with a screening behavior. In [Rothschild and Stiglitz's](#) model only a two-stage game is considered. First, the uninformed insurer offers a menu of contracts to the informed customers, who choose among the contracts in the second stage.

Let us start with [Rothschild and Stiglitz's \(1976\)](#) model in which the insurers set premia with constant marginal costs. Each insurer knows the proportions of good risks and bad risks in the market but has no information on an individual's type. Moreover, each insurer cannot, by assumption, buy insurance from many insurers. Otherwise, the individual insurers would not be able to observe the individuals' total amount of insurance and would not be able to discriminate easily.²¹ Each insurer observes all offers in the market. Finally, the insurer only needs to observe the claims he receives.²²

¹⁸See [Cresta \(1984\)](#) and [Eisen \(1989\)](#) for other analyses of problems of equilibria with asymmetric information.

¹⁹A Riley or reactive equilibrium leads to the [Rothschild–Stiglitz](#) separating equilibrium regardless of the number of individuals in each class of risk.

²⁰Multiple equilibria are the rule in two-stage signaling models. However, when such equilibria are studied, the problem is to find at least one that is stable and dominates in terms of welfare. For a more detailed analysis of signaling models see the survey by [Kreps \(1989\)](#). On the notion of sequential equilibrium and on the importance of consistency in beliefs see [Kreps and Wilson \(1982\)](#).

²¹[Jaynes \(1978\)](#) and [Hellwig \(1988\)](#) analyze the consequences of relaxing this assumption. Specifically, they specify the conditions under which an equilibrium exists when the sharing of information about customers is treated endogenously as part of the game among firms. They also contend that it is possible to overcome [Rothschild–Stiglitz's](#) existence problem of an equilibrium if insureds cannot buy more than one contract. Finally, [Hellwig \(1988\)](#) maintains that the resulting equilibrium is more akin to the [Wilson](#) anticipatory equilibrium than to the competitive Nash equilibrium.

²²This is a consequence of the exclusivity assumption. Because we consider static contracts, observing accidents or claims does not matter. This conclusion will not necessarily be true in dynamic models.

Clearly, the properties of the equilibrium depend on how firms react to rival offers. In a competitive environment, it seems reasonable to assume that each insurer takes the actions of its rivals as given. The basic model by Rothschild and Stiglitz described in the following lines considers that firms adopt a (pure) Nash strategy. A menu of contracts in an insurance market is an equilibrium in the Rothschild and Stiglitz sense if (a) no contract in the equilibrium set makes negative expected profits and (b) there is no *other* contract added to the original set that earns positive expected profits.

Under this definition of the equilibrium, Rothschild and Stiglitz obtained three significant results:

Proposition 7. *When insurers follow a pure Cournot–Nash strategy in a two-stage screening game:*

- a) *A pooling equilibrium is not possible; the only possible equilibria are separating contracts.*
- b) *A separating equilibrium may not exist.*
- c) *The equilibrium, when it exists, is not necessarily a second-best optimum.*

A pooling equilibrium is an equilibrium in which both types of risk buy the same contract. The publicly observable proportions of good-risk and bad-risk individuals are, respectively, q_L and q_H (with $q_H + q_L = 1$) and the average probability of having an accident is \bar{p} . This corresponds to line C^0F in Fig. 10.4a. To see why the Nash definition of equilibrium is not compatible with a pooling contract, assume that C_1 in the figure is a pooling equilibrium contract for a given insurer. By definition, it corresponds to zero aggregate expected profits; otherwise, another insurer in the market will offer another pooling contract. Because of the relative slopes of the risk-type indifference curves, there always exists a contract C_2 that will be preferred to contract C_1 by the low-risk individuals. The existence of contract C_2 contradicts the above definition of a Nash equilibrium. Consequently, if there exists an equilibrium, it has to be a separating one in which different risk-type consumers receive different insurance contracts.

As for the monopoly case, the formal solution is obtained by adding to Problem 2 one self-selection constraint (10.3) that guarantees that individual i prefers C_i to C_j . By a similar argumentation to the one used in the determination of the optimal solution in the monopoly situation, it can be shown that only the self-selection constraint of the H risk type is binding at full insurance. Again the profit constraint is binding on each type, so the problem is limited to finding an optimal contract to the low-risk individual because that of the high-risk individual corresponds to the full information case ($\alpha_H^{**} = \alpha_H^* = D - \beta_H^*$):

Problem 3.

$$\text{Max}_{\alpha_L, \beta_L, \lambda_L, \lambda_{HL}} p_L U(W - D + \beta_L) + (1 - p_L) U(W - \alpha_L)$$

subject to the zero-profit constraint

$$(1 - p_L)\alpha_L = p_L\beta_L$$

and the self-selection constraint

$$U(W - \alpha_H^{**}) = p_H U(W - D + \beta_L) + (1 - p_H) U(W - \alpha_L).$$

At equilibrium, high-risk individuals receive full insurance because the low-risk self-selection constraint is not binding. The solution of Problem 3 implies that the low-risk type receives less than full insurance.²³ We can summarize the description of the separating equilibrium with the following proposition:

²³Partial coverage is generally interpreted as a monetary deductible. However, in many insurance markets, the insurance coverage is excluded during a probationary period that can be interpreted as a sorting device. Fluet (1992) analyzed the selection of an optimal time deductible in the presence of adverse selection.

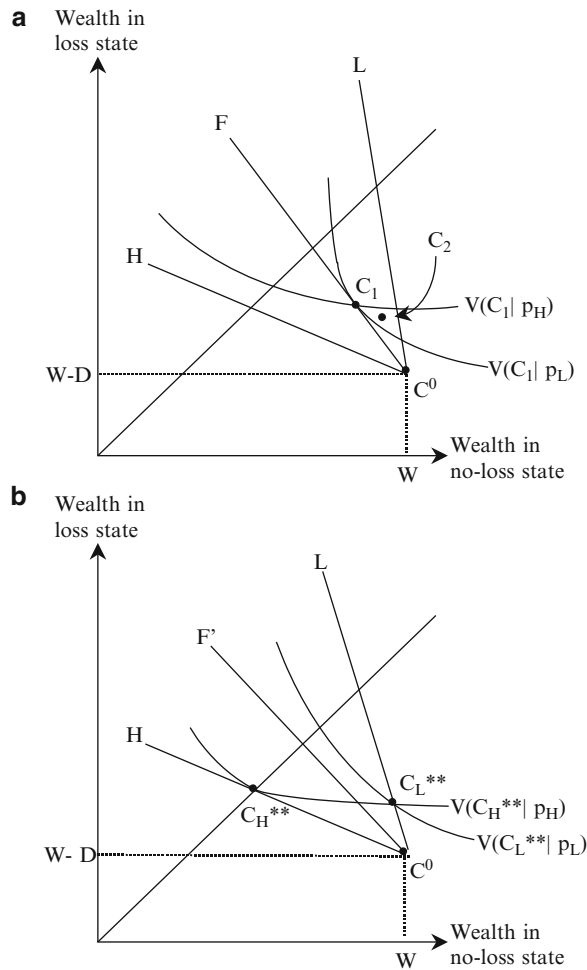


Fig. 10.4 (a) Inexistence of a Rothschild–Stiglitz pooling equilibrium. (b) Existence of a Rothschild and Stiglitz separating equilibrium

Proposition 8. *In the presence of private information, an optimal menu of separating one-period contracts between a competitive insurer and individuals of types H and L has the following characteristics:*

- a) $\beta_H^{**} = D - \alpha_H^{**}; \beta_L^{**} < D - \alpha_L^{**}$
- b) $V(C_i^{**} | p_i) > V(C^0 | p_i) \quad i = H, L$
- c) $V(C_H^{**} | p_H) = V(C_L^{**} | p_H); \quad V(C_L^{**} | p_L) > V(C_H^{**} | p_L)$

Graphically, C_H^{**} and C_L^{**} in Fig. 10.4b correspond to a separating equilibrium. In equilibrium, high-risk individuals buy full insurance (C_H^{**}), while low-risk individuals get only partial insurance C_L^{**} .²⁴ Each firm earns zero expected profit on each contract. This equilibrium has the advantage for

²⁴On the relationship between the coverage obtained by a low-risk individual under monopoly compared to that under the pure Nash competitive equilibrium, see Dahlby (1987). It is shown, for example, that under constant absolute risk aversion, the coverage obtained by a low-risk individual under monopoly is greater than, equal to, or less than that

the low-risk agents that their equilibrium premium corresponds to their actuarial risk and does not contain any subsidy to the high-risk individuals. However, a cost is borne by low-risk insureds in that their equilibrium contract delivers only partial insurance compared with full insurance in the full information case. Only high-risk individuals receive the first-best allocation. Finally, the separating equilibrium is not necessarily second-best optimal when it is possible to improve the welfare of individuals in each class of risk. We will revisit this issue.

The second important result from Rothschild and Stiglitz is that there are conditions under which a separating equilibrium does not exist. In general, there is no equilibrium if the costs of pooling are low for the low-risk individuals (few high-risk individuals or low q_H , which is not the case in Fig. 10.4b because the line $C^0 F'$ corresponds to a value of q_H higher than the critical level q_H^{RS} permitting separating equilibria) or if the costs of separating are high (structure of preference). In the former case, given the separating contracts, the cost of sorting (partial insurance) exceeds the benefits (no subsidy) when profitable pooling opportunities exist. As already shown, however, a pooling contract cannot be an equilibrium. This negative result has prompted further theoretical investigations given that many insurance markets function even in the presence of adverse selection.

One extension of the existence of an equilibrium is to consider a mixed strategy in which an insurer's strategy is a probability distribution over a pair of contracts. Rosenthal and Weiss (1984) show that a separating Nash equilibrium always exists when the insurers adopt this strategy. However, it is not clear that such a strategy has any particular economic interpretation in one period contracting unlike in many other markets.²⁵ Another extension is to introduce a three-stage game in which the insurer may reject in the third stage the insured's contract choice made in the second stage. Hellwig (1986, 1987) shows that a pooling contract may correspond to a sequential equilibrium of the three-stage game or it can never be upset by a separating contract whenever pooling is Pareto preferred. Contrary to the Rothschild and Stiglitz two-stage model, the three-stage game always has a sequential equilibrium in pure strategies. The most plausible sequential equilibrium is pooling rather than sorting, while in a three-stage game in signaling models (Cho and Kreps 1987) it is the pooling rather than the separating equilibria that lack robustness. As pointed out by Hellwig (1987), the conclusions are very sensitive to the details of game specification.²⁶

Another type of extension that permits equilibria is to allow firms to consider other firms' behavior or reactions in their strategies and then to abandon the Nash strategy in the two-stage game. For example, Wilson (1977) proposes an anticipatory equilibrium concept where firms drop policies so that those remaining (after other firms anticipated reactions) at least break even. By definition, a Wilson equilibrium exists if no insurer can offer a policy such that this new policy (1) yields nonnegative profits and (2) remains profitable after other insurers have withdrawn all unprofitable policies in reaction to the offer. The resulting equilibrium (pooling or separation) always exists. A Wilson equilibrium corresponds to the Nash equilibrium when a separating equilibrium exists; otherwise, it is a pooling equilibrium such as C_1 in Fig. 10.4a.²⁷ Finally, we may consider the Riley (1979a,b) reactive equilibrium where competitive firms add new contracts as reaction to entrants. This equilibrium always corresponds to separating contracts.

obtained under competition because the monopolist's expected profit on a policy purchased by low-risk individuals is greater than, equal to, or less than its expected profit on the policy purchased by high-risk individuals.

²⁵See also Dasgupta and Maskin (1986), Rothschild and Stiglitz (1997), and Allard et al. (1997). On randomization to improve market functioning in the presence of adverse selection see Garella (1989) and Arnott and Stiglitz (1988).

²⁶See also Fagart (1996a) for another specification of the game. She extends the work of Rothschild and Stiglitz. Her article presents a game where two principals compete for an agent, when the agent has private information. By considering a certain type of uncertainty, competition in markets with asymmetric information does not always imply a loss of efficiency.

²⁷See Grossman (1979) for an analysis of the Wilson-type equilibrium with reactions of insureds rather than reactions of sellers.

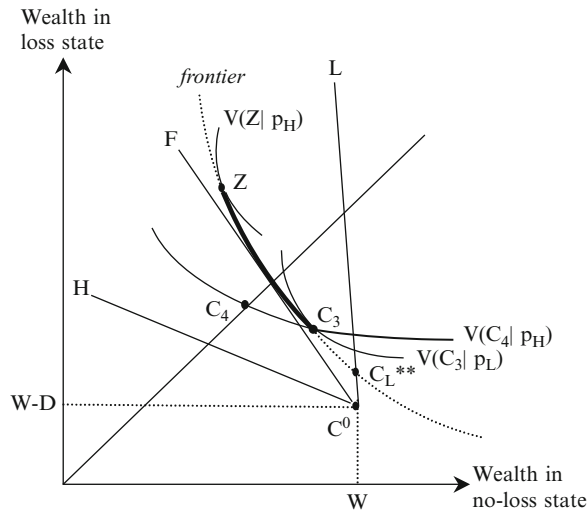


Fig. 10.5 A Wilson–Miyazaki–Spence equilibrium

Wilson also considers subsidization between policies, but Miyazaki (1977) and Spence (1978) develop the idea more fully. They show how to improve welfare of both classes of risk (or of all n classes of risk; Spence 1978) with the low-risk class subsidizing the high-risk class. Spence shows that in a model in which firms react (in the sense of Wilson) by dropping loss-making policies, an equilibrium always exists. In all the above models, each of the contracts in the menu is defined to permit the low-risk policyholders to signal their true risk. The resulting equilibrium is a break-even portfolio of separating contracts and exists regardless of the relative value of q_H . The separating solution has no subsidy between policies when $q_H \geq q_H^{WMS}$. More formally we have

Proposition 9. A Wilson–Miyazaki–Spence (WMS) equilibrium exists regardless of the value of q_H . When $q_H \geq q_H^{WMS}$, the WMS equilibrium corresponds to the Rothschild–Stiglitz equilibrium.

One such equilibrium (C_3, C_4) is presented in Fig. 10.5 for the case of two risk classes with cross-subsidization from the low- to the high-risk group. The curve denoted by *frontier* in Fig. 10.5 is the zero aggregate transfer locus defined such that the contract pairs yield balanced transfers between the risk types, and the subset (C_3, Z) in bold is the set of contracts for the low-risk individuals that are second-best efficient. The derivation of the optimal contracts with transfers is obtained by maximizing the following program:

Problem 4.

$$\text{Max}_{\alpha_L, \beta_L, t, s} p_L U(W - D + \beta_L - t) + (1 - p_L) U(W - \alpha_L - t)$$

subject to the nonnegative aggregate profit constraint

$$q_L t \geq q_H s$$

the zero-profit constraint before cross-subsidization

$$(1 - p_L) \alpha_L \geq p_L \beta_L$$

the self-selection constraint

$$U(W - \alpha_H^{**} + s) \geq p_H U(W - D + \beta_L - t) + (1 - p_H) U(W - \alpha_L - t)$$

and the positivity constraint

$$s \geq 0$$

where s and t are for subsidy and tax, respectively.

When the positivity constraint is binding, (C_3, C_4) corresponds to the Rothschild–Stiglitz contracts (C_H^{**}, C_L^{**}) without cross-subsidization. When the positivity constraint holds with a strict inequality, the equilibrium involves subsidization from low risks to high risks.²⁸

The Wilson–Miyazaki–Spence (WMS) equilibrium (C_3, C_4) solves this program if (C_3, C_4) is second-best efficient in the sense of Harris and Townsend (1981). An allocation is second-best efficient if it is Pareto optimal within the set of allocations that are feasible and the zero-profit constraint on the portfolio.²⁹ In competitive insurance markets, Crocker and Snow (1985) prove the following proposition, which can be seen as an analogue with the welfare first theorem (Henriet and Rochet 1990):

Proposition 10. *A Wilson–Miyazaki–Spence (WMS) equilibrium is second-best efficient for all values of q_H .*

Proof. See Crocker and Snow (1985). ■

Subsidization between different risk classes is of special interest for characterizing the notion of second-best optimality and simultaneously the shape of optimal redistribution in insurance markets. Indeed, the optimal allocation on these markets (given the incentive constraints imposed by adverse selection) involves cross-subsidization between risk types. Thus, the *second-best efficient* contracts resulting from this redistribution are described for low-risk individuals by the frontier in bold in Fig. 10.5 (see Crocker and Snow 1985). It can be shown that a Rothschild and Stiglitz equilibrium is second-best efficient if and only if q_H is higher than some critical value q_H^{WMS} ,³⁰ which is itself higher than the critical value q_H^{RS} , permitting the existence of a Nash equilibrium. Then, as mentioned, a Nash equilibrium is not necessarily efficient. The same conclusion applies to the Riley equilibrium because it sustains the Rothschild and Stiglitz solution, regardless of the value of q_H . In the income-states space, the shape of this curve can be convex as shown in Fig. 10.5 (Dionne and Fombaron 1996) under some unrestrictive assumptions about utility functions. More precisely, some conditions about risk aversion and prudence indexes guarantee the strict convexity of the efficiency frontier: the insurance coverage β_L offered to low risks is a convex function in the subscribed premium α_L . High risks are offered a coverage β_H which is a linear function in the premium α_H . It is shown by Dionne and Fombaron (1996) that this frontier can never be strictly concave under risk aversion. At least a portion of the frontier must be convex.³¹

Despite the presence of non-convexities of this locus in the income-states space, the correspondence between optimality and market equilibrium is maintained (see Prescott and Townsend 1984, for a general proof of this assertion, and Henriet and Rochet 1986, for an analysis in an insurance context). Consequently, the conventional question about the possibility of achieving a second-best

²⁸For a proof that the equilibrium can never imply subsidization from high-risk individuals to low-risk individuals, see Crocker and Snow (1985).

²⁹See Crocker and Snow (1985, 1986) for more details. See Lacker and Weinberg (1999) for a proof that a Wilson allocation is coalition proof.

³⁰On the relationship between risk aversion and the critical proportion of high risks so that the Rothschild–Stiglitz equilibrium is second-best efficient, see Crocker and Snow (2008). Their analysis shows that, when the utility function U becomes more risk averse, the critical value of high risks increases if U exhibits nonincreasing absolute risk aversion.

³¹For more general utility functions, the curvature can be both convex and concave in the premium but must necessarily be convex around the full insurance allocation under risk aversion. For more details, see Pannequin (1992) and Dionne and Fombaron (1996).

efficient allocation by a decentralized market does not arise. An analogue to the second optimality theorem holds for an informationally constrained insurance market (Henriet and Rochet 1986): even though government cannot a priori impose risk-discriminating taxes on individuals, it can impose a tax on their contracts and thus generate the same effect as if taxing individuals directly (Crocker and Snow 1986).

Another attempt of introducing some form of dynamics in a noncooperative model was made by Asheim and Nilssen (1996). Their model allows insurers to make a second move after having observed the contracts that their applicants initially sign, under the restriction that this renegotiation is nondiscriminating (a contract menu offered by an insurer to one of its customers has to be offered to all its customers). Such nondiscriminating renegotiation weakens the profitability of cream skimming, to the extent that the unique (renegotiation-proof) equilibrium of the game is the WMS outcome.

In contrast, Inderst and Wambach (2001) solve the nonexistence problem by considering firms which face capacity constraints (due to limited capital, for instance). Under the constraint that no single insurer can serve the whole market (implying that a deviating firm with a pooling contract cannot be assured of a fair risk selection), each customer receives in equilibrium his Rothschild–Stiglitz contract. However, the equilibrium is not unique. The same conclusion prevails if, instead of capacity constraints, the authors assume that firms face the risk of bankruptcy (or they are submitted to solvency regulation). In both contexts, more customers can make each policy less attractive to a potential insured.

Finally, as we will see in Sect. 10.7, another possibility to deal with equilibrium issues is to use risk categorization (see Crocker and Snow 2014, and Dionne and Rothschild 2011, for detailed analyzes).

10.4.3 Multi-period Contracts and Competition

The aspect of competition raises new technical and economic issues on multi-period contracting. Indeed, the value of information affects the process of decision making in a competitive insurance market considerably. Let us begin with Cooper and Hayes' (1987) analysis of two-period contracts with full commitment on the supply side.

10.4.3.1 Full Commitment

Cooper and Hayes use the Nash equilibrium concept in a two-period game where the equilibrium must be separating.³² They consider two different behaviors related to commitment on the demand side. First, both insurers and insureds commit themselves to the two-period contracts (without possibility of renegotiation) and second, the insurers commit to a two-period contract, but the contract is not binding on insureds. We will refer these respective situations as contracts with *full commitment* and *with semi-commitment*, respectively. When competitive firms can bind agents to the two periods, it is easy to show that, in the separating solution, the contracts offered are qualitatively identical to that of the monopoly solution with commitment: high-risk agents receive full insurance at an actuarial price in each period while low-risk agents face price and quantity adjustments in the second period. Suppose that q_H is such that a Rothschild and Stiglitz equilibrium is second-best efficient. It can be shown that the two-period contract with full commitment dominates a repetition of Rothschild and Stiglitz contracts without memory. As for the monopoly case, this result is due to the memory effect (see Chiappori et al. 1994, for a survey on the memory effect).

³²In other words, they implicitly assume that the conditions to obtain a Nash separating equilibrium in a single-period contract are sufficient for an equilibrium to exist in their two-period model.

When the authors relax the strong commitment assumption in favor of semi-commitment and consider that insureds can costlessly switch to other firms in the second period, they show that the presence of second-period competition limits but does not destroy the use of experience rating as a sorting device. The difference between the results with full commitment and semi-commitment is explained by the fact that the punishment possibilities for period-one accidents are reduced by the presence of other firms that offer single-period contracts in the second period.

The semi-commitment result was obtained by assuming that, in the second period, entrant firms offer single-period contracts without any knowledge of insureds' accident histories or their choice of contract in the first period. The new firms' optimal behavior is to offer Rothschild and Stiglitz separating contracts³³ to the market.³⁴ By taking this decision as given, the design of the optimal two-period contract by competitive firms with semi-commitment has to take into account at least one supplementary binding constraint (no-switching constraint) that reduces social welfare compared to full commitment. The formal problem consists of maximizing the low-risks' two-period expected utility by choosing C_H^2 and C_L^2 under the incentive compatibility constraints, the nonnegative intertemporal expected profit constraint, and the *no-switching* constraints:

Problem 5.

$$\begin{aligned} & \max_{C_H^2, C_L^2} V(C_L^2 | p_L) \\ & \text{s.t.} \\ & V(C_i^2 | p_i) \geq V(C_j^2 | p_i) \quad i, j = H, L, i \neq j \\ & \pi(C_L | p_L) + [p_L \pi(C_{La} | p_L) + (1 - p_L) \pi(C_{Ln} | p_L)] \geq 0 \\ & V(C_{is} | p_i) \geq V(C_i^* | p_i) \quad i = H, L \quad s = a, n. \end{aligned}$$

By the constraint of nonnegative expected profits earned on the low-risks' multi-period contract, this model rules out the possibility of insurers offering cross-subsidizations between the low and the high risks (and circumvent any problems of inexistence of Nash equilibrium). Because this constraint is obviously binding at the optimum, Cooper and Hayes allow only intertemporal transfers.

Using the above model, Cooper and Hayes proved the following results, summarized by Proposition 11:

Proposition 11. *Under the assumption that a Nash equilibrium exists, the optimal two-period contract with semi-commitment is characterized by the following properties:*

- 1) *High-risk individuals obtain full insurance coverage and are not experience rated:*
 $V(C_{Ha}^* | p_H) = V(C_{Hn}^* | p_H) = V(C_H^* | p_H) = U(W - \alpha_H^*)$,
while low-risk individuals receive only partial insurance coverage and are experience rated:
 $V(C_{La}^* | p_L) < V(C_{Ln}^* | p_L)$.
- 2) *High-risk agents are indifferent between their contract and that intended for low risks, while low risks strictly prefer their contract:*
 $V(C_H^{2*} | p_H) = V(C_L^{2*} | p_H)$ and $V(C_L^{2*} | p_L) > V(C_H^{2*} | p_L)$.
- 3) *Both high and low risks obtain a consumer surplus:*
 $V(C_i^{2*} | p_i) > 2V(C^0 | p_i), i = H, L$.

³³The Rothschild and Stiglitz contracts are not necessarily the best policy rival firms can offer. Assuming that outside options are fixed is restrictive. This issue is discussed in the next section.

³⁴The authors limited their focus to separating solutions.

4) *The pattern of temporal profits is highballing on low-risks' contracts and flat on high-risk ones:*

$$\pi(C_L^* | p_L) \geq 0 \geq [p_L \pi(C_{La}^* | p_L) + (1 - p_L) \pi(C_{Ln}^* | p_L)]$$

$$\text{and } \pi(C_H^* | p_H) = \pi(C_{Ha}^* | p_H) = \pi(C_{Hn}^* | p_H) = 0.$$

In other words, the presence of competition, combined with the agents' inability to enforce binding multi-period contracts, reduces the usefulness of long-term contracts as a sorting device and, consequently, the potential gains of long-term relationships. This conclusion is similar to that obtained in the monopoly case (in which the principal cannot commit on nonrenegotiation) because the no-switching constraints imposed by competition can be reinterpreted as rationality constraints in a monopolistic situation.

The fourth property in Proposition 11 means that, at equilibrium, firms make positive expected profits on old low-risk insureds (by earning positive profits on the low-risks' first-period contract) and expected losses on new low-risk insureds (by making losses on the second-period contract of low risks who suffered a first-period loss, greater than positive profits on the low-risks' contract corresponding to the no-loss state in the first period). In aggregate, expected two-period profits from low risks are zero.

As in the monopoly situation, all the consumers self-select in the first period and only low-risk insureds are offered an experience-rated contract in the second period based on their accident history.³⁵ This arrangement provides an appropriate bonus for accident-free experience and ensures that low risks who suffer an accident remain with the firm.³⁶ This temporal profit pattern, also called *highballing* by D'Arcy and Doherty (1990), was shown to contrast with the *lowballing* predicted in dynamic models without commitment. In particular, D'Arcy and Doherty compare the results obtained by Cooper and Hayes under the full commitment assumption with those of the *lowballing* predicted by Kunreuther and Pauly (1985) in a price competition. With similar assumptions on commitment, Nilssen (2000) also obtains a *lowballing* prediction in the classic situation of competition in price-quantity contracts.

Although Cooper and Hayes were the first to consider a repeated insurance problem with adverse selection and full commitment, some assumptions are not realistic, namely the insurers' ability to commit to long-term relationships. Indeed, because the first-period contract choices do reveal the individual risks, the initial agreement on the second-period contract could be renegotiated at the beginning of the second period (under full information) in a way that would improve the welfare of both parties. Consequently, the two-period contract with full commitment is Pareto inefficient *ex post*, i.e., relative to the information acquired by insurers at that time. Recent articles in the literature have investigated other concepts of relationships between an insurer and its insureds, involving limited commitment: the *no-commitment* assumption represents the polar case of the full commitment situation (Sect. 10.4.3.2) and the *commitment with renegotiation* appears to be an intermediate case between full commitment and no commitment (Sect. 10.4.3.3).

As a result of the strong hypotheses above, the literature obtains the same predictions as in the static model about the equilibrium existence issue³⁷ and about the self-selection principle. These predictions do not hold any longer when we assume limited commitment and/or endogenous outside options.

³⁵But not on their contract choice.

³⁶The corresponding expected utility of the low-risk individual who did not have an accident in the first period is strictly greater at equilibrium than that corresponding to the entrant one-period contract.

³⁷Cross-subsidizations between risk types remain inconsistent with equilibrium, such that problems for equilibrium existence also exist in a multi-period context.

10.4.3.2 No Commitment

In this section, the attention is paid to competitive insurance models in which the contractual parties can commit only to one-period incentive schemes, i.e., where insurers can write short-term contracts, but not long-term contracts. The no commitment is bilateral in the sense that each insured can switch to another company in period two if he decides to do so. Such situations are particularly relevant in liability insurance (e.g., automobile or health insurance) where long-term contracts are rarely signed. Despite this inability to commit, both parties can sign a first-period contract that should be followed by second-period contracts that are conditionally optimal and experience rated. This sequence of one-period contracts gives rise to a level of intertemporal welfare lower than that of full commitment, but, in some cases, higher than in a repetition of static contracts without memory.

Kunreuther and Pauly (1985) were the first to study a multi-period model without commitment in a competitive insurance context. However, their investigation is not really an extension of the Rothschild and Stiglitz analysis because the authors consider competition in price and not in price–quantity.³⁸ They argue that insurers are unable to write exclusive contracts; instead they propose that insurers offer pure price contracts only (Pauly 1974). They also assume that consumers are myopic: they choose the firm that makes the most attractive offer in the current period. At the other extreme, the classic dynamic literature supposes that individuals have perfect foresight in the sense that they maximize the discounted expected utility over the planning horizon.

Despite the major difference in the assumption about the way insurers compete, their model leads to the same lowballing prediction as other studies, like the one developed by Nilssen (2000), using the basic framework of the Rothschild and Stiglitz model where firms compete by offering price–quantity contracts. Insurers make expected losses in the first period and earn expected profits on the policies they renew. This prediction of lock-in is due to the assumption that insurers do not write long-term contracts while, as we saw, Cooper and Hayes permitted long-term contracting. In Nilssen’s model, an important result is to show that pooling contracts could emerge in dynamic equilibrium (pooling on the new insureds) when the ability to commit lacks in the relationships, which makes the cross-subsidizations compatible with equilibrium. Contrary to the Kunreuther and Pauly model, the absence of commitment does not rule out separation.

The program presented below (Problem 6) includes Nilssen’s model as a particular case (more precisely, for both $x_H = 1, x_L = 0$ where $x_i \in [0; 1]$ measures the level of separation of type i). In other words, we introduce strategies played by insureds in Nilssen’s model, such that at equilibrium, semi-pooling can emerge in the first period, followed by separation in the second period. This technical process, also labeled *randomization*, serves to defer the revelation of information and thus encourages compliance with sequential optimality constraints required by models with limited commitment. It was used by Hosios and Peters (1989), as we saw, in a monopoly situation without commitment and by Dionne and Doherty (1994) in a competitive context with commitment and renegotiation.³⁹

Solving the two-period model without commitment requires the use of the concept of Nash perfect Bayesian equilibrium (NPBE).⁴⁰ Given this notion of sequential equilibrium, we work backwards and begin by providing a description of the Nash equilibrium in the last period.

In period 2, \widehat{C}_{ia} and \widehat{C}_{in} solve the following subprograms imposed by the constraints of sequential optimality, for $s \in \{a, n\}$, respectively, where a means accident in the first period and n means no accident:

³⁸They let insurers offer contracts specifying a per-unit premium for a given amount of coverage.

³⁹On limited commitment and randomized strategies, see also Dionne and Fluet (2000).

⁴⁰This concept implies that the set of strategies satisfies sequential rationality given the system of beliefs and that the system of beliefs is obtained from both strategies and observed actions using Bayes’ rule whenever possible.

Problem 6.

$$\widehat{C}_{is} \in \arg \max \sum_{i=H,L} q_{is}(x_i)\pi(C_{is}|p_i)$$

$$s.t.$$

$$V(C_{is}|p_i) \geq V(C_{js} | p_i) \quad i, j = H, L, \quad i \neq j$$

$$V(C_{is}|p_i) \geq V(C_i^{RS} | p_i) \quad i = H, L$$

where posterior beliefs⁴¹ are defined by

$$q_{ia}(x_i) = \frac{q_i p_i x_i}{\sum_{k=H,L} q_k p_k x_k}$$

$$\text{and } q_{in}(x_i) = \frac{q_i(1-p_i)x_i}{\sum_{k=H,L} q_k(1-p_k)x_k}, \quad i = H, L.$$

For given beliefs, the second-period optimization subprogram is similar, in some sense, to a single-period monopoly insurance model with adverse selection (Stiglitz 1977, in Sect. 10.3.2) for a subgroup of insureds and where no-switching constraints correspond to usual participation constraints. In the absence of commitment and because of informational asymmetries between insurers, each informed firm can use its knowledge of its old insureds to earn positive profits in the second period. However, this profit is limited by the possibility that old insureds switch to another company at the beginning of the second period. Contrary to a rival company, a firm that proposes sets of contracts in the second period to its insureds can distinguish among accident groups on the basis of past accident observations. Each company acquires over time an informational advantage relative to the rest of competing firms on the insurance market.

The PBE of the complete game is a sequence of one-period contracts $(C_i^*, C_{ia}^*, C_{in}^*)$ for every $i = H, L$, such that

Problem 7.

$$(C_i^*, C_{ia}^*, C_{in}^*) \in \arg \max_{(C_i, C_{ia}, C_{in})} V(C_L | p_L) + \delta[p_L V(\widehat{C}_{La} | p_L) + (1 - p_L)V(\widehat{C}_{Ln} | p_L)]$$

$$s.t.$$

$$x_i(1 + \delta)V(C_i^{RS}|p_i) + (1 - x_i)[V(C_i|p_i) + \delta(p_i V(\widehat{C}_{ia}|p_i) + (1 - p_i)V(\widehat{C}_{in}|p_i))]$$

$$\geq V(C_j|p_i) + \delta(p_i V(\widehat{C}_{ja}|p_i) + (1 - p_i)V(\widehat{C}_{jn}|p_i))$$

$$\sum_{i=H,L} q_i(x_i)\pi(C_i|p_i) + \delta[\sum_{i=H,L} q_{ia}(x_i)\pi(\widehat{C}_{ia}|p_i) + \sum_{i=H,L} q_{in}(x_i)\pi(\widehat{C}_{in}|p_i)] \geq 0$$

where $\widehat{C}_{La}, \widehat{C}_{Ln}$ solve Problem 6 for $s = a, n$, respectively.

Problem 7 provides the predictions summarized in Proposition 12.

⁴¹Put differently, $q_{ia}(x_i)$ and $q_{in}(x_i)$ are the probabilities at the beginning of the second period that, among the insureds having chosen the pooling contract in the first period, an insured belongs to the i -risk class if he has suffered a loss or no loss in the first period, respectively.

Proposition 12. *In the presence of private information, each company may increase the individuals welfare by offering two contracts, a sequence of one-period contracts and a multi-period contract without commitment with the following characteristics:*

- 1) Both high- and low-risk classes obtain partial insurance coverage in each period and are experience rated: $V(C_{ia}^* | p_i) \leq V(C_{in}^* | p_i)$, $i = H, L$.
- 2) High-risk classes are indifferent between a mix of a sequence of Rothschild–Stiglitz contracts and the multi-period contract, also subscribed by low-risk individuals:

$$x_H(1 + \delta)V(C_H^{RS} | p_H) + (1 - x_H)V(C_H^{2*} | p_H) = V(C_L^{2*} | p_H)$$
and the low risks strictly prefer the multi-period contract:

$$V(C_L^{2*} | p_L) > x_L(1 + \delta)V(C_L^{RS} | p_L) + (1 - x_L)V(C_L^{2*} | p_L)$$
, $x_L \in [0, 1]$.
- 3) High- and low-risk individuals obtain a consumer surplus:

$$V(C_i^{2*} | p_i) > (1 + \delta)V(C^0 | p_i)$$
, $i = H, L$.
- 4) Aggregate expected profits earned on the multi-period contract increase over time:

$$\sum_{i=H,L} q_i(x_i)\pi(C_i^* | p_i) < \sum_{i=H,L} \sum_{s=a,n} q_{is}(x_i)\pi(C_{is}^* | p_i)$$
.

Concerning the existence property, it can be shown that a NPBE exists for some values of parameters (i.e., for every q_H such that $q_H \geq q_H^{NC}$ ($> q_H^{RS}$) where NC is for no commitment). As a consequence, the existence property of equilibrium is guaranteed for a set of parameters smaller than in the static model. More importantly, this model exhibits a lowballing configuration of intertemporal profits (increasing profits over time; each firm earns a positive expected profit on its old customers because it controls information on past experience⁴²), contrary to the highballing prediction resulting from models with full commitment.

Finally, particular attention could be paid to interfirm communication and the model could make the outside options endogenous to the information revealed over time. In Cooper and Hayes' and Nilssen's models and in most dynamic models, firms are supposed to offer the same contract to a new customer (the outside option is C_i^{RS}), whatever his contractual path and his accident history. In other words, it is implicitly assumed that the information revealed by the accident records and by contractual choices does not become public.⁴³ However, this assumption is not very realistic with regard to the presence, in some countries, of a specific regulatory law that obliges insurers to make these data public.⁴⁴ This is the case in France and in most European countries for automobile insurance, where the free availability of accident records is a statutory situation. Consequently, models with endogenous outside options would be more appropriate to describe the functioning of the competitive insurance market in these countries. To evaluate the effects of a regulatory law about interfirm communication, let us consider the extreme situation in which insurers are constrained to make data records public, such that rival firms do have free access to all accident records. Formally, this amounts to replacing C_i^{RS} by C_i^{cc} in no-switching constraints of Problem 6 (C_i^{cc} is the best contract a rival uninformed company can offer to i -risk type at the beginning of period 2).

In other words, C_i^{cc} describes the switching opportunities of any insured i and depends on x_i). At one extreme case, when the first-period contracts are fully separating, the contract choice reveals individual risk types to any insurer on the insurance market, and C_i^{cc} will be the first-best contract C_i^{FB} .

⁴²Cromb (1990) considered the effects of different precommitment assumptions between the parties to the contract on the value of accident history. Under fully binding contracts, the terms of the contract depend only on the number of accidents over a certain time horizon, while under other assumptions (partially binding and no binding) the timing of accidents becomes important.

⁴³When an individual quits a company A and begins a new relationship with a company B, he is considered by the latter as a new customer on the insurance market.

⁴⁴For a more detailed argumentation of information sharing, see Kunreuther and Pauly (1985), D'Arcy and Doherty (1990), and Dionne (2001).

If competing firms have identical knowledge about insureds' risks over time, no experience rating is sustainable in equilibrium and allocative inefficiency results from dynamic contractual relationships. The "too large" amount of revealed information destroys efficiency and eliminates dynamic equilibria. In contrast, when rival firms do not have access to accident records, equilibrium involves experience rating and dynamic contracts achieve second-best optimality, because informational asymmetries between competing firms make cross-subsidization compatible with the Nash equilibrium. As a consequence, insureds are always better off when accidents remain private information.⁴⁵ The next section is devoted to an analysis of multi-period contracts under an intermediary level of commitment from insurers.

10.4.4 Commitment and Renegotiation

Dionne and Doherty (1994) introduced the concept of renegotiation in long-term relationships in insurance markets. Here, the two-period contracts are considered where insureds can leave the relation at the end of the first period and the insurer is bound by a multi-period agreement. It differs from Cooper and Hayes' model due to the possibility of renegotiation. Indeed, insurers are allowed to make a proposition of contract renegotiation with their insureds which can be accepted or rejected. In other words, parties cannot precommit to not make Pareto-improving changes based on information revealed at the end of the first period. As shown in Dionne and Doherty (1994), the Cooper and Hayes solution is not renegotiation proof. This means that sequential optimality fails because parties' objectives change over time. If renegotiation cannot be ruled out, the company and its insureds anticipate it, and this will change the nature of the contracts. Thus, to ensure robustness against renegotiation procedure described above, we must impose either the constraint of pooling in the first period or the constraint of full insurance for both types in the second period in addition to standard constraints in Cooper and Hayes' optimization program. The new program can be written as Problem 7 except for the second-period constraints imposed by sequential optimality. Indeed, renegotiation proofness means that the second-period contracts are robust to Pareto-improving changes and not only for increasing the insurers' welfare. Consequently, second-period contracts cannot be solved as a subprogram that maximizes insurers' expected profits. In contrast, they must solve, in the last period, a standard competitive program that optimizes the low risks' welfare (in each group a and n). Moreover, no-switching constraints must appear in these subprograms in a similar way as in the model without commitment.

If we consider a general model in which all kinds of transfers are allowed (intertemporal and intertype transfers), Problem 6 can be rewritten in the context of semi-commitment with renegotiation as follows:

Problem 8.

$$\widehat{C}_{is} \in \arg \max V(C_{Ls} | p_L) \text{ for } s = a, n$$

s.t.

$$V(C_{is} | p_i) \geq V(C_{js} | p_i) \quad i, j = H, L, \quad i \neq j$$

⁴⁵In a context of symmetric imperfect information (see Sect. 10.7.3), De Garidel (2005) also finds that accident claims should not be shared by insurers.

$$\sum_{i=H,L} q_{is}(x_i)\pi(C_{is} | p_i) \geq \bar{\pi}_s$$

$$V(C_{is} | p_i) \geq V(C_i^{RS} | p_i) \quad i = H, L.$$

Dionne and Doherty (1994) first show that fully separating strategies, once made robust to renegotiation, degenerate to an outcome that amounts to that of a replication of single-period contracts in terms of welfare, when insureds are bound in relationships. If insureds are allowed to leave their company at the end of period 1, the program includes, in addition, no-switching constraints. As a result of this more constrained problem, the outcome will be worse in terms of welfare relative to a sequence of static contracts without memory. This negative result on separating contracts suggests efficiency will be attained by a partial revelation of information over time (as in the no-commitment model). Dionne and Doherty then show that the solution may involve semi-pooling in the first period followed by separated contracts. They argue that the equilibrium is fully separating when the discount factor is low and tends to a pooling for large discount factors. They also obtain a highballing configuration of intertemporal profits, contrary to the lowballing prediction resulting from models without commitment. Thus, commitment with renegotiation provides the same predictions as those in Proposition 12 except for the fourth result, which becomes:

$$\sum_{i=H,L} q_i(x_i)\pi(C_i^* | p_i) > \sum_{i=H,L} \sum_{s=a,n} q_{is}(x_i)\pi(C_{is}^* | p_i).$$

However, if a more general model is considered, in which outside options are endogenous (in which case C_i^{cc} replace C_i^{RS} in Problem 8, $i = H, L$), the configuration in equilibrium does not necessarily exhibit a decreasing profile of intertemporal profits for the company, meaning that models with commitment and renegotiation do not necessarily rule out the possibility of lock-in.⁴⁶ As in models without commitment, insureds are always better off when the information about accident records remains private, i.e., in a statutory situation where no regulatory law requires companies to make record data public.

Finally, the issue of consumer lock-in and the pattern of temporal profits should motivate researchers to undertake empirical investigations of the significance of adverse selection and of the testable predictions that permit discrimination between the competing models. To our knowledge, only two published studies have investigated these questions with multi-period data; their conclusions go in opposite directions. D'Arcy and Doherty (1990) found evidence of lowballing that supports the noncommitment assumption while Dionne and Doherty (1994) report that a significant group of insurers in California used high balling—a result that is more in line with some form of commitment. It is interesting to observe that this group of insurers attracts selective portfolios with disproportionate numbers of low risks. This result reinforces the idea that some form of commitment introduces more efficiency and the fact that there is adverse selection in this market.

⁴⁶However, it is possible to establish that a competitive insurance market always has an equilibrium, due to the compatibility of cross-subsidization with equilibrium, as opposed to the result in static models. The economic intuition is the following: an additional instrument can serve to make rival offers less attractive. It consists in informed insurers' offering of unprofitable contracts in the second period. This instrument is possibly used in a case of commitment with renegotiation but cannot be enforced in no-commitment situations.

10.5 Moral Hazard and Adverse Selection

Although in many situations principals face adverse selection and moral hazard problems simultaneously when they design contracts, these two types of asymmetric information have been given separate treatments so far in the economic literature on risk-sharing agreements. Both information problems have been integrated into a single model where all the parties of the contract are risk neutral (Laffont and Tirole 1986; Picard 1987; Caillaud et al. 1988; Guesnerie et al. 1988). Although these models involve uncertainty, they are unable to explain arrangements where at least one party is risk averse. In particular they do not apply to insurance. More recently, some authors have attempted to integrate both information problems into a single model where the agent is risk averse.

As discussed by Dionne and Lasserre (1988) such an integration of both information problems is warranted on empirical grounds. Applied studies are still few in this area, but researchers will find it difficult to avoid considering both kinds of information asymmetry (see, however Dionne et al. 2013).

10.5.1 Monopoly and Multi-period Contracts

Dionne and Lasserre (1988) show how it is possible to achieve a second-best allocation of risks when moral hazard and adverse selection problems exist simultaneously. While they draw heavily on the contributions of Dionne (1983); Rubinstein and Yaari (1983) and Dionne and Lasserre (1985), the integration of the two types of information problems is not a straightforward exercise. Given that an agent who has made a false announcement may now choose an action that is statistically compatible with his announcement, false announcements may go undetected. They propose a contract under which the agent cannot profit from this additional degree of freedom. Under a combination of moral hazard and adverse selection, several types of customers can adopt different care levels such that they have identical expected losses. When this happens, it is impossible to distinguish those who produce an efficient level of care from the others on the basis of average losses.

However, deviant behaviors can be detected by monitoring deviations from the mean. Thus the insurer's strategy can be written with more than one simple aggregate (Dionne and Lasserre 1988 and Rubinstein and Yaari 1983). In Dionne and Lasserre (1988) the principal has to monitor two aggregates: the average loss experienced by a given agent and its squared deviation from the mean. It was sufficient to get the desired result because in their model the information problem has only two dimensions. More generally, the insurer would have to monitor one moment of the distribution for each hidden dimension.

Combining moral hazard with adverse selection problems in models that use past experience might involve some synergetic effects. In the model presented in Dionne and Lasserre (1988), the same information required to eliminate either the moral hazard problem alone (Rubinstein and Yaari) or adverse selection alone (Dionne and Lasserre) is used to remove both problems simultaneously. A related subject concerns the efficient use of past information, and the allocation of instruments, toward the solution of each particular information problem. Self-selection mechanisms have long been proposed in response to adverse selection while nonlinear pricing was put forth as a solution to moral hazard. In one-period contracts both procedures used separately involve inefficiency (partial insurance) which can be reduced by the introduction of time in the contracts. Dionne and Lasserre show that self-selection may help solve both moral hazard problems and adverse selection problems. We will now discuss how the use of two instruments may improve resource allocation and welfare when both problems are present simultaneously in single-period competitive contracts.

In a static model which can be considered as a special case of the Dionne and Lasserre (1988) model, Chassagnon (1994) studies the optimality of a one-period model when both problems are

present simultaneously. Three results are of interest in this contribution: (1) the Spence–Mirrlees property is not always verified. Indifference curves may have more than one intersection point; (2) contrarily to the [Stiglitz \(1977\)](#) model where the low-risk individual may not have access to any insurance coverage, in Chassagnon’s model, there are configurations (in particular, the configuration *du pas de danse*, “dance step”) where all agents obtain insurance; finally, (3) both types of agents may receive a positive rent according to their relative number in the economy.

The model is specific in the sense that the accident probabilities keep the same order when the effort level is the same. Suppose that there are only two levels of efforts that characterize the accident probabilities of type i : $\underline{p}_i < \bar{p}_i$, $i = H, L$. In Chassagnon’s model, $\underline{p}_H > \underline{p}_L$ and $\bar{p}_H > \bar{p}_L$ while \underline{p}_H can be lower than \bar{p}_L . In fact the effect of introducing moral hazard in the pure principal–agent model becomes interesting when the high-risk individual is more efficient at care activities than the low-risk individual. Otherwise, when $\underline{p}_H > \bar{p}_L$, the results are the same as in the pure adverse selection model where only the \bar{H} type receives a positive rent.

10.5.2 Competitive Contracts

One of the arguments often used to justify the prohibition of risk categorization is that it is based on fixed or exogenous characteristics such as age, race, and sex. However, as pointed out by [Bond and Crocker \(1991\)](#), insurers also use other characteristics that are chosen by individuals. They extend [Crocker and Snow \(1986\)](#) previous analysis of risk categorization in the presence of adverse selection and examine the equilibrium and efficiency implications of risk categorization based on consumption goods that are statistically related to individual’s risks, which they termed “correlative products.”

Formally, their model introduces endogenous categorization in an environment characterized by both moral hazard and adverse selection. They show that while there is a natural tension between the sorting of risk classes engendered by adverse selection and the correction of externalities induced by moral hazard, the use of risk classification improves efficiency in resource allocation. They also obtain that the sorting of risks based on correlative consumption may give a first-best allocation as Nash equilibria when adverse selection is not too severe and when the insurer can observe individual consumption of the hazardous good.

This is particularly interesting as an alternative view of how firms, in practice, may overcome the nonexistence of Nash equilibrium problems. They then consider the case where the insurer cannot observe both the individual’s consumption and the individual’s characteristics. However, the planner can observe aggregate production of the good. They show that taxation of the consumption good now has two roles (reducing moral hazard and relaxing self-selection constraints) that permit Pareto improvements.

[Cromb \(1990\)](#) analyzes the simultaneous presence of moral hazard and adverse selection in competitive insurance markets and concludes that the addition of moral hazard to the standard Rothschild–Stiglitz (1976) model with adverse selection has qualitative effects on the nature and existence of equilibrium. Under certain circumstances the addition of moral hazard may eliminate the adverse selection problem, but, more generally, it constitutes a new source of nonexistence of a Nash equilibrium.

[Chassagnon and Chiappori \(1995\)](#) also propose an extension to the pure adverse selection model to consider incentives or moral hazard: the individual’s probability of accidents is no longer completely exogenous; it depends on the agent’s level of effort. In general, different agents choose different effort levels even when facing the same insurance contract. The equilibrium effort level does not depend on the level of accident probability but on its derivative. Consequently, the H type may have more incentive to produce safety to have access to a low insurance premium, but he may not have access to efficient technology.

As in [Chassagnon \(1994\)](#), indifference curves may intersect more than once which rules out the Spence–Mirrlees condition. As a result, when an equilibrium exists, it may correspond to many Rothschild and Stiglitz equilibria, a situation that is ruled out in the pure adverse selection model. Consequently, the equilibrium must be ranked, and [Chassagnon and Chiappori \(1995\)](#) use Hahn’s concept of equilibrium to select the Pareto efficient equilibrium from the Rothschild–Stiglitz candidates. In the pure adverse selection world, both equilibrium concepts are equivalent.

In the same spirit, [De Meza and Webb \(2001\)](#) formalize the argument of “advantageous selection” and examine the relation between risk preference and choice of precaution with a specification that the taste-for-risk parameter is additive in wealth. Under this nonmonetary formulation of the cost of prevention, the authors show that the single-crossing condition between risk-neutral and risk-averse individuals may not be satisfied (while [Jullien et al. 2007](#) show that this property always holds with a monetary formulation of the cost of precaution).

As a starting point, cautious types (more inclined to buy insurance and to put forth more effort) initially coexist with risk-tolerant types (disinclined to insure and to take precautions). The precautionary effort is thus positively correlated with insurance purchase. Depending on parameter values, separating, full pooling, and partial pooling equilibria are possible. What allows pooling (partial or full) is the double-crossing of indifference curves.

Another important conclusion is about the condition to obtain an equilibrium. It was shown in a previous section that a Rothschild–Stiglitz equilibrium exists if and only if there are enough high-risk agents in the economy. When both problems are present simultaneously, this condition is no longer true. Depending on the parameters of the model, an equilibrium may exist whatever the proportions of agents of different types or may even fail to exist whatever the respective proportions.

Finally, it is important to emphasize that the individual with higher accident probability, at equilibrium, always has access to the more comprehensive insurance coverage, a conclusion that is shared by the standard model. However, here, this individual is not necessarily of type *H*. This result is important for empirical research on the presence of asymmetric information problems.⁴⁷

In contrast, several studies suggest that the correlation between risk level and insurance purchases is ambiguous. The above-mentioned “advantageous selection” is called “propitious selection” by [De Donder and Hindriks \(2009\)](#), who also assume that applicants who are highly risk averse are more likely to try to reduce the hazard and to purchase insurance. In a model with two types of individuals differing in risk aversion, two properties (regularity and single-crossing) formalize the propitious argument. Under these two properties, the more risk-averse individuals will both exert more precaution and have a higher willingness to pay for insurance. [De Donder and Hindriks \(2009\)](#) thus prove that there cannot exist a pooling equilibrium. Indeed, a deviating firm can always propose a profitable contract, attractive only for the more risk-averse agents (who are also less risky in accordance with the propitious argument). Finally, the equilibrium contracts are separating with the more risk-averse individuals buying more insurance. Despite the propitious selection, the correlation between risk levels and insurance purchases is ambiguous at equilibrium: even though more risk averse agents behave more cautiously, they also buy more insurance at equilibrium, and with moral hazard, risk increases with coverage.

In a two-period model combining moral hazard and adverse selection, [Sonnenholzner and Wambach \(2009\)](#) propose another explanation of why the relationship between level of risk and insurance coverage can be of any sign. They stress the role of (unobservable) individual personal discount in explaining the decision to purchase insurance. Impatient individuals (with a high discount

⁴⁷See [Cohen and Siegelman \(2010\)](#) for a survey and a discussion about empirical work on the coverage–risk correlation that the pure asymmetric information model predicts. See also [Chiappori and Salanié \(2014\)](#) for a more recent review of empirical models on asymmetric information and [Dionne et al. \(2013\)](#) for a model that separates moral hazard from adverse selection and learning.

factor) initially coexist with patient individuals (with a low discount factor). A separating equilibrium exists in which patient consumers exert high precaution and are partially covered with a profit-making insurance contract, while the impatient consumers exert low effort and buy a contract with lower coverage or even prefer to remain uninsured. In contrast with the usual prediction, there is a negative correlation between risk and quantity.^{48,49}

These works are very close to the literature on multidimensional adverse selection where preferences are not necessarily single-crossing (see Sect. 10.7.2 in this chapter). However, in these multidimensional models, the higher risks buy more insurance.

10.6 Adverse Selection When People Can Choose Their Risk Status

An real twist on the adverse selection problem is to allow the information status of individuals to vary as well as the risk status. A traditional adverse selection problem arises when individuals know their risk status, but the insurer does not. What will happen in a market where some insureds know their risk status and others do not? The answer to this question depends on whether the information status is observed by the insurer. A further variation arises when the uninformed insureds can take a test to ascertain their risk status. Whether they choose to take the test depends on the menu they will be offered when they become informed and how the utility of this menu compares with the utility of remaining uninformed. Thus, the adverse selection problem becomes entwined with the value of information.

These questions are especially important in the health-care debate. Progress in mapping the human genome is leading to more diagnostic tests and treatment for genetic disorders. It is important to know whether the equilibrium contract menus offered to informed insureds or employees are sufficiently attractive to encourage testing. The policy debate is extended by considering laws that govern access of outsiders (such as employers and insurers) to medical records. For example, many laws require that medical records cannot be released to outsiders without the consent of the patient.⁵⁰

⁴⁸Without loss of generality, [Fombaron and Milcent \(2007\)](#) obtain the same conclusion in a model of health insurance in which they introduce a gap between the reservation utilities. This formulation implies that the low risks may be more inclined to buy insurance than the high risks when loss probabilities are symmetric information. This finding suggests that preference heterogeneity may be sufficient in explaining the opposite selection of insurance coverage in various markets.

⁴⁹[Cutler et al. \(2008\)](#) present empirical evidence in life insurance and in long-term care insurance in the USA that is consistent with this negative correlation (those who have more insurance are lower risk because they produce more prevention). However, in annuity markets, for example, higher-risk people seem to have more insurance, as the standard theory would predict. See also [Finkelstein and McGarry \(2006\)](#) and [Fang et al. \(2008\)](#).

⁵⁰For an overview of regulations and policy statements, see [Hoel and Iversen \(2002\)](#) and [Viswanathan et al. \(2007\)](#). The latter describes four major regulatory schemes for genetic information in many states, from no regulation to the most strict regulatory structure: in the Laissez-Faire approach, insurers have full freedom to request new tests, disclosure of existing tests, and use tests results in underwriting and rating; under the Disclosure Duty approach, individuals have to disclose to insurers the result of existing tests but cannot be required to undergo additional tests, while under the Consent Law approach, consumers are not required to divulge genetic tests results, but if they do, insurers may use this information. Finally, in the Strict Prohibition approach (there is a tendency in most countries to adopt this regulation of information in health insurance policies), insurers cannot request genetic tests and cannot use any genetic information in underwriting and rating.

10.6.1 A Full Information Equilibrium with Uninformed Agents

The basic analysis will follow [Doherty and Thistle \(1996a\)](#). This model uses fairly standard adverse selection technology and is illustrated with health insurance. However, further works by [Hoy and Polborn \(2000\)](#) and [Polborn et al. \(2006\)](#) have shown that similar results can be derived in a life insurance market where there is no natural choice of coverage and where individuals can buy from many insurers.⁵¹

Consider the simplest case in which there are initially three groups, uninformed, informed high risks, and informed low risks that are labeled “ U ,” “ H ,” and “ L ,” respectively. The contracts offered to each group will be labeled C_U , C_H , and C_L . We assume that type U has a probability q_H of being high risk, so we can rank the a priori loss probabilities as $p_H > p_U > p_L$. If insurers know the information and risk status of any individual (i.e., they know whether she is U , H , or L) the equilibrium competitive contracts are the first-best contracts C_U^* , C_H^* , and C_L^* depicted in [Fig. 10.6](#). This conclusion seems pretty obvious, but there is a potential problem to be cleared before we can be comfortable with this equilibrium contract set. If all the uninformed chose to become informed, then the equilibrium contract set would contain only C_H^* and C_L^* . Thus, we must check when uninformed would choose to become informed and face a lottery over C_H^* and C_L^* (the former if the test showed them to be high risk and the latter if low risk). In fact, the decision to become informed and receive policy C_H^* with probability q_H , and receive policy C_L^* with probability q_L , is a fair lottery (with the same expected value as staying with C_U^*) and would not be chosen by a risk-averse person. This confirms that the full information equilibrium is C_U^* , C_H^* , and C_L^* .

10.6.2 Sequential Equilibrium with Insurer Observing Information Status but Not Risk Type

It is a short step from this to consider what happens when the information status is known to the insurer but not the risk status of those who are informed.⁵² For this case and remaining ones in this section, we will look for sequential Nash equilibria. In this case, the insurer can offer a full information zero-profit contract C_U^* to the uninformed and the standard Rothschild–Stiglitz contracts, C_H^* and C_L^{**} as shown again in [Fig. 10.6](#). The intuition for this pair is clear when one considers that the uninformed can be identified and, by assumption, the informed high risks cannot masquerade as uninformed. To confirm this in the equilibrium contract set, we must be sure that the uninformed choose to remain so. The previous paragraph explained that the uninformed would prefer to remain with C_U^* than take the fair lottery of C_H^* and C_L^* . C_L^* would be strictly preferred by an informed low risk than the Rothschild–Stiglitz policy C_L^{**} (which has to satisfy the high-risk self-selection constraint). Thus, by transitivity, the uninformed would prefer to remain with C_U^* than face the lottery of C_H^* and C_L^{**} .

⁵¹Because insurance companies do not share information about the amount of insurance purchased by their customers in the context of life insurance, price–quantity contracts are not feasible. As a consequence, insurers can only quote a uniform (average) premium for all life insurance contracts. However, contrary to standard insurance setting, consumers can choose the size of loss and this loss is positively dependent on the probability of death. Hence, increasing symmetric information about risk type leads to changes in the demand for life insurance and in the average price quoted by insurers, contrary to standard setting.

⁵²This case may stretch plausibility slightly because it is difficult to imagine an insurer being able to verify that someone claiming to be uninformed is not really an informed high risk. However, we will present the case for completeness.

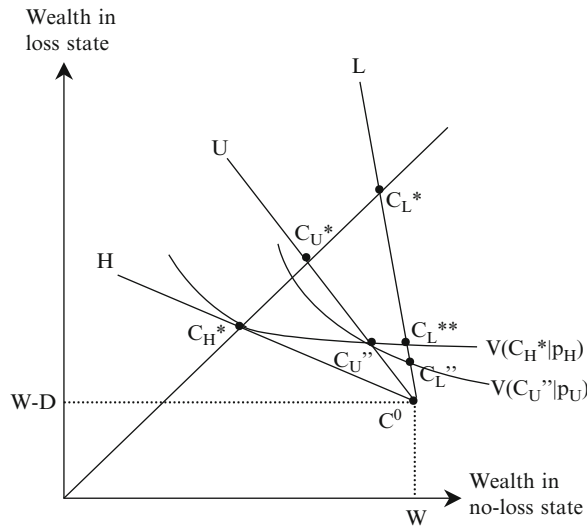


Fig. 10.6 Endogenous information

10.6.3 Sequential Equilibrium When Insurer Cannot Observe Information Status or Risk Type

We now come to the more appealing case in which the information status of individuals cannot be observed. This raises the interesting possibility that people can take a test to become informed and, if the news is bad, pretend they are uninformed. Because the insurer cannot observe information status, he has no way of separating these wolves in sheep's clothing from the uninformed sheep. This presents a problem for the uninformed. To signal that they are really uninformed and thus avoid subsidizing the high risks, they must accept a contract that would satisfy a high-risk self-selection constraint. This contract, C_U'' , is shown in Fig. 10.6. Suppose for the time being they accept this contract. Now what zero-profit contract can be offered to the informed low risks? To prevent the uninformed buying a low-risk contract, the latter must satisfy an uninformed risk self-selection constraint and such a contract set is C_L'' . Can this triplet, C_H^* , C_U'' , and C_L'' , be an equilibrium? The answer depends on the costs of information.

If the uninformed could choose to stay at C_U'' or become informed and take a lottery over C_H^* and C_L'' , what would they do? It turns out the value of the test is positive. Even though the test introduces more risk, there is a compensating factor that tips the balance in favor of the lottery. Remaining uninformed entails a real cost; policy C_U'' must bear risk to satisfy the high-risk self-selection constraint. Thus, the uninformed will remain so only if the cost of the test is sufficiently high. Accordingly the triplet C_H^* , C_U'' , and C_L'' can only be a Nash equilibrium if there are high costs of testing. If the test costs are low, we must consider another possible equilibrium. Suppose insurers expected all the uninformed to take the test, but they could not observe risk status after the test. In that case the only pair satisfying the high-risk self-selection constraint is the Rothschild–Stiglitz pair, C_H^* and C_L^{**} . It is fairly straightforward to show that, if the uninformed remained so, they would choose C_L^{**} over C_H^* . Thus the choice for the uninformed is to keep C_L^{**} valued without knowledge of risk type or face a lottery between C_H^* (valued with full information of high-risk type) and C_L^{**} (valued with knowledge of low-risk status). It turns out that the value of this lottery is zero. Thus, if the cost of information was zero, and using a tiebreaker rule, the uninformed would take the test, and the pair, C_H^* , C_L^{**} , is a sequential Nash equilibrium. Regardless of the cost of the test, this cannot be an equilibrium.

We can now summarize. If the costs of information are sufficiently high, there is a sequential equilibrium set C_H^* , C_U'' , and C_L'' . If the information costs are positive but below a threshold, then no sequential Nash equilibrium exists. Finally, there is a knife-edge case with an equilibrium of C_H^* , C_L^{**} which exists only with zero cost of information.

Hoel et al. (2006) show that the introduction of heterogeneity about perceived probability of becoming ill in the future allows to circumvent this nonexistence of equilibrium. In Hoel et al. (2006), testing is assumed to be costless, but consumers differ with respect to the disutility or anxiety of being informed about future health risk. Using a model with state-dependent utility, the authors assume that some individuals are attracted to chance, while others are repelled by chance. The first ones are more reluctant to choose testing than the second ones. Like Doherty and Thistle (1996a), Hoel et al. (2006) conclude that a regulatory regime in which the use of genetic information by insurers is allowed is better than one in which it is prohibited, but in contrast to Doherty and Thistle (1996a,b), they obtain that more people undertake the test when test results are verifiable than when they are not. Indeed, in uncertain but symmetric information setting, when being offered full insurance contracts, some individuals sufficiently repelled from chance choose to take a test. When information is asymmetric with test results being verifiable, untested individuals are offered partial insurance, to dissuade high-risk agents from claiming that they were not tested. By relaxing the verifiability of test results, both (tested) low-risk and untested agents are offered partial insurance to dissuade untested agents to claim being low risk. In contrast to Doherty and Thistle (1996a) who find that all agents choose to be tested when insurers cannot distinguish between untested agents and high-risk agents (for $c = 0$), Hoel et al. (2006) explain why some consumers prefer to stay uninformed even when information on test status is asymmetric.

For another model of insurance purchasing decisions with state-dependent utilities, see Strohmenger and Wambach (2000) who argue that results from standard insurance market models may not be simply transferred to health insurance markets (due to the assumption that treatment costs are sometimes higher than willingness to pay). State-contingent utilities take into account the fact that people in case of illness have the choice between undergoing a treatment or suffering from their diseases. Here again, making the results of genetic tests available to the insurer might be welfare-improving.

10.6.4 The Case of Consent Laws

One of the interesting policy applications of this analysis is *consent laws*. Many states have enacted laws governing the disclosure of information from genetic (and other medical) tests. The typical law allows the patient to choose whether to divulge information revealed by the test to an employer or insurer. This issue was considered by Tabarrok (1994) who suggested that consent laws would encourage people to take the test. This was examined further by Doherty and Thistle (1996b), who derive alternative Nash equilibria under consent laws. The principal feature of their analysis is that informed low risks can verify their low-risk status by presenting the results of the test. Alternatively, informed high risks will conceal their identity, i.e., withhold consent. This leads to a potential equilibrium containing policies of set $A \equiv \{C_H^*, C_U'', C_L''\}$ or set $B \equiv \{C_H^*, C_L^*\}$. For B to be an equilibrium, the uninformed must choose to take a diagnostic test when faced with this contract menu. The value of information, $I(B)$, turns out to be positive; this can only be an equilibrium if the information value exceeds the cost of the diagnostic test, c . The other possible equilibrium, A , can hold only if the uninformed remains so. Because the value of information is positive, the equilibrium can only hold if the cost of the test is sufficiently high to discourage testing, $I(A) < c$. Thus, the possible equilibria are A if the cost of the test is sufficiently high and B if the cost of the test is

sufficiently low. There are possible situations where no Nash equilibrium exists or where there are multiple equilibria. Summarizing:

| | |
|-------------------|-----------------------------------|
| $I(A) < c < I(B)$ | two equilibrium sets, A and B |
| $c < I(A), I(B)$ | equilibrium set is B |
| $I(A), I(B) < c$ | equilibrium set is A |
| $I(A) > c > I(B)$ | no Nash equilibrium exists. |

In the context of life insurance, [Hoy and Polborn \(2000\)](#) and later [Polborn et al. \(2006\)](#) obtain positive and normative results that are either consistent with or differ from those described in standard insurance setting. A significant difference is that prohibiting insurance from using information about risk type may increase welfare. In a static setting with initial adverse selection, [Hoy and Polborn \(2000\)](#) argue that genetic testing has a possible dimension for providing positive social value by allowing better informed consumption choices (while in [Doherty and Thistle](#), the social value of the testing opportunity is negative). The authors construct three scenarios in which the existence of the test is either Pareto-worsening, Pareto-improving, or is worse off for some consumers and better off for others. The intuition why additional information may lead to a private benefit is as follows. Even if the average equilibrium premium increases as a result of testing, those who are tested (with good or bad news) gain because they can adjust their life insurance demand to their real risk type. In a three-period model, [Polborn et al. \(2006\)](#) assume that people can buy term insurance covering the risk of death either early in life (period 1) before they have received information about their mortality risk and before risk type is known and/or later (period 2) after they have received this information (people face the risk of death only at the beginning of period 3). Here again, if there are sufficiently few individuals who receive bad news about their genetic type, restricting insurers from not using information about genetic testing may provide alternative assurance against the risk of classification, in combination with a cap that limits adverse selection.

However, empirical studies deal with the consequences of a ban on the use of genetic testing in life insurance. [Hoy and Witt \(2007\)](#) provide an economic welfare analysis of the adverse selection costs associated with regulations that ban insurers from access to these tests for the specific case of information relating to breast cancer. These adverse selection costs are shown to be very modest in most circumstances and the authors argue in favor of restricting the use of genetic test results for rate-making purposes. Using a discrete Markov chain model, [Viswanathan et al. \(2007\)](#) find similar results. They track the insurance demand behavior of many cohorts of women who can change their life insurance benefit at the end of each policy year, influenced by the results of tests relating to breast and ovarian cancers (and consequently by their premium changes).

10.6.5 Moral Hazard, Public Health, and AIDS Testing

If the costs and benefits to patients of the potential use of information in insurance markets when consent laws are in place are considered, the value of information is positive, and insurance markets can be encouraged to endorse testing. Whether people actually take medical tests also depends on the costs of those tests. These costs are critical in determining which, if any, Nash equilibrium exists. One can generalize the discussion and talk not simply of the costs of the test but also of other benefits. Quite obviously, testing yields a medical diagnosis that can be useful in treating any revealed condition. In general we would expect this option for treatment to have a positive private and social value (see [Doherty and Posey 1998](#)). Accounting for the private value of this option has the same

effect as lowering the cost of the test and tends to favor the equilibrium contract set B in which all people take the test. However, this opens up the wider issue of other costs and benefits to acquiring information related to risk status.

An interesting twist on this literature concerns the case of AIDS testing. The result that insurance markets tend to raise the private benefit from testing may be reassuring to those interested in public health who normally consider testing for diseases such as AIDS and inherited disorders to be socially beneficial. Several studies have analyzed behavioral choices in sexual activities and their effect on the transmission of AIDS and the effectiveness of public health measures (Castillo-Chavez and Haderler 1994; Kremer 1996). The work of Philipson and Posner (1993) is particularly pertinent: they examine the effect of taking AIDS test on opportunities to engage in high-risk sexual activity. Without going into detail, the point can be made by recognizing that people might take the test to verify their uninfected status so they can persuade partners to engage in high-risk sexual activity. Without such certification, they may have been unable to secure partners for high-risk sex. While this is only one part of their analysis, it is sufficient to illustrate their point that AIDS testing can conceivably *increase* the spread of the disease. In spite of the possible social costs of testing, it also shows there are private benefits to diagnostic tests because they expand opportunities for sexual trade.

These works tend to tilt the previous analysis of insurance equilibrium at least for the case of AIDS testing. The insurance equilibrium required a comparison of the costs of testing with the value of (insurance) information revealed by the test. Philipson and Posner (1993) report an exogenous private benefit of testing. Such a private benefit is the same as lowering the cost of testing. Accordingly, it creates a bias in favor of those equilibria in which all individuals are fully informed of their risk status, i.e., contract set B .

Hoel and Iversen (2002) extend Doherty and Thistle's (1996a, b) results by taking into account the availability of preventive measures (as private information).⁵³ In addition to focusing on the regulation of access to information about individual test status,⁵⁴ Hoel and Iversen (2002) are interested in the possible inefficiencies due to a compulsory/voluntary mix of health insurance.⁵⁵ First, they show that genetic testing and prevention may not be undertaken although testing is socially efficient (this inefficiency is likely to occur for systems with high proportion of compulsory insurance). However, tests may be undertaken when testing is socially inefficient (more likely for systems with substantial voluntary supplementary insurance and more important the less prevention is).

Finally, while the above-mentioned models have investigated primary prevention (which reduces the probability of illness), Barigozzi and Henriët (2009) consider a model in which secondary prevention measures (which reduces the health loss when illness occurs) are available. They characterize market outcomes under the four regulatory schemes described by Viswanathan et al. (2007) and derive an unambiguous ranking of these schemes in terms of social welfare. The Disclosure Duty approach weakly dominates all the other regulatory structures. At the other extreme, the Strict Prohibition approach is dominated by all the other regulatory schemes. The Laissez-Faire and the *Consent Law* approaches appear to be intermediate situations.

⁵³See also Fagart and Fombaron (2006) for a discussion of the value of information under alternative assumptions about what information is available to insurers in a model with preventive measures.

⁵⁴As in Doherty and Thistle, an individual decides whether or not he wishes to obtain the information from testing.

⁵⁵More precisely, voluntary health insurance is considered as a supplement to compulsory insurance.

10.7 Concluding Remarks: Extensions to the Basic Models

10.7.1 Risk Categorization and Residual Adverse Selection

Adverse selection can explain the use of risk categorization in insurance markets based on variables that procure information at a low cost (Hoy 1982, 1989; Rea (1992); Browne and Kamiya 2012). For example, in automobile insurance, age and sex variables are significant in explaining probabilities of accidents and insurance premia (Dionne and Vanasse 1992; Puelz and Snow 1994; Chiappori and Salanié 2000; Dionne et al. 2001; Dionne et al. 2006). Particularly, young male drivers (under age 25) are much riskier to insure than the average driver. Because it is almost costless to observe age and sex, an insurer may find it profitable to offer policies with higher premiums to young males. However, such categorization is now prohibited in some states and countries. For surveys on adverse selection and risk classification, see Crocker and Snow (2014) and Dionne and Rothschild (2011).

Dahlby (1983, 1992) provides empirical evidence that adverse selection is present in the Canadian automobile insurance market. He also suggests that his empirical results are in accordance with the Wilson–Miyazaki–Spence model that allows for cross-subsidization between individuals in each segment defined by a categorization variable such as sex or age: low-coverage policies (low risks) subsidizing high-coverage policies (high risks) in each segment.⁵⁶ This important statistical result raises the following question: does statistical categorization enhance efficiency in the presence of adverse selection? In other words, can welfare be improved by using the public information on agents' characteristics (such that age and sex) in offering insurance contracts in the presence of adverse selection? Crocker and Snow (1985, 1986) show that, if the observable variables are correlated with hidden knowledge, costless imperfect categorization always enhances efficiency where efficiency is defined as in Harris and Townsend (1981). Another important contribution in Crocker and Snow (1986) concerns the existence of a balanced-budget tax–subsidy system that provides private incentives to use costless categorization. Note that the corresponding tax is imposed on contracts, not on individuals. If a redistribution is made from gains earned on the group in which low risks are predominant (e.g., old male drivers) to the group in which high risks are predominant (young male drivers), the classification always permits expansion of the set of feasible contracts. The reason is that the use of categorization relaxes the incentive compatibility constraints. Consequently, with appropriate taxes, no agent loses as a result of categorization. The results are shown for the Wilson–Miyazaki–Spence equilibrium concept but can also sustain an efficient allocation in a Nash equilibrium with a tax system (Crocker and Snow 1986). These conclusions can be applied to the Wilson anticipatory equilibrium or to the Riley reactive equilibrium, for some values of parameters, both with a tax system. It then becomes clear that prohibiting discrimination on equity considerations imposes efficiency costs in insurance markets (such as automobile insurance where categorization based on age and sex variables is costless).

Finally, Crocker and Snow (1986) argue that the welfare effects are ambiguous when categorical pricing is costly. In contrast, Rothschild (2011) shows that Crocker and Snow's (1986) result that categorical pricing bans are inefficient applies even when the categorical pricing technology is costly. In practice, if the government provides break-even partial social insurance and allows firms to categorize with supplemental contracts, the market will choose to employ the categorical pricing only when doing so is Pareto-improving. In other words, providing partial social insurance socializes the provision of the cross-subsidization.

⁵⁶However, Riley (1983) argued that the statistical results of Dahlby (1983) are also consistent with both the Wilson anticipatory equilibrium (1977) and the Riley reactive equilibrium (1979). Both models reject cross-subsidization.

In recent empirical studies, [Chiappori and Salanié \(2000\)](#) and [Dionne et al. \(2001, 2006\)](#) (see also [Gouriéroux 1999](#)) showed that risk classification is efficient to eliminate asymmetric information from an insurer's portfolio, in the sense that there is no residual asymmetric information in the portfolio studied (see [Richaudeau 1999](#), for an application with a different data set).⁵⁷ They conclude that the insurer was able to control for asymmetric information by using an appropriate risk classification procedure. Consequently, no other self-selection mechanisms inside the risk classes (such as the choice of deductible) are necessary to reduce the impact of asymmetric information, which justify active underwriting activities by insurers ([Browne and Kamiya, 2012](#)). See [Chiappori \(1994\)](#), [Chiappori and Salanié \(2014\)](#), and [Dionne \(2014\)](#) for more detailed analyses of methodologies to isolate information problems in insurance data.

10.7.2 *Multidimensional Adverse Selection*

Up to now, it was assumed that risk categories are determined up to the loss probability. However, residual asymmetric information between the insured and the insurers could consist of attitude toward risk. [Villeneuve \(2003\)](#) and [Smart \(2000\)](#) explore the implication of assuming that differences in risk aversion combined with differences in accident probabilities create a multidimensional adverse selection problem where the equilibrium allocation differs qualitatively from the classical results of [Rothschild and Stiglitz \(1976\)](#). In [Villeneuve \(2003\)](#), not only may positive profits be sustainable under several equilibrium concepts (Nash, Rothschild and Stiglitz, Wilson, Riley), but equilibria with random contracts are also possible. The former situation is more likely when low-risk agents are more risk averse, whereas the latter is more likely when the low risk is less risk averse. Villeneuve explores the origin of these phenomena. He gives necessary and sufficient conditions for the comparison of risk aversions that either guarantee or exclude atypical equilibria.

In a companion article, [Smart \(2000\)](#) obtains similar results. In his model, indifference curves of customers may cross twice; thus the single-crossing property does not hold. When differences in risk aversion are sufficiently large, firms cannot use policy deductibles to screen high-risk customers. Types may be pooled in equilibrium or separated by raising premiums above actuarially fair levels. This leads to excessive entry of firms in equilibrium.⁵⁸

[Wambach \(2000\)](#) has extended the model of RS by incorporating heterogeneity with respect to privately known initial wealth.⁵⁹ He assumes four unobservable types of individuals; those with high or low risk with either high or low wealth. When the wealth levels are not too far apart, then types with different wealth but the same risk are pooled, while different risks are separated. The possibility of double-crossing indifference curves occurs for large differences in wealth. In this case, self-selection contracts that earn positive profit might hold in equilibrium. However, in [Villeneuve \(2003\)](#) and [Wambach \(2000\)](#), insurers are restricted to offering only one contract each (in and off the equilibrium).⁶⁰

[Snow \(2009\)](#) argues that profitable contracting advanced in these modified Rothschild–Stiglitz environments cannot be sustained as a Nash equilibrium under competitive conditions, if insurers are allowed to offer menus of contracts. In the three above-mentioned models, the configuration in which the high-risk contract breaks even while the low-risk contract earns a positive profit cannot be

⁵⁷In contrast, [Cohen \(2005\)](#) does not reject residual asymmetric information with data from Israel.

⁵⁸See also [Landsberger and Meilijson \(1994, 1996\)](#) for an analysis of a monopolistic insurer with unobserved differences in risk aversion.

⁵⁹Similar conclusions would be obtained if individuals differed in the size of losses (in addition to the difference in risk).

⁶⁰In contrast, Smart restricts the entry by a fixed barrier.

a two-stage Nash equilibrium; there always exists a pair of incentive-compatible and jointly profitable contracts attractive to both risk types (an unprofitable contract with full coverage attracting only high risks and a profitable contract attracting low risks). Similar reasoning applies to the model investigated by [Sonnenholzner and Wambach \(2009\)](#), combining moral hazard with adverse selection.⁶¹

[Snow \(2009\)](#) resolves the problem of nonexistence of equilibrium in the related instances by appealing to the three-stage game introduced by [Hellwig \(1987\)](#). When insurers can modify their contractual offers in a third stage of the contracting game, the break-even pooling contract is the strategically stable Nash equilibrium.

Other studies, including [Fluet and Pannequin \(1997\)](#), [Crocker and Snow \(2011\)](#), and [Koehl and Villeneuve \(2001\)](#), focus on situations where two types of individuals with multiple risks coexist. [Fluet and Pannequin \(1997\)](#) analyze two situations: one where insurers offer comprehensive policies against all sources of risk (complete insurance) and one where different risks are covered by separate policies (incomplete contracts). In the second case, they analyze the possibility that the insurer has perfect information about the coverage of other risks by any insurer in the market. They show that when market conditions allow for bundling (getting information to protect insurers against undesirable risks), the low-risk individual in a particular market (or for a particular source of risk) does not necessarily buy partial insurance in that market as in the Rothschild and Stiglitz model.

Their analysis emphasizes the trade-off between bundling and spanning. Multiple-risk contracts allow for perfect spanning (taking correlations between different risks into account) and for perfect bundling (considering all information available to the insurers) while single contracts with imperfect information on contract choice for other risks are inferior because they do not permit risk diversification and information sharing. They show that the former is the more efficient which confirms the practice by insurers in many countries.

In contrast with [Fluet and Pannequin](#) who consider the possibility to bundle several (independent) risks, [Crocker and Snow \(2011\)](#) decompose a given risk of loss into its distinct potential causes. The knowledge of the conditional probability of a particular peril occurring is private as in the model of one-dimensional screening, but applicants signal their type in more than one dimension through the choice of a vector of deductibles. Bundling of coverage for all the perils into a single policy is efficient as in [Fluet and Pannequin](#) (relative to the solution where the perils were covered by separate contracts) and does not fundamentally alter the structure of screening; high risks are unaffected by the introduction of multidimensional screening while low risks obtain more coverage than the high risks for perils from which they are more likely to suffer. By reducing the externality cost that low-risk agents must bear to distinguish themselves from high-risk agents, multidimensional screening enhances the efficiency of insurance contracting and circumvents the nonexistence problem (by decreasing the critical value above which Nash equilibrium exists).

In the same spirit, [Koehl and Villeneuve \(2001\)](#) consider a multiple-risk environment, but in which exclusivity cannot be enforced and insurers are specialized. The authors compare the profits of the global monopoly and the sum of the profits each monopoly would make in the absence of the other. It is shown that specialization prevents second-best efficiency because it weakens insurers' ability to screen applicants. Even if the market exhibits a form of complementarity that limits the conflict between the insurers (by limiting the conflict between insurers, specialization implicitly sustains collusion between competitors), there are efficiency losses due to specialization, and the profits at the industry level are decreased.

⁶¹In this model, one case in which profitable self-selection contracting arises, with patient types only partially covered exerting high effort (while impatient types exert low effort and receive a lower coverage).

10.7.3 *Symmetric Incomplete Information*

According to recent empirical studies that test the presence of adverse selection in automobile insurance markets (Chiappori and Salanié 2000; Dionne et al. 2001), it seems that we can reject the presence of residual asymmetric information in some markets. More precisely, even though there is potential adverse selection on these markets, insurers are able to extract all information on individuals' risk type through very fine risk categorization.

By focusing on these recent empirical results, De Garidel (2005) rejects the presence of initial asymmetries of information and, on the contrary, assumes that information between insurers and insureds is incomplete, but initially symmetric (at the beginning of a two-period contract). He provides a dynamic competitive model in which each agent, together with his initial insurer, learns about his type through accidents. However, other insurers may not, depending on informational structures.

In the absence of ex ante adverse selection, he shows that "(i) keeping information about accident claims private is welfare-improving, (ii) such a policy does not jeopardize the existence of an equilibrium, and (iii) this equilibrium exhibits both bonus and malus." Thus, in a two-period model, adverse selection arises endogenously through differentiated learning about type and leads to reconsider the widespread idea according to which competition in markets with adverse selection may be undesirable. Indeed, De Garidel (2005) shows that it is welfare-enhancing to produce adverse selection of this kind.⁶²

10.7.4 *Reversed Adverse Selection and Double-Sided Adverse Selection*

In the literature on decentralized markets under asymmetric information, it is commonly assumed that the uninformed party possesses all the bargaining power. This is also the usual assumption of insurance models, whereas it is often argued that companies may be better able to assess the risk of an individual than this individual himself. The contribution by Bourgeon (1998) reverses this usual assumption, giving the relevant information to the insurers, in addition to the bargaining power. Under this hypothesis, the insurers' activity is not only to sell a particular good or service but also to produce a diagnosis of the buyers' needs. This is the case in some insurance markets, including health and life, where the sellers appear to be the experts in the relationship.

Assuming risk-averse buyers and risk-neutral sellers, the focus of Bourgeon's model is on symmetric-steady-state equilibria of the market game. The only candidates for equilibria are semi-separating ones, i.e., equilibria where the buyers carrying the good state of nature are partially pooled with the low-state ones. Separating equilibria are invalid simply because they violate the sellers' incentive constraints: assuming a separating equilibrium, the equilibrium contracts involve full coverage of the damages, which are the same in both states accident and no accident. The only difference between these contracts is thus the premium, which is higher for the high-risk individuals. A seller would thus increase its profit by offering the high-risk contract to a low-risk buyer. A pooling equilibrium cannot occur because of a trickier reason related to the (limited) monopoly power of sellers: knowing that its competitors propose a pooling contract, a seller offers a contract corresponding to the buyer's reservation value. Because the contract is pooling, however, the buyer cannot revise his beliefs and his reservation value is unchanged since his entrance in the market. Consequently, he has no reason to begin a time-consuming search, and therefore the market shuts down. If an equilibrium exists, it thus entails a search, which is long-lasting for all buyers carrying

⁶²See Cohen (2012) for a model of asymmetric learning among insurers on insured risk.

a bad state: sellers always propose high-risk contracts, but because there is a chance that the buyer's risk is low, he visits several sellers before accepting this contract. Moreover, he is never convinced of the true price, and sellers consequently charge a lower price than they would charge if the buyer knew the true information. The informational asymmetry is thus advantageous to the high-risk individuals, because they are not charged the entire risk premium corresponding to this state. When choosing a contract for a low risk, a seller balances between offering the contract for low risks, which is certain to be accepted by the buyer but gives small profits, and offering a high-risk contract, which is accepted only by some of the buyers but is more profitable.

In a static approach, [Fagart \(1996b\)](#) explores a competitive market of insurance where two companies compete for one consumer. Information is asymmetric in the sense that companies know the value of a parameter ignored by the consumer. The model is a signaling one, so that insureds are able to interpret offered insurance contracts as informative signals and may accept one among these offers or reject them. The features of the equilibrium solution are the following: the information is systematically revealed and profits are zero.

[Villeneuve \(2000\)](#) studies the consequences for a monopolistic insurance firm of evaluating risk better than customers under the adverse selection hypothesis reversed. In a more general model ([Villeneuve 2005](#)), he suggests that information retention and inefficiency have to be expected in many contexts. In a competitive insurance market, he shows that neither revelation of information nor efficiency are warranted and that the surplus may be captured by some insurers rather than the consumers. Thus, in his model, the classical predictions of Rothschild and Stiglitz are reversed: types may be pooled, high-risk consumers may remain uninsured or obtain partial coverage, and profits are not always zero. The key argument is that the way consumers interpret offers may restrict competitive behavior in the ordinary sense.

[Seog \(2009\)](#) formalizes a double-sided adverse selection by decomposing the risk of a policyholder into two risks: a general risk and a specific risk. He considers that each party to the insurance contract has superior information; policyholders have superior information about specific risk while insurers have superior information about general risk (e.g., policyholders have superior information on their own driving habits, but automobile insurers have superior information about accident risks). High-general-risk consumers are self-insured in equilibrium while low-general-risk consumers are covered by an insurance contract (full insurance for high-specific-risk people and partial insurance for low-specific-risk people). As a consequence, when insurers make their information about general risk public, efficiency is unambiguously improved.

[Chassagnon and Villeneuve \(2005\)](#) and [Jeleva and Villeneuve \(2004\)](#) propose two extensions of the classical model in which each party knows something that the other does not. Assuming less than perfect risk perception (subjective beliefs), [Chassagnon and Villeneuve \(2005\)](#) characterize the efficient frontier in a competitive setting, while [Jeleva and Villeneuve \(2004\)](#) analyze the equilibrium between a monopolistic insurer confronted with policyholders having beliefs different from the objective probabilities (the authors formalize this disparity using the rank-dependent expected utility model proposed by [Quiggin, 1982](#) and [Yaari, 1987](#)). Both articles find that the optimal offer can be a pooling contract and that better risks can be better covered.

10.7.5 Uberrima Fides

An insurance contract is under *uberrima fides* when an insured makes a full disclosure of all facts pertaining to his risk that are known to him *ex ante*. Under this type of arrangement, the insurer asks questions about the individual risk at the signing of the contract, but keep the right to investigate the truth only when the claim is made, to reduce the audit costs. If the answers are found to be false, the insurer can refuse to pay the claim. This scheme provides a new way to select low risks at a lower

social cost than the Rothschild–Stiglitz method. Some life insurers used individuals' declarations about their smoking behavior to set insurance prices. In fact, [Dixit \(2000\)](#) shows that *uberrima fides* is Pareto-improving when compared to Rothschild–Stiglitz equilibrium.

10.7.6 *Adverse Selection and Participating Contracts*

The literature on insurance contract design has focused on nonparticipating contracts, even if participating contracts are more consistent with Borch's mutualization principle. In the nonparticipating contracts, the premiums are conditioned only on the individual loss (the risk is only transferred to an external risk bearer (stock insurer)), whereas participating contracts condition pay out both on the individual loss and the portfolio experience (the premium is subject to a retroactive adjustment or dividend, which depends on the collective loss experience of the pool).

Extending the earlier work of Borch (1962), [Marshall \(1974\)](#) argues that in the presence of aggregate or social risk and in the absence of adverse selection, mutual insurance is more efficient, unless there are enough independent risks that the law of large numbers to be applied. In the same spirit, [Doherty and Dionne \(1993\)](#) show how the composite risk transfer implicit in mutual insurance (weakly) dominates the simple risk transfer implicit in stock insurance. They suggest that an efficient insurance contract will decompose risk into diversifiable (or idiosyncratic) and non-diversifiable elements and will let the parties bargain on the sharing of each component.

[Smith and Stutzer \(1990\)](#) introduce adverse selection with undiversifiable aggregate risk. Owing to their participating nature, mutual insurance policies are an efficient risk-sharing mechanism. Smith and Stutzer show that high-risk policyholders fully insure against both individual and aggregate risk, while low-risk individuals partially insure against both risk types.

Because small mutual insurance firms appear to be less risk sharing, [Ligon and Thistle \(2005\)](#) argue that they must offer their policyholders other advantages, namely in solving problems of adverse selection. Even in the absence of aggregate risk, their analysis suggests that organization size may be an important component of the institutional structure and provides an alternative explanation both for the existence of mutual insurance firms and for the coexistence of stock and mutual insurers. Ligon and Thistle assume that even when a risk pool cannot control its composition directly (due to adverse selection), adverse selection can create incentives for the formation of distinct mutual insurers. Adverse selection limits the size of these low-risk mutuals. The combination of stock and mutual insurers is thus shown to solve adverse selection problems, by allowing consumers to choose from a menu of contracts.

As in Smith and Stutzer,⁶³ high-risk individuals buy conventional fixed-premium policies from stock insurers while low-risk individuals form mutuals. In addition, Ligon and Thistle derive the conditions⁶⁴ under which stock insurers (for the monopoly and competitive cases) and mutual insurers can coexist, and show that the mutual can offer higher expected indemnity to low-risk members than the stock insurance policy without attracting high-risk individuals. Low-risk individuals are strictly better off forming mutuals than buying stock insurance policies. High-risk individuals are no worse off (under monopoly) or are strictly better off (under competition) buying insurance from the stock insurer than joining the mutual. Finally one empirical implication of their theoretical analysis is that adverse selection may create incentives for some mutuals to be small (while there is no corresponding incentive for stock insurers). Ligon and Thistle find that empirical distribution of insurer size by type corresponds precisely with what their theoretical analysis predicts.

⁶³Even if their approach differs from Smith and Stutzer because the problem is one of cooperative game theory.

⁶⁴The conditions under which this separating equilibrium exists are analogous to those under which a separating equilibrium exists in the standard Rothschild–Stiglitz model.

More recently, [Picard \(2009\)](#) finds that allowing insurers to offer either nonparticipating or participating policies guarantees the existence of an equilibrium in the Rothschild–Stiglitz model. Participating policies act as an implicit threat that dissuades deviant insurers that would like to attract low-risk agents only (when there is cross-subsidization between risk types) and the WMS allocation can be sustained as a subgame perfect equilibrium of a noncooperative game. In words, an equilibrium holds with high-risk agents having taken out a participating policy subsidized by low-risk individuals because if low-risk agents switch to another insurer, the situation of high-risk agents deteriorates because of the participating nature of their insurance contract. Consequently, it is more difficult for the deviant insurer to attract only low-risk types without attracting high-risk types as well. When there is no equilibrium in the Rothschild–Stiglitz model with nonparticipating contracts, an equilibrium with cross-subsidized participating contracts actually exists. Further, this model predicts that the mutual corporate form should be prevalent in insurance lines with cross-subsidization between risk types, while there should be stock insurers in other cases.

In each of these models, coexistence of stock and mutual insurers occurs because of either exogenous aggregate risk ([Doherty and Dionne 1993](#); [Smith and Stutzer 1990](#)) or adverse selection ([Smith and Stutzer 1990](#); [Ligon and Thistle 2005](#); [Picard 2009](#)). A third explanation for the coexistence of mutual and stock insurers focuses on the possibility of a stock insurer's becoming insolvent (i.e., unable to pay all the promised indemnities). [Rees et al. \(1999\)](#) take into account this possibility and assume that insolvency can be avoided by choosing appropriate capital funds and that agents are fully informed about this choice. In a somewhat similar vein, [Fagart et al. \(2002\)](#) consider that when unbounded losses are possible, insolvency cannot be excluded. The contracts a stock insurer company offers imply a fixed premium that may be negatively adjusted at the end of the contractual period when the losses of stock insurers are too large to be covered by the company's reserves (capital funds and the collected premia), while the optimal contract offered by a mutual firm involves a systematic ex post adjustment (negative or positive). These assumptions point to a network effect in insurance (or size effect): the expected utility of an agent insured by a mutual firm is an increasing function of its number of members. For the insurance companies, network externalities also exist but are positive or negative depending on the amount of the capital funds. In an oligopoly game, either one mutual firm or insurance company is active in equilibrium, or a mixed structure emerges in which two or more companies share the market with or without a mutual firm. [Bourlès \(2009\)](#) extends this analysis by endogenizing the choice of capital and gives a rationale for mutualization and demutualization waves.

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Chapter 11

The Theory of Risk Classification

Keith J. Crocker and Arthur Snow

Abstract Risk Classification is the avenue through which insurance companies compete in order to reduce the cost of providing insurance contracts. While the underwriting incentives leading insurers to categorize customers according to risk status are straightforward, the social value of such activities is less clear. This chapter reviews the theoretical and empirical literature on risk classification, which demonstrates that the efficiency of permitting categorical discrimination in insurance contracting depends on the informational structure of the environment, and on whether insurance applicants become informed by the classification signal.

Keywords Risk categorization • Classification • Informational asymmetry • Information • Insurance

11.1 Introduction

The efficiency and equity effects of risk classification in insurance markets have been a source of substantial debate, both amongst economists and in the public policy arena.¹ The primary concerns have been the adverse equity consequences for individuals who are categorized unfavorably, and the extent to which risk classification enhances efficiency in insurance contracting. While equity effects are endemic to any classification scheme that results in heterogeneous consumers being charged actuarially fair premiums, whether such classification enhances market efficiency depends on specific characteristics of the informational environment.

In this contribution we set out the theory of risk classification in insurance markets and explore its implications for efficiency and equity in insurance contracting. Our primary concern is with

¹ See Crocker and Snow (1986) for references to U.S. Supreme Court rulings disallowing gender-based categorization in pensions, and to discussions of the laws and public policies related to categorization practices. Tabarrok (1994) provides further references to the policy and popular debate on categorical discrimination.

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economic efficiency and the role of risk classification in mitigating the adverse selection that arises when insurance applicants are better informed about their riskiness than insurers. We are also interested in the role of classification risk, that is, uncertainty about the outcome of a classification procedure. This uncertainty imposes a cost on risk averse consumers and is thus a potential cause of divergence between the private and social value of information gathering. In addition, the adverse equity consequences of risk classification bear directly on economic efficiency as they contribute to the social cost of classification risk.

11.2 Risk Classification in the Absence of Hidden Knowledge

We begin by considering as a benchmark the case in which both insurers and insurance applicants are symmetrically uninformed about the applicants' propensities for suffering an insurable loss.

11.2.1 Homogeneous Agents

Formally, the insurance environment consists of a continuum of risk averse consumers, each of whom possesses an initial wealth \bar{W} and may suffer a (publicly observed) loss D with known probability \bar{p} . Each consumer's preferences are represented by the von Neumann–Morgenstern utility function $U(W)$, which is assumed to be strictly increasing and strictly concave, reflecting risk aversion.

A consumer may purchase insurance against the loss by entering into a contract $C \equiv (m, I)$, which specifies the premium m paid to the insurer and the indemnification I received by the insured when the loss occurs. A consumer's expected utility under the insurance contract C is given by

$$V(\bar{p}, C) \equiv \bar{p}U(W_D) + (1 - \bar{p})U(W_N), \quad (11.1)$$

where $W_D \equiv \bar{W} - m - D + I$ and $W_N \equiv \bar{W} - m$ denote the consumer's state-contingent wealth levels. The expected profit of providing the insurance contract C is given by

$$\pi(\bar{p}, C) \equiv m - \bar{p}I. \quad (11.2)$$

In order to be feasible, a contract must satisfy the resource constraint

$$\pi(\bar{p}, C) \geq 0, \quad (11.3)$$

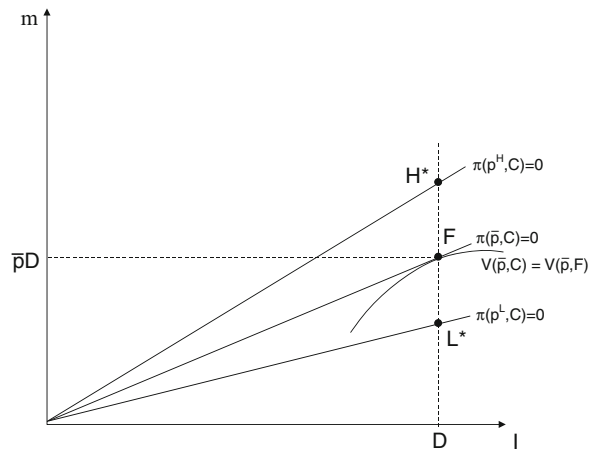
which requires that the premium be sufficient to cover the expected insurance indemnity.

In this setting, an optimal insurance contract is a solution to the problem of maximizing (11.1) subject to the feasibility constraint (11.3), which results in full coverage for losses ($I = D$) at the actuarially fair premium ($m = \bar{p}D$). This contract, which is depicted as F in Fig. 11.1, is also the competitive equilibrium for an insurance market with free entry and exit when all consumers have the same (publicly observed) probability \bar{p} of suffering loss.

11.2.2 Classification with Heterogeneous Agents

We now turn to the case in which both insurers and insurance applicants have access to a costless and public signal that dichotomizes applicants into two groups. After the signal has been observed, a

Fig. 11.1 Classification risk



proportion λ of the agents are known to be *high risk* with probability p^H of suffering the loss, while $1-\lambda$ are *low risk* with loss propensity p^L , where $p^H > p^L$ and $\bar{p} = \lambda p^H + (1 - \lambda)p^L$. When each individual's type (p^H or p^L) is publicly observable, insurers in a competitive market equilibrium offer full coverage ($I = D$) to all consumers, and charge the actuarially fair premium $m^\tau = p^\tau D$ appropriate for the p^τ -types. These contracts are depicted as H^* (L^*) for p^H -types (p^L -types) in Fig. 11.1.

Notice that competitive pressures force firms to implement risk classification based on the insureds' publicly observed characteristic, p^τ . Any insurer attempting to offer a contract that would pool both high and low risks (such as F) recognizes that a competitor could offer a profitable contractual alternative that would attract only the low risks. The exodus of low risks caused by such cream-skimming would render the pooling contract unprofitable.

The introduction of symmetric information about risk type accompanied by categorization based on this information increases the utility of some of the insured agents (low risks, who receive L^*), but reduces the utility of others (high risks, who receive H^*) relative to the pre-classification alternative (when both types receive F). From an efficiency perspective, however, the relevant question is whether the insureds *expect* to be better off when moving from a status-quo without information and risk-based categorization to a regime with information and risk classification. If an individual who is classified as a p^τ -type receives the contract C^τ , then the expected utility of the insured in the classification regime is

$$E\{V\} \equiv \lambda V^H + (1 - \lambda)V^L \tag{11.4}$$

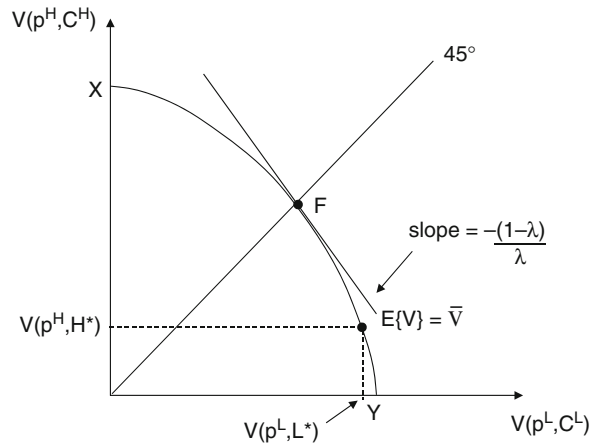
where $V^i \equiv V(p^i, C^i)$ for $i \in \{H, L\}$. The corresponding resource constraint is

$$\lambda \pi(p^H, C^H) + (1 - \lambda)\pi(p^L, C^L) \geq 0, \tag{11.5}$$

requiring that premiums collected cover expected indemnity payments per capita.

An *efficient classification contract* is a solution to the problem of maximizing (11.4) subject to (11.5), which turns out to be the pooling contract, depicted as F in Fig. 11.1, and which provides full coverage at the pooled actuarially fair premium $\bar{p}D$. The intuition behind this result is straightforward. From an ex ante perspective, there are four possible payoff states: The two loss states and the two risk types. Since individuals are risk averse, ex ante expected utility maximization of (11.4) subject to the resource constraint (11.5) requires equal consumption in all states, and F is the only zero-profit contract with this property.

Fig. 11.2 Ex ante optimum



The technical rationale for this result can be illustrated with reference to Fig. 11.2, which illustrates the utilities possibilities frontier for the classification regime as locus XFY. The concavity of XFY is dictated by the risk aversion of consumers, and movement along the frontier from X toward Y makes L-type (H-types) better (worse) off. From (11.4), we infer that the slope of an indifference curve for the expected utility of an insured confronting classification risk, dV^H/dV^L , is $-(1-\lambda)/\lambda$. By the concavity of U and Jensen’s inequality, the pool F is the unique optimum for the consumer anticipating risk classification.

We conclude that the efficient contract in the classification regime ignores the publicly observed signal, and treats all insureds the same independently of their types. Put differently, when information is symmetric between insurers and insureds, uninformed insureds prefer to remain uninformed if they anticipate that the information revealed will be used to classify the risks. The reason is that the pooling contract F provides full coverage against two types of risk, the *financial risk* associated with the occurrence of the loss state, and the *classification risk* faced by insurance applicants, who may find out that they are high risk. The competitive equilibrium contracts H^* and L^* satisfy the resource constraint (11.5) and, therefore, are candidate solutions for optimal classification contracts. However, while they provide complete protection from financial risk, they leave consumers wholly exposed to classification risk. Thus, insurers would use public information to classify insurance applicants, even though risk classification based on new information actually reduces efficiency in this setting, and is therefore undesirable.

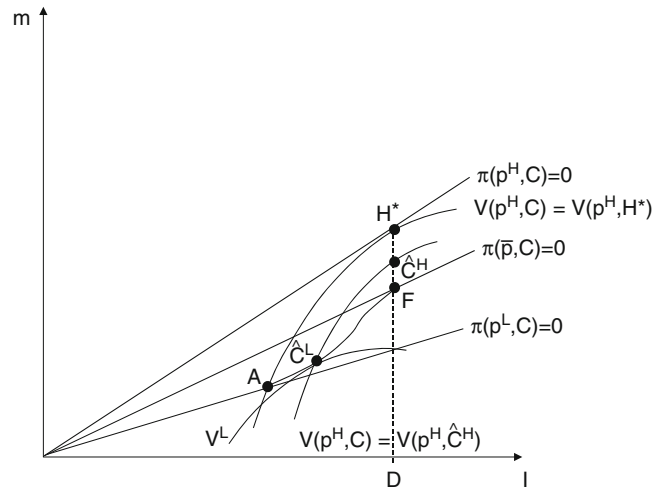
11.3 Risk Classification in the Presence of Hidden Knowledge

We now turn to an environment in which the individuals to be insured all initially possess private information about their propensities for suffering loss, as in the model introduced by [Rothschild and Stiglitz \(1976\)](#). Each consumer has prior hidden knowledge of risk type, p^H or p^L , but insurers know only that they face a population of consumers in which a proportion $\lambda(1-\lambda)$ have the loss probability p^H (p^L). Given the nature of the informational asymmetry, in order to be attainable a pair of insurance contracts (C^H, C^L) must satisfy the incentive compatibility (self-selection) constraints

$$V(p^\tau, C^\tau) \geq V(p^{\tau'}, C^{\tau'}) \text{ for every } \tau, \tau' \in \{H, L\} \tag{11.6}$$

as a consequence of the Revelation Principle exposted by [Myerson \(1979\)](#) and [Harris and Townsend \(1981\)](#).

Fig. 11.3 The M-W-S allocation



In this informationally constrained setting, an efficient insurance contract can be characterized as a solution to the problem of maximizing the expected utility of low-risk consumers $V(p^L, C^L)$ subject to the resource constraint (11.5), the incentive constraints (11.6), and a utility constraint on the welfare of high-risk types

$$V(p^H, C^H) \geq \bar{V}^H. \tag{11.7}$$

As discussed by Crocker and Snow (1985a), a solution to this problem yields full (partial) coverage for H-types (L-types); both the resource constraint (11.5) and the utility constraint (11.7) hold with equality; and the incentive constraint (11.6) binds (is slack) for high (low) risks.

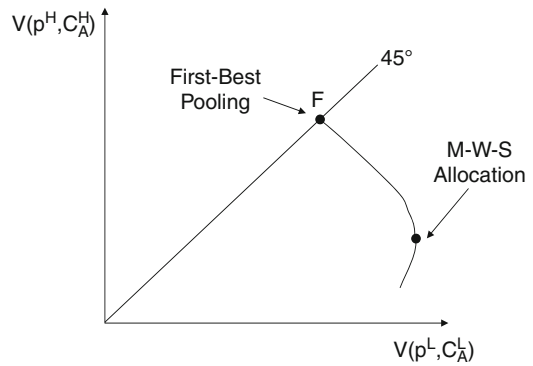
One element of the class of efficient contracts is depicted in Fig. 11.3 as $\{\hat{C}^H, \hat{C}^L\}$. By construction, the locus FA depicts the set of contracts awarded to low risks that, when coupled with a full-insurance contract to which high risks are indifferent, satisfies the resource constraint with equality.² The full class of efficient contracts is obtained by varying the utility level \bar{V}^H in constraint (11.7). Setting $\bar{V}^H = V(p^H, F)$ yields the first-best pooling allocation F as a solution to the efficiency problem. Setting lower values for \bar{V}^H results in a redistribution away from H-types toward L-types and a solution in which the types receive distinct contracts, as described above, which entail a deductible for L-types and so are strictly second-best. The particular solution depicted in Fig. 11.3, $\{\hat{C}^H, \hat{C}^L\}$, is obtained when the constraint level of utility for the H-types, \bar{V}^H , is set equal to $V(p^H, H^*)$ and results in the efficient contract most preferred by the L-type individuals. The allocation $\{\hat{C}^H, \hat{C}^L\}$ will be referred to in the discussion below as the M-W-S allocation.³

Also depicted in Fig. 11.3 is the Rothschild–Stiglitz separating allocation (H^*, A) , which is the Pareto dominant member of the family of contracts that satisfy the incentive constraints (11.6) and

²Even though the shape of the locus FA is ambiguous, concavity is guaranteed around F. Indeed, the slope of this locus (see Crocker and Snow 1986, page 448) is the right-hand side of condition (c) evaluated at $\delta = 0$: $\frac{\lambda(1-p^H)U'(W_1^L) + (1-\lambda)(1-p^L)U'(W_2^H)}{\lambda p^H U'(W_2^L) + (1-\lambda)p^L U'(W_2^H)}$. Since we have $W_1^H = W_2^H = W_1^L = W_2^L$ at F, the slope can be rewritten as follows: $\frac{\lambda(1-p^H) + (1-\lambda)(1-p^L)}{\lambda p^H + (1-\lambda)p^L}$. This reduces to $\frac{1-\bar{p}}{\bar{p}}$, which is the slope of the aggregate zero-profit line. So the AF locus is tangent to the aggregate zero-profit line (see Dionne and Fombaron 1996).

³This nomenclature arises because this is the particular allocation supported as an equilibrium in the analyses of Miyazaki (1977), Wilson (1977), and Spence (1978).

Fig. 11.4 Utilities possibilities frontier



the requirement that each type of contract break even individually. The Rothschild–Stiglitz allocation is not an element of the (second-best) efficient set when the proportion of H-types (λ) is sufficiently small. Such a situation is depicted in Fig. 11.3, since both types of customers can be made strictly better off at $\{\hat{C}^H, \hat{C}^L\}$ than they would be at $\{H^*, A\}$. In this particular case, all of the efficient contracts involve a cross-subsidy from L-types to H-types. Only when λ is sufficiently large, so that $\{H^*, A\}$ is contained in the class of efficient allocation, is there an efficient contract that does not entail a cross-subsidy. The utility possibilities frontier associated with the solutions to the efficiency problem is depicted in Fig. 11.4. At one end is the utilities distribution associated with the first-best pooling contract F which involves a large cross-subsidy but no inefficiency since the L-types are not subject to a deductible. As one moves along the efficiency frontier toward the point associated with the M-W-S allocation, the degree of cross subsidy is reduced and the amount of inefficiency increases as the L-types are choosing contracts with higher deductibles.⁴

At this juncture, it is useful to elaborate on the differences between the efficiency approach that we have adopted in this chapter, and the equilibrium analyses that have characterized much of the insurance literature. The potential for the nonexistence of a Nash equilibrium in pure strategies that was first observed by Rothschild and Stiglitz is an artifact of the incentives faced by uninformed insurers who compete in the offering of screening contracts to attract customers. This result has spawned a substantial body of work attempting to resolve the nonexistence issue, either through the application of non-Nash equilibrium concepts (Wilson 1977; Riley 1979; Miyazaki 1977) or by considering alternative extensive form models of the insurance process with Nash refinements (Hellwig 1987; Cho and Kreps 1987). Unfortunately, the insurance contracts supported as equilibrium allocations generally differ and depend on the particular concept or extensive form being considered.

In contrast, the characterization of second-best efficient allocations that respect the informational asymmetries of the market participants is straightforward. The model is that of a social planner guided by the Pareto criterion, and who has the power to assign insurance allocations to the market participants.⁵ While the planner is omnipotent, in the sense of having the ability to assign any allocation that does not violate the economy’s resource constraints, it is not omniscient, and so is constrained to have no better information than the market participants.⁶ Hence, the issue of how

⁴Figure 11.4 depicts the portion of the utilities possibilities frontier that is better for L-types than the pooling contract F. As discussed in Crocker and Snow (1985a), there is a symmetric portion of the frontier above the 45° line that is better for H-types.

⁵Both Harris and Townsend (1981) and Myerson (1979) have demonstrated that no alternative organization of the economy’s allocation process can dominate the allocations attainable by a social planner.

⁶So, for example, in the efficiency problem just considered, the goal of the social planner is to maximize the expected utility of one arbitrarily selected agent (V^L) subject to the constraints of (1) not making the other agent worse off

firms compete in the offering of insurance contracts does not arise, since the social planner assigns allocations by dictatorial fiat subject to the (immutable) informational and resource constraints of the economy. This exercise permits an identification of the best outcomes that could, in principle, be attained in an economy. Whether any particular set of equilibrium mechanics can do as well is, of course, a different issue, and one that we consider in more detail in Sect. 11.5 below.

Finally, as we close this section, notice that risk classification, accomplished through self-selection based on hidden knowledge of riskiness, is required for efficient contracting in this environment. Specifically, with the exception of the first-best pooling allocation F , all efficient allocations are second best, as they entail costly signaling by low-risk types. These consumers retain some risk as their contract incorporates a positive deductible, but in so doing they are best able to exploit opportunities for risk sharing given the potential adverse selection of low-risk contracts by high-risk consumers.

11.3.1 Categorization Based on Immutable Characteristics

We suppose for the purposes of this section that consumers differ by an observable trait that is immutable, costless to observe, and correlated with (and, hence informative about) the unobservable risk of loss. Examples of such categorizing tools are provided by, but not restricted to, an insured's gender, age or race, which may be imperfectly correlated with the individual's underlying probability of suffering a loss. The interesting question is whether the information available through categorical discrimination, which can be used by insurers to tailor the contracts that are assigned to insureds based on their observable characteristics, enhances the possibilities for efficiency.

In the first attempt to examine the implications of permitting insurers to classify risks in this environment, Hoy (1982) considered the effects of categorization on market equilibria. Since there was, and still is, little consensus on the identity of the allocations supported by equilibrium behavior, Hoy considered the pure strategy Nash equilibrium of Rothschild and Stiglitz, the "anticipatory" equilibrium of Wilson (1977), and the equilibrium suggested by Miyazaki (1977) which assumes anticipatory behavior but permits cross-subsidization within an insurer's portfolio of contractual offerings. Hoy found that the efficiency consequences of permitting risk classification were ambiguous, depending on the particular equilibrium configuration posited. The primary reason for this ambiguity is that, with the exception of the Miyazaki equilibrium, none of the allocations supported by the equilibrium behaviors considered is guaranteed to be on the efficiency frontier.⁷ Thus, a comparison of the equilibrium allocations pre- and post-categorization provides no insights regarding whether permitting categorization enhances the efficiency possibilities for insurance contracting.

A more fruitful approach is explored by Crocker and Snow (1986), who compare the utilities possibilities frontier for the regime where categorization is permitted to the one in which it is not. Throughout the remainder of this section, we assume that each insurance applicant belongs either to group A or to group B , and that the proportion of low-risk applicants is higher in group A than in group B . Letting λ_k denote the proportion of H-types in group k , we have $0 < \lambda_A < \lambda_B < 1$, so

than a specified level of expected utility $\bar{V}^H (V^H \geq \bar{V}^H)$; (2) the economy's resource constraint (11.5); and (3) the informational constraints of the market participants (11.6). By varying \bar{V}^H , the entire set of (second-best) efficient allocations may be determined.

⁷Since Hoy was concerned with comparing equilibrium allocations in the pre- and post-categorization regimes, the pertinent efficiency issue—can the winners from categorization compensate, in principle, the losers—was not considered. As Crocker and Snow (1986) demonstrate, the answer to this question, at least in the case of the Miyazaki equilibrium, is that they can.

that group membership is (imperfectly) informative. Assuming that a proportion ω of the population belongs to group A , it follows that $\omega\lambda_A + (1 - \omega)\lambda_B = \lambda$.

Let $C_k \equiv (C_k^H, C_k^L)$ denote the insurance contracts offered to the members of group k . Since insurers can observe group membership but not risk type, the contractual offerings must satisfy separate incentive constraints for each group, that is,

$$V(p^\tau, C_k^\tau) \geq V(p^\tau, C_k^{\tau'}) \text{ for all } \tau, \tau' \in \{H, L\} \tag{11.8}$$

for each group $k \in \{A, B\}$. In addition, contracts must satisfy the resource constraint

$$\omega[\lambda_A\pi(p^H, C_A^H) + (1 - \lambda_A)\pi(p^L, C_A^L)] + (1 - \omega)[\lambda_B\pi(p^H, C_B^H) + (1 - \lambda_B)\pi(p^L, C_B^L)] \geq 0, \tag{11.9}$$

which requires that the contracts make zero profit on average over the two groups combined.

To demonstrate that risk categorization may permit Pareto improvements⁸ over the no-categorization regime, it proves useful to consider the efficiency problem of maximizing $V(p^L, C_B^L)$ subject to the incentive constraints (11.8), the resource constraint (11.9), and the utility constraints

$$V(p^\tau, C_A^\tau) \geq V(p^\tau, \hat{C}^\tau) \text{ for } \tau \in \{H, L\} \tag{11.10}$$

and

$$V(p^H, C_B^H) \geq V(p^H, \hat{C}^H), \tag{11.11}$$

where $\hat{C} \equiv (\hat{C}^H, \hat{C}^L)$ is an efficient allocation in the no-categorization regime. By construction, we know that this problem has at least one feasible alternative, namely the no-categorization contract \hat{C} which treats the insureds the same independently of the group (A or B) to which they belong. If \hat{C} is the solution, then the utilities possibilities frontier for the categorization and the no-categorization regimes coincide at \hat{C} . However, if \hat{C} does not solve the problem, then categorization admits contractual opportunities Pareto superior to \hat{C} and the utilities possibilities frontier for the categorization regime lies outside the frontier associated with the no-categorization regime.

Let δ denote the Lagrange multiplier associated with the utility constraint (11.7) for the efficiency problem in the no-categorization regime, and let μ_H be the multiplier associated with the incentive constraint (11.6) for $\tau = H$. The following result is from Crocker and Snow (1986, p. 329).

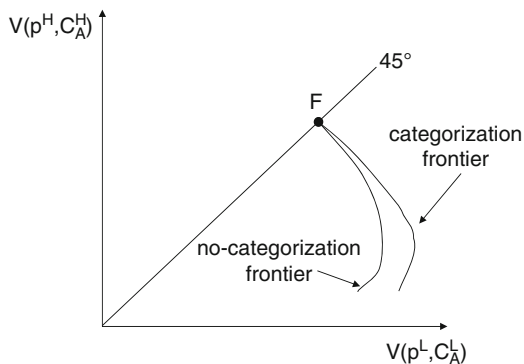
Result: Categorization permits a Pareto improvement to be realized over efficient contracts without categorization if and only if

$$\frac{\delta}{\mu_H} < \frac{\lambda - \lambda_A}{\lambda_A(1 - \lambda)}. \tag{11.12}$$

For the inequality to hold, it is sufficient that $\delta = 0$, which necessarily obtains whenever the utility constraint, \bar{V}^H , in (11.7) is set sufficiently low. When $\delta > 0$, the location of the utilities possibilities frontiers depends on the informativeness of the categorization. When categorization

⁸An actual Pareto improvement requires that at least one type of agent be made better off while no agents are made worse off. A potential Pareto improvement requires only that the winners from the regime change be able, in principle, to compensate the losers, so that the latter would be made no worse off from the move. As Crocker and Snow (1985b) have demonstrated, there exists a balanced-budget system of taxes and subsidies that can be applied by a government constrained by the same informational asymmetries as the market participants, and which can transform any potential Pareto improvement into an actual improvement. In the discussion that follows, we will use the term ‘‘Pareto improvement’’ to mean ‘‘potential Pareto improvement,’’ recognizing throughout that any potential improvements can be implemented as actual improvements.

Fig. 11.5 Utilities possibilities frontiers: costless categorization



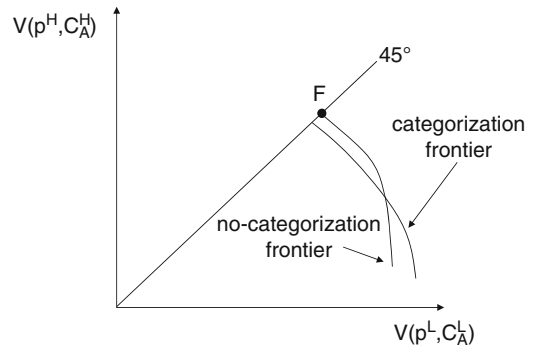
is more informative, λ_A is smaller and the right hand side of (11.12) is larger. If categorization were uninformative ($\lambda = \lambda_A$), then (11.12) could never hold, and if categorization were perfectly informative ($\lambda_A = 0$), then (11.12) would always be satisfied. Finally the inequality can never hold when $\mu_H = 0$, which occurs when the incentive constraint (11.6) for the efficiency problem in the no-categorization regime is slack. Contract F is the only efficient contract for which the incentive constraint is slack, so that the utilities possibilities frontiers always coincide at F regardless of the degree of informativeness of the categorization. The relative positions of the utilities possibilities frontiers for the categorization and the no-categorization regimes for those in group A are depicted in Fig. 11.5, while a similar diagram applies to those in group B .

To evaluate the efficiency of categorization, we employ the Samuelson (1950) criterion for potential Pareto improvement. Risk classification through a priori categorization by insurers is defined to be efficient (inefficient) if there exists (does not exist) a utility distribution in the frontier for the no-categorization regime Pareto dominated by a distribution in the frontier for the categorization regime, and there does not exist (exists) a distribution in the categorization frontier Pareto dominated by one in the no-categorization frontier. Since costless categorization shifts outward the utilities possibilities frontier over some regions and never causes the frontier to shift inward, we conclude that categorization is efficient.

Crocker and Snow (1985b) show that omniscience is not required to implement the hypothetical lump-sum transfers needed to effect movement along a utilities possibilities frontier. Although the appropriate lump-sum transfers cannot be assigned directly to individual consumers, since their risk types are hidden knowledge, these transfers can be built into the premium-indemnity schedule so that insurance applicants self-select the taxes or transfers intended for their individual risk types. In this manner, a government constrained by the same informational asymmetry confronting insurers can levy taxes and subsidies on insurance contracts to implement redistribution, while obeying incentive compatibility constraints and maintaining a balanced public budget. Our application of the Samuelson criterion is thus consistent with the informational environment.

The situation is somewhat different when consumers differ by an observable, immutable trait that is correlated with the unobservable risk of loss, but is costly to observe. Crocker and Snow (1986) show that the utilities possibilities frontiers cross in this case, so long as the cost is not too high. Intuitively, the cost of categorization amounts to a state-independent tax on each consumer's wealth. As a result, when the adverse selection externality is not very costly and low-risk types are nearly fully insured, categorization costs dominate the small efficiency gains realized by the winners leaving no possibility of compensating the losers. Conversely, if the adverse selection externality imposes sufficient cost on the low-risk consumers, then gains from categorization realized by the winners are sufficient for potential Pareto improvement provided categorization is not too costly. This situation is depicted in Fig. 11.6.

Fig. 11.6 Utilities possibilities frontiers: costly categorization



If categorization were required, then insurers would sometimes categorize insurance applicants even when the result is not a potential Pareto improvement over not categorizing. In this scenario the efficiency effects of costly categorization are ambiguous. As [Rothschild \(2011\)](#) points out, however, the second-best efficient allocations when categorizing is costly do not require the use of categorization. Consider a social planner with the power to assign insurance contracts to applicants subject to the economy's resource and informational constraints, and who has access to the same costly categorizing technology as insurers. Because the social planner can choose not actually to employ the categorizing technology, the second-best Pareto frontier for the planner is the outer envelope of utility possibilities. The Samuelson criterion therefore leads to the conclusion that allowing costly categorization is more efficient than either banning or requiring categorization.

Rothschild further shows that this application of the Samuelson criterion is again consistent with the informational environment. Specifically, for any allocation in the no-categorization regime, a government constrained by the same informational asymmetry confronting insurers can simultaneously provide a properly calibrated social insurance policy and also legalize categorization so that, in response, insurers choose to employ categorization precisely when doing so yields a Pareto improvement over not categorizing. In this sense, the no-categorization regime is inefficient.

11.3.2 An Empirical Estimate: The Case of Annuities

[Finkelstein et al. \(2009\)](#) adapt the basic framework of [Hoy \(1982\)](#) and [Crocker and Snow \(1986\)](#) to facilitate empirical estimates of the efficiency and distributional consequences of prohibiting categorical discrimination in real-world insurance markets. Their approach is to use an empirically calibrated model to estimate the welfare consequences of restricting gender-based pricing in the compulsory annuities market of the UK. In this market, which is described in greater detail in [Finkelstein and Poterba \(2002, 2004\)](#), retirees are required to annuitize a substantial portion of their accumulated tax-preferred retirement savings, but there is scope for annuity providers to screen different risk types by offering annuity contracts with different lifetime payout structures.

Their adaptation requires two significant modifications of the standard insurance model. First, the model is extended to allow many "indemnity" states that correspond to annuity payments in future years, where the uncertainty arises because the annuity is paid only if the annuitant survives. From the insurer's perspective, low-risk (high-risk) individuals are those that have a lower longevity (higher longevity), and this is assumed to be private information known only to the annuitant. Second, the model allows for the possibility that individuals could, in a fashion that is not observable to the insurer, save a portion of their annuity income to supplement the consumption provided by the annuity at later ages, in effect, permitting individuals to engage in a form of "self-insurance".

Using mortality data from a major insurer, maximum likelihood estimation is used to calibrate a model with two unobservable types (high-risk and low-risk) and two observable categories (male and female). The categories are observable to the insurer and each category contains both high- and low-risk types, although the female category contains a higher proportion of high-risk (longer-lived) individuals. When insurers are permitted to categorize their insurance offerings on observable gender, the market segments into male and female sub-markets in which insurers screen each category for unobservable risk type through their contractual offerings. The result is screening of types in both gender categories in the manner of Fig. 11.3, but with different contracts offered to male and female applicants. In contrast, when such categorical discrimination is prohibited, insurers still screen types as in Fig. 11.3, but now are constrained to offer the same screening contracts to both genders. As a result, when calculating the efficiency costs of prohibiting gender-based pricing, there are in principle three efficiency frontiers that must be considered: those associated with each of the two genders when categorical discrimination is permitted, and the one associated with the regime in which such discrimination is prohibited.

The goal in Finkelstein et al. is to calculate bounds on the welfare costs associated with a ban on gender-based pricing. Their approach is to assume that when gender discrimination is allowed, the segmented markets provide a second-best efficient allocation to each category, and that there is no cross-subsidy between the two observable categories. In contrast, when gender-based pricing is banned, the market is assumed to attain an allocation on a no-categorization efficiency frontier of the type described by Fig. 11.4. As noted by Crocker and Snow (1986, p. 329), starting from an efficient contract on the no-categorization frontier, it is possible to make the category composed of fewer high risks better off, and at a lower resource cost, if risk categorization were to be introduced. This saving in resources represents the efficiency cost of the categorization ban. Thus, the potential efficiency cost of a ban on gender-based pricing ranges from zero if the post-ban market achieves the first-best pooling allocation F (which results in maximal across-gender redistribution) to its maximum value when the post-ban result is the M-W-S allocation (which results in the minimal across-gender redistribution).

Figure 11.7 (which is Figure 4 from Finkelstein et al.) depicts the efficient annuity contracts associated with the W-M-S allocation in the presence of a ban on gender-based pricing. High-risk (long-lived) types receive a full insurance annuity that provides constant real payments for the duration of their retirements. Low-risk types, by contrast, receive a front-loaded annuity. This front loading allows them to receive substantially higher annuity payments for most of their expected lifetimes while still effectively discouraging the high-risks from selecting the annuity targeted to the low-risk types. Moreover, the efficient annuities involve a cross-subsidy from low- to high-risk types since the latter obtain a better than actuarially fair annuity payment. Since the high-risks are the recipients of the subsidy, and the female category contains a disproportionate share of the high-risk annuitants, the effect is to generate a cross subsidy from males to females. Column (9) of the Table 11.1 (which is Table 3 from Finkelstein et al.) quantifies the cross-subsidy associated with the post-ban W-M-S allocation, which is on the order of a 2–4% transfer of the retirement wealth, depending on the degree of risk aversion. As one moves along the utility possibilities frontier, the size of this cross-subsidy increases and achieves its maximum at the full insurance pooling allocation F , which is reported in column (10) as 7.14%.

The table also quantifies the efficiency costs associated with a ban on the gender-based pricing of annuities. The maximum efficiency cost occurs if the post-ban market achieves the M-W-S allocation, which is column (5) of the table and results in an efficiency cost ranging from .018 to 0.025% of retirement wealth, depending on the degree of risk aversion. Other post-ban allocations result in lower efficiency costs, and the first-best pooling contract (point F on the efficiency frontier) results in no efficiency cost, as reported by column (6). While the efficiency costs of the ban on gender-based pricing are nonzero, as predicted by Crocker and Snow (1986), they are small relative to the degree of redistribution effected by the ban.

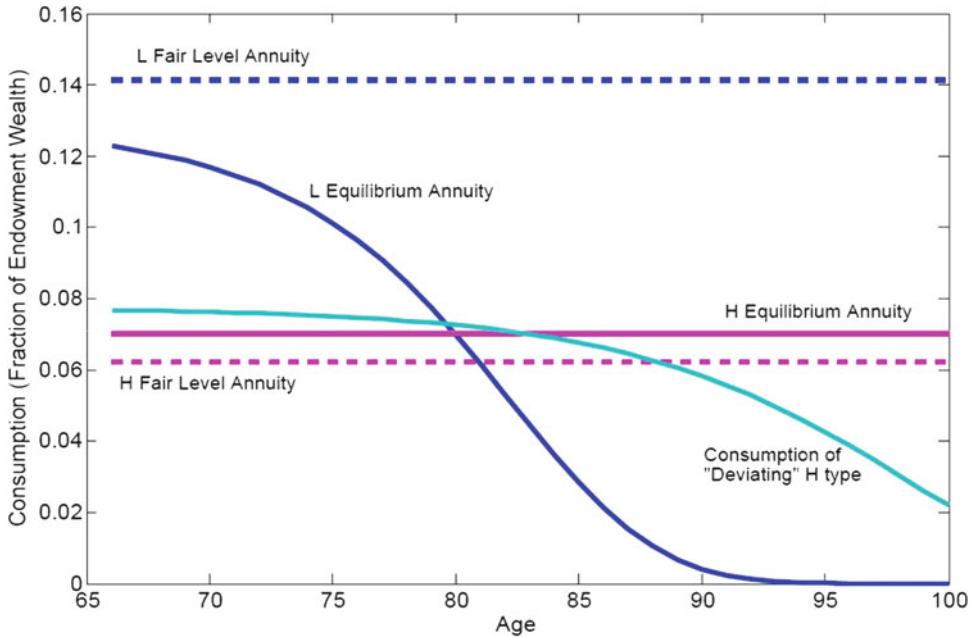


Fig. 11.7 Efficient annuities

Table 11.1 Range of efficiency and distributional consequences of unisex pricing

| Relative risk aversion | Required per-person endowment needed to achieve utility level from non-categorizing equilibrium when categorization is allowed | | | | | | Efficiency cost as % of total endowment | | Redistribution to women (\bar{R}^W), per woman, % of endowment | | Efficiency cost per dollar of redistn |
|------------------------|--|-------|---------------|-------|--------------------------|-----|---|-----|--|------|---------------------------------------|
| | Women (E^W) | | Men (E^M) | | Total population (E) | | MWS | SS | MWS | SS | |
| | MWS | SS | MWS | SS | MWS | SS | | | | | |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | |
| $\gamma = 1$ | 1.020 | 1.071 | 0.979 | 0.929 | 0.9996 | 1 | 0.038% | 0% | 2.08% | 7.14 | 3.66% |
| $\gamma = 2$ | 1.033 | 1.071 | 0.966 | 0.929 | 0.9998 | 1 | 0.025 | 0 | 3.39 | 7.14 | 1.45 |
| $\gamma = 3$ | 1.040 | 1.071 | 0.959 | 0.929 | 0.9998 | 1 | 0.018 | 0 | 4.06 | 7.14 | 0.89 |

Notes: Estimates are based on the model and algorithm described in the text. Columns labeled MWS refer to the high efficiency cost/low redistribution end of the range of possible consequences which obtains when the market implements the Miyazaki–Wilson–Spence equilibrium when the gender-based pricing is banned. Columns labeled SS refer to the zero efficiency cost/high redistribution end of the range which obtains when the market implements a pooled-fair full insurance “Social Security-like” outcome when gender based pricing is banned. The MWS contracts are computed using (11.6) and the risk type-distributions estimated in Table 11.1, pooled across genders. Columns (1)–(6) are computed using (11.15) and columns (9)–(10) are computed using (11.16)

11.3.3 Categorization Based on Consumption Choices

In contrast to categorical discrimination based on observable but immutable characteristics, in many situations consumers use products, such as cigarettes or stodgy automobiles, with the anticipation that such consumption will affect their opportunities for insuring. The actuarial relationship between the

consumption of such a *correlative product* and underlying risk may be the consequence of a direct causal link (smoking and heart disease) or merely a statistical relationship (people who drive stodgy automobiles are more likely to be careful drivers). In both cases, however, the observed consumption of a correlative product permits insurers to design contracts that mitigate the problems of moral hazard and adverse selection inherent in insurance markets with private information.

To analyze the efficiency effects of permitting insurers to classify applicants on the basis of their consumption choices, [Bond and Crocker \(1991\)](#) assume that consumers' utility functions have the additively separable form

$$U(W) + \theta G(x) \quad (11.13)$$

where W and x are the consumer's wealth and consumption of the correlative product, respectively, and θ is a taste parameter. There are two types of consumers distinguished by their taste for the correlative product $\theta \in \{\theta^H, \theta^L\}$ where $\theta^H > \theta^L$. The proportion of θ^H -types in the population is λ .

Each consumer faces two possible wealth states, so W_D (W_N) represents consumption of other goods (i.e., wealth net of expenditures on the correlative productive) in the loss (no-loss) state. The probability of the loss state for a θ^τ -type consumer is $p^\tau(x)$, with $\partial p^\tau(x)/\partial x \geq 0$ and $1 \geq p^H(x) \geq p^L(x) \geq 0$ for every x . Thus, the consumption of the correlative product either affects directly, or may be positively correlated with, the potential for loss. While we restrict our attention to the case of hazardous goods whose level of consumption increases the probability of a loss ($\partial p^\tau/\partial x > 0$) or where the consumer's taste for the product is positively correlated with loss propensity ($p^H(x) > p^L(x)$), consideration of other correlative relationships is straightforward.

Under the assumption that consumers purchase the hazardous good x before the wealth state is revealed, the expected utility of a type θ^τ individual is

$$V^\tau(W_D, W_N, x) \equiv p^\tau(x)U(W_D) + (1 - p^\tau(x))U(W_N) + \theta^\tau G(x). \quad (11.14)$$

When the hazardous good is supplied by a competitive market at marginal cost c , the state-contingent wealth of an insured is now $W_N \equiv \bar{W} - m - cx$ and $W_D \equiv \bar{W} - m - cx + I - D$. The expected profit of providing the insurance policy $\{m, I\}$ to a θ^τ -type agent who consumes x is

$$\pi^\tau(m, I, x) \equiv m - p^\tau(x)I. \quad (11.15)$$

A contract $C \equiv \{m, I, x\}$ determines the consumption bundle for the insured, and an *allocation* (C^H, C^L) is a pair of contracts assigned to insureds based on their types. Feasible contracts must satisfy the resource constraint

$$\lambda \pi^H(C^H) + (1 - \lambda) \pi^L(C^L) \geq 0, \quad (11.16)$$

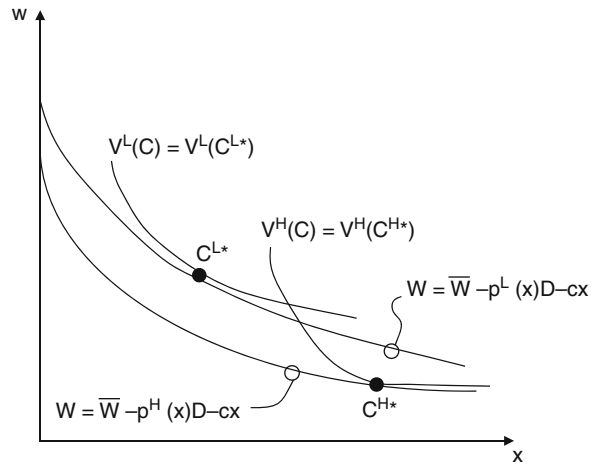
which ensures that premiums are sufficient to cover expected indemnity payments per capita.

When the insureds' taste parameters and the consumption of the hazardous good can be observed publicly, first-best allocations are attainable. In that event, an efficient allocation, denoted (C^{L*}, C^{H*}) , is a solution to the problem of maximizing $V^L(C^L)$ subject to (11.16) and a utility constraint on H-types, $V^H(C^H) \geq \bar{V}^H$. An efficient allocation results in full insurance ($W_D^\tau = W_N^\tau = W^\tau$) for both types of agents, and consumption levels for the hazardous good, x^τ , that equate each type of consumer's marginal valuation of consumption with its marginal cost, that is,

$$\frac{\theta^\tau G'(x^\tau)}{U'(W^\tau)} = c + D \partial p^\tau(x^\tau)/\partial x, \quad (11.17)$$

Notice that the marginal cost of the hazardous good includes its production cost c as well as its marginal effect on the expected loss.

Fig. 11.8 A first best allocation



The interesting case from the perspective of risk classification arises when consumption of the hazardous good, x , is observable but the consumer’s taste parameter θ , is private information. In this setting with asymmetric information, allocations must satisfy the incentive constraints

$$V^\tau(C^\tau) \geq V^\tau(C^{\tau'}) \text{ for all } \tau, \tau' \in \{H, L\}. \tag{11.18}$$

This case is referred to as *endogenous risk classification* since the consumers’ insurance opportunities may depend on their choices regarding consumption of the hazardous good.

An efficient allocation is a solution to the problem of maximizing $V^L(C^L)$ subject to $V^H(C^H) \geq \bar{V}^H$, the incentive constraints (11.18), and the resource constraint (11.16). There are two classes of solutions, which differ based on whether any of the incentive constraints (11.18) are binding.

11.3.4 First-Best Allocations: A Pure Strategy Nash Equilibrium

When the incentive constraints (11.18) do not bind at a solution to the efficiency problem, the efficient allocation provides full coverage to all individuals and charges actuarially fair premiums $p^\tau(x^\tau)D$ that depend on the amount of the hazardous good consumed (as determined by (11.17)). The insurance premium offered is bundled with a consumer’s observed consumption of the hazardous good, so that individuals are classified based on their consumption choices for x . An efficient allocation in this case is depicted as (C^{H*}, C^{L*}) in Fig. 11.8.

The moral hazard aspect of hazardous goods consumption is reflected by the curvature of a consumer’s budget constraint $W = \bar{W} - p^\tau(x)D - cx$, which reflects the fact that the risk of loss depends on consumption of the hazardous good, given $\partial p^\tau(x)/\partial x \neq 0$. The potential for adverse selection arises because the budget constraint for θ^H -types lies below that for θ^L -types, since $p^H(x) > p^L(x)$. In the special case where there is no adverse selection ($p^H(x) = p^L(x)$), the budget constraints of the two types of consumers coincide, and a first-best allocation solves the efficiency problem. Effectively, the insurer levies a Pigouvian tax based on the observed consumption levels of the hazardous good, thereby forcing the insured to internalize the moral hazard externality. Introducing a small amount of private information still permits the attainment of first-best allocations, as long as the difference in loss probabilities ($p^H(x) - p^L(x)$) is not too great.

It is easy to see that the first-best allocation (C^{H*}, C^{L*}) is necessarily a Nash equilibrium in pure strategies whenever the incentive constraints (11.18) are not binding. This result provides an important insight concerning the desirability of permitting insurers to classify applicants on the basis of their consumption of goods that directly affect loss propensities. In the polar case, where the level of hazardous good consumption completely determines an individual's loss probability (so $p^H(x) = p^L(x) \equiv p(x)$), endogenous risk classification allows first-best allocations to be attained as Nash equilibria. Indeed, to disallow such categorization would cause a reversion to the typical adverse selection economy where the Nash equilibrium, if it exists, lies strictly inside the first-best frontier.

Even in cases where endogenous risk classification is imperfect, so that some residual uncertainty about the probability of loss remains after accounting for consumption of the hazardous good ($p^H(x) \neq p^L(x)$), the pure strategy Nash equilibrium exists and is first-best efficient as long as the risk component unexplained by x is sufficiently small. Consequently, insurers may alleviate the problems of adverse selection in practice by extensively categorizing their customers on the basis of factors causing losses, which may partly offset the insureds' informational advantage and permit the attainment of first-best allocations as equilibria.

11.3.5 Second-Best Allocations

When incentive constraints are binding at a solution to the efficiency problem, an optimal allocation generally results in distortions in both the insurance dimension and in the consumption of the hazardous good. While the nature of a second-best allocation depends on the specifics of the model's parameters, there are several generic results.

Result: When the incentive constraint (11.18) binds for the θ^H -type consumer, an efficient allocation is second best. Also,

- (i) if $p^H(x) > p^L(x)$, then θ^H -types (θ^L -types) receive full coverage (are under-insured); and
- (ii) if $\left\{ \begin{array}{l} \text{either } p^H(x) = p^L(x) \text{ (no adverse selection case)} \\ \text{or } \frac{\partial p^r(x)}{\partial x} = 0 \text{ (pure adverse selection case) and } \frac{\theta^H}{\theta^L} = \frac{p^H}{p^L} \end{array} \right\}$

then θ^L -types (θ^H -types) under-consume (over-consume) the hazardous good relative to the socially optimal level (11.17).

These results indicate the extent to which there is a tension between discouraging consumption of the hazardous good to mitigate moral hazard, on one hand, and using such consumption as a signal to mitigate adverse selection, on the other hand. An optimal contract reflects a balance between the signaling value of hazardous goods consumption, and the direct social costs imposed by the consumption of products that increase the probability of loss.

As an example, consider those who ride motorcycles without wearing safety helmets, which is a form of hazardous good consumption. On one hand, those who choose to have the wind blowing through their hair are directly increasing their probabilities of injury (the *moral hazard* effect), which increases the cost of riding motorcycles. On the other hand, the taste for not wearing helmets may be correlated with a propensity of the rider to engage in other types of risk-taking activities (the *adverse selection* effect), so that the rider's observable choice to ride bare-headed may be interpreted by insurers as an imperfect signal of the motorcyclist's underlying risk. Interestingly, to require the use of safety helmets eliminates the ability of insurers to utilize this signal, with deleterious effects on efficiency.

11.4 Risk Classification and Incentives for Information Gathering

As discussed originally by [Dreze \(1960\)](#) and subsequently by [Hirshleifer \(1971\)](#), because information resolves uncertainty about which of alternative possible outcomes will occur, information destroys valuable opportunities for risk-averse individuals to insure against unfortuitous outcomes. This phenomenon lies behind the observation, made earlier in Sect. 11.2.2, that new information used by insurers to classify insurance applicants has an adverse effect on economic efficiency. As emphasized in the “no-trade” theorem of [Milgrom and Stokey \(1982\)](#), if applicants were able to insure against the possibility of adverse risk classification, then new information would have no social value, either positive or negative, as long as consumers initially possess no hidden knowledge.

By contrast, the results of [Crocker and Snow \(1986\)](#) and [Bond and Crocker \(1991\)](#) show that new information can also create valuable insurance opportunities when consumers are privately informed. Information about each consumer’s hidden knowledge, revealed by statistically correlated traits or behaviors, allows insurers to sort consumers more finely, and thereby to reduce the inefficiency caused by adverse selection. In this section, we investigate the effects of risk classification on incentives for gathering information about underlying loss probabilities.

11.4.1 Symmetric Information

Returning to the benchmark case of symmetric information, we now suppose that some consumers initially possess knowledge of being either high-risk or low-risk, while other consumers are initially uninformed. Being symmetrically informed, insurers can classify each insurance applicant by informational state and can offer customers in each class a contract that provides full coverage at an actuarially fair premium. Thus, with reference to Fig. 11.1, informed consumers receive either H^* or L^* , while uninformed consumers receive the first-best pooling contract F .

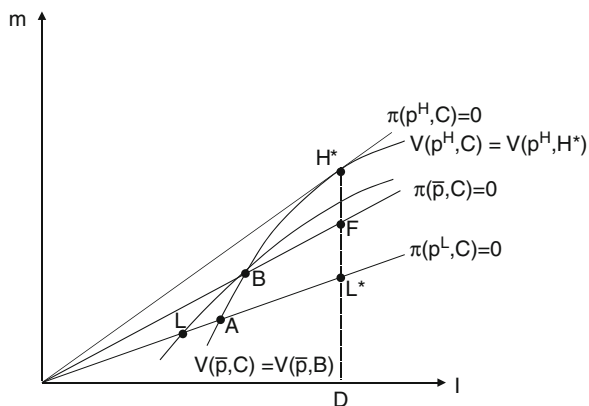
Observe that uninformed consumers in this setting have no incentive to become informed, since they would then bear a classification risk. In Fig. 11.2, the line tangent to the utilities possibilities frontier at point F corresponds to an indifference curve for an uninformed consumer.⁹ Clearly, the pooling contract F is preferred to the possibility of receiving H^* with probability λ or L^* with probability $1-\lambda$, that is,

$$V(\bar{p}, F) > \lambda V(p^H, H^*) + (1 - \lambda)V(p^L, L^*),$$

where $\bar{p} = \lambda p^H + (1 - \lambda)p^L$. Since all three of the contracts (F, L^*, H^*) fully insure consumers against the financial risk associated with the loss D , becoming informed in this environment serves only to expose a consumer to classification risk, with no countervailing gain in efficiency. The incentive for uninformed consumers to remain uninformed is consistent with socially optimal information gathering, since the classification risk optimally discourages individuals from seeking information.

⁹Since the expected utility of an uninformed agent is $\lambda V^H + (1-\lambda)V^L$ where V^i represents the agent’s utility in the informational state i , the slope of the associated indifference curve is $dV^H/dV^L = -(1-\lambda)/\lambda$.

Fig. 11.9 The Pareto-dominant separating allocation



11.4.2 Initial Acquisition of Hidden Knowledge

Hidden knowledge can be acquired either purposefully or serendipitously as a by-product of consumption or production activities. In this section we consider environments in which some consumers initially possess *hidden knowledge* of their riskiness, while others do not. Moreover, we assume that insurers cannot ascertain a priori any consumer’s informational state. Figure 11.9 illustrates the Pareto-dominant separating allocation in which each contract breaks even individually, which is the analogue to the Rothschild and Stiglitz equilibrium with three types (p^H , \bar{p} and p^L) of consumers.¹⁰ Consumers with hidden knowledge of risk type (either p^H or p^L) select contract H^* or contract L , while those who are uninformed (perceiving their type to be \bar{p}) select contract B on the pooled fair-odds line. Notice that the presence of uninformed consumers adversely affects low-risk types, who could otherwise have received the (preferred) contract A . Thus, the presence of uninformed consumers may exacerbate the adverse selection inefficiency caused by the hidden knowledge of informed consumers.

In this setting, and in contrast to the case of symmetric information in Sect. 11.4.1 above, uninformed consumers *do* have an incentive to become informed despite the classification risk they must bear as a result. Ignoring any cost of acquiring information, and assuming for the moment that contracts H^* and L continue to be offered, the expected gain to becoming informed is given by

$$\lambda V(p^H, H^*) + (1 - \lambda)V(p^L, L) - V(\bar{p}, B) = (1 - \lambda)[V(p^L, L) - V(p^L, B)],$$

where the equality follows from the fact that

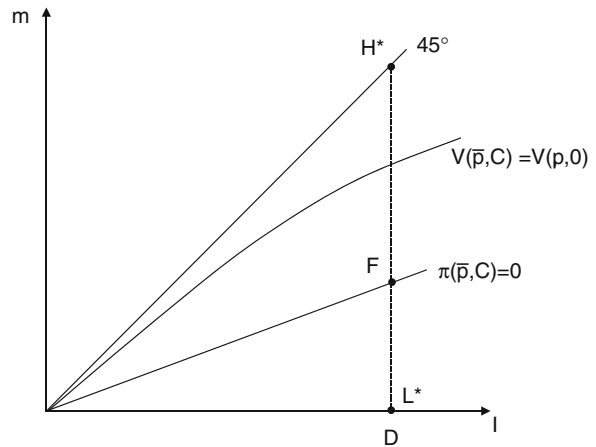
$$V(\bar{p}, B) \equiv \lambda V(p^H, B) + (1 - \lambda)V(p^L, B),$$

and from the binding self-selection constraint requiring that $V(p^H, H^*) = V(p^H, B)$. The incentive constraints also require that $V(p^L, L)$ exceeds $V(p^L, B)$. Hence, for an uninformed consumer, the expected gain in utility to becoming informed of risk type (p^H or p^L) is unambiguously positive.

¹⁰The Rothschild and Stiglitz allocation is the Pareto dominant member of the class of *informationally consistent* allocations, which is defined as the set of contracts that satisfy self-selection, and that each make zero profit given the class of customers electing to purchase them.

While the analysis of the previous sections indicates that these allocations are not always elements of the efficient set (for some parameter configurations), we will, in the interests of expositional ease, assume that they are in the arguments that follow. This is without loss of generality, for in cases where cross-subsidization between risk types is required for efficiency, the same arguments will apply, except with the zero-profit loci relabeled to effect the desired level of subsidy.

Fig. 11.10 The case of perfect hidden information



Finally, when all consumers possess hidden knowledge, contract *A* replaces contract *L*, which enhances the expected value of becoming informed, while also raising the utility of low-risk insureds. We conclude that, in the presence of adverse selection, risk classification through self-selection provides an incentive for uninformed consumers to acquire hidden knowledge, and that this action enhances the efficiency of insurance contracting by reducing, in the aggregate, the amount of signaling required to effect the separation of types.

This result strengthens the finding reported by [Doherty and Posey \(1998\)](#), who adopt the additional assumption that high-risk consumers, whose test results have indicated a risk in excess of p^H , can undergo a treatment that reduces the probability of loss to p^H . They emphasize the value of the treatment option in showing that initially uninformed consumers choose to acquire hidden knowledge. Our demonstration of this result abstracts from the possibility of treatment and reveals that risk classification is valuable to uninformed consumers in markets where some consumers possess hidden knowledge, despite uncertainty about the class to which one will be associated. Thus, private incentives for information gathering accurately reflect the social value of initially acquiring hidden knowledge.

A case of special concern arises when information reveals whether a loss has occurred, as when an incurable disease is diagnosed. Figure 11.10 illustrates this situation with $p^H = 1$ and $p^L = 0$. The equilibrium indifference curve for H-type consumers coincides with the 45° line, while that for L-types coincides with the horizontal axis. Although informed consumers possess no insurable risk, uninformed consumers do possess an insurable risk. However, when insurers are unable to distinguish between insurance applicants who are informed and those who are not, the market fails to provide any insurance whatsoever.¹¹ This result, obtained by [Doherty and Thistle \(1996\)](#), represents the extreme case in which uninformed consumers have no incentive to acquire hidden knowledge. Notice that the acquisition of such knowledge has no social value as well, so that private incentives are once again in accord with economic efficiency.

¹¹The problem arises because the H-types have no insurable risks when $p^H = 1$. Whenever $p^H \neq 1$, the allocations *B* and *L* depicted in Fig. 11.6 are non-degenerate (in the sense that they do not correspond with the origin). This holds even when $p^L = 0$, although in this particular case the allocation *L* would reside on the horizontal axis. In contrast, when $p^H = 1$, *B* and *L* necessarily correspond with the origin, so there are no insurance opportunities for the uninformed agent (since *B* is degenerate). This argument holds for any $p^L \geq 0$.

11.4.3 Acquisition of Additional Hidden Knowledge

Henceforth, we assume that all consumers possess hidden knowledge. In this section, we investigate the private and social value of acquiring additional hidden knowledge. Since hidden knowledge introduces inefficiency by causing adverse selection, it is not surprising to find that additional hidden knowledge can exacerbate adverse selection inefficiency. However, we also find that additional hidden knowledge can expand opportunities for insuring, and thereby mitigate the adverse selection inefficiency.

We assume that all insurance applicants have privately observed the outcome of an experiment (the α -experiment) that provides information about the underlying probability of loss, and we are concerned with whether the acquisition of additional hidden knowledge (the β -experiment) has social value. Prior to observing the outcome of the α -experiment, all consumers have the same prior beliefs, namely that the loss probability is either p^1 or $p^2 (> p^1)$ with associated probabilities denoted by $P(p^1)$ and $P(p^2)$ such that

$$\bar{p} = p^1 P(p^1) + p^2 P(p^2).$$

After the α -experiment, consumers who have observed $\alpha^\tau \in \{\alpha^L, \alpha^H\}$ have formed posterior beliefs such that

$$p^\tau = p^1 P(p^1|\alpha^\tau) + p^2 P(p^2|\alpha^\tau).$$

A proportion $\lambda = P(\alpha^H)$ have observed α^H .

At no cost, consumers are permitted to observe a second experiment (the β -experiment) whose outcome $\beta^i \in \{\beta^1, \beta^2\}$ reveals the consumer's actual loss probability $p^i \in \{p^1, p^2\}$. In what follows, the notation $P(\beta^i, \alpha^j)$ denotes the joint probability of observing the outcome (β^i, α^j) of the two experiments, where $i \in \{1, 2\}$ and $j \in \{H, L\}$, while $P(\beta^i)$ denotes the marginal probability $P(\beta^i, \alpha^L) + P(\beta^i, \alpha^H)$.

For this environment, Crocker and Snow (1992) establish the following propositions concerning the efficiency implications of the additional hidden knowledge represented by the second experiment β . The experiment has a positive (negative) social value if the utilities possibilities frontier applicable when consumers anticipate observing β prior to contracting lies (weakly) outside (inside) the frontier applicable when observing β is not an option.

Result: The additional hidden knowledge represented by experiment β has a positive social value if

$$p^2 P(\beta^2, \alpha^L) - p^1 P(\beta^1, \alpha^H) \leq \min\{P(\beta^2, \alpha^L) - P(\beta^1, \alpha^H), P(\beta^2)(p^2 - p^1)/(1 - p^H)\},$$

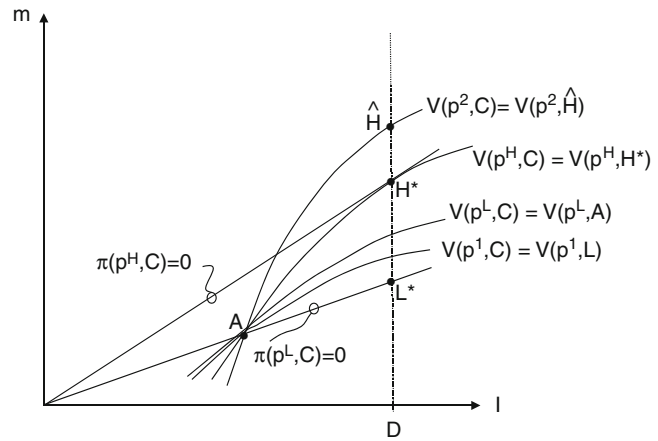
but has a negative social value if

$$p^2 P(\beta^2, \alpha^L) - p^1 P(\beta^1, \alpha^H) \geq \max\{0, [p^2 P(\beta^2) - p^H P(\alpha^H)]/p^H\}$$

So, for example, if the probability difference $P(\beta^2, \alpha^L) - P(\beta^1, \alpha^H)$ is positive, then the weighted difference $p^2 P(\beta^2, \alpha^L) - p^1 P(\beta^1, \alpha^H)$ cannot be too large, for then the acquisition of the hidden knowledge β would have negative social value. Similarly, if the probability difference is negative, then the weighted difference must also be negative in order for β to have positive social value. Although these conditions are not necessary for additional hidden knowledge to have a positive or negative social value, they depend only on exogenous parameters of the informational environment without regard to consumers' risk preferences.

Figure 11.11 illustrates the sources of social gains and losses from additional hidden knowledge. In the absence of experiment β , a typical efficient separating allocation is depicted by the pair (H^*, A) . Once consumers have privately observed β , the pair (H^*, A) is no longer incentive compatible.

Fig. 11.11 Gains and losses from additional hidden knowledge



The α^L -type consumers who discover their type to be p^2 now prefer H^* to their previous allocation A , while the α^H -types who find out that their loss propensity is p^1 now prefer A . The effect of consumers' acquiring additional hidden knowledge through the β -experiment is to alter irreversibly the set of incentive compatible allocations, and to render previously feasible contracts unattainable. From a social welfare perspective, for the β -experiment to have positive social value, there must exist allocations that (a) are incentive compatible under the new (post β -experiment) informational regime, (b) allow consumers to be expectationally at least as well off as they were at (H^*, A) prior to the experiment, and (c) earn nonnegative profit.

It is easy to verify that the incentive compatible pair (\hat{H}, A) , when evaluated by consumers ex ante, prior to observing β , affords α^L -types (α^H -types) the same expected utility they enjoy at A (H^*).¹² Notice that α^L -types who observe β^2 no longer bear signaling costs since they no longer choose the deductible contract A , while α^H -types who observe β^1 now absorb signaling costs. Since, by construction, consumers are indifferent between not observing the β -experiment and receiving (H^*, A) , or observing the β -experiment and being offered (\hat{H}, A) , the acquisition of the additional hidden information has positive social value if the contracts (\hat{H}, A) yield positive profit to the insurer.¹³ Whether this occurs depends on the proportion of consumers signaling less when newly informed, $p^2 P(\beta^2, \alpha^L)$, relative to the proportion signaling more, $p^1 P(\beta^1, \alpha^H)$, as indicated by conditions stated in the Result above.

Private incentives for information gathering may not accord with its social value in the present environment. We will illustrate this result in a setting where insurance markets attain separating equilibria in which contracts break even individually. First, notice that, if α^L -types acquire access to the β -experiment, then α^H -types prefer also to become informed, even though they may be worse off than if neither type has access to the β -experiment. To see this, refer to Fig. 11.12, which illustrates the equilibrium when only α^L -types will observe β and receive either H^2 or L , and α^H -types will not observe β and bear adverse selection costs by receiving H instead of H^* . The α^H -types would be indifferent between remaining uninformed and receiving H , or observing β and afterwards selecting either H^2 or H , since

¹²For example, the expected utility of α^L -types is given by $P(\beta^2|\alpha^L)V(p^2, \hat{H}) + P(\beta^1|\alpha^L)V(p^1, A)$, where the allocation \hat{H} is depicted in Fig. 11.11 below. Using the self-selection condition $V(p^2, \hat{H}) = V(p^2, A)$, we can rewrite this expression as $P(\beta^2|\alpha^L)V(p^2, A) + P(\beta^1|\alpha^L)V(p^1, A)$, which is equal to $V(p^L, A)$ since $P(\beta^2|\alpha^L)p^2 + P(\beta^1|\alpha^L)p^1 = p^L$. Thus, the pair (\hat{H}, A) provides α^L -types the same expected utility that they enjoy at A .

¹³These profits could then be rebated to the consumers through lower premiums, so that they would be made strictly better off in the post β -experiment regime.

Fig. 11.12 The case in which only α^L -types observe β

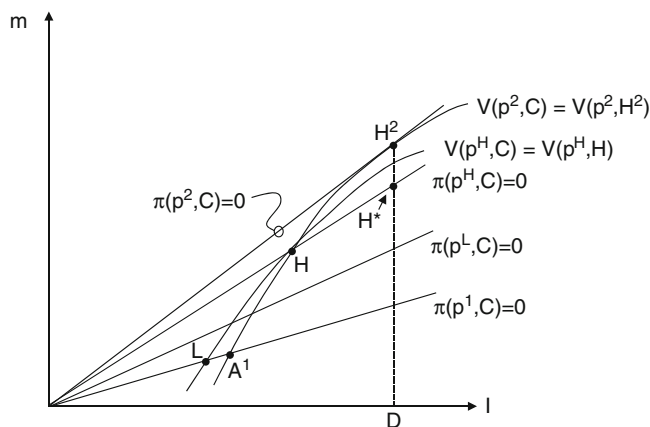
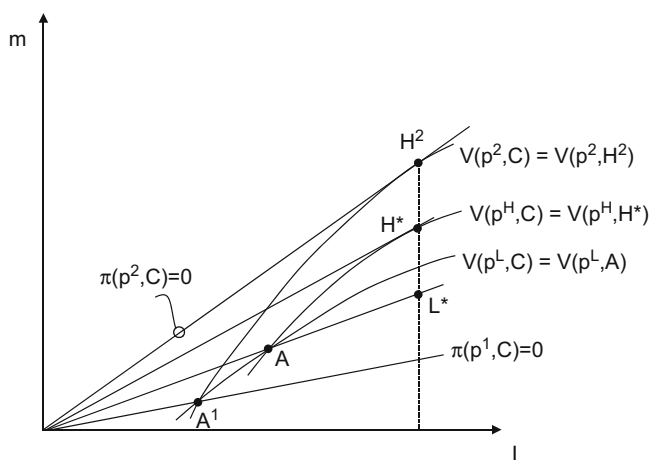


Fig. 11.13 The knife-edge case



$$P(\beta^2|\alpha^H)V(p^2, H^2) + P(\beta^1|\alpha^H)V(p^1, H) = V(p^H, H)$$

given the equality $V(p^2, H^2) = V(p^2, H)$ implied by incentive compatibility. Moreover, it follows that α^H -types would strictly prefer to observe β and afterwards select H^2 or A^1 , even though they may be worse off than they would have been receiving H^* , which is rendered unattainable once α^L -types have private access to experiment β . Thus, once the α^L -types become informed, it is in the best interests of α^H -types to do so as well.

Second, note that α^L -types will demand the β -experiment even if their gains are negligible and are more than offset by the harm imposed on α^H -types, so that the social value of the β -experiment is negative. To demonstrate this result, refer to Fig. 11.13 which illustrates a “knife-edge” case where α^L -types are just indifferent to acquiring additional hidden knowledge.¹⁴ The α^H -types, however, are necessarily worse off, since

$$V(p^H, H^*) > V(p^H, A^1) = P(\beta^2|\alpha^H)V(p^2, H^2) + P(\beta^1|\alpha^H)V(p^1, A^1),$$

¹⁴By construction in Fig. 11.13, the α^L -types are indifferent between A , and observing the β -experiment followed by a selection of H^2 or A^1 .

where the equality follows from the self-selection condition $V(p^2, H^2) = V(p^2, A^1)$. If α^L -types were to experience a small expected gain from acquiring additional hidden knowledge, they would demand access to the β -experiment even though this information would be detrimental to efficiency in insurance contracting. In such an environment, private incentives for information gathering do not reflect its social value. The problem is that the acquisition of private information by some consumers generates an uncompensated externality for others through its effect on the incentive constraints.

11.4.4 *Acquisition of Private Information: The Case of Genetic Tests*

There are substantial differences worldwide in how countries regulate (or not) the use of genetic testing for life, private health, and long-term disability insurance purposes. Regulation varies from total to partial legislative prohibition banning the use of genetic test results by insurers, on one hand, to voluntary moratoria or laissez faire with no regulatory or voluntary restrictions, on the other hand. In most of Western Europe the ban is almost total, falling in line with the UNESCO Declaration on Human Genetic Data 2003. In Belgium, insurers are prohibited from even accepting favorable genetic test results provided voluntarily by consumers. In the UK and the Netherlands, companies can ask for genetic test results only for large policies (those exceeding \$500,000 in Britain and, for life insurance in the Netherlands, policies exceeding 300,000 Dutch guilders, the latter adjusted every 3 years to the cost of living¹⁵). In Britain, the types of genetic tests that insurers can request for policies exceeding the cap are restricted to tests deemed relevant by an independent committee. Australia, New Zealand, and Canada are among those who have not introduced any legislation. The USA is a particular case in that the discussion there, in the absence of socialized medical insurance, involves both the health and the life insurance industries, and the regulations vary from state to state. Federally, the Genetic Information Nondiscrimination Act (GINA) passed in May of 2008 addresses the use of genetic testing in health insurance although only 14 states have introduced some laws to govern the use of genetic testing in life insurance and these laws generally entail restrictions rather than outright bans.¹⁶

Restricting the use of genetic test results for pricing life insurance or annuity products seems likely to have the potential for strong adverse selection effects. However, much less is known about the actuarial relevance of genetic test results in the population. Most people do not currently possess genetic test results and those genes with strong actuarial impact, such as the Huntington Disease gene, are very rare, approximately 1 in 10,000. Most empirical and simulation analysis to date suggest that restricting insurers' use of genetic test results for ratemaking purposes is unlikely to have a significant impact on insurance markets.

In a review of the current actuarial (academic) literature [MacDonald \(2009, p. 4\)](#) concludes that "little, if any strong empirical evidence has been found for the presence of adverse selection (although it is admittedly hard to study)." Simulation exercises based on population genetics and epidemiological data by [Hoy et al. \(2003\)](#) and [Hoy and Witt \(2007\)](#) also find, for the most part, little impact is likely to occur from a ban on insurers using genetic test results for health and life insurance markets, respectively. [Oster et al. \(2010\)](#), however, report "strong evidence of adverse selection" in the long-term care insurance market due to individuals holding private information about their Huntington Disease carrier status. Moreover, [Hoy and Witt \(2007\)](#) demonstrate that the effect of adverse selection on market behavior for many diseases is likely to depend on family history. This follows since those

¹⁵[Marang-van de Mheen et al. \(2002\)](#).

¹⁶See [Joly et al. \(2010\)](#) for details. See also [Hoy and Ruse \(2005\)](#) for a discussion of the broader issues.

Table 11.2 The effect of BRCA mutation on the incidence of breast cancer

| Family Background | Prob of BC (next 10 years) | Prob of BRCA mutation | Prob of BC given BRCA Positive | Prob of BC given BRCA Negative |
|-------------------|----------------------------|-----------------------|--------------------------------|--------------------------------|
| Low-risk | 0.013 | 0.001 | 0.141 | 0.012 |
| High-risk | 0.029 | 0.065 | 0.295 | 0.011 |

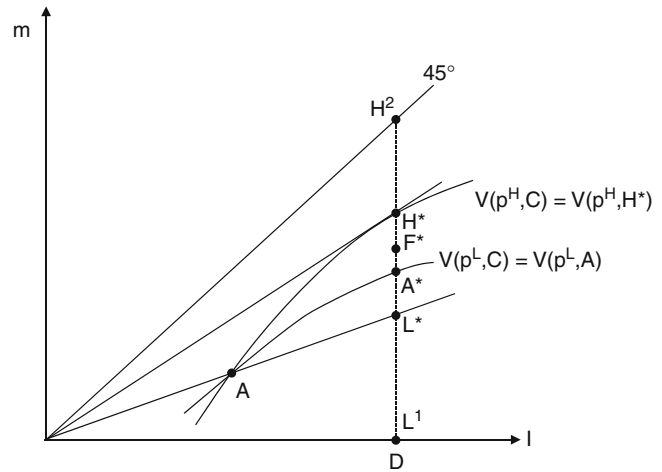
with a family history of the particular disease—even those associated with so-called predisposition genes such as the BRCA1/2 genes—are more likely to obtain a genetic test and are more likely to carry the gene. Those who do possess the relevant gene are even more likely to incur the disease than their family history alone would suggest. Table 11.2, which is based on 2 of the 13 different types of family history analyzed in [Hoy and Witt \(2007\)](#), illustrates this point. The “low family risk” background reflects women (aged 35–39 years) who have no family background of breast or ovarian cancer (from mother or sisters), while the “high family risk” background reflects women who have had a mother who had ovarian cancer before age 50 as well as breast cancer (after age 50). The unconditional probability of incurring breast cancer within 10 years for a woman with the high-risk family background is greater by a factor of approximately 2.2 and the probability of the high risk woman having one of the BRCA1/2 mutations present is higher by a factor of 65. The table also shows the probability of breast cancer conditional on the result of a genetic test and the probability is much higher for both family backgrounds if one of the mutations is present.

In a simulation model of 10-year term life insurance purchases, which is based on socioeconomic factors as well as various assumptions regarding the degree of risk aversion, it turns out that if 100% of all women in each risk group were to obtain a genetic test for one of the BRCA1/2 genes and were allowed to keep that information private, then the effect on price would be about a 1.5% increase for the low family risk type but almost a threefold increase in price for those with the high-risk background. This result demonstrates how sensitive the market reaction may be to the fraction of people who may hold important genetic information. It also raises interesting questions about the use of family history—which is at least in part crude genetic information—as a relevant and allowed categorical variable. Given the potential growth of genetic information among the public through direct-to-consumer testing services, the future holds substantial uncertainty in this regard and continued empirical research will be necessary in order to help resolve the debate about the use of genetic information in insurance markets.

There are two popular and conflicting views of the importance of discrimination in deciding on whether insurers should be allowed to use genetic test results (or family background of diseases for that matter) in pricing insurance. The “actuarial” view is that any actuarially relevant information should be allowed, even if imperfect, and it is not discriminatory to charge people who impose higher expected costs on insurers a higher price. This accords well with the economist’s notion of price discrimination, the notion being that it would be discriminatory not to charge those who create higher costs a higher price. Roughly speaking, if price to cost ratios are the same for each group, then discrimination does not occur. However, [Hoy and Lambert \(2000\)](#) show that if an immutable characteristic (such as geno-type) that is related to risk type is used and it is an imperfect signal, then although the more accurate is the information the fewer people are “misclassified,” it is also the case that for those who are misclassified there is a higher the price-cost differential. If one assumes that the impact of discrimination is not linear in price-cost ratios, and is strictly convex instead, then aggregate discrimination may rise as a result of the use of increasingly informative signals.

The view of discrimination often put forward by bioethicists, who are much more active in this research area, is that it is unfair if a “system”—be it public or private—treats some people more harshly due to differences that are beyond their control (such one’s gender or geno-type). Using a genetic test in such a setting leads to price differentials that implement “unfair” discrimination. However, this does not imply that a ban will unambiguously eliminate discrimination. If the

Fig. 11.14 The case of perfect public information



Rothschild–Stiglitz separating equilibrium were to obtain as a result of a ban, then the party “discriminated against” (in this case, the high-risk types) would receive no better treatment than if there were no ban. The low-risk types would be worse off and, although they voluntarily choose the policy with a lower level of coverage, one could argue that they were discriminated against in the quantity dimension. Certainly, for the case of life insurance, the survivor families of low risk types tend to end up very badly off as a result of the ban. (See [Hoy and Ruse 2008](#)).

11.4.5 Acquisition of Public Information

In this section we examine incentives for gathering public information. We continue to assume that all consumers initially possess hidden knowledge, having privately observed the outcome of experiment α . Outcomes of the second experiment β , however, are now observed publicly.

Let us first consider the case in which the β -experiment reveals to insurers, but not to consumers, information about the latter’s underlying loss probability. A special case of this environment is considered by [Crocker and Snow \(1986\)](#), where the consumer has already observed the outcome of the α -experiment (α^H or α^L) which is fully informative of the individual’s underlying probability of loss, and in which the β -experiment consists of observing consumer traits, such as gender, that are imperfectly correlated with the private information held by insurance applicants. The β -experiment provides no information to consumers, who already know their types, but is informative to the informationally constrained insurers. As discussed earlier in Sect. 11.4.3, this type of categorization, in which the outcome of the β -experiment is publicly observable, enhances efficiency when consumers know a priori the outcomes that they will observe for the β -experiment (i.e., their gender). Specifically, a consumer of either β type is at least as well off with categorization based on β as without it.

Since the β -experiment is not informative for consumers concerning their loss propensities, and does not in any other way influence their preferences, the set of feasible contracts does not depend on whether consumers have prior knowledge of β . Moreover, because each consumer, regardless of β type, is at least as well off with categorization, each consumer must expect to be at least as well off when the outcome of the β -experiment is not privately known ex ante. Thus, it is efficient for insurers to categorize applicants on the basis of a publicly observed experiment that is informative for insurers but not for insurance applicants.

The analysis is somewhat different when the β -experiment reveals to consumers information about their underlying loss propensities. In this instance, public information could have a negative social value. As an example, Fig. 11.14 illustrates the extreme situation in which the underlying probability $p^1 = 0$ or $p^2 = 1$ is perfectly revealed by the outcome of the experiment β . Pooling contracts based on β that provide H^* to those revealed to have incurred the loss and A^* to everyone else would allow consumers to attain the same expected utility levels they would realize in the absence of experiment β , when they self-select either H^* or A . Whenever the pair (H^*, A^*) at least breaks even collectively, experiment β has positive social value. It follows that β is socially valuable if and only if the first-best pooling contract lies below the point $F^* \equiv \lambda H^* + (1-\lambda)A^*$ in Fig. 11.14. In that event, those consumers revealed to have incurred the loss can be fully compensated by redistributing some of the gains realized by those who have not incurred the loss, permitting attainment of an allocation Pareto superior to (H^*, A) .

When the first-best pooling contract lies above F^* , no redistribution of the gains can fully compensate those revealed to have incurred the loss. In these instances, public information has a negative social value. No insurable risk remains after the public information is revealed, hence its social value is determined by the stronger of two opposing effects, the efficiency gains realized by eliminating adverse selection and the costs of classification risk.¹⁷

As in the case of hidden information, private incentives for gathering public information may not accord with its social value when consumers initially possess hidden knowledge. In the example depicted in Fig. 11.14, the market outcome (H^2, L^1) that occurs when public information is available prior to contracting provides an expected utility equal to the expected utility of the endowment, which is always below the expected utility realized by α^L -types at A and α^H -types at H^* . It follows that, in the present context, the costs of risk classification always discourage the gathering of public information whether or not that information would enhance efficiency.

In contrast with the symmetric information environment, in which public information used to classify consumers has negative social value, when consumers initially possess hidden knowledge, public information can have a positive social value. In the symmetric information environment, the use of public information imposes classification risk on consumers with no countervailing gains in contractual efficiency. However, in markets with asymmetric information, risk classification reduces adverse selection inefficiencies, and these gains may outweigh the costs of classification risk.

11.4.6 Equity/Efficiency Tradeoffs

Concerns about the distributional equity effects of risk classification are not limited to the results of genetic tests. Using gender, age, or race, as well as genetic test results to price insurance coverage may be deemed “unfair” discrimination or otherwise inconsistent with societal norms. As we have seen, these traits would be used in competitive insurance pricing when they are correlated with unobservable risk characteristics. Banning their use to avoid their undesirable distributional equity consequences creates adverse selection inefficiencies. Hoy (2006) and Polborn et al. (2006) refer to the government-created externalities associated with proscriptions on the use of informative risk classification as “regulatory” adverse selection.

To investigate the equity/efficiency tradeoffs involved in public policies concerning the use of risk classification in insurance pricing, consider the case where insurers and insurance applicants are symmetrically informed about each applicant’s risk class, but insurers can be prohibited from

¹⁷The result of Crocker and Snow (1992, p. 334) showing that public information always has positive social value applies in a linear signaling environment with risk neutral consumers, so the classification risk has no social cost.

using this information in pricing insurance coverage. Implementing such a ban entails foregoing first-best insurance contracting to achieve competing distributional equity goals. One possible approach to analyzing this tradeoff is to quantify separately the distributional and efficiency effects of such a ban. This is the approach taken by Finkelstein et al. discussed in Sect. 11.3.2 above. While this approach has the advantage of making the tradeoff explicit, it has the twin disadvantages of (1) not providing an explicit answer to the question of whether the distributional benefits outweigh the efficiency costs, and (2) not providing any guidance about the correct way to evaluate the tradeoff between the two quantities.

Hoy (2006) and Polborn et al. (2006) observe that there is often a natural way to strike the balance between distributional equity and allocative efficiency by adopting the “veil-of-ignorance” [Harsanyi (1953, 1955)], or “contractarian” [Buchanan and Tullock (1962)] methodology to assess the social value of individual utilities. In this approach, although risk class is public knowledge, each consumer’s welfare is evaluated as though the individual were behind a hypothetical veil of ignorance with respect to identity, including risk class. Thus each consumer’s welfare is evaluated as though belonging to the high-risk class (p^H) with probability λ .¹⁸ Further, as consumers are ignorant of their true identities, they adopt the utilitarian social welfare function.

It follows from the observations of Sect. 11.2.2 that a regulation banning the use of risk class in pricing insurance eliminates exposure to classification risk (which is a relevant concern behind the veil of ignorance), but fails to efficiently insure the financial risk because of the induced regulatory adverse selection. Adopting the veil of ignorance approach, Hoy (2006) and Polborn et al. (2006) show that, for some market equilibria, the social benefit of avoiding classification risk can outweigh the social cost of the regulatory adverse selection. Although each analysis investigates a unique environment, the essence of their arguments can be illustrated by relaxing the exclusivity assumption underlying the price-quantity competition that sustains equilibria in the Rothschild–Stiglitz model.

Hoy (2006) observes that, when exclusivity can be practiced, the social cost of regulatory adverse selection always outweighs the social benefit of avoiding classification risk if insurance markets attain the separating Rothschild–Stiglitz equilibrium. Since the market uses risk class to price insurance competitively, utilitarian social welfare in the absence of a ban on its use is given by

$$\lambda V(p^H, H^*) + (1 - \lambda)V(p^L, L^*) \quad (11.19)$$

as both risk types fully insure at actuarially fair prices, whereas social welfare under a ban on the use of risk class in pricing is the expected value of the Rothschild–Stiglitz contracts,

$$\lambda V(p^H, H^*) + (1 - \lambda)V(p^L, A). \quad (11.20)$$

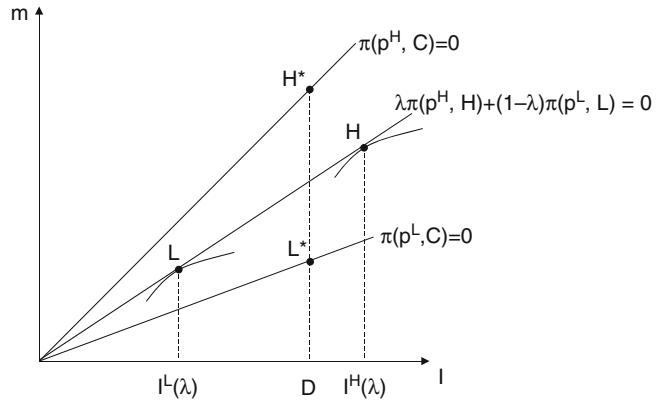
Social welfare is clearly lower when the ban is in place, since L -types have lower expected utility in the Rothschild–Stiglitz equilibrium, as they bear the cost of the deductible.

However, when insurers cannot practice exclusivity, applicants are free to purchase from the market any amount of coverage at a price p that is the same for all applicants, and that also results in zero profit given the applicants’ coverage choices. Figure 11.15 illustrates the linear-pricing equilibrium that arises with non-exclusivity. Optimizing the choice of coverage along the same equilibrium opportunity locus, H -types over-insure opting for H , while L -types under-insure, choosing L . Recognizing that these equilibrium choices, along with the equilibrium price of coverage, depend on λ , utilitarian social welfare in the linear-pricing equilibrium can be written as

$$\lambda V(p^H, H(\lambda)) + (1 - \lambda)V(p^L, L(\lambda)), \quad (11.21)$$

¹⁸In environments where risk class is not known by consumers, as in Sect. 11.2.2, the veil of ignorance is an actual veil with respect to risk class, leading to the same measure of consumer welfare.

Fig. 11.15 The linear-pricing equilibrium



where the contracts resulting in the contingent wealth allocations $H(\lambda)$ and $L(\lambda)$ satisfy the zero-profit condition

$$\lambda[p(\lambda) - p^H]I^H(\lambda) + (1 - \lambda)[p(\lambda) - p^L]I^L(\lambda) = 0, \tag{11.22}$$

given the coverage $I^i(\lambda)$ optimal for risk class p^i at the market price $p(\lambda)$.

To show that social welfare can be higher when risk classification is banned and insurers cannot practice exclusivity, subtract (11.19) from (11.21) and consider the effect of increasing λ starting from $\lambda = 0$, while maintaining the zero-profit condition (11.22). One obtains

$$\begin{aligned} \frac{\partial}{\partial \lambda} \Big|_{\lambda=0} & \{ \lambda[V(p^H, H(\lambda)) - V(p^H, H^*)] + (1 - \lambda)[V(p^L, L(\lambda)) - V(p^L, L^*)] \} \\ & = V(p^H, H(0)) - V(p^H, H^*) - U'(W - p^L D)(p^H - p^L)I^H(0). \end{aligned} \tag{11.23}$$

The third term on the right-hand side of the equality is the marginal effect of an increase in λ on $V(p^L, L(\lambda))$. With $\lambda = 0$, we have $L(0) = L^*$, providing L -types with full-and-fair insurance. Thus, as an envelope result, the marginal change in their coverage, $\partial I^L / \partial \lambda$, has no effect on social welfare, leaving only the general equilibrium effect of an increase in λ on the price they pay for insurance, as dictated by the zero-profit condition (11.22).¹⁹

To establish that (11.23) has a positive value in some environments, consider the case of constant absolute risk aversion, where $U(W) = -\exp[-W]$ and the optimal indemnity for an H -type, $I = I^H(0)$, satisfies the first-order condition

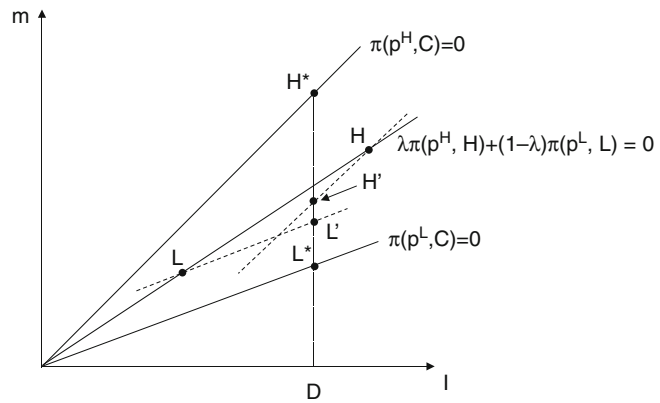
$$-p^L(1 - p^H) \exp[-W + p^L I] + (1 - p^L)p^H \exp[-W - (1 - p^L)I + D] = 0.$$

Using this equation, $V(p^H, H(0))$ can be written as

$$\begin{aligned} & -(1 - p^H) \exp[-W + p^L I^H] - p^H \exp[-W - (1 - p^L)I^H + D] \\ & = -(p^H / p^L) \exp[-W - (1 - p^L)I^H + D]. \end{aligned}$$

¹⁹Differentiating the zero-profit condition (11.22) with respect to λ and evaluating the result with $\lambda = 0$, while recognizing that $p(0) = p^L$ and $I^L(0) = D < I^H(0)$ yields $\partial p(\lambda) / \partial \lambda|_{\lambda=0} = (p^H - p^L)[I^H(0) / D]$. Hence, the premium increases by $(p^H - p^L)I^H(0)$.

Fig. 11.16 The potential pareto dominance of linear pricing through risk classification



Hence, (11.23) is positive if

$$1 - (p^H / p^L) \exp[-(1 - p^L)I^H + (1 - p^H)D] > (p^H - p^L)I^H \exp[-(p^H - p^L)D], \quad (11.24)$$

which is obtained from (11.23) after dividing by $V(p^H, H^*) = -\exp[-W + p^H D]$. As p^H approaches p^L , the right-hand side of inequality (11.24) approaches zero, while the left-hand side approaches one. It follows that inequality (11.24) holds and (11.23) is positive when p^H is close to p^L . Thus, a ban on the use of information revealing risk class can increase utilitarian social welfare when insurers cannot practice exclusivity and the proportion of H -types is sufficiently low.

Hoy (2006) obtains a stronger result by demonstrating that, regardless of probabilities and the degree of risk aversion, utilitarian social welfare is higher when insurance markets attain a Wilson anticipatory (pooling) equilibrium in the regime where the use of risk class in pricing insurance is banned if the proportion of H -types is sufficiently low. Polborn et al. (2006) derive a similar result in a rich, two-period model of contracting in competitive life insurance markets, where insurers cannot practice exclusivity to deal with regulatory adverse selection.

In each instance, a ban on the use of risk classification in insurance pricing results in allocative inefficiency. Nonetheless, from an ex ante perspective, each consumer trades off gains in prospective H -type utility against losses in prospective L -type utility at the same rate and, when the proportion of H -types is sufficiently small, they agree that the ban increases the expected value of being an H -type by more than it reduces the expected value of being an L -type. Intuitively, the smaller the proportion of H -types, the smaller is their effect on market price, which both mitigates the harm to L -types and enhances the gain to H -types.²⁰

Thus, the veil-of-ignorance approach can place sufficient relative weight on the distributional equity concerns associated with adverse risk classification to endorse bans on the use of public information in some lines of insurance despite their adverse effects on allocative efficiency. Nonetheless, eliminating a ban on the use of such information passes Samuelson’s test for potential Pareto improvement.

The resolution of these conflicting prescriptions is illustrated in Fig. 11.16 where, again, H -types choose H and L -types choose L in the linear-pricing equilibrium. The dashed lines through H and

²⁰Hoy and Polborn (2000) obtain a yet stronger result showing that when some consumers are uninformed demanders in the life insurance market, social welfare can increase when they become informed. From an ex ante perspective, uninformed consumers gain from the opportunity to purchase insurance knowing the risk class to which they belong in a manner similar to the analysis in Sect. 11.4.2. Further, in the linear-pricing equilibrium, newly informed demanders may be less risky than the average of those initially in the market, in which case the equilibrium price declines to the benefit of all demanders.

L depict iso-profit lines for H -type and L -type contracts, respectively. The lines must intersect along the pooled fair-odds line, since the zero-profit condition is satisfied. The allocations labeled H' and L' thus also jointly yield zero profit, and are preferred to H and L , respectively, as they provide full coverage at fair marginal prices for the same real cost. Moreover, both allocations can be implemented once risk-based insurance pricing is permitted. It follows that any linear-pricing equilibrium is Pareto dominated by an allocation that categorizes applicants by risk class.

The problem is that, when the redistribution needed to compensate for the adverse equity effects of risk classification is not actually implemented, some non-Paretian ethical judgment must validate eliminating a ban on risk classification, since eliminating the ban results in the pair (H^*, L^*) as the alternative to (H, L) , rather than (H', L') , to the benefit of L -types at the expense of H -types. The hypothetical veil-of-ignorance approach to deriving a social ranking of alternative public policy regimes offers a cogent alternative to the ethical judgments of the Samuelson hypothetical compensation test that we have employed in the preceding sections to address the need for a non-Paretian evaluation of the distributional effects of public policy reforms.

11.5 Competitive Market Equilibrium and Extensions of the Basic Model

Although we have emphasized efficiency possibilities in a stylized model of risk classification by insurers, our discussion has practical implications insofar as no critical aspect of insurance contracting is omitted from the model that would have a qualitative effect on efficiency possibilities, and unregulated markets for insurance exploit potential efficiency gains. In this section, we address the issue of market equilibrium and the implications of several innovations of the model to account for additional features relevant to insurance contracting.

11.5.1 Competitive Market Equilibrium

As shown by Hoy's (1982) original analysis of risk categorization based on immutable characteristics, predictions concerning the performance of an unregulated, competitive insurance market depend on the equilibrium concept employed to account for the presence of asymmetric information. Although the appropriate equilibrium concept remains an unsettled issue, the first empirical evidence was reported by Puelz and Snow (1994) and supported theories that predict the separating Rothschild and Stiglitz allocation (i.e., the pure Nash strategy equilibrium suggested by Rothschild and Stiglitz (1976), the non-Nash reactive equilibrium proposed by Riley (1979) in which insurers anticipate profitable competing entrants, or the take-it-or-leave-it three-stage game analyzed by Cho and Kreps (1987) in which the informed insurance applicants move first), rather than those predicting either a pooling allocation (which can occur in the non-Nash anticipatory equilibrium suggested by Wilson (1977) in which the exit of unprofitable contracts is anticipated, the dissembling equilibrium advanced by Grossman (1979), or the three-stage game analyzed by Hellwig (1987) in which the uninformed insurers move first) or separation with all risk types paying the same constant price per dollar of coverage (as in the linear-pricing equilibrium suggested by Arrow (1970) and analyzed by Pauly (1974) and Schmalensee (1984)).

The evidence reported by Puelz and Snow (1974), however, was also inconsistent with the presence of cross-subsidization between types, first analyzed by Miyazaki (1977) in labor market context, and cross-subsidization is necessary for second-best efficiency in the stylized model unless high-risk types are sufficiently prevalent, as shown by Crocker and Snow (1985a). Moreover, if competition always leads to the Rothschild and Stiglitz allocation, then the model predicts that the market fails to exploit

efficiency gains available through risk categorization based on immutable traits, since all categories have the same risk types represented, so that customers in every category would choose from the same menu consisting of the Rothschild and Stiglitz contracts.

Bond and Crocker (1991) have shown that categorization based on the observed consumption of a product that is correlated with underlying risk alleviates and, in some instances, can eliminate the problem of adverse selection. If endogenous risk classification is imperfect, then further categorization based on immutable traits may be exploited by an unregulated market even in the absence of cross-subsidization when different categories have different risk types represented as a result of the insurer's simultaneous risk classification based on behavior by the insured that influences the risk of loss.

Our discussion of incentives for information gathering reveals that, when categorization is informative for insurance applicants, incentive compatibility constraints are irreversibly altered, and the social value of this type of information could therefore be positive or negative depending on parameters of the environment. As our analysis shows, private incentives for information gathering may not be consistent with efficiency. In unregulated markets, public information or additional hidden knowledge may be acquired when it has negative social value, but go unexploited when it has positive social value.

11.5.2 *Extensions of the Model*

We have abstracted from a number of considerations that may be of practical relevance to insurance contracting. Here we shall take note of three which appear to be particularly relevant to risk classification.

11.5.2.1 **Multiple Periods**

Categorization of risks through experience rating is a common practice in insurance contracting, which we have ignored in this review by analyzing an atemporal model. The analysis of Cooper and Hayes (1987) reveals the critical factors that influence contracting with asymmetric information in temporal contexts. For an environment with adverse selection, (costless) experience rating has positive social value if and only if experience is serially correlated with hidden knowledge, as when risk of loss is hidden knowledge and unchanging over time.

The overriding factor determining whether unregulated, competitive markets exploit the efficiency gains of experience rating is the ability of insurers and insurance customers to commit credibly to long-term contracts. If they can, and the market attains the pure strategy Nash equilibrium, then high-risk types receive full and fair insurance, while the coverage and premium for low-risk types is adjusted in the second period based on experience in the first. However, if insurance customers cannot credibly commit to a two-period contract, then experience rating is less valuable as a sorting device, and when renegotiation is introduced, the separating equilibrium degenerates to replications of the single-period equilibrium, as shown by Dionne and Doherty (1991). Hosios and Peters (1989) showed that accident underreporting is possible with commitment and renegotiation, further limiting the market's ability to exploit efficiency gains available through experience rating.

11.5.2.2 **Moral Hazard**

We have abstracted from moral hazard as a source of informational asymmetry, focusing exclusively on adverse selection. In many insurance markets, however, both informational asymmetries influence

contracting possibilities and, as shown by [Cromb \(1990\)](#), the pure strategy Nash equilibrium can be strongly affected by the presence of an unobservable action taken by the insured that influences the risk of loss. In some instances, moral hazard eliminates the adverse selection problem, and thereby eliminates any social value to risk categorization. In other instances, moral hazard constitutes a new source of nonexistence of a pure strategy Nash equilibrium, and the social value of risk categorization may be enhanced if risk types can be grouped in categories for which the Nash equilibrium exists.

11.5.2.3 Risk Preferences

In the stylized model, all insurance applicants have the same preferences for risk bearing, giving rise to a single crossing of indifference curves for applicants of different risk type. In practice, the willingness to bear risk differs among consumers and is also not directly observable by insurers. [Smart \(2000\)](#) shows that incentive compatibility constraints and the market equilibrium can be fundamentally altered when risk preferences as well as risk type are hidden knowledge, since indifference curves of different risk types may cross twice because of differences in the willingness to bear risk.

In some instances, the qualitative properties of the incentive constraints and the pure strategy Nash equilibrium are not affected, but when differences in risk preferences are sufficiently great, the pure strategy equilibrium, if it exists, may entail pooling of different risk classes, which is inefficient relative to separating contracts. Additionally, for some risk preferences firms charge premiums that are actuarially unfair, resulting in partial coverage with strictly positive profit. For these environments, the model is closed by a fixed cost of entry that dissipates profits through excessive entry. In each of these instances, categorization based on observable traits, either immutable or endogenous, that are correlated with willingness to bear risk has the potential to provide insurers with information that reduces the variation in risk aversion within categories sufficiently to avoid the additional adverse selection inefficiencies created when insurance applicants with hidden knowledge of risk class have different risk preferences.

11.6 Summary and Conclusions

In insurance markets with symmetric information, opportunities for risk pooling can be fully exploited so that perfectly competitive market outcomes are first-best efficient, and consumers are charged actuarially fair premia for insurance coverage. In such markets, the gathering of information and the attendant risk classification have negative social value, even when the information is public, because of the classification risk that must be borne by consumers.

For insurance markets with asymmetric information, risk classification enhances efficiency possibilities. Whether effected through self-selection by insurance applicants possessing hidden knowledge of riskiness (signaling by choice of deductible) or through a priori categorization by insurers based on observable traits or behaviors correlated with riskiness (gender, age, race, smoking, or driving sporty cars), risk classification provides insurers with information that relaxes the incentive compatibility constraints and mitigates the adverse selection inefficiency.

The unambiguous social benefit of permitting insurers to categorize applicants based on observable characteristics (such as gender, age, or race) that are imperfectly correlated with underlying loss probabilities depends crucially on the assumption that such classification is informative to insurers, but not to their customers. When applicants are fully informed of their underlying loss probabilities, the use of risk classification by insurers expands, and in no way diminishes, the set of feasible (incentive compatible) insurance contracts. Put differently, the pre-categorization insurance contracts are always feasible in the post-categorization regime. It is the nesting of the regimes that guarantees the efficiency of categorical discrimination.

In contrast, when consumers obtain information about their underlying loss probabilities from the classification procedure (such as in the case of a genetic test), the act of categorization immutably and irreversibly alters the feasible set of insurance contracts. The insurance possibilities that were feasible prior to the classification procedure are precluded by the consumers' changed information sets, which alter the incentive constraints faced by the social planner when designing optimal insurance contracts. Since the pre- and post-categorization regimes are not nested when consumers are informed by the classification procedure, such classification has ambiguous social value.

The adverse equity consequences of risk classification are of special concern to policy analysts when information reveals that some consumers are, in fact, uninsurable. As emphasized by [Hoy \(1989\)](#), these concerns are compounded when action could be taken to diminish the severity of loss, but consumers are discouraged from gathering information and taking such action. We have shown that in markets with either symmetric or asymmetric information, private incentives for initially acquiring hidden knowledge accurately reflect its social value. However, in markets with asymmetric information, private incentives for gathering either public information or additional hidden knowledge are not necessarily consistent with the goal of efficiency in insurance contracting.

The adverse equity consequences of risk classification are precisely the effects that underlie the costs of classification risk. Although we have emphasized these costs as the factor responsible for discouraging consumers from gathering information that has positive social value, we may also observe that these costs appropriately discourage the gathering of information that has negative social value.

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Chapter 12

The Economics of Liability Insurance

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Abstract This chapter examines key elements of the liability system in the USA: the basic theory on the role of liability rules in providing incentives for loss control; the effects of limited liability on the demand for liability insurance and on the ability of tort liability to provide optimal incentives; the problem of correlated risk in liability insurance markets; issues in liability insurance contract design; and the efficiency of the US tort liability and liability insurance system. The troublesome areas of medical malpractice, directors' and officers' liability and general liability insurance crises are highlighted.

12.1 Introduction

This chapter updates the original version by [Harrington and Danzon \(2000\)](#) appearing in the previous edition of this volume. A review of the general liability, law, and economics literature published subsequent to their chapter uncovered relatively little new research that revised basic theory, as opposed to that which explored narrow, special cases of existing theory. As such, much of the text from [Harrington and Danzon \(2000\)](#) remains intact;¹ we have incorporated new works with more general implications to theory and streamlined the previous version somewhat to allow for a case study section of recent challenges in liability insurance markets at the end.

The market for liability insurance arises from the legal liability of individuals and corporations for personal injuries and financial losses caused to third parties, as distinct from first-party insurance which covers losses suffered directly by the policyholder. Private passenger auto liability insurance is by far the largest liability-related line of business in terms of premium volume in the USA.

¹We thank the previous authors for permission to use their work.

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However, the lines that have grown most rapidly and often attracted the most attention in recent years are workers' compensation insurance and commercial general liability (GL) insurance, which includes product liability, directors' and officers' liability, environmental liability, professional liability, municipal liability and related coverages.²

This chapter focuses on issues that distinguish liability insurance from first-party insurance and emphasizes general liability insurance.³ Particular attention is given to basic relationships between legal liability law, liability insurance, and loss control, with the US system providing the institutional framework. This is an area of growing importance as liability regimes are introduced in developing economies and are evolving in developed economies. The US system provides a useful model because liability regimes outside the US have adopted key elements of the US model. Because the academic literature related to tort liability, and to liability insurance, is large, the approach here is necessarily selective. The objective is to introduce key elements of the liability system and discuss a sample of the research most directly relevant to liability insurance.

Section 12.2 sets the context by introducing basic theory on the role of liability rules in providing incentives for loss control. Section 12.3 considers the implications of limited liability for both the demand for liability insurance and for the ability of tort liability to provide optimal incentives to prevent harm. Sections 12.4 and 12.5 discuss the problems of correlated risk in liability insurance markets and liability insurance contract disputes. The debate over the efficiency of the US tort liability/liability insurance system is considered in Sect. 12.6. Section 12.7 discusses empirical work in the troublesome areas of medical malpractice, directors' and officers' liability, and the general liability insurance crisis of the mid-1980s. Concluding observations are made in Sect. 12.8.

12.2 Legal Liability, Deterrence, and Insurance

The tort liability system operates with two objectives. The first is the fairness goal under which it is thought to be equitable for an injurer to bear the cost of injuries caused by his or her actions. This idea leads to the second objective; deterrence of the behavior that may cause injuries. If potential injurers are made financially responsible for the costs of their actions, they should factor those costs into their decisions about the extent of risk involved in their behavior. Some scholars argue that the existence of liability insurance undermines both the fairness goal and the deterrence effect of tort liability.⁴ When a potential injurer is covered by a liability insurance policy, costs arising from a liability claim are at least partially covered by the liability insurer. Those injury costs are then allocated over the pool of the liability insurance policyholders in the form of insurance premiums. In this case, the injurer only bears the costs associated with the portion of liability claims not covered under the insurance policy, rendering the fairness goal only partially met. Further, since insured injurers do not bear the full financial costs associated with their actions, they may be less likely to take care to prevent others from harm. Thus, liability insurance may also interfere with the deterrence objective of tort liability.

Schwartz (1990) notes that liability insurance was first introduced in the USA in 1886. Shortly thereafter, a number of early legal challenges were made to the use of liability insurance to cover a

²Much of the exposure to liability losses in these areas is self-insured and thus is not reflected in premium volume. Commercial multi-peril coverage also includes coverage for many general liability hazards. General liability insurance often is called "other liability" insurance; this term is used in insurance company annual statements filed with regulators. We use the term general liability throughout.

³Other chapters in this volume consider auto liability and workers' compensation. See Danzon and Harrington (1992) for an earlier introduction to the liability insurance literature.

⁴Quoting Prosser (1971), Shavell (1982a) notes serious objections raised to the sale of liability insurance in the USA because it was thought to be against public policy.

tort liability. (See [McNeely \(1941\)](#) for a thorough discussion of the development of this litigation.) However, the definitive case, *Breeden v. Frankford Marine Plate Accident and Glass Insurance Company*, 220 Mo. 327, 119 S.W. 576, was decided by the Missouri Supreme Court in 1909. Since that time, legal doctrine accepts that liability insurance policies will be given force to cover tort liability claims against an insured injurer. But liability insurance coverage is not comprehensive; both courts and insurance companies have drawn lines around the types of liability that can be insured. For example, no coverage exists under general liability policies for actions by an insured that are intended to cause harm. Similarly, insurance against punitive damages is illegal in some states because it is considered counter to the deterrence effect of tort law.⁵ On balance, the social value of liability insurance in its current form seems to outweigh the costs, as shown by both economic evidence and legal opinion. The sections below discuss these issues in more detail.

12.2.1 Efficient Deterrence

Since the pioneering work by [Coase \(1960\)](#), [Calabresi \(1970\)](#), and [Posner \(1972, 1973\)](#), the burgeoning field of law and economics has applied standard tools of positive and normative economics to analyze the structure of common law, including the law of tort liability. A major focus of this analysis has been to show that appropriately designed liability rules can lead to an optimal allocation of resources to risk reduction in contexts where market forces alone would fail because of imperfect information or transactions costs. This extensive literature on optimal liability rules is only briefly introduced here to provide a framework for understanding key issues related to liability insurance.⁶ This subsection focuses on the role of liability rules in providing incentives for controlling risky activity and taking care to prevent loss in the absence of limited wealth and limited liability constraints.

The production of safety (risk reduction) can be modeled either in a standard production framework ([Brown 1973](#)) or as a joint product or spillover associated with other beneficial activities ([Williamson et al. 1967](#); [Shavell 1980](#); [Polinsky 1980](#)). Formally, the activity of one party, the “injurer,” can result in risk of injury to another party, the “victim.” The probability or size of loss may depend on both the level of the activity and the amount of care per unit of activity exercised by the injurer (unilateral accidents) and possibly also on activity level and care per unit taken by the victim (bilateral accidents).

In the general case of bilateral accidents where both injurers and victims choose levels of care and activity levels, the social optimum is defined as the solution to the problem of maximizing the sum of injurers’ and victims’ utilities from engaging in their activities, net of their costs of care, and expected accident losses (using the notation in [Shavell 1987](#), pp. 43–44):

$$\text{Max } [u(s) - sx] + [v(t) - ty - stl(x, y)]$$

where

s = injurer’s activity level,

$u(s)$ = injurer’s gross dollar benefits from the activity,

t = victim’s activity level,

$v(t)$ = victim’s gross dollar benefits from the activity,

x = injurer’s level of care, measured in unit costs,

y = victim’s level of care, measured in unit costs, and

$stl(x, y)$ = expected accident losses.⁷

⁵As of year end 2011, punitive damages were not insurable in 16 states ([McCullough, Campbell, and Lane 2011](#)).

⁶For reviews of this literature, see [Polinsky \(1983\)](#), [Shavell \(1987, 2007\)](#), [Landes and Posner \(1981\)](#), [Cooter and Ulen \(1987\)](#), [Miceli \(1997\)](#), [Abraham \(2008\)](#) and references cited therein.

⁷Since the product of st and $l(x,y)$ is defined as expected losses, the model implicitly allows for losses to be of differing severity.

The optimal values x^* , y^* , s^* , and t^* are defined by the first order conditions

$$\begin{aligned} tl_x(x, y) &= -1 \\ sl_y(x, y) &= -1 \\ u'(s) &= x + tl(x, y) \\ v'(t) &= y + sl(x, y) \end{aligned}$$

These conditions imply that the marginal cost of taking care must equal the marginal benefit in terms of reduction in expected accident costs, and that the marginal utility of increasing the level of activity must equal the sum of the marginal cost of taking optimal care and the increase in expected accident costs.

The standard results of the Coase theorem apply. Optimal investment in all dimensions of risk reduction will be achieved, regardless of the liability rule, if both parties are informed about the risks and if the costs of negotiation are low. An important corollary is that if risks are obvious and if the parties are in an ongoing contractual relation, as employer/employee or producer/consumer, then market prices will reflect the potential victim's demand for safety and induce optimal levels of safety. Market contracts will also generate an optimal allocation of risk between the parties and optimal levels of compensation in the event of injury.⁸

In the case of accidents involving strangers, transaction costs may prevent the achievement of a first best solution by voluntary contract. And even in buyer–seller situations where contracting costs are low, the classic contribution by Spence (1977) shows that if consumers misperceive risk, producers have nonoptimal incentives for care and consumers will be non-optimally insured. Liability rules are one among several possible policy tools for achieving efficient levels of loss prevention and risk allocation where voluntary contracting in private markets fails. Regulatory standard setting, taxes and subsidies, fines and injunctions are other possible corrective policies. Among other dimensions, liability rules differ from regulatory standard setting in that they do not proscribe a specific course of action.⁹ Rather, liability rules define general conditions for allocating the cost of accidents and determining the amount of damages payable.

12.2.1.1 Negligence and Strict Liability

The two benchmark liability rules are negligence and strict liability. Under a negligence rule, the injurer is liable only if he or she failed to take due care and this failure was the cause of injury to the victim. Under a strict liability rule, the injurer is liable if his activities caused an injury to the victim, regardless of the injurer's level of care. In the USA, negligence is the prevailing rule for personal and professional liability (including medical malpractice) and for automobile injuries except in states that have explicitly adopted first-party no-fault statutes that limit tort liability for minor injuries. Strict liability is exemplified by the workers' compensation statutes whereby employers are absolutely liable for statutory benefits for work-related injuries, regardless of own or victim negligence. For product-related injuries, manufacturers can be sued under theories of negligence and strict liability, but liability is strict only for injuries caused by defective products.¹⁰ Important variants of these benchmark rules

⁸For formal models and empirical estimates of the wage premium for risk-bearing in risky employments, and use of such estimates to infer a willingness-to-pay for safety or "value of life," see, e.g., Viscusi (1983) and Viscusi and Moore (1987).

⁹See Shavell (1984) for comparisons of tort liability and safety regulation as means to promote loss control.

¹⁰This notion of product defect reintroduces an issue of reasonable care, defined by some weighing of risks and benefits of additional care, analogous to a due care standard under a negligence rule. Thus strict liability for products is not absolute liability in the sense of the simple theoretical models.

are the application of a contributory negligence defense (which shifts liability to the victim if he or she failed to take due care, regardless of the defendant's care) and comparative negligence, whereby damages are apportioned between the parties in proportion to their degree of negligence.

Brown (1973) first formally modeled the effects of these alternative liability rules on levels of care. Under certain assumptions including risk neutrality, costless administration, and perfect information, three liability rules are potentially efficient: negligence, with or without a contributory negligence defense, and strict liability with a contributory negligence defense. Haddock and Curran (1985), Cooter and Ulen (1987), and Rubinfeld (1987) show that it is possible to define an efficient comparative negligence rule.¹¹ Shavell (1980) generalized Brown's model to allow both levels of care and levels of activity as determinants of risk. A negligence rule is potentially efficient if potential victims are informed about accident risk. If average risk is misperceived, no liability rule is fully efficient. (See also Polinsky 1980). Neil and Richter (2003) suggest that while strict liability is often imposed in situations of highly risky activity, a negligence rule will be more efficient in such situations if a market relationship exists between the injurer and the victim.

12.2.1.2 Efficient Damages

Tort awards simultaneously provide deterrence to injurers and compensation to victims. Viewing tort liability as a system of (conditional) compulsory insurance (Oi 1973; Danzon 1984b), it is unique among systems of social and private insurance in that the amount of compensation is determined after the injury, traditionally by jury and without contractual or statutory limits, and is intended to provide full compensation of monetary and non-monetary loss.

A single award is optimal for both deterrence and compensation only in a restricted set of circumstances. (Cook and Graham 1977). Absent those circumstances, the optimal compensatory award is no longer identical to the optimal deterrence penalty on the injurer, and Spence (1977) shows that a first best result requires supplementing compensatory awards with a system of fines, paid initially to the state and refunded as subsidies to the risky activity. Danzon (1985a) shows that the optimal compensatory award to the victim is inversely related to the load on the defendant's liability insurance.¹² Rea (1981) demonstrates that lump sum awards are more efficient than periodic payments contingent on losses actually incurred. Contingent periodic payment overinsures the victim and encourages ex post moral hazard.¹³

¹¹Cooter and Ulen (1987) argue that a comparative negligence rule is superior to a negligence rule when injurers and victims bear risk and there is evidentiary uncertainty. Rubinfeld (1987) reinforces this conclusion when injurers and victims are heterogeneous. Fluet (2010) shows that, under evidentiary uncertainty, comparative negligence may require more informative evidence than contributory negligence. Hence, there are situations where contributory negligence will do better.

¹²These conclusions follow from the standard assumption that the optimal damage award is chosen to maximize the utility of the victim, subject to a reservation level of utility for the defendant. Thus by assumption, the incidence of costs of liability is on victims. This is reasonable assuming a perfectly elastic long-run supply of the products or services that are subject to strict liability. But with imperfectly elastic supply in the short run, the incidence of unanticipated changes in liability costs is partly on defendants (Danzon 1990).

¹³Noncontingent periodic payment of awards, where the amount is determined at time of trial or settlement (also called "structured settlements") are potentially more efficient than lump sum awards if the defendant is permitted to provide for the payment of these future damages by the purchase of an annuity or other financial instrument. This transfers from the jury to financial markets the issue of determining expected rates of inflation and interest (Danzon 1984b). Perhaps more important, structured settlements may reduce income tax costs.

12.2.2 *Liability Insurance, Moral Hazard, and Experience Rating*

12.2.2.1 Risk Neutrality/Actuarially Fair Premiums and No Judgment Proof Problem

The early models of effects of liability on levels of care assume purely financial losses, either risk neutrality or the availability of actuarially fair insurance, and unlimited liability for potential injurers, i.e., injurers are not “judgment proof.” Shavell (1982a) introduced risk aversion of victims and injurers and the availability of first-party and liability insurance into a model examining the demand for liability insurance.¹⁴ A first best solution now requires (a) a level of care that minimizes expected accident losses plus the cost of care and (b) an optimal allocation of risk for both parties.¹⁵ The demand for liability insurance and its effect on social welfare depend critically on the information available to courts and to insurers.¹⁶

With perfect information and a negligence rule with the standard of care optimally defined and perfectly implemented, there is no demand for liability insurance. It is cheaper for defendants to be non-negligent and bear no risk than to be negligent and insure against the resulting liability.¹⁷ Under strict liability when liability insurance is not available, a first best outcome is not attainable; both victims and injurers bear risk, and injurers may take excessive care or engage sub-optimally in risky activities. When liability insurance is available and insurers can observe defendant care perfectly and price accordingly, injurers can be fully protected against risk while preserving optimal incentives for care, and optimal damage awards provide full compensation to victims. Thus liability insurance unambiguously improves social welfare and permits a first best solution for level of care and allocation of risk.

The demand for liability insurance under a negligence rule changes with imperfect information. When victims or courts fail to file or award liability in all instances of negligence (Type 1 errors), it is cheaper for defendants to be negligent and to insure at the actuarial price against the resulting liability than to be non-negligent. Conversely, if claimants or courts erroneously file or find negligence, then defendants are exposed to a risk akin to strict liability and will demand liability insurance (Shavell 1982a, 1987; Danzon 1985a).^{18,19} The efficiency of the negligence rule with liability insurance under conditions of imperfect information depends on the extent to which insurance contracts can be based on the same evidence, and the weighing thereof, that courts use to determine blame (Fagart and Fluet 2009).

¹⁴Corporate demand for liability insurance may be explained by risk aversion of customers, suppliers, managers, or employees or by other factors, such as indirect losses, that cause the firm value to be a concave function of firm cash flows (Mayers and Smith 1982; Froot et al. 1993).

¹⁵Formally, the problem is to maximize expected utility of the victim, subject to constraints of (a) a reservation utility level for the defendant, (b) an overall resource constraint, (c) victims and injurers choose first party and liability insurance to maximize their respective utilities, and (d) insurers break even. If insurance is not available, then the choice between liability rules depends on which party is better able to bear risk. In particular, strict liability is preferable to negligence if injurers are risk neutral or better able to bear risk.

¹⁶Bajtelsmit and Thistle (2009) investigate efficiencies and incentives to insure when the information available to the potential injurer varies.

¹⁷A first best outcome is achieved only if victims can eliminate risk by buying actuarially fair first-party insurance.

¹⁸If the insured’s level of care is observable to the insurer, the optimal contract would exclude coverage if the defendant acted negligently. But if insurers had the information necessary to implement such a policy, the courts could use the information and eliminate the errors that generated the demand for insurance in the first place.

¹⁹Calfee and Craswell (1984) analyze effects of uncertain legal standards on compliance under a negligence regime in the absence of liability insurance.

Under strict liability, if insurers cannot observe defendants' care, defendants will choose less than full coverage and the outcome for both level of care and allocation of risk is not first best. Thus in the single period context, moral hazard induced by asymmetric information results in a trade-off between loss prevention and risk spreading in the context of liability insurance, as in first-party insurance (Shavell 1979). But Shavell concludes that even with imperfect observation of care, government intervention in liability insurance markets is not warranted.²⁰

12.2.2.2 Efficient Co-Payments

If the probability and size of injury depend only on the defendant's level of care and there is a proportional loading, optimal co-payments would include a deductible, a coinsurance rate, or both in the single period case. In the multiperiod case, the optimal policy is priced based on the level of care taken.²¹ When care is not observable, co-payments levied against paid claims may not accurately reflect the defendant's degree of negligence.²² The private and socially optimal policy would require insurers to invest in information and relate co-payments only to losses caused by suboptimal care.

When the courts lack perfect information about the defendant's care, the victim's damages or the injury production function, both parties have incentives to invest in legal effort to influence the outcome.²³ But when both the insurer and the policyholder can affect the magnitude of loss, no simple loss sharing contract can simultaneously provide both with optimal marginal incentives. In general, if it is costly for policyholders to monitor the insurer's legal defense effort, the privately optimal co-payment is lower than on first-party coverage with comparable policyholder moral hazard and even lower if defense effort reduces plaintiff's incentives to file claims (Danzon 1985a).²⁴ When claim outcomes depend on legal defense effort, defendants may choose policies with too little co-payment: from a social standpoint, too many resources may be devoted to fighting claims and too few to preventing injuries. Private and social optima diverge unless potential victims are in a contractual relationship with defendants and accurately perceive the nature of the defendant's insurance coverage and its likely effects on claim outcomes—but in that case the liability rule is irrelevant.

Deductibles are common for product liability and professional liability policies for attorneys, accountants, corporate directors and officers, but not for medical malpractice, where rating based on

²⁰This assumes that government has no information advantage, damage awards are optimally set and defendants are not judgment proof.

²¹In the liability context, socially optimal coverage if the insurer could observe the insured's care would provide full coverage of losses if care is efficient ($x \geq x^*$) and zero coverage if care is suboptimal ($x < x^*$). But if there are Type I errors (failure to file or find liability for all injuries caused by $x < x^*$) then defendants may prefer a policy that provides coverage even if $x < x^*$ (Danzon 1985a).

²²Paid claims do not convey perfect information about whether negligence occurred even if courts are unbiased because over 90 % of paid claims are settled out of court. The decision to settle and amount of settlement may be influenced by many factors other than the defendant's level of care and plaintiff's true damages, including the parties' misperceptions of the expected verdict, costs of litigation, risk aversion, concerns over precedent, and other factors. This literature is reviewed in Cooter and Rubinfeld (1989).

²³For product liability and medical malpractice, plaintiff and defense legal expenditures each average about one half of the net compensation received by plaintiffs (Danzon 1985b; Kakalik James and Pace (1986). For the effects of costly litigation on the efficiency of liability rules see, for example, Polinsky and Rubinfeld (1988), Cooter and Rubinfeld (1989). Also see Sarath (1991).

²⁴For example, a deductible undermines the insurer's incentives to fight claims that can be settled for less than the deductible. Incurring legal expense in excess of damages may be a privately optimal strategy if it deters other potential claims.

the physician's individual claim record is relatively limited.²⁵ If more experience rating is statistically feasible than in fact occurs for medical malpractice insurance, this suggests a lack of demand. The apparent lack of co-payment may be deceptive if physicians face significant co-payment in the form of uninsurable time and disutility of being sued, or higher premium costs if they are denied coverage by more selective, lower cost insurers (Danzon 1985a). To the extent co-payment and experience rating exist, it is usually based on additional information to distinguish Type 2 errors from valid claims, rather than automatic co-payment for all paid claims, consistent with the hypothesis that the risk of judicial error contributes to the lack of demand for experience rated policies.²⁶

12.2.2.3 Bundling Defense and Indemnity

The optimal insurance contract under conditions of moral hazard has been extensively studied in the context of first-party insurance (see, e.g., Winter 1992). For liability insurance against loss caused by the policyholder to a third party, control of moral hazard is more complex. The liability insurance loss depends not only on the policyholder's activity and care, but also on the insurer's defense and the policyholder's cooperation in this defense. A distinguishing feature of liability insurance is the nearly universal bundling of indemnity and defense coverage in a single contract: most liability insurance contracts specify the right and duty of the insurer to defend the policyholder and the right to control the defense.

The bundling of defense and indemnity in liability insurance contracts reflects three main influences. First, with imperfect information about care and the application of liability rules, potential injurers often face substantial risk associated with legal defense costs. Their total loss exposure reflects the sum of judgments and defense costs. It is hardly surprising that parties that seek coverage for indemnity to third parties would also seek coverage for defense. Second, insurers have specialized expertise in defending claims, which favors the purchase of defense services from insurers (e.g., Mayers and Smith 1982). Third, and as suggested in our earlier discussion of co-payments, bundling indemnity and defense helps provide efficient incentives for minimizing the sum of indemnity and defense costs (see Danzon 1984b; Cooter and Rubinfeld 1989; also see Syverud 1990). For claims that exceed the deductible and are materially below the policy limit, a liability insurer has a clear incentive to minimize this sum, which generally is consistent with policyholder preferences *ex ante*.²⁷ In contrast, separation of the financial responsibility for defense and indemnity would dilute incentives for cost minimization and/or lead to higher monitoring costs.

²⁵Several studies have shown that the actual distribution of claims and awards is inconsistent with a purely random distribution, after controlling for specialty (Rolph 1981; Ellis et al. 1990; Sloan 1989a and b).

²⁶Professional liability policies explicitly exclude coverage of intentional acts. The existence of a demand for and a supply of coverage for punitive damages in states where this is permitted suggest a significant risk of Type 2 errors, despite the higher standard of proof (gross negligence or willful misconduct) for punitive awards.

²⁷Buyers with preferences that are inconsistent with cost minimization may make arrangements with accommodating insurers. Also see McInnes (1997).

12.3 Limited Liability, Insurance, and Deterrence

12.3.1 Limited Wealth and Limited Coverage

A fundamental factor that distinguishes liability coverage from property insurance is that the harm suffered by the injured party may exceed the assets of the injurer that are exposed to risk given limited liability and bankruptcy law.²⁸ As a result, potential injurers generally will not seek full insurance coverage for liability which can affect levels of risky activity and care (see [Sinn 1982](#); [Huberman et al. 1983](#); [Keeton and Kwerel 1984](#); and [Shavell 1986](#)). It is first useful, however, to consider the demand for upper limits on liability insurance coverage in the simple case where activity and care are exogenous.²⁹

[Sinn \(1982\)](#) analyzes the demand for liability (and human wealth) insurance in the case where gross losses can exceed the socially guaranteed minimum level of wealth. Using a simple two-state framework (loss and no loss), he shows that the incentive to buy full coverage for loss increases with wealth in the no-loss state and risk aversion, and decreases with the (exogenous) probability of loss, the severity of loss, and the lower bound on net wealth in the loss state. His analysis of the demand for partial insurance has qualitatively similar implications. Upper limits on coverage are shown to be optimal because beyond some point, the expected benefit of additional coverage is smaller than the cost given that the price of coverage must include losses that otherwise would fall on other parties. The willingness of parties to insure declines when part of the premium is required to finance loss that they would not have to bear if uninsured.³⁰

[Huberman, Mayers, and Smith \(1983\)](#) consider the demand for liability insurance with bankruptcy protection and continuous loss distributions. Like [Sinn \(1982\)](#) they show that bankruptcy protection can lead parties to demand upper limits on liability coverage. They illustrate the demand for upper limits assuming exponential utility. Because expected utility is not differentiable with a lower bound on net wealth they note that the general solution to the assumed maximization problem is “complicated and there is no obvious economic interpretation of the derived restrictions” (p. 418).

The key conclusion that lower bounds on net wealth reduce the demand for liability insurance arises from the resulting convexity of the utility function. Similar results are implied in the case where corporations are assumed to maximize firm value provided that firm value is a convex function of realized payoffs for sufficiently low realizations. More generally, this result is closely related to the literature on why firms hedge or insure (e.g., [Mayers and Smith 1982](#); [Smith and Stulz 1985](#); [Froot et al. 1993](#); also see [MacMinn and Han 1990](#)). Limited assets and lower bounds on wealth due to limited liability/bankruptcy law reduce incentives for firms to hedge risk and buy liability insurance.³¹

²⁸The same general issue arises in the case of medical expense insurance, where the cost of the amount of care provided exceeds the assets of the patient or patient’s family. [Easterbrook and Fischel \(1985\)](#) provide comprehensive discussion of the rationale for the limited liability doctrine.

²⁹[Raviv \(1979\)](#) provides an early treatment of upper limits of coverage that does not consider bounds on wealth net of indemnity for losses.

³⁰See also [Shavell \(1986\)](#). To illustrate with a simple example consider a party with \$10,000 of assets at risk who faces a 0.01 probability of causing \$100,000 of harm to others. The expected loss to the party without insurance is \$100; the actuarially fair premium for full liability insurance protection is \$1,000. An unwillingness to insure fully in this case is hardly surprising.

³¹A large amount of anecdotal evidence on the demand for liability and workers’ compensation insurance is consistent with the prediction that parties with low wealth will demand little or no coverage.

12.3.2 *The Judgment Proof Problem and Compulsory Liability*

If injurers lack sufficient assets to fully satisfy a judgment, incentives to purchase liability insurance are clearly diminished. Moreover, incentives to take precautions also may be diluted (Calabresi 1970; Keeton and Kwerel 1984; Shavell 1986; also see Sykes 1984; Beard 1990, and Posey 1993). Under a negligence rule, if the injurer's wealth is some critical level less than the potential loss, incentives for care are suboptimal. Under strict liability, if insurers perfectly observe injurers' levels of care, full coverage is purchased and the level of care is efficient if injurers' wealth exceeds some critical level; at lower levels of wealth, injurers do not buy insurance and the level of care is suboptimal. If insurers cannot observe care, above some (higher) critical level of wealth, injurers buy partial coverage but the level of care is nonoptimal.

Many authors have considered whether making the purchase of liability insurance compulsory can restore efficient incentives for safety (e.g., Keeton and Kwerel 1984; Shavell 1986, 2004; also see Williamson et al. 1967; and Vickrey 1968).³² Shavell (1986, 2004) shows that compulsory insurance can restore efficient incentives for care under both negligence and strict liability, provided that enforcement is complete and that insurers can observe defendants' care and rate premiums appropriately.³³ However, if injurers' care is unobservable, compulsory coverage that fully protects injurers' assets will lead to an inefficiently low level of care, even though it reduces incentives to engage in excessively risky activity. The intuition is straightforward. Compulsory coverage is analogous to a tax on risky activity, but moral hazard associated with liability insurance may reduce care compared to the case where the potential injurer is exposed to a material loss absent insurance.

In lieu of compulsory insurance, requirements for injurers to hold some minimum level of assets may be imposed as incentive to induce care. Shavell (2004) finds that such requirements may improve parties' decisions to undertake risk activity, although those with low asset levels may excessively avoid risky activity. In comparison to compulsory insurance, minimum asset requirements may actually provide better incentives to reduce risk if insurers cannot observe the level of care taken by potential injurers.

In the USA, insurance or ex ante proof of financial responsibility is compulsory for workers' compensation, medical malpractice, and certain forms of environmental liability in all states, and in most states for automobile liability. Two arguments can be made for compulsory coverage even in the absence of rating that reflects observation of individuals' levels of care. First, and as suggested above, with experience rating at the level of the group but not the individual, compulsory coverage still internalizes accident costs to the responsible activity or class of individuals. The cost of insurance operates like a tax on the activity and achieves general but not specific deterrence. Second, compulsory insurance helps assure the compensation function of tort liability. On the other hand, concern with the resulting distributive effects between classes of injurers and victims may influence the political demand for compulsory insurance, associated enforcement, and price regulation of compulsory coverage in ways that undermine its deterrent function.³⁴ Moreover, the efficiency case for compulsory

³²A related literature considers whether compulsory first-party insurance against catastrophic property losses can improve incentives for efficient investment and precautions (e.g., Kaplow 1986). Similar issues arise with respect to uninsured medical care.

³³Other possible remedies are vicarious liability (see Sykes 1984, 1994) and imposing asset requirements for participating in the activity. Shavell (1986) shows that imposing asset requirements equal to the maximum possible loss may overdeter, because it is socially efficient for parties to participate in an activity if their assets equal the expected loss, which is less than the maximum possible loss.

³⁴Keeton and Kwerel (1984) raise the theoretical possibility that subsidized liability insurance could be efficient. On the other hand, if compulsory coverage leads to a political demand for rate regulation that guarantees availability of coverage for high risks at subsidized rates, incentives for care will likely be undermined. The political economy of compulsory automobile insurance is analyzed in Harrington (1994b); for workers' compensation, see Danzon and Harrington (1998).

coverage rests implicitly on the assumption that the tort liability/liability system is efficient. As we elaborate in Sect. 12.4, many observers challenge this assumption, arguing that the tort liability system leads to excessive deterrence, as well as suboptimal compensation. In addition, the redistributive effects of compulsory coverage are to some extent regressive. As a result, the case for compulsory coverage is an uneasy one, at least for some types of risk, such as the risk of auto accidents.

The judgment proof problem may manifest itself in the form of inefficiently high levels of risky activity and inefficiently low levels of care. It may include strategies that attempt to shield assets from judgments and, in extreme cases, perhaps even planned bankruptcy (see [Ringleb and Wiggins 1990](#); [Akerloff and Romer 1993](#); [Swanson and Mason 1998](#); also see [LoPucki 1996](#)) and has kindled debate over the efficiency of the traditional doctrine of limited liability, at least for corporations that own corporations or that have many diversified shareholders (see [Hansman and Kraakman 1991](#)).

12.4 Correlated Risk

12.4.1 Sources of Correlated Risk

The demand for liability insurance and optimal form of contract is affected by correlated risk among policyholders.³⁵ Positive correlation of liability risks derives from the dependence of number of claims and size of awards on unanticipated changes in law and social norms. By the operation of legal precedent, a ruling by one court can influence the outcome of related cases, but given the multiplicity of courts and jurisdictions, it may be many years before new majority standards become firmly established.

The undiversifiable risk associated with common factors increases with the duration of insurer liability, which is typically longer for liability insurance than for first-party insurance. Delay between the writing of the policy and the ultimate disposition of all claims is caused partly by delay in the legal process of settling claims. More significant time lapse derives from discovery-based statutes of limitations which do not begin to run until the injury and its cause have been, or with reasonable diligence should have been, discovered, which could be 20 years for some cancers or birth defects. The longer the duration of liability, the greater the risk that unanticipated information about hazards or new legal standards will shift the distribution of expected loss for all outstanding policies. Socio-legal risk has become more significant with the expansion of liability for defects in product design and warnings, and the adoption of statutory liability for environmental damage and clean-up (see below). A single ruling can influence hundreds or even thousands of claims.³⁶

³⁵The effect of correlated risk on “crises” and cycles in the supply of liability insurance is discussed below. There are two aspects of correlated risk: (a) unfavorable realizations in underlying loss distributions that are correlated across policyholders and (b) errors in forecasting the mean of the underlying distributions. The actuarial literature refers to the former aspect as process risk and the latter as parameter uncertainty. The economics/behavioralist literature sometimes calls the latter type of risk “ambiguity” (see [Kunreuther et al. 1993](#)).

³⁶Many of the thousands of asbestos claims arose out of exposure to asbestos in the 1940s and 1950s and are based on allegations of failure to warn of the hazards of asbestos exposure. [Epstein \(1982\)](#) argues that even if the medical risks were knowable at the time of exposure, the tort liability of asbestos manufacturers could not have been anticipated because at that time a worker’s sole recourse would have been through a workers’ compensation claim against his employer. Similarly, environmental liability under Superfund could not have been anticipated. Even if courts admit a state-of-the-art defense for product injuries in principle, some degree of retroactivity is implicit in basic common law rules of procedure and damages, and some courts have explicitly disallowed a state of the art defense. Retroactivity in tort is discussed in [Henderson \(1981\)](#), [Schwartz \(1983\)](#), [Danzon \(1984b\)](#) and [Abraham \(1988b\)](#).

12.4.2 *Effects on Premiums and Contract Design*

The basic theory of insurance pricing implies that “fair” premiums equal the discounted value of all expected costs associated with writing coverage including the expected cost of claim payments, underwriting expenses, income taxes, and capital (see Myers and Cohn 1986, and Cummins and Phillips 2000). Much attention has been paid to the measurement of underwriting risk borne by suppliers of capital and the appropriate treatment of income taxes. The amount of capital that is committed to support underwriting has a major impact on the fair premium level because of the tax and agency costs of capital, as well as any systematic risk for which investors demand compensation. Higher levels of capital lead to higher premiums and lower default risk (e.g., Myers and Cohn 1986; Cummins and Lamm-Tennant 1994).

Correlated risk across liability claims requires insurers to hold more capital to achieve the same level of solvency as under uncorrelated risk. This increased risk of forecast error need not imply that liability insurance necessarily requires more capital than certain other types of coverage.³⁷ The key point is that intertemporal increases in risk for a line of business will increase the amount of capital and hence the price needed to offer coverage in that line.^{38,39}

Severely correlated risk also may affect the optimal form of contract and organizational form of insurers. Doherty and Dionne (1993; also see Marshall 1974) show that with correlated risk claims-made policies may dominate occurrence policies and mutual forms of organization have a comparative advantage over stock forms.⁴⁰ An alternative mechanism for sharing risk with respect to the distribution of aggregate losses is use of a contract that provides for retroactive adjustment in the premium, through dividends or assessments on policyholders. Such contracts are costly to enforce when there is asymmetric information between insurer and policyholder in observing the true loss or the realized loss depends in part on the insurer’s incentive for legal defense (Danzon 1985a). The mutual form, which eliminates the policyholder–shareholder conflict, may thus have an advantage in assuring optimal investment in legal defense and offering contracts with retroactive adjustment or multiperiod policies. Conversely, mutual insurers are less able than stock insurers to raise external capital following large losses, which could increase the capital that mutuals need to hold ex ante.

The effect of correlated risk on the optimal structure of damage awards and duration of liability (statutes of limitations) is discussed informally in Danzon (1984b) and Rubinfeld (1987) but has not been analyzed rigorously in formal models. More generally, the effect of the current structure of liability rules on the risk faced by liability insurers has played a major role in the debate over tort reform and liability insurance crises (see Sect. 12.6 and 12.7).

³⁷For example, the long-tail associated with liability claims may allow insurers time to respond gradually to unexpected increases in costs; this option is not available for catastrophe property losses. An analogous issue arises in assessing the risk of long-term versus short term debt instruments.

³⁸Sommer (1996) and Phillips et al. (1998) provide evidence using insurer level data that insurance prices are positively related to measures of underwriting risk and capital. Also see Cummins and Lamm-Tennant (1994). Viscusi (1993) obtains inconclusive evidence of a relationship between premium rates and measures of ambiguity using ISO ratemaking files for 1980–1984.

³⁹Use of capital market instruments or insurance derivative contracts is an alternate to holding more capital. However, the use of these types of instruments to manage long-tailed liability risk appears problematic given the long claims tail and lack of a suitable index that is highly correlated with changes in the value of claims liabilities (Harrington et al. 1995).

⁴⁰Danzon (1984b, 1985a, 1985b) makes similar arguments in explaining the switch from claims-made to occurrence coverage and the growth of physician-owned mutuals following the medical malpractice “crisis” of the 1970s. Also see Doherty (1991) and Winter (1994).

12.5 Contract Interpretation and Litigation

The demand for and supply of liability insurance also are influenced both directly and indirectly by the existence and likelihood of extensive litigation over contractual terms in the event of large claims against policyholders. Hundreds of millions of dollars have been spent on liability insurance coverage litigation during the past few decades.⁴¹ Doherty and Smith (1993) argue that litigation over coverage terms is much more likely in the event of large claims involving multiple policyholders, suggesting in effect that the potential benefits of litigation dwarf reputation and other influences that otherwise discourage litigation.

Specific issues that have been extensively litigated for occurrence liability insurance coverage include (1) the meaning and timing of the occurrence of loss, (2) what constitutes covered damages, (3) the meaning of damage that is “expected or intended” by the insured, and (4) allocation of responsibility for indemnity and defense among insurers when an occurrence is deemed to have spanned multiple policies.^{42,43} Economic analyses have focused on the effects of correlated risk on the price of coverage, the optimality of occurrence vs. claims made coverage, and optimal policy for dealing with environmental clean-up (see Danzon 1984b; Menell 1991). While this literature may help shed light on the possible intentions of the contracting parties, it generally is not dispositive with respect to coverage issues.

A large legal literature also deals with insurer and policyholder obligations with respect to the duty to defend. For general liability insurance contracts where defense costs are borne by the insurer and are in addition to the policy limits, there may be a conflict between the insurer and the insured over whether to defend or settle a claim. Since the insured does not bear defense costs, he or she may resist efforts by the insurer to settle a claim to control its own costs. Also, since the insured is unlikely to be fully insured, a vigorous effort by the insurer to defend a claim mitigates against the insured having an out-of-pocket liability expense. Recognizing these potential conflicts, general liability insurance policies typically vest authority to settle claims with the insurer alone.

For some types of liability insurance contracts, notably professional malpractice liability, the insured has a contractual right to participate in the claims settlement process because a settlement by the insurer may be damaging to the insured professional’s reputation. To help control its costs, insurers may include defense costs within the policy limits, so that expenses in defense of the claim reduce the limits available to pay any ultimate judgment or settlement of the claim. In this case, the insured must balance the costs of defense and settlement in determining the litigation strategy.

Syverud (1990) provides a detailed treatment of the duty to defend, including analyses of insurer incentives when the settlement or judgment is highly likely to equal or exceed the policy limits. He discusses the potential efficiency of a legal standard that imposes the duty on the insurer to settle the claim as if there were no policy limits and suggests that standard contractual remedies, as opposed to bad faith actions, are sufficient to provide insurers with incentives to comply with this type of standard.

⁴¹Much of this litigation has dealt with the interpretation of general liability insurance policies for environmental claims associated with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, which imposed strict, retroactive, and joint and several liability on firms involved in the creation, transport, and disposal of environmental toxins. See Abraham (1988b, 1991) for detailed discussion of the numerous aspects of environmental coverage litigation.

⁴²See Abraham (1991), in the context of environmental litigation. Cummins and Doherty (1996) analyze the allocation issue; also see Doherty (1997) and Fischer (1997).

⁴³Court resolution of these issues often has been influenced by the doctrine of *contra proferentem* (ambiguous terms should be construed against the drafter) and the doctrine of reasonable expectations (see, e.g., Rappaport 1995). A large legal literature deals with these issues.

12.6 Efficiency of the Tort Liability/Liability Insurance System

The US tort liability/liability insurance system has been the subject of enormous debate during the past two decades. One polar view is that the tort liability system is reasonably efficient and, if anything, requires further expansion to achieve efficient deterrence. The alternative polar view is that the tort liability system has devolved into a system of expensive and unpredictable rent seeking by plaintiffs' attorneys, which involves an excessive tax on the US economy.⁴⁴ This section identifies some of the main points in the debate. A related issue, but one outside the scope of this chapter, is the efficiency of private incentives to litigate, which can be either socially excessive or socially inadequate in the US legal system. See, among others, [Shavell \(1982b, 1997, 1999\)](#), [Kaplow \(1986\)](#), and [Spier \(1994\)](#) for a full discussion of private versus social incentives to sue.

12.6.1 *Efficient Compensation Vs. Efficient Deterrence*

Ignoring deterrence, it generally is recognized that the tort liability system is an inefficient mechanism of compensation for harm and risk spreading. The policy dilemma is that deterrence cannot be ignored. Most characteristics of the tort system that seem clearly inefficient from a compensation perspective provide at least some deterrent to harm. Because it is exceedingly difficult to provide concrete evidence of whether a particular tort liability rule is efficient, it is likewise difficult to reach intellectual consensus, let alone political consensus, on whether material changes in the tort liability system would enhance efficiency.

12.6.1.1 Transaction Costs of Third-Party Vs. First-Party Insurance

The load on liability insurance generally appears to be much greater than that on first-party insurance but a simple comparison of loading charges is an inappropriate measure of overall efficiency. Part of the purpose of the litigation expense component of liability insurance is enforcement of liability rules which in principle serve a deterrent as well as a compensation function. Liability insurance provides the joint products of compensation of the victim, insurance of the defendant, and deterrence, in contexts that intrinsically involve asymmetric information and multiple agency problems. Thus from a social perspective, liability and first-party insurance perform different functions and are used in contexts that make them noncomparable. About all that can be said is that the administrative costs of tort liability are not justified if the impact of legal rules on deterrence is less than some critical level (see [Shavell 1987](#), ch. 11).

[Epstein \(1982\)](#) and [Priest \(1987\)](#) examine product liability as an insurance market and argue that it is much less efficient than first-party insurance for purposes of controlling moral hazard and adverse selection. But in the context of two party accidents such as consumer product injuries, first-party insurance is relatively inefficient at controlling moral hazard on the part of producers, just as liability insurance does little to control moral hazard on the part of consumers. There is an exact parallel here between liability insurance and liability rules: just as one-sided liability rules such as caveat emptor and strict liability without a contributory negligence defense are inefficient for controlling bilateral accidents, the associated insurance arrangements similarly fail to provide efficient incentives for care to the party that is immune from liability. It is not obvious a priori that for bilateral accidents, first-party insurance is more efficient than liability insurance.

⁴⁴[Huber \(1990\)](#) and [Olson \(1992\)](#) provide discussions of this view.

12.6.1.2 Non-Pecuniary Losses, Collateral Sources, and Punitive Damages

Two of the most common examples of alleged inefficiency in tort damages from the perspective of optimal compensation and risk spreading are damages for pain and suffering and punitive damage awards. Requiring injurers to compensate the injured for non-pecuniary losses, such as pain and suffering, and not allowing offset for the injured party's collateral sources of compensation can be justified on efficiency grounds. The basic argument is that failure to hold injurer's liable for the "full" loss leads to inefficient incentives to control losses. However, damages for non-pecuniary losses are inefficient from a compensation and risk spreading incentive as has been emphasized in the literature on automobile insurance no-fault laws and in the products liability literature. Whether rational consumers would choose to insure non-pecuniary losses is theoretically ambiguous, given that higher marginal utility of wealth following such losses cannot be ruled out from first principles. Many authors presume that higher marginal utility following non-pecuniary losses is unlikely, citing the relative dearth of first-party insurance for non-pecuniary losses as support (e.g. [Rubin 1993](#)). Viscusi and Evans (1990) use survey data on wage premia that chemical workers would demand to be exposed to various chemicals. Their analysis provides some support for the hypothesis that marginal utility declines following non-pecuniary loss. These arguments and evidence, however, are not dispositive. The theory is ambiguous; insurance markets for non-pecuniary loss might fail due to transaction costs and moral hazard, and the empirical evidence on pre- and post-loss marginal utility is slender. [Thiel \(1998\)](#) provides detailed discussion of these issues (also see [Croley and Hansen 1995](#)).⁴⁵

12.6.1.3 Distributive Effects

A popular view among some segments of society is that litigation, including in many cases punitive damages, is necessary to promote social justice, although others point out that laws and regulations should not be enacted for distributional effects as they can be altered via taxation. While addressing issues of justice/fairness is beyond the scope of this chapter, implicit in this view is that an expansive tort liability system achieves a progressive redistribution of income. However, the distributional effects of the tort liability system are complex, with some, if not most of the costs borne by consumers of products and services and individuals involved in mundane risky activities. A number of studies have analyzed ways in which the tort liability/liability insurance system could have regressive distributional effects. If consumers with different levels of wealth purchase the same risky products, the increment in price necessary to cover expected costs of product injuries will be invariant to income, but the expected indemnity from tort liability action increases with wages. Moreover, compulsory auto liability laws generally can be expected to transfer some wealth from low-wealth persons who otherwise would drive uninsured to higher wealth persons who would buy coverage without compulsion (e.g., [Harrington 1994b](#)).

⁴⁵[Thiel \(1998\)](#) also argues that incorporating concern for post-accident utility into pre-accident preferences can motivate rational consumers to demand compensation for pain and suffering even if marginal utility does not increase following non-pecuniary loss. The argument may border on tautology; consumers demand compensation for pain and suffering because knowing that it will be paid ex post makes them happier ex ante.

12.6.2 *Endogeneity of Insurance, Liability Rules, and Litigation*

Much of the law and economics literature on tort liability focuses on efficient deterrence, explicitly or implicitly assuming that injurers are either risk neutral or can purchase actuarially fair insurance. A smaller but important literature adopts a positive approach to explain why certain liability rules have been adopted in particular circumstances, arguing that strong incentives exist for efficiency in common law (e.g., [Landes and Posner 1981](#), [Landes 1987](#)). The implication—that common law tort liability rules efficiently deter harm—provides a strong intellectual foundation for the current US tort liability system, thereby undercutting the case that material changes in tort liability law would produce significant efficiencies. Nonetheless, it can be argued that the tort liability system is biased in several respects towards excessive awards. Intuition and analysis suggest that the incentives of injured parties to maximize damages ex post is inefficient ex ante (see [Kaplow and Shavell 1996](#)). A sizable literature considers the efficiency of contingency fee systems in this regard. There is also evidence that jury decisions, in particular the size of awards, are influenced by knowledge of the defendant's liability insurance coverage, although in principle this is not admissible evidence.⁴⁶

More generally, many persons argue that the shift to strict product liability in recent years and other expansions in tort liability reflect in large part the perception of courts that corporate defendants can obtain and pass on the costs of liability insurance more readily than individuals can obtain first-party insurance. Indeed, this risk spreading rationale played a central role in the adoption of strict liability. The earlier discussion in this chapter makes it clear, however, that risk spreading through product markets and liability insurance is far from costless.

[Syverud \(1994\)](#) argues that feedback effects between liability insurance coverage and litigation have produced socially excessive levels of litigation and costs (also see [D'Arcy 1994](#)). The basic argument is that expanding tort liability increases the demand for liability insurance, which in turn leads to additional and expansive litigation because of the greater prevalence of liability coverage. Bias on the part of sympathetic jurors, costly risk-spreading through product and liability insurance markets, and the cost-increasing effects of widespread liability insurance coverage on incentives to litigate undermine the efficient deterrence justification for the current US tort liability system.

12.6.3 *Evidence on Deterrence*

Despite the policy interest in the effect of liability rules on resource allocation to risk reduction and the possible dulling effect of liability insurance, empirical evidence is so far limited and inconclusive. One fundamental problem is the unobservability of relevant rules of common law and of injury rates as opposed to claim rates. Moreover, the rate of injuries, claim frequency and severity, legal expenditures and even the legal rules are simultaneously determined. Data necessary to identify the structural equations of this system are generally not available. Several studies have estimated the effects of liability on resource allocation in medical care, but without a measure of injury rates have been unable to distinguish cost-justified improvements in prevention that liability is intended to induce from wasteful defensive medicine (e.g., [Danzon 1989](#)). Several studies have estimated the impact of a limited set of legal rules on the frequency and severity of claims (for medical malpractice, see [Danzon 1984a, 1986](#); [Danzon 1983](#); [Sloan 1989a](#) and [b](#); for product liability, see [Viscusi 1989](#) and the literature

⁴⁶For example, [Chin and Peterson \(1985\)](#) find that jury verdicts are significantly higher for the same type of injury if the defendant is a corporation or physician, rather than an individual. [Danzon \(1980\)](#) provides evidence of a positive relation between award and limits of the defendant's insurance coverage.

on tort reform discussed below). None of these studies have measured whether liability insurance with pricing based on imperfect observation of the care taken by insureds undermines the incentive effects of liability rules.⁴⁷

Measurement of the relevant law and insurance parameters is generally easier where liability is governed by statute rather than common law, as in workers' compensation and no-fault automobile regimes. Data on accident rates as opposed to claim rates are also available, although subject to reporting error. Most of the evidence is for work-related injuries and automobile. Empirical studies, for example, provide evidence of a positive relation between workers' compensation benefit levels and claim rates, in part due to increased reporting of injuries by workers, and/or that experience rating influences claim rates. A number of studies of automobile injuries (e.g., [Landes 1982](#); [Zador and Lund 1986](#)) provide evidence of a relationship between auto no-fault laws and motor vehicle fatality rates, especially outside the USA.

Nonetheless, the scarcity of direct and reliable evidence of the deterrent effects of tort liability impedes reaching tight conclusions about the efficiency of various tort liability rules and procedures. While some advances on this dimension will be likely in the future, the general problem will likely remain. If more hard evidence on deterrent effects were available, reliable estimates on the costs of deterrence and whether other means of achieving deterrence would involve lower or higher costs would still be unavailable in most situations.

12.6.4 Effects of Tort Reform

Many states adopted modest reforms in their tort liability systems following the mid-1980s hard market in commercial liability insurance, such as partial limits on pain and suffering awards and partial modification of the collateral source rule. These changes to some extent paralleled earlier changes in laws governing medical malpractice liability. The policy debate over tort reform often hinges, at least in part, on how much a reform might be expected to reduce premium rates (e.g., [Harrington 1994a](#)). A number of studies have analyzed the effects of tort reforms that have been enacted on liability insurance claims and claim costs (see [Danzon 1984a](#); [Viscusi 1993](#); [Born and Viscusi 1994](#); [Lee et al. 1994](#) and discussion below). The evidence generally suggests that at least some of the reforms helped reduce costs. However, reliable analysis of the effects of changes in tort law on injuries, claim costs, and premiums, must confront several particularly challenging econometric issues. These include the large variety of statutory changes, clustered in calendar time for a relatively small number of cross-sectional units (states), as well as potential endogeneity/self-selection issues.

12.7 Challenges in Liability Insurance Markets: Case Studies

The structure of the market for most property–liability insurance lines, including general liability insurance, generally has been regarded as highly competitive (e.g., [MacAvoy 1977](#), [Danzon 1984b](#), [Clarke et al. 1988](#), and [Winter 1988](#); also see [Joskow 1973](#)). Market concentration generally is low whether measured at the state or national level, especially for commercial lines, and most studies concur that there exist no substantial barriers to entry in liability insurance. Large insurers might have

⁴⁷Consistent with a possible disciplining effect on the level of risky activity, [Core \(1997\)](#) presents evidence that insurers charge higher premiums for directors' and officers' liability insurance to firms with weaker measures of corporate governance.

a significant advantage over small insurers in forecasting future claims although certain cooperative activities among small firms may reduce the fixed costs of ratemaking and mitigate this potential entry barrier (see, for example, [Danzon 1983, 1992](#)). Studies of accounting returns on insurer capital suggest that property–liability insurer returns have been average or even below average over time compared to other industries.

The property–liability insurance market has been characterized historically by “soft” markets, in which prices are stable or falling and coverage is readily available, followed by “hard” markets, in which prices rise rapidly and some coverage is alleged to be unavailable at any price. The traditional view of underwriting cycles by insurance industry analysts emphasizes fluctuations in capacity to write coverage caused by changes in surplus and insurer expectations of profitability on new business. Competition purportedly drives prices down to the point where underwriting losses deplete capital; insurers ultimately constrain supply in order to prevent financial collapse. Price increases then replenish surplus until price-cutting ensues once again.⁴⁸

With this general background on commercial liability markets, we look specifically at three problem areas: the general liability insurance crisis in the mid-1980s, directors’ and officers’ liability, and medical malpractice. The previous sections of this chapter have focused largely on the theoretical underpinnings of the liability system and liability insurance markets but there is a large empirical literature that tests many of the elements of theory, focusing specifically on the deterrence function of tort liability versus the potential for moral hazard generated by liability insurance. Although some of these studies have been cited above, it is useful to look in detail at the empirical work in specific areas. The general liability crisis has been both well studied and influential in subsequent research and practice. The medical malpractice market has been a difficult one for both insurers and potential insureds for many years in the USA; there is a well-developed empirical literature that examines some of the problems in this market. In contrast, the directors’ and officers’ liability exposure is relatively new, with very little empirical research extant. In addition, this market makes an interesting case because both frequency and severity of claims is rising, particularly for financial services firms. We examine a sample of the empirical work and discuss these issues below.

12.7.1 The Liability Insurance Crisis

The so-called liability insurance crisis of the mid-1980s received enormous attention by the policymakers and the public, influenced the enactment of a variety of tort reforms by the states, and stimulated extensive research and debate on the causes of the crisis, the dynamics of liability insurance prices, and the efficiency of the US tort liability/liability insurance system. Premiums increased sharply following the operating losses and declining premium rates of the early 1980s and were coupled with widespread reports of availability problems.

A large literature has sought to explain the mid-1980s hard market in general liability insurance, arguably the most severe hard market in the twentieth century.⁴⁹ Possible explanations that have been

⁴⁸[Cummins and Outreville \(1987\)](#) examine the question of whether cycles in reported underwriting results are simply caused by financial reporting procedures and lags in price changes due to regulation. They note that these phenomena are unlikely to explain large price fluctuations in the commercial liability insurance market in the mid-1980s. In a related vein, [Doherty and Kang \(1988\)](#) essentially argue that cycles reflect slow adjustment of premiums to the present value of future costs, but they do not identify causes of lags in adjustment.

⁴⁹See [Harrington \(1990\)](#), [Abraham \(1988a, 1991\)](#), [Cummins and MacDonald \(1991\)](#), and [Winter \(1991a\)](#) for further background and discussion of possible causes. Also see [Trebilcock \(1988\)](#).

analyzed include changes in the discounted expected cost of providing coverage, adverse selection, negative shocks to insurer capital from unexpected growth in claim costs, and excessive price cutting by some insurers in the early 1980s.

12.7.1.1 Cost Growth

Harrington (1988a) and Harrington and Litan (1988) provide evidence that rapid premium growth in general liability insurance was associated with upward revisions in loss reserves for prior years' business and rapid growth in reported losses for new business. The results suggest that growth in expected losses and changes in interest rates can explain a large portion of premium growth. Additionally, the Tax Reform Act of 1986 substantially increased income taxes on property-liability insurers by requiring discounting of loss reserves for tax purposes. Logue (1996) argues that this increase in effective tax rates, which was anticipated in 1985, may have had a material effect on the prices increases in long-tailed liability lines during 1985–1986. Bradford and Logue (1996), however, conclude that while the changes in the tax law likely had a material effect on prices of long-tailed liability lines, the effect was small relative to the variability of loss experience.

Clarke et al. (1988) attributed price increases and availability problems to growth in the expected value and uncertainty of future liability claim costs (see Abraham 1988a and b). Several studies argue that increased uncertainty would be expected to lead to increases in prices needed to cover expected future costs including the cost of capital (e.g., Danzon 1984b, Clarke et al. 1988, and Winter 1988). That liability insurance claim costs became less predictable during the 1980s seems plausible given growth in jury awards, punitive damages, and expansive interpretations of liability insurance contract terms by the courts.⁵⁰ Indeed, Clarke et al. (1988) show that the standard deviation of loss ratios for general liability insurance increased during the 1980s compared to the 1970s and Cummins and MacDonald (1991) analyze liability insurance claim data during the late 1970s and early 1980s. They provide empirical evidence of an increase in the variability of claim cost distributions during this period.⁵¹

Priest (1987) argues that an expansion in tort law and an associated increase in uncertainty aggravated adverse selection to the point where coverage became unavailable at any price.⁵² He also suggests that an unraveling of insurance pools as a result of expanded tort liability and associated adverse selection can explain much of the general liability insurance price increases as relatively low risk buyers ceased to buy coverage.⁵³

The overall evidence on cost increases suggests that increased conditional expectations of claim costs, lower interest rates, higher taxes, increased risk, and increased adverse selection combined to have a material effect on prices during the mid 1980s. However, these cost-based explanations have a difficult time explaining the suddenness of the premium increases.

⁵⁰Abraham (1988b) argues that expansive court decisions concerning contract language contributed to availability problems in the market for environmental impairment liability coverage in the mid 1980s.

⁵¹Increased variability in liability insurance claim costs need not be caused by an increase in idiosyncratic variation in individual awards and, of course, does not imply that court awards are largely unpredictable. Osborne (1999), for example, provides evidence of substantial predictability of awards given pretrial information.

⁵²Berger and Cummins (1992) formally model adverse selection in liability insurance where buyer loss distributions are characterized by mean-preserving spreads.

⁵³The anecdotal evidence about widespread availability problems strongly suggests that adverse selection played a role in these problems and price increases. Other observers and evidence, however, generally suggest that increased adverse selection was not the primary cause of the crisis (see, e.g., Abraham 1991, and Winter 1991a).

12.7.1.2 Shocks to Capital

A large literature on the effects of shocks to capital, such as a large, unexpected increase in claim costs, on the supply of insurance arose following the liability crisis including theoretical studies by Winter (1988, 1991b, 1994), Gron (1994a), Doherty and Posey (1993), Cagle and Harrington (1995), Doherty and Garven (1995), and Cummins and Danzon (1997). The main implication of these analyses is that shocks to capital can cause price increases and quantity reductions consistent with a hard market. The intuition is simple. The supply of capital to the industry is inelastic in the short run due to market imperfections. A sudden reduction in capital therefore causes insurers to reduce supply to prevent a large increase in insolvency risk, which would jeopardize insurer-specific assets and reduce the price that default risk-sensitive buyers would be willing to pay for coverage.⁵⁴ The higher prices and lower quantities associated with the backward shift in supply then help to replenish insurer capital, gradually shifting the supply curve out, lowering price and increasing quantity.

The most important prediction of the capital shock models is that insurance prices are negatively related to insurer capital and loss ratios should be positively related to capital. That prediction holds in most of Winter's (1994) specifications regressing an economic loss ratio for general liability insurance against insurer capital; during the 1980s, however, the negative correlation between domestic insurer capital and the economic loss ratio fails to explain the liability insurance crisis.⁵⁵ Gron's (1994b) results analyzing industry aggregate underwriting profit margins for four lines of business including general (other) liability suggest a negative relationship between the ratio of capital to GDP and underwriting profits, consistent with the notion that prices increase when capital (capacity) falls.⁵⁶ Based on 1979–1987 insurer panel data, the results of Cummins and Danzon (1997) suggest a negative relation between prices and capital and that insurers are more likely to raise capital following a price increase. Doherty and Garven (1995) use insurer panel data to estimate the sensitivity of insurer underwriting returns to interest rate changes and then explain cross-firm differences in interest rate sensitivity. Their results suggest that capital shocks are due to interest rate changes.

Like the cost-based explanations described above, the capital shock explanation cannot explain the sudden sharp price increases of the mid 1980s hard market. Nonetheless, the underlying theory and empirical evidence suggest that upward revisions in loss reserves, which depleted capital, and increases in the discounted expected cost of providing coverage can explain much of what occurred.

12.7.1.3 Excessive Price Cutting in the Early 1980s

Did excessive price cutting in the early 1980s aggravate losses and contribute to the mid-1980s hard market? Winter's models (1988, 1994) imply that positive shocks to capital may explain the soft phase of the underwriting cycle and short-run prices below long-run equilibrium prices.⁵⁷ McGee (1986)

⁵⁴Some authors suggest that regulatory constraints, such as restrictions on the allowable ratio of premiums to capital, exacerbate the shift in supply (see Winter 1991b, for detailed analysis of this case). In practice, however, constraints on premiums relative to capital are informal. As is true for risk-based capital requirements adopted in the 1990s, these constraints are unlikely to be binding for most insurers at once, even at the time of a hard market.

⁵⁵Winter (1994) suggests that ex post unfavorable realizations of losses or omission of reinsurance capacity from the capital variables may explain the 1980s results. Berger et al., (1992) analyze shocks to reinsurance supply during the 1980s crisis and provide evidence that shocks disrupted the price and availability of reinsurance.

⁵⁶Gron (1994a) regresses both the difference between premiums and underwriting expenses and the difference in the ratio of all lines premiums to underwriting expenses on lagged capital and a variety of control variables. The results indicate that changes in the margin between premiums and underwriting expenses are negatively related to lagged values of capital, providing some support for the capital shock model.

⁵⁷Yuengert (1991) also considers the issue of whether excess capacity leads to soft markets.

suggests that heterogeneous expectations of future claim costs among insurers could affect pricing behavior during soft markets. Harrington (1988a) posits that aggressive behavior by firms with little to lose in the event of default and risk-insensitive policyholders could influence price reductions during soft markets. Harrington and Danzon (1994) consider whether some firms may price below cost because of moral hazard that results from limited liability and risk-insensitive guaranty programs or due to heterogeneous information concerning future claim costs. A key aspect of these hypotheses is that aberrant behavior by a relatively small number of firms may induce market wide responses as other firms may cut prices to preserve market share. Cross-sectional data from the early 1980s provide some evidence consistent with the moral hazard hypothesis behind differences in general liability insurance prices and premium growth rates among firms.

12.7.2 *Directors' and Officers' Liability Insurance*

The Directors' and Officers' liability exposure is growing in the United States and globally. Broadly speaking, directors and officers have a legal duty to monitor managers of organizations to ensure that the interests of shareholders and other stakeholders are protected. Directors and officers of public, private, and nonprofit firms may face personal liability for the decisions they make on behalf of the organizations they serve if they fail to fulfill that duty. Like other liability exposures, the goal of imposing liability in this case is to deter directors and officers from taking actions that harm stakeholders.⁵⁸ Directors' and Officers' (D&O) liability claims may be filed by shareholders of firms, employees, regulators, customers, and competitors. Because exposure to personal liability may make it difficult for organizations to attract qualified directors and officers, organizations often purchase D&O liability insurance. D&O liability insurance protects personal assets by either reimbursing corporations that directly indemnify directors and officers for liability costs incurred or by indemnifying the D&O's directly.⁵⁹

According to a recent D&O survey (Towers Watson 2011), both the number and size of claims have increased significantly since 2008. The financial crisis that began in 2008 with the failure of Lehman Brothers led to widespread bank failures that continue into 2011. Between January 2008 and December 2010, a total of 322 financial institutions failed (Wall Street Journal Online 2011), with an additional 90 failures through November 2011. As of November 14, 2011, the FDIC has initiated recovery suits against 340 individuals in 37 failed financial institutions. The estimated cost associated with these claims is approximately \$7.6 billion. (FDIC 2011). In addition to regulatory claims filed against bank officers, the number of claims filed by shareholders related to the credit crisis approached 200 for the period 2007–2009 (Ryan and Simmons 2010). Outside the financial service industry, the Towers Watson survey reports that the most common type of claim filed against publicly traded firms is a shareholder direct or derivative suit, while nonprofits are more likely to face employment-related claims, which are also increasing.⁶⁰ These trends indicate that the directors' and

⁵⁸Of course, many decisions made by directors and officers may have adverse consequences. However, the “business judgment rule” protects D&O from liability in cases where a loss is incurred as a result of directors and officers making a business decision within the scope of their authority and acting in good faith and in accordance with the standard of reasonable care.

⁵⁹Of course, motives for the corporate purchase of any type of insurance also apply here.

⁶⁰A shareholder derivative suit is a suit brought by shareholders on behalf of a corporation against directors and/or officers of a firm. This type of suit is typically filed when the corporation has a cause of action against a director or officer but chooses not to exercise it. Proceeds from a shareholder derivative suit are distributed to the corporation rather than the shareholders themselves. In contrast, a direct shareholder suit is a brought by a single or group of shareholders on their own behalf with the proceeds going directly to the claimants.

officers' liability insurance market may become more expensive and difficult to navigate in the near term, particularly for financial services industry participants.

Compared to some other areas of liability insurance research, empirical research in the D&O area is relatively sparse because of a lack of data. There are two reasons for the lack of data. First, publicly traded firms in the USA, the largest market in the world, are not required to disclose purchases of D&O insurance. Second, liability insurers are not required to report premium or loss data for D&O insurance separately from general liability insurance lines. Thus, we have neither reliable supply nor demand based data for the US market.⁶¹

However, as a result of recommendations by the UK and Canadian financial services oversight authorities in the early 1990s, publicly traded firms in the UK and Canada do report D&O purchases, premiums, and limits of coverage. Consequently, while much of the theory that explores incentives under liability regimes relies on the institutional features of the US model, the majority of the empirical literature examines firms in the UK and Canadian markets. Because the securities regulation and institutional features of liability systems are similar to those in the USA, the empirical results may apply as well to US firms.

The academic research in this area examines the trade-offs between the potential moral hazard effects of D&O insurance, and the role of insurers in ensuring that the deterrence goals of the liability system are met. The moral hazard argument is the standard one: that the presence of insurance causes managers to exercise less care in protecting the interests of shareholders since managers do not bear the full wealth effects of their actions when insurance is in force. If true, we would expect to find that firms that purchase D&O insurance (or higher limits of D&O insurance) underperform their peers on some dimension.

Alternately, the deterrence goals of the liability system may be satisfied if insurance prices reflect the liability risk of the insured firm. If insurers can set prices to reflect their evaluation of the risk of a claim, more careful buyers will pay lower prices, all else equal. If potential buyers desire low prices, they will exercise more care to protect shareholders, perhaps through the adoption of tighter corporate governance structures or other loss control measures, and the deterrence goal is met (Holderness 1990). Of course, this effect will be necessarily imperfect because competition across insurers for business may result in lower prices than optimal. Below, we review a sample of this literature.

Core (1997) and O'Sullivan (1997) were among the first to investigate the hypothesized effects of D&O insurance empirically. Core (1997) uses a sample of 222 Canadian firms across a number of industries for the fiscal year 1993–1994 to test for differences between characteristics of firms that purchased D&O insurance and those that did not. The latter group accounted for one-third of the sample. Core found that the most important predictors of the purchase of D&O insurance were the risk of a lawsuit and the probability of financial distress. This supports the idea of insurer as monitor. However, Core also finds that as the proportion of insider voting control increases, firms are more likely to purchase D&O insurance, and also are more likely to purchase higher limits. This implies that moral hazard plays a role in the insurance purchase decision. Core (2000) tests the relation between D&O insurance premiums and litigation risk for the same sample and finds that premiums increase as governance is weaker. However, Boyer (2003, 2007) reports no significant association between D&O insurance limits or deductibles and board composition for Canadian firms during the 1993–1998 period.

O'Sullivan (1997) tests the monitoring hypothesis by examining the association between corporate governance characteristics and the purchase of D&O insurance. The sample consists of 336 publicly traded firms in the UK in 1991, the first year that such reporting was required. The important independent variables are board composition, managerial ownership, and external shareholder control.

⁶¹Note that the Towers Watson (2011) survey of publicly traded US firms reports that nearly all survey respondents purchase D&O insurance.

The results indicate that as firm size increases, firms are more likely to use both outside directors and D&O insurance to monitor managers. A strong negative relationship between D&O and the proportion of equity holdings of directors was also found, indicating that equity ownership and D&O insurance are substitute monitoring mechanisms.

In contrast, [Chalmers, Dann, and Harford \(2002\)](#) find no association between insurance coverage or premiums and board independence or the presence of institutional shareholders. Using a sample of 72 IPOs in Canada between 1992 and 1996, Chalmers et al. find that the amount of D&O insurance is negatively related to stock-price returns three years after the IPO. This suggests that managers in firms with higher D&O limits either initially overprice IPOs or fail to take sufficient efforts to increase firm value post-IPO. In either case, the conclusion points to managerial opportunism in the presence of D&O insurance.

Also using a sample of Canadian firms, [Lin et al. \(2011\)](#) analyze the relation between D&O insurance and the outcome of corporate acquisitions. The empirical question is whether managers of firms that carry D&O insurance (or higher D&O limits) make significantly better (worse) merger and acquisition decisions that result in higher (lower) returns for shareholders. Significantly worse outcomes would support the idea that D&O insurance may induce moral hazard on the part of managers. The sample includes 709 merger and acquisition deals by 278 firms listed on the Toronto Stock Exchange for the period 2002–2008. Using event study methodology, the authors measure cumulative abnormal returns (CARs) around the date of the M&A announcement. They find that firms with D&O insurance (or higher D&O limits) experience significantly lower CARs than do other firms. Further, they find that firms with higher levels of D&O insurance pay higher acquisition premiums and capture fewer synergies, resulting in lower returns for shareholders. This is strong support for the moral hazard hypothesis of the effect of D&O insurance.

[Baker and Griffith \(2007\)](#) take a different approach, relying on a survey of over forty participants in the D&O market, including actuaries, underwriters, brokers, and risk managers.⁶² The participants were asked whether insurers provided loss control incentives or otherwise directly monitored the corporate governance activities of insured firms. Their responses unanimously indicate that D&O insurers do not do so, calling into question the deterrence role of corporate securities law.

In a recent study of the Chinese market, [Zou et al. \(2008\)](#) examine the purchase of D&O insurance by publicly listed firms for the period 2000–2004. This study adds valuable insight to the existing literature because the institutional structures for corporate governance are quite different from those in common law countries. First, the countries studied in prior literature are relatively litigious. Second, publicly traded firms in those markets are subject to diffuse ownership, so that the actions of minority shareholders in those markets rarely affect overall shareholder value. However, this is not the case in China. In general, publicly traded firms are majority owned by a concentrated ownership group that may include the government. Further, there are often two classes of shares; those that are non-tradable owned by the controlling shareholders, and tradable shares owned by the minority. The authors argue that the incentive conflicts that arise between controlling and minority shareholders generate a demand for D&O insurance. Using a matched sample of 53 firms that announced the desire to purchase D&O insurance and those that did not over the period 2000–2004, they find that firms that engage in earnings management, and have more Board representation of large shareholders, both indicators of increased liability risk, are more likely to seek to purchase D&O insurance. This supports the idea that managers who are responsive to controlling shareholders may purchase D&O insurance to protect them against the risk associated with expropriation of minority shareholders.

⁶²This survey included only publicly traded firms, so the findings might not apply to private or not-for-profit insureds.

Overall, the results of empirical research are mixed. There is some evidence that managers in firms with D&O insurance behave opportunistically. There is also some evidence that D&O insurers provide some monitoring and oversight functions through the pricing process. However, there is very little research into the question of whether insurance improves firm value. This is an important area for future investigation.

12.7.3 Medical Malpractice

The medical malpractice tort environment and the medical malpractice insurance market together comprise what many refer to as the medical malpractice system. How well this system functions is an issue that regularly gets public attention, likely due to recurring medical malpractice insurance “crises,” periods typically characterized by a significant increase in premium levels and often a corresponding decrease in coverage availability. Physicians may respond to such premium hikes by relocating to areas where malpractice premiums are lower, leaving the practice of medicine, avoiding higher risk patients, or engaging in strikes or work slowdowns ([Anonymous 2002](#)). These actions may affect physicians’ incomes and patient welfare by reducing access to care. Distortions in the medical malpractice system often draw the attention of public policymakers, with a common solution being the reform of the tort liability system. Reforms are designed to reduce medical malpractice insurance premiums, thus attracting qualified physicians to underserved geographic or practice areas.⁶³

However, there is evidence that medical errors are not uncommon ([Institute of Medicine 2001](#)), calling into question the ability of the medical malpractice system to provide incentives for quality care. When reforms are introduced that have the effect of weakening the deterrence incentives of the liability system, this may increase medical errors and thus malpractice claims frequency.⁶⁴ We examine the research on this point below.⁶⁵

12.7.3.1 Effect of Reforms on Claims and Premiums

In the earlier medical malpractice crises of the mid-1970s and the mid-1980s, many states responded to pressure for market intervention by enacting various reforms to stabilize premiums and make coverage more affordable and available by reducing the frequency and severity of claims. Principal among these actions were changes in several areas of tort liability. Legal interventions that limited damage awards or attorney fees, changed collateral source evidence or joint and several liability rules, required pretrial screening or arbitration, or shortened statutes of limitations were common.

In addition to legal market interventions through tort reform, some states responded to earlier crises by more directly intervening in the medical malpractice insurance market. One such intervention was the authorization of state-mandated risk pooling mechanisms known as Joint Underwriting Associations, or JUAs. States formed JUAs to improve the availability of insurance coverage by

⁶³The recent passage of health care reform has focused attention on ways to reduce health care costs and improve patient outcomes. Because malpractice costs are perceived to be a driver of health care cost increases, there is interest in experimenting with new systems for compensating patients with iatrogenic injuries. Consequently, consumer groups, physicians, and medical associations have created pressure for government intervention in, or reform of, the system.

⁶⁴The recently enacted Patient Protection and Affordable Care Act may change the liability exposure for physicians and other medical care providers, but the potential impact of the Act is outside the scope of this chapter.

⁶⁵ For a comprehensive resource that reviews multiple dimensions of the medical malpractice system, see [Sloan and Chepke \(2008\)](#).

requiring all medical malpractice insurers in a state to share responsibility for the claims of high-risk medical providers. A second direct market intervention was the establishment of state-run insurance arrangements known as Patient Compensation Funds (PCFs). In essence, these funds are government-sponsored excess or reinsurance coverage, offering coverage to medical providers for claims above some specified, privately insured threshold amount. The intention of PCFs is to give patients a source of compensation for catastrophic incidents and to stabilize premiums in the private market by creating a source of insurance coverage for the most severe claims, which are the most difficult to predict.

The empirical evidence on the effects of these reforms yields rather mixed results. Following the medical malpractice crisis of the mid-1970s, [Danzon \(1984a, 1985a and b, 1986, 1987\)](#) analyzed data on malpractice claims over the period of 1975–1984 and considered the effects of many of the tort reforms outlined above. In general, she found that caps on awards significantly reduced claims severity and that shorter statutes of limitations reduced the frequency of claims. Collateral source offsets reduced both claim frequency and severity. Mediation or screening panels, periodic payments of awards, and limits on contingent fees had no consistently significant effects, although an earlier study by [Danzon \(1983\)](#) suggested that periodic payments and contingency fee limitations reduced both the size of awards in out-of-court settlements as well as the probability that the case goes to verdict.

Sloan also has performed many analyses of tort reform influences in medical malpractice insurance. In his 1985 study, premium levels for general practitioners, ophthalmologists, and orthopedic surgeons from 1974 to 1978 were found to be largely unaffected by state legislative tort reforms and JUAs. Only binding arbitration had a weakly significant positive influence on premiums for general practitioners and ophthalmologists. [Sloan et al. \(1989b\)](#) examined the effect of tort reforms on the probability, the size, and the speed of claim payment using data on closed medical malpractice claims from 1975 to 1978 and 1984. Tort reforms were divided into four categories: those that created barriers to tort-system based compensation (such as statute of limitations or pretrial screening), legislative changes directly affecting plaintiff litigation costs (such as limits on attorneys' fees), limitations on payments (like damage caps and collateral source offsets), and other tort variables (consisting of JUA and PCF in operation). Their strongest results were found for reforms involving screening, damage caps, mandatory collateral source offsets, and operating JUAs. Mandatory screening panels had a significant positive effect on size of claim payments, measured both with and without loss adjustment expenses. However, limits on both noneconomic and total damages reduced indemnity and loss adjustment expense payments and also decreased the delay between filing and closing of a claim. Mandatory offset of compensation from collateral sources also significantly reduced indemnity and loss adjustment payments while decreasing the probability of an award and increasing delay between filing and closing a claim. Lastly, lower indemnity and loss adjustment payments were also found in states with JUAs although the presence of a PCF had no effect on any dependent variable measure other than increasing the time to claim closure. [Zuckerman, Bovbjerg, and Sloan \(1990\)](#) examined the period following the 1970s crisis with data covering 1974–1986 and found that reforms that place caps on physician liability or reduce the time period plaintiffs have to file a claim significantly reduced premiums, as did the presence of a JUA.

[Barker \(1992\)](#) considered how seven different tort reforms affected relative prices and profitability (as measured by the loss ratio) and underwriting risk (measured by the standard deviation of the loss ratio). Using statewide loss ratio data from 1977 to 1986, she found that caps on noneconomic and total damages significantly decreased mean loss ratios for insurers across the industry but that caps only decreased underwriting risk for insurers writing business in a single state. Patient compensation funds had no significant effect on loss ratios or underwriting risk.

Following the mid-1980s crisis, another round of research was undertaken. [Viscusi \(1993\)](#) studied state-level premiums and losses from 1985 to 1988 in conjunction with a variety of reforms including joint and several liability and collateral source rule modifications, caps on noneconomic damages, and restrictions on punitive damages. The only significant effect detected was that of a decrease in medical

malpractice losses associated with caps on noneconomic damages; premiums and loss ratios were not similarly affected. [Viscusi and Born \(1995\)](#) analyzed firm-level data for the period of 1984–1991 with similar findings. In general, tort reform significantly reduced losses and loss ratios with the reduction apparently driven primarily by damage cap reforms and limits on attorney fees. Collateral source rule modifications negatively affected only losses. No reforms, taken in tandem or individually, influenced premiums.

[Viscusi and Born \(2005\)](#) again analyzed the period following the 1980s crisis (1984–1991) but with a specific focus on punitive damages reforms. Interestingly, they found a significant negative relationship between punitive damages caps and both premiums and losses, but results were mixed for caps on noneconomic damages. While they found these caps significantly reduced losses, they did not consistently find the same effect on premiums. Patient compensation funds, however, did exhibit a significant negative influence on premiums earned. This latter result is consistent with those of [Hanson, Ostrum, and Rottman \(1996\)](#), who analyzed 1992 data on malpractice tort cases in 45 large urban areas in 21 states and found that the existence of a PCF in a state has a significant negative impact on malpractice litigation rates. If PCFs reduce claims frequency, they should also reduce premiums as well, other things equal.

Using data for 1985–2001, a period encompassing the post-1980s crisis and the beginning of the more recent crisis, [Thorpe \(2004\)](#) found that caps on awards were associated with lower premiums and lower loss ratios. [Zeiler's \(2004\)](#) period of study also extends into the most recent crisis. She researches the effect of disclosure laws and damage caps on medical malpractice premiums (as a proxy for ex ante expected damages) from 1991 to 2001. Her results show that damage caps in the absence of disclosure laws significantly decrease premiums as well as losses incurred, but have no significant effect when disclosure laws are present. [Ambrose and Carroll \(2007\)](#) examined the effect of malpractice reforms on insurer loss adjustment expenses from 1998 to 2002. Insurers were found to spend more on claims defense in the presence of limits on damages and attorney fees but less when mandatory pretrial screening requirements and PCFs are in place. [Danzon, Epstein, and Johnson \(2004\)](#) thoroughly discuss and analyze the most recent crisis in terms of detecting the effects on premium increases and insurer exits of capital shocks, risk taking measures, and tort and insurance market reforms. Analyzing data from 1996 to 2002, they find evidence that limits on joint and several liability and noneconomic damage caps at or below \$500,000 significantly reduced premium increases. JUA and PCFs did not affect premium increases.

Overall, the evidence seems to indicate that caps on noneconomic damages, and to a lesser extent, collateral source offsets, have the most influence in reducing claims and premiums. However, this evidence can provide only limited insight regarding how effectively the system achieves its twin goals of injury compensation and deterrence. Claims reduction as a result of reform may just reflect a shifting of loss costs from providers to injured patients, creating less incentive for providers to deter injuries. Damage caps in particular may induce loss cost-shifting and may have a negative effect on severely injured plaintiffs, creating an inequitable compensation system.

12.7.3.2 Effect of Reforms on Delivery of Care

A smaller body of research attempts to answer more directly the question of how tort reforms actually affect physician behavior so that we may better understand how these reforms affect providers' incentives to prevent injuries. Specifically, researchers have investigated how tort reform affects the practice of defensive medicine. Providers may order tests, procedures, and/or prescriptions that may be of small marginal benefit (or even potentially harmful) to patients as a way to reduce potential liability claims. Several methods are used to assess the impact of reforms on defensive medicine. One is to survey physicians about their perceptions of their defensive practices. Another is to look at how the incidence of tests and procedures thought to be associated with defensive medicine differs in

different regulatory environments. The former approach measures opinions, not outcomes, thus is not a good basis upon which to make policy decisions. Approaches that look at actual outcomes are more objective and informative and a handful are summarized below.

Obstetrics is a specialty where malpractice claims and premiums have been relatively high. A commonly held belief is that obstetricians perform Cesarean-sections to reduce the risk of a complicated vaginal delivery that may result in a negative birth outcome. [Dubay, Kaestner and Waidmann \(1999\)](#) found that where there are higher malpractice premiums (a measure of malpractice claims risk), C-section rates are higher. Further, birth outcomes were not improved with higher C-section rates, suggesting defensive medicine is practiced. [Grant and McInnes \(2004\)](#) found that obstetricians who had large malpractice claims increased their C-section rates by nearly a percentage point. [Currie and MacLeod \(2008\)](#) looked specifically at how tort reform affects provider behavior and found that reforms of joint and several liability reduce induction and stimulation of labor, C-sections, and complications of labor and delivery, whereas caps on noneconomic damages increase them.

Diagnostic imaging is another health care service that is thought to be especially vulnerable to the practice of defensive medicine. [Smith-Bindman et al. \(2011\)](#) found that the greater the number of reforms enacted within a state, the lower the rate of diagnostic imaging for head injuries in the emergency room. Reforms that limited monetary damages, mandated periodic award payments or that limited double indemnity through collateral source offset rules decreased the odds of imaging by about 40%, which suggests that tort reforms may reduce defensive medicine practices.

While the evidence suggests that defensive medicine is practiced and can be reduced to some extent by tort reform, from a policy perspective it is important to understand the magnitude of the cost-savings that would accrue if reforms were more widely adopted. [Thomas et al. \(2010\)](#) attempt to answer that question by looking at how reductions in medical malpractice premiums (a measure of perceived liability risk) affect costs of a wide array of clinical conditions. They conclude that the impact of defensive medicine is small, with the savings from widespread tort reform less than 1% of total medical costs, a result consistent with that of the [Congressional Budget Office \(2009\)](#).

12.7.3.3 Medical Malpractice and Moral Hazard

Medical malpractice insurance is typically rated on the basis of limits of coverage, medical specialty, and geographic location. Individual rating on the basis of exposure (performance of high risk procedures), volume of business, and individual claim record is relatively limited. Several studies have shown that the actual distribution of claims and awards is inconsistent with a purely random distribution, after controlling for specialty ([Rolph 1981](#); [Nye and Hofflander 1988](#); [Ellis et al. 1990](#); [Sloan et al. 1989b](#)). This suggests that moral hazard may be an issue in the medical malpractice insurance market; the broad risk pooling that occurs in this line of coverage reduces the incentives for providers to take care. This potential is significantly diminished for hospitals, however, since they are more likely to self-insure significant portions of their malpractice risk. Thus, we can look to behaviors of these providers to better understand the extent that moral hazard plays a role on medical decision making. [Fenn et al. \(2007\)](#) examined UK (which operates under similar liability principles as the USA) hospitals' risk-sharing arrangements with their insurers and found that those who bore more risk through higher deductibles used diagnostic imaging tests more frequently. Whether these additional tests represented clinically valuable behavior was not addressed in this study but the results could be indicative of defensive medicine.

Generally, the research on the medical malpractice system indicates that there is still room to improve the incentives in our medical malpractice system. More work needs to be done to better understand how our liability and insurance systems affect cost, quality, and access to care. Certain

reforms may reduce costs (e.g., caps on noneconomic damages) while also reducing the incentive to deter injuries. Policymakers need to have a fuller understanding of how reforms affect all dimensions of health care delivery (Kachalia and Mello 2011).

12.8 Conclusions

The theory of efficient deterrence of harm through tort liability is one of the main pillars of modern law and economics. The basic notion that well-designed legal rules can help minimize the total cost of risk in society is fundamentally sound. Unfortunately, numerous complications arise from imperfect information, limited wealth, and limited liability, and a variety of factors that impede and increase the cost of risk-spreading through liability insurance. Liability insurance is often a blunt and costly instrument for transmitting tort liability incentives to potential injurers. There is an unavoidable trade-off between efficient deterrence and efficient compensation/risk-spreading. Although key policy issues are often theoretically ambiguous and resistant to empirical analysis, increased understanding of the limits of liability rules and liability insurance markets as mechanisms for promoting efficient deterrence and risk-spreading represents academic progress. How best to transfer that intellectual progress into action in a complex legal system overlapping with the state-regulated insurance industry, all under political pressures from many competing interests, will remain challenging.

Periodic pockets of liability insurance market dysfunction such as those highlighted in Sect. 12.7 can draw significant attention to system inefficiencies and often result in public and political calls for reform in both tort law and insurance regulation. Enhancing efficiency may be possible by restricting tort liability in a number of ways (e.g., by allowing greater freedom to restrict damages by contract, by requiring losers in litigation to pay winners' legal costs under more circumstances, and/or by statutory limits on pain and suffering awards, punitive damages, and the doctrine of joint and several liability) and some empirical support exists for this assertion when viewing medical malpractice reforms as a test case. Given enough concern about reduced deterrence, such restrictions might be combined with greater reliance on other tools for deterring harmful activity and inadequate precautions. But as market crises tend to resolve or fade from public attention with time and consensus among legal minds and politicians proves elusive, any efficiency-increasing changes to the tort liability system will be slow and incremental absent compelling evidence that the system produces widespread, sizable, and lasting reductions in living standards. As of now, the costs of the present system's excesses and the potential benefits of reform are sufficiently opaque, and the political climate sufficiently contentious, to encourage a bias toward the status quo.

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Chapter 13

Economic Analysis of Insurance Fraud

Pierre Picard

Abstract We survey recent developments in the economic analysis of insurance fraud. This chapter first sets out the two main approaches to insurance fraud that have been developed in the literature, namely the costly state verification and the costly state falsification. Under costly state verification, the insurer can verify claims at some cost. Claims' verification may be deterministic or random, and it can be conditioned on fraud signals perceived by insurers. Under costly state falsification, the policyholder expends resources for the building-up of his or her claim not to be detected. We also consider the effects of adverse selection, in a context where insurers cannot distinguish honest policyholders from potential defrauders, as well as the consequences of credibility constraints on antifraud policies. Finally, we focus attention on the risk of collusion between policyholders and insurance agents or service providers.

Keywords Fraud • Audit • Verification • Falsification • Collusion • Buildup

13.1 Introduction

Insurance fraud is a many-sided phenomenon.¹ Firstly, there are many different degrees of severity in insurance fraud, going from buildup to the planned criminal fraud, through opportunistic fraud. Furthermore, insurance fraud refers primarily to the fact that policyholders may misreport the magnitude of their losses² or report an accident that never occurred, but there is also fraud when a policyholder does not disclose relevant information when he takes out his policy or when he deliberately creates further damages to inflate the size of claim. Lastly, insurance fraud may result from autonomous decision-making of opportunist individuals, but often it goes through collusion with a third party.

¹ See the chapter by Georges Dionne in this book on empirical evidence about insurance fraud.

² Note that a claimant is not fraudulent if he relies in good faith on an erroneous valuation of an apparently competent third party—see [Clarke \(1997\)](#). However, insurance may affect fraud in markets for credence goods, i.e., markets where producers may provide unnecessary services to consumers who are never sure about the extent of the services they actually need. See [Darby and Karni \(1973\)](#) on the definition of credence goods and [Dionne \(1984\)](#) on the effects of insurance on the possibilities of fraud in markets for credence goods.

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Since [Becker \(1968\)](#) and [Stigler \(1970\)](#), the analysis of fraudulent behaviors is part and parcel of economic analysis and there is a growing theoretical literature dealing with insurance fraud. Making progress in this field is all the more important that combating insurance fraud is nowadays a major concern of most insurance companies.

This survey of recent developments in the economic theory of insurance fraud is organized as follows. Sections [13.2–13.4](#) set out the two main approaches to insurance fraud that have been developed in the literature: the costly state verification and the costly state falsification. Both approaches should be considered as complementary. Under the costly state verification hypothesis, the insurer can verify damages, but he then incurs a verification (or audit) cost. Under costly state falsification, the policyholder expends some resources for the building-up of his or her claim not to be detected by the insurer. In [Sect. 13.2](#), we first describe the general framework used in most parts of our study, namely a model in which a policyholder has private information about the magnitude of his losses and who may file fraudulent claims. We then turn to the analysis of costly state verification procedures under deterministic auditing. In practice, claim handlers are, to some extent, entrusted with claims verification, but, more often than not, state verification involves some degree of delegation. Indeed, there are specific agents, such as experts, consulting physicians, investigators, or attorneys, who are in charge of monitoring claims. Under deterministic auditing, claims are either verified with certainty or not verified at all, according to the size of the claim. The developments in the economic theory of insurance fraud surveyed in [Sects. 13.3](#) and [13.4](#) emphasize the fact that policyholders may engage in costly claims falsification activities, possibly by colluding with a third party such as an automechanic, a physician, or an attorney. [Section 13.3](#) remains within the costly state verification approach. It is devoted to the analysis of audit cost manipulation: policyholders may expend resources to make the verification of damages more difficult. [Section 13.4](#) addresses the (*stricto sensu*) costly state falsification approach: at some cost, policyholders are supposed to be able to falsify the actual magnitude of their losses. In other words, they can take acts that misrepresent the actual losses and then the claims' buildup cannot be detected. [Sections 13.5–13.8](#) set out extensions of the costly state verification model in various directions. [Section 13.5](#) focuses on random auditing. [Section 13.6](#) characterizes the equilibrium of a competitive insurance market where trades are affected by adverse selection because insurers cannot distinguish honest policyholders from potential defrauders. [Section 13.7](#) focuses on credibility constraints that affect antifraud policies. [Section 13.8](#) shows that conditioning the decision to audit on fraud signals improves the efficiency of costly state verification mechanisms and it makes a bridge between auditing and scoring. [Section 13.9](#) contemplates some indirect effects of insurance contracts on fraud. [Sections 13.10](#) and [13.11](#) focus on collusion, respectively, between policyholders and agents in charge of marketing insurance contract in [Sect. 13.10](#) and between policyholders and service providers in [Sect. 13.11](#). [Section 13.12](#) concludes. Proofs and references for proofs are gathered in an appendix.

13.2 Costly State Verification: The Case of Deterministic Auditing

Identical insurance buyers own an initial wealth W and they face an uncertain monetary loss x , where x is a random variable with a support $[0, \bar{x}]$ and a cumulative distribution $F(x)$. The no-loss outcome—i.e., the “no-accident” event—may be reached with positive probability. Hence x is distributed according to a mixture of discrete and continuous distributions: x has a mass of probability $f(0)$ at $x = 0$, and there is a continuous probability density function $f(x) = F'(x)$ over $(0, \bar{x}]$. In other words $f(x)/[1 - f(0)]$ is the density of damages conditional on a loss occurring.

The insurance policy specifies the premium P paid by the policyholder and the (nonnegative) payment $t(x)$ from the insurer to the policyholder if the loss is x . The realization of x is known only to the policyholder unless there is verification, which costs c to the insurer.

For the time being, we assume that the insurer has no information at all about the loss suffered by the policyholder unless he verifies the claim through an audit, in which case he observes the loss perfectly.³ We will later on consider alternative assumptions, namely the case where the insurer has partial information about the loss suffered (he can costlessly observe whether an accident has occurred but not the magnitude of the loss) and the case where the claim is a falsified image of true damages.

The policyholder's final wealth is $W_f = W - P - x + t(x)$. Policyholders are risk averse. They maximize the expected utility of final wealth $EU(W_f)$, where $U(\cdot)$ is a twice differentiable von Neumann–Morgenstern utility function, with $U' > 0$, $U'' < 0$.

A *deterministic auditing policy* specifies whether a claim is verified or not depending on the magnitude of damages. More precisely, following Townsend (1979), we define a deterministic audit policy as a verification set $M \subset [0, \bar{x}]$, with complement M^c , which specifies when there is to be verification. A policyholder who experiences a loss x may choose to file a claim \hat{x} . If $\hat{x} \in M$, the claim is audited, the loss x is observed and the payment is $t(x)$. If $\hat{x} \in M^c$, the claim is not audited and the payment to the policyholder is $t(\hat{x})$.

A contract $\delta = \{t(\cdot), M, P\}$ is said to be *incentive compatible* if the policyholder truthfully reveals the actual loss, i.e., if $\hat{x} = x$ is an optimal strategy for the policyholder. Lemma 1 establishes that any contract is weakly dominated⁴ by an incentive compatible contract, in which the payment is constant in the no-verification set M^c and always larger in the verification set than in the no-verification set.

Lemma 1. *Any contract $\delta = \{t(\cdot), M, P\}$ is weakly dominated by an incentive compatible contract $\tilde{\delta} = \{\tilde{t}(\cdot), \tilde{M}, \tilde{P}\}$ such that*

$$\begin{aligned}\tilde{t}(x) &= t_0 \text{ if } x \in \tilde{M}^c, \\ \tilde{t}(x) &> t_0 \text{ if } x \in \tilde{M},\end{aligned}$$

where t_0 is some constant.

The characterization of the incentive compatible contracts described in Lemma 1 is quite intuitive. In the first place, truthful revelation of the actual loss is obtained by paying a constant indemnity in the no-verification set, for otherwise the policyholder would always report the loss corresponding to the highest payment in this region. Secondly, if the payment were lower for some level of loss located in the verification set than in the no-verification set, then, for this level of loss, the policyholder would announce falsely that his loss is in the no-verification set.⁵

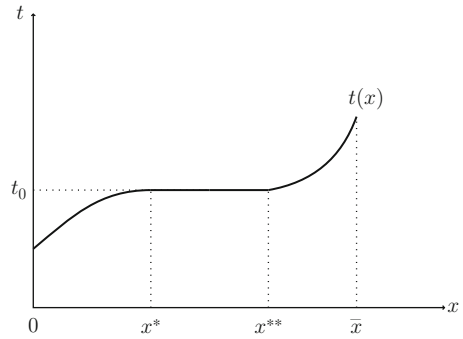
Lemma 1 implies that we may restrict our characterization of optimal contracts to such incentive compatible contracts. This is proved by defining $\tilde{t}(x)$ as the highest indemnity payment that the policyholder can obtain when his loss is x , by choosing \tilde{M} as the subset of $[0, \bar{x}]$ where the indemnity is larger than the minimum and by letting $\tilde{P} = P$. This is illustrated in Fig. 13.1, with $M = (x^*, \bar{x}]$, $\tilde{M} = (x^{**}, \bar{x}]$, $\tilde{t}(x) = t_0$ if $x \leq x^{**}$ and $\tilde{t}(x) = t(x)$ if $x > x^{**}$. Under δ , for any

³On imperfect auditing, in contexts which are different from insurance fraud, see Baron and Besanko (1984) and Puelz and Snow (1997).

⁴Dominance is in a Pareto-sense with respect to the expected utility of the policyholder and to the expected profit of the insurer.

⁵If both payments were equal, then it would be welfare improving not to audit the corresponding level of loss in the verification region and simultaneously to decrease the premium. Note that Lemma 1 could be presented as a consequence of the Revelation Principle (see Myerson 1979).

Fig. 13.1 Characterization of incentive compatible contracts



optimal reporting strategy, the policyholder receives t_0 when $x \leq x^{**}$ and he receives $t(x)$ when $x > x^{**}$, which corresponds to the same payment as under $\tilde{\delta}$. Furthermore, under δ , any optimal strategy $\hat{x}(x)$ is such that $\hat{x}(x) \in M$ if $x > x^{**}$, which implies that verification is at least as frequent under δ (for any optimal reporting strategy) as when the policyholder tells the truth under $\tilde{\delta}$. Thus, δ and $\tilde{\delta}$ lead to identical indemnity payments whatever the true level of the loss and expected audit costs are lower when there is truthtelling under $\tilde{\delta}$ than under δ .

From now on, we restrict ourselves to such incentive compatible contracts. The optimal contract maximizes the policyholder’s expected utility

$$EU = \int_M U(W - P - x + t(x))dF(x) + \int_{M^c} U(W - P - x + t_0)dF(x), \tag{13.1}$$

with respect to $P, t_0, t(\cdot) : M \rightarrow R_+$ and $M \subset [0, \bar{x}]$, subject to a constraint that requires the expected profit of the insurer $E\Pi$ to meet some minimum preassigned level normalized at zero

$$E\Pi = P - \int_M [t(x) + c]dF(x) + \int_{M^c} t_0dF(x) \geq 0, \tag{13.2}$$

and to the incentive compatibility constraint

$$t(x) > t_0 \text{ for all } x \text{ in } M. \tag{13.3}$$

Lemma 2. For any optimal contract, we have

$$t(x) = x - k > t_0 \text{ for all } x \text{ in } M,$$

and

$$M = (m, \bar{x}] \text{ with } m \in [0, \bar{x}].$$

Lemma 2 shows that it is optimal to verify the claims that exceed a threshold m and also to provide full insurance of marginal losses when $x > m$. The intuition of these results is as follows. The optimal policy shares the risk between the insured and the insurer without inducing the policyholder to misrepresent his loss level. As shown in Lemma 1, this incentive compatibility constraint implies that optimally the indemnity schedule should be minimal and flat outside the verification set, which means that no insurance of marginal losses is provided in this region. On the contrary, nothing prevents the insurer to provide a larger variable coverage when the loss level belongs to the verification set. Given the concavity of the policyholder’s utility function, it is optimal to offer the flat minimal coverage when losses are low and to provide a larger coverage when losses are high. This leads us to define

the threshold m that separates the verification set and its complement. Furthermore, conditionally on the claim being verified, i.e., when $x > m$, sharing the risk optimally implies that full coverage of marginal losses should be provided.

Hence, the optimal contract maximizes

$$EU = \int_0^m U(W - x - P + t_0)dF(x) + [1 - F(m)]U(W - P - k),$$

with respect to $P, m \geq 0, t_0 \geq 0$ and $k \geq t_0 - m$ subject to

$$E\Pi = P - t_0F(m) - \int_{m+}^{\bar{x}} (c + x - k)dF(x) \geq 0.$$

At this stage it is useful to observe that EU and $E\Pi$ are unchanged if there is a variation in the coverage, constant among states, compensated by an equivalent variation in the premium, i.e., $dEU = dE\Pi = 0$ if $dt_0 = dk = dP$, with m unchanged. Hence, the optimal coverage schedule is defined up to an additive constant. Without loss of generality, we may assume that no insurance payment is made outside the verification set, i.e., $t_0 = 0$. We should then have $t(x) = x - k > 0$ if $x > m$, or equivalently $m - k \geq 0$. In such a case, the policyholder files a claim only if the loss level exceeds the threshold m . This threshold may be viewed as a deductible.

Note that the optimal coverage is no more indeterminate if we assume, more realistically, that the cost c is the sum of the audit cost and of an administrative cost which is incurred whenever a claim is filed, be it verified or not. In such a case, choosing $t_0 = 0$ in the no-verification set is the only optimal solution since it saves the administration cost—see [Picard \(2000\)](#).

The optimal contract is derived by maximizing

$$EU = \int_0^m U(W - x - P)dF(x) + [1 - F(m)]U(W - P - k), \tag{13.4}$$

with respect to $m \geq 0, k$ and P , subject to

$$E\Pi = P - \int_{m+}^{\bar{x}} (c + x + k)dF(x) \geq 0, \tag{13.5}$$

$$m - k \geq 0. \tag{13.6}$$

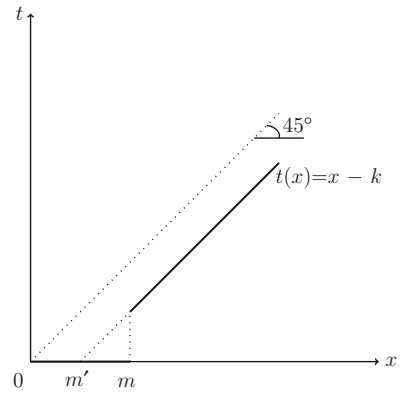
Proposition 1. *Under deterministic auditing, an optimal insurance contract $\delta = \{t(\cdot), M, P\}$ satisfies the following conditions:*

$$\begin{aligned} M &= (m, \bar{x}] \text{ with } m > 0, \\ t(x) &= 0 \text{ if } x \leq m, \\ t(x) &= x - k \text{ if } x > m, \end{aligned}$$

with $0 < k < m$.

The optimal contract characterized in Proposition 1—established by [Gollier \(1987\)](#)—is depicted in Fig. 13.2. First, it states that it is optimal to choose a positive threshold m . The intuition is as follows. When $m = 0$, all positive claims are verified and it is optimal to offer full coverage, i.e., $t(x) = x$ for all $x > 0$. Starting from such a full insurance contract an increase $dm > 0$ entails no first-order

Fig. 13.2 Optimal insurance coverage under deterministic auditing



risk-sharing effect. However, this increase in the threshold cuts down the expected audit cost, which is beneficial to the policyholder. In other words, in the neighborhood of $m = 0$, the trade-off between cost minimization and risk sharing always tips in favor of the first objective.

Secondly, we have $0 < k < m$ which means that partial coverage is provided when $x > m$. Intuitively, the coverage schedule is chosen so as to equalize the marginal utility of final wealth in each state of the verification set with the expected marginal utility of final wealth, because any increase in the insurance payment has to be compensated by an increase in the premium paid whatever the level of the loss. We know that no claim is filed when $x < m$, which implies that the expected marginal utility of final wealth is larger than the marginal utility in the no-loss state. Concavity of the policyholder's utility function then implies that a partial coverage is optimal when the threshold is crossed.

Thus far we have assumed that the insurer has no information at all about the loss incurred by the policyholder. In particular, the insurer could not observe whether a loss occurred ($x > 0$) or not ($x = 0$). Following [Bond and Crocker \(1997\)](#), we may alternately assume that the fact that the policyholder has suffered some loss is publicly observable. The size of the loss remains private information to the policyholder: verifying the magnitude of the loss costs c to the insurer.

This apparently innocuous change in the information structure strongly modifies the shape of the optimal coverage schedule. The insurer now pays a specific transfer $t = t_1$ when $x = 0$, which occurs with probability $f(0)$. Lemmas 1 and 2 are unchanged and we now have

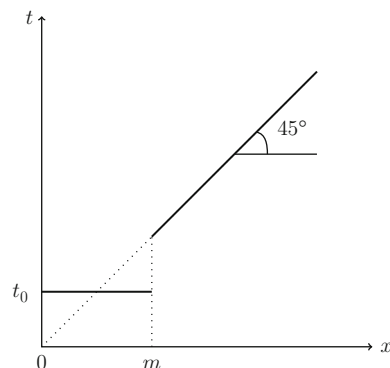
$$\begin{aligned}
 EU &= f(0)U(W - P + t_1) + \int_{0+}^m U(W - x - P + t_0)dF(x) \\
 &\quad + [1 - F(m)]U(W - P - k), \\
 E\Pi &= P - t_1f(0) - t_0[F(m) - f(0)] - \int_{m+}^{\bar{x}} (c + x - k)dF(x).
 \end{aligned}$$

The optimal contract maximizes EU with respect to $P, m \geq 0, t_0 \geq 0, t_1 \geq 0$, and $k \geq t_0 - m$ subject to $E\Pi \geq 0$. We may choose $t_1 = 0$, since P, t_0, t_1 , and k are determined up to an additive constant: no insurance payment is made if no loss occurs.

Proposition 2. *Under deterministic auditing, when the fact that the policyholder has suffered some loss is publicly observable, an optimal insurance contract $\delta = \{t(\cdot), M, P\}$ satisfies the following conditions:*

$$\begin{aligned}
 M &= (m, \bar{x}] \text{ with } m > 0, \\
 t(0) &= 0,
 \end{aligned}$$

Fig. 13.3 Optimal insurance coverage under deterministic auditing when the insurer can observe whether an accident has occurred but not the magnitude of the actual loss



$$t(x) = t_0 \text{ if } 0 < x \leq m,$$

$$t(x) = x \text{ if } x > m,$$

with $0 < t_0 < m$.

Proposition 2 is established by Bond and Crocker (1997). It is depicted in Fig. 13.3. When an accident occurs but the claim is not verified (i.e., $0 < x \leq m$), the incentive compatibility requires the insurance payment to be constant: we then have $t(x) = t_0$. The payment should be larger than t_0 when the claim is verified (i.e., when $x > m$). Optimal risk sharing implies that the policyholder’s expected marginal utility (conditional on the information of the insurer) should be equal to the marginal utility in the no-accident state. This implies first that, in the no-verification region, an optimal insurance contract entails overpayment of small claims (when $0 < x \leq t_0$) and underpayment of large claims (when $t_0 < x \leq m$). Secondly, there is full insurance in the verification region (i.e., when $x > m$).

Neither Fig. 13.2 nor Fig. 13.3 looks like the coverage schedules that are most frequently offered by insurer for two reasons: firstly because of the upward discontinuity at $x = m$ and secondly because of overpayment of smaller claims in the case of Fig. 13.3. In fact, such contracts would incite the policyholder to inflate the size of his claim by intentionally increasing the damage. Consider, for example, the contract described in Proposition 1 and illustrated by Fig. 13.2. A policyholder who suffers a loss x less than m but greater than m' would profit by increasing the damage up to $x = m$, insofar as the insurer is not able to distinguish the initial damage and the extra damage.⁶ In such a case, the contract defined in Proposition 1 is dominated by a contract with a straight deductible, i.e., $t(x) = \text{Sup}\{0, x - m'\}$ with $M = (m', \bar{x}]$. As shown by Huberman et al. (1983) and Picard (2000), in different settings, a straight deductible is indeed optimal under such circumstances. We thus have:

Proposition 3. *Under deterministic auditing, when the policyholders can inflate their claims by intentionally increasing the damage, the optimal insurance contract $\delta = \{t(\cdot), M, P\}$ is a straight deductible*

$$t(x) = \text{Sup}\{0, x - m\},$$

with $m > 0$ and $M = (m, \bar{x}]$.

⁶In fact, the policyholder would never increase the damage if and only if $t(x) - x$ were nonincreasing over $[0, \bar{x}]$. Given that $t(x)$ is nondecreasing (see Lemma 2), this no-manipulability condition implies that $t(x)$ should be continuous. Note that extra damages can be made either deliberately by the policyholder (arson is a good example) or, thanks to a middleman, such as a car repairer or a health-care provider. In such cases, gathering verifiable information about intentional overpayment may be too time consuming to the insurer. See Bourgeon and Picard (1999) on corporate fire insurance when there is a risk of arson.

Proposition 3 explains why insurance policies with straight deductibles are so frequently offered by insurers, in addition to the well-known interpretations in terms of transaction costs (Arrow 1971) or moral hazard (Holmström 1979).

13.3 Costly State Verification: Deterministic Auditing with Manipulation of Audit Costs

In the previous section, the policyholder was described as a purely passive agent. His only choices were whether he files a claim or not and, should the occasion arise, what is the size of the claim? As a matter of fact, in many cases, the policyholder involved in an insurance fraud case plays a much more active part. In particular, he may try to falsify the damages in the hope of receiving a larger insurance payment. Usually, falsification goes through collusion with agents, such as health-care providers, car repairers, or attorneys, who are in position to make it more difficult or even impossible to prove that the claim has been built up or deliberately created.⁷ Even if fraudulent claiming may be deterred at equilibrium, the very possibility for policyholders to falsify claims should be taken into account in the analysis of optimal insurance contracts.

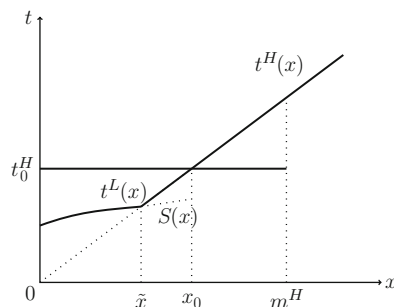
Two main approaches to claims falsification have been developed in the literature. Firstly, Bond and Crocker (1997) and Picard (2000) assume that the policyholder may manipulate audit costs, which means that they expend resources to make the verification of claims more costly or more time consuming to the auditor. In this approach, deterring the policyholder from manipulating audit cost is feasible and, sometimes, optimal. What is most important is the fact that the coverage schedule affects the incentives of policyholders to manipulate audit costs, which gives a specific moral hazard dimension to the problem of designing an optimal insurance contract. In another approach, developed by Crocker and Morgan (1997), it is assumed that policyholders may expend resources to falsify the actual magnitude of their losses in an environment where verification of claims is not possible. Here also the coverage schedule affects the incentives to claims falsification, but the cost of generating insurance claims through falsification differs among policyholders according to their true level of loss. These differential costs make it possible to implement loss-contingent insurance payments with some degree of claims falsification at equilibrium.

In this section and the following, we review both approaches in turn. For the sake of expositional clarity, we refer to them as costly state verification with manipulation of audit cost and costly state falsification, although in both cases the policyholder falsifies his claim, i.e., he prevents the insurer observing the true level of damages. In the first approach, the policyholder deters the auditor from performing an informative audit while in the second one he provides a distorted image of his damages.

The audit cost manipulation hypothesis has been put forward by Bond and Crocker (1997) in the framework of a model with deterministic auditing. They assume that policyholders may take actions (referred to as *evasion costs*) that affect the audit cost. Specifically, Bond and Crocker assume that, after observing their loss x , a policyholder may incur expenditures $e \in \{e_0, e_1\}$, with $e_1 > e_0$, which randomly affects the audit cost. If $e = e_i$, then the audit cost is $c = c^H$ with probability p_i and $c = c^L$ with probability $1 - p_i$, with $i \in \{0, 1\}$, $c^H > c^L$ and $p_1 > p_0$. In other words, a large level of manipulation expenditures makes it more likely that the audit cost will be large. Without loss of

⁷On collusion between physicians and workers, see the analysis of workers' compensations by Dionne and St-Michel (1991) and Dionne et al. (1995). See Derrig et al. (1994) on empirical evidence about the effect of the presence of an attorney on the probability of reaching the monetary threshold that restricts the eligibility to file a tort claim in the Massachusetts no-fault automobile insurance system. In the Tort system, Cummins and Tennyson (1992) describe the costs to motorists experiencing minor accidents of colluding with lawyers and physicians as the price of a lottery ticket. The lottery winnings are the motorist's share of a general damage award.

Fig. 13.4 Optimal no-manipulation contract in the Bond–Crocker (1997) model



generality, assume $e_0 = 0$. Let us also simplify by assuming $c^L = 0$. These expenditures are in terms of utility so that the policyholder’s utility function is now $U(W_t) - e$.

Bond and Crocker assume that the actual audit cost is verifiable, so that the insurance contract may be conditioned on c . Under deterministic auditing, an insurance contract δ is then defined by a premium P , a state-contingent coverage schedule $t^i(x)$ and a state-contingent verification set $M^i = (m^i, \bar{x}]$, where $i = H$ if $c = c^H$ and $i = L$ if $c = c^L$. Bond and Crocker also assume that the insurer can observe whether an accident has occurred, but not the size of the actual damages and (without loss of generality) they assume that no insurance payment is made if $x = 0$.

An optimal *no-manipulation* insurance contract maximizes the expected utility of the policyholder subject to:

- The insurer’s participation constraint
- Incentive compatibility constraints that may be written as

$$t^i(x) = \begin{cases} t_0^i & \text{if } x \in (0, m^i] \\ > t_0^i & \text{if } x \in (m^i, \bar{x}] \end{cases}$$

for $i = H$ or L .

- The constraint that the policyholder does not engage in audit cost manipulation whatever his loss, i.e.,

$$\begin{aligned} & p_1 U(W - x - P + t^H(x)) + (1 - p_1) U(W - x - P + t^L(x)) - e_1 \\ & \leq p_0 U(W - x - P + t^H(x)) + (1 - p_0) U(W - x - P + t^L(x)) \end{aligned}$$

for all x in $(0, \bar{x}]$.

Bond and Crocker (1997) show the following proposition.

Proposition 4. *The optimal no-manipulation insurance contract $\delta = \{t^H(\cdot), t^L(\cdot), m^H, m^L, P\}$ has the following properties:*

- $m^H < \bar{x}$ and $m^L = 0$
- $t^H(x) = x$ for $x > m^H$ and $t^H(x) = t_0^H$ for $0 < x \leq m^H$
- $t^L(x) = x$ for $\tilde{x} \leq x \leq \bar{x}$ and $t^L(x) = S(x)$ for $0 < x < \tilde{x}$ where $S(x)$ is given by

$$(p_1 - p_0)[U(W - x - P + t_0^H) - U(W - x - P + S(x))] - e_1 = 0.$$

The optimal no-manipulation contract is depicted in Fig. 13.4. If there were no possibility of audit cost manipulation, then the optimal insurance contract would involve $m^L = 0$ and $t^L(x) = x$ for all x (since $c^L = 0$) and $m^H > 0$, $t^H(x) = x$ if $x > m$ and $0 < t_0^H < m_H$ (see Proposition 2). This suggests that manipulating audit cost (i.e., choosing $e = e_1$) may be a profitable strategy for low values of x . Proposition 4 shows that overcompensating easily verified losses is an appropriate strategy to mitigate the policyholder's incentive to engage in audit cost manipulation. This overcompensation is defined by the $S(x)$ function. $S(x)$ denotes the minimum payoff in the c^L state that makes the policyholder indifferent between manipulating or not and \tilde{x} is the threshold under which the policyholder chooses to evade if he is offered the full insurance contract in the c^L state.

Since overcompensating is costly to the insurer, it may be optimal to allow for some degree of manipulation at equilibrium. Bond and Crocker provide a characterization of this optimal contract with audit cost manipulation at equilibrium. In particular, they show that there is still a subinterval $[s_2, s_1]$ in $(0, m^H)$ where the insurer overcompensates the loss in the c^L state, with $t^L(x) = S(x) > x$ when $s_2 \leq x < s_1$. Finally they show that when U exhibits constant absolute risk aversion, then the optimal contract in the presence of audit cost manipulation results in lower payoffs and less monitoring in the c^H state than would an optimal contract in an environment where claims manipulation was not possible.⁸

The analysis of Bond and Crocker (1997) is interesting firstly because it is a first step toward a better understanding of the active part that policyholders may take in insurance fraud. Furthermore, it provides a rationale for the fact that insurers may be willing to settle small claims generously and without question when the loss is easily monitored to forestall a claim that may be larger and more difficult to verify. From a normative point of view, the Bond–Crocker analysis suggests that the appropriate way to mitigate buildup is not to increase the amount of monitoring but to design coverage schedules in such a way that policyholders have less incentive to engage in fraudulent claiming.

Two other aspects of the Bond–Crocker model have to be emphasized. First, the optimal coverage schedule is such that small claims are overcompensated whatever the audit cost, which may incite the policyholder to intentionally bring about damages. This issue has already been addressed in Sect. 13.2, and we will not hark back to it any further. Secondly, Bond and Crocker assume that the actual audit cost is verifiable so that the insurance coverage may be conditioned on it. This is a very strong assumption. In most cases, claims verification is performed by an agent (an expert, a consulting physician, an attorney, an investigator. . .) who may have private information about the cost entailed by a specific claim. Picard (2000) focuses attention on the agency relationship that links the insurer and the auditor when policyholders may manipulate audit costs and the insurer does not observe the cost incurred by the auditor. His analysis may be summarized as follows.

The auditor sends a report $\tilde{x} \in [0, \bar{x}]$ which is an evaluation of the magnitude of the loss. Let $\tilde{x} = \emptyset$ when no audit is performed. Observing the magnitude of the loss costs c_a to the auditor. The policyholder may incur a manipulation cost e and, in such a case, the cost of eliciting *verifiable* information about the size of the damages become $c_a + be$, where the parameter $b > 0$ characterizes the manipulation technology. Furthermore, verifiable information is necessary to prove that the claim has been built up (i.e., to prove that $x < \hat{x}$). The insurer does not observe the audit cost. He offers an incentive contract to his auditor to motivate him to gather verifiable information about fraudulent claims. Let t and r be, respectively, the insurance payment and the auditor's fees. Contracts $T(\cdot)$ and $R(\cdot)$ specify t and r as functions of the auditor's report.⁹ We have $t = T(\tilde{x})$ and $r = R(\tilde{x})$ where $T(\cdot) : [0, \bar{x}] \cup \emptyset \rightarrow R_+$ and $R(\cdot) : [0, \bar{x}] \cup \emptyset \rightarrow R$.

⁸The CARA assumption eliminates wealth effects from incentive constraints.

⁹The payment $R(\cdot)$ is net of standard audit cost c_a .

The auditor–policyholder relationship is described as a three-stage audit game. At stage 0, a loss x , randomly drawn in $[0, \bar{x}]$, is privately observed by the policyholder.¹⁰ At stage 1, the policyholder reports a claim $\hat{x} \in [0, \bar{x}]$ and he incurs the manipulation cost $e \geq 0$. At stage 2, the claim is audited whenever $\hat{x} \in M = (m, \bar{x}]$. When $\hat{x} \in M$, the auditor observes x and he reports $\tilde{x} \in \{x, \hat{x}\}$ to the insurer. If $\tilde{x} = x \neq \hat{x}$, the auditor incurs the cost $c_a + be$ so that his report incorporates verifiable information. If $\tilde{x} = \hat{x}$, the auditor’s cost is only c_a . The payments to the policyholder and to the auditor are, respectively, $T(\tilde{x})$ and $R(\tilde{x})$.

In this setting, an allocation is described by $\delta = \{t(\cdot), M, P\}$, with $M = (m, \bar{x}]$ and by $\omega(\cdot) : [0, \bar{x}] \rightarrow R$, where $\omega(x)$ is the auditor’s equilibrium payoff (net of audit cost) when the loss is equal to x .

Contracts $\{T(\cdot), R(\cdot)\}$ are said to implement the allocation $\{\delta, \omega(\cdot)\}$ if at a perfect equilibrium of the audit game, there is no audit cost manipulation (i.e., $e = 0$ for all x), the claim is verified if and only if $x \in M$ and the net payoffs—defined by $T(\cdot)$ and $R(\cdot)$ —are equal to $t(x), \omega(x)$ when the loss is equal to x .¹¹

In such a setting, the equilibrium audit cost is $\omega(x) + c_a$ if $x \in M$ and $\omega(x)$ if $x \in M^c$. Furthermore, the auditor’s participation constraint may be written as

$$\int_0^{\bar{x}} V(\omega(x))dF(x) \geq \bar{v}, \tag{13.7}$$

where $V(\cdot)$ is the auditor’s von Neumann-Morgenstern utility function, with $V' > 0, V'' \leq 0$ and \bar{v} is an exogenous reservation utility level.

The optimal allocation $\{\delta, \omega(\cdot)\}$ maximizes the policyholder’s expected utility, subject to the insurer’s and the auditor’s participation constraints and to the constraint that there exist contracts $\{T(\cdot), R(\cdot)\}$ that implement $\{\delta, \omega(\cdot)\}$.

Picard (2000) characterizes the optimal allocation in a setting where the policyholder can inflate their claim by intentionally increasing the damages, which implies that $t(x) - x$ should be nonincreasing (see Sect. 13.2). His main result is the following:

Proposition 5. *When the auditor is risk averse ($V'' < 0$), the optimal insurance contract is a deductible with coinsurance for high levels of damages:*

$$\begin{aligned} t(x) &= 0 \text{ if } 0 \leq x \leq m, \\ t(x) &= x - m \text{ if } m \leq x \leq x_0, \\ t'(x) &\in (0, 1) \text{ if } x_0 \leq x \leq \bar{x}, \end{aligned}$$

with $0 \leq m < x_0 \leq \bar{x}$ and $M = (m, \bar{x}]$.

Furthermore, the auditor’s fees (expressed as function of the size of the claim) are

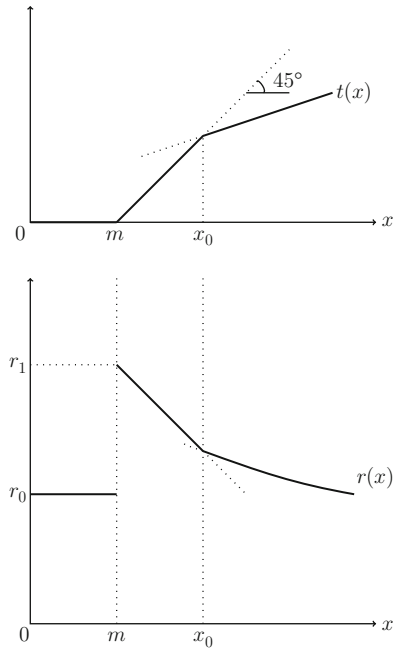
$$\begin{aligned} r &= r_1 - bt(x) \text{ if } x > m, \\ r &= r_0 \text{ if } x \leq m, \end{aligned}$$

where r_0 and r_1 are constant.

¹⁰Contrary to the Bond-Crocker (1997) model, it is assumed that the insurer cannot observe whether an accident has occurred, i.e., he cannot distinguish the event $\{x = 0\}$ from $\{x > 0\}$. Furthermore, the manipulation cost e is in monetary terms and not utility terms as in Bond-Crocker (1997).

¹¹Picard (2000) shows that allowing for audit cost manipulation (i.e., $e > 0$) at equilibrium is a weakly dominated strategy for the insurer.

Fig. 13.5 Optimal insurance contract and auditor's contingent fees



Picard (2000) also gives sufficient conditions for $m > 0$ and $x_0 < \bar{x}$. The contracts characterized in Proposition 5 are depicted in Fig. 13.5. We have $t(x) = 0$ when x is in the no-verification set $[0, m]$. Hence, the threshold m may be interpreted as a deductible under which no claim is filed. In the verification set, there is coinsurance of large losses (i.e., the slope of the coverage schedule is less than one when $x > x_0$). Furthermore, the insurer should pay contingent fees to his auditor: the auditor's fees are (linearly) decreasing in the insurance indemnity payment.

The intuition for these results is as follows. Let $x \in M$. A deviation from truthful revelation of loss without audit cost manipulation (i.e., $\hat{x} = x, e = 0$) to $\hat{x} = x' > x, e > 0$ is profitable to the policyholder if $T(x') - e > T(x)$ provided the claim is accepted by the auditor, which implies $R(x') \geq R(x) - be$. Both conditions are incompatible (for all e) if

$$R(x') + bT(x') \leq R(x) + bT(x).$$

For all $x \in M$, we have $t(x) = T(x), \omega(x) = R(x)$. This means that $\omega(x) + bt(x)$ should be nonincreasing for manipulation of audit cost to be deterred. In other words, a 1\$ increase in the indemnity payment should lead at least to a b \$ decrease in the auditor's fees. Because the auditor is risk averse, it would be suboptimal to have $\omega'(x) < -bt'(x)$, which gives the result on contingent fees. Because of condition $\omega'(x) = -bt'(x)$, a greater scope of variation in insurance payments entails a greater variability in the auditor's fees and thus a larger risk premium paid to the auditor for his participation constraint to be satisfied. Some degree of coinsurance for large losses then allows the insurer to decrease the auditor's expected fees which is ultimately beneficial to the policyholder. This argument does not hold if the auditor is risk neutral and, in that case, a straight deductible is optimal. Inversely, a ceiling on coverage is optimal when the auditor is infinitely risk averse or when he is affected by a limited liability constraint.

13.4 Costly State Falsification

Let us come now to the analysis of state falsification first examined by [Lacker and Weinberg \(1989\)](#)¹² and applied to an insurance setting by [Crocker and Morgan \(1997\)](#).¹³ The policyholders are in position to misrepresent their actual losses by engaging in costly falsification activities. The outcome of these activities is a claim denoted by $y \in R_+$. The insurer only observes y : contrary to the costly state verification setting, verifying the actual magnitude of damages is supposed to be prohibitively costly. Hence, an insurance contract only specifies a coverage schedule $t = T(y)$. Claims falsification is costly to the policyholder, particularly because it may require colluding with a provider (an automechanic, a physician) or using the services of an attorney. Let $C(x, y)$ be the falsification cost. The policyholder's final wealth becomes

$$W_f = W - x - P + T(y) - C(y, x).$$

Let $y(x)$ be the (potentially falsified) claim of a policyholder who suffers an actual loss x . Given a falsification strategy $y(\cdot) : [0, \bar{x}] \rightarrow R_+$, the policyholder's final wealth may be written as a function of his loss:

$$W_f(x) \equiv W - x - P + T(y(x)) - C(y(x), x) \quad (13.8)$$

An optimal insurance contract maximizes $EU(W_f(x))$ with respect to $T(\cdot)$ and P subject to

$$P \geq \int_0^{\bar{x}} T(y(x)) dF(x), \quad (13.9)$$

$$y(x) \in \text{Arg Max}_{y'} T(y') - C(y', x) \text{ for all } x \in [0, \bar{x}]. \quad (13.10)$$

Equation (13.9) is the insurer's participation constraint, and (13.10) specifies that $y(x)$ is an optimal falsification strategy of a type- x policyholder.

Since the payments $\{P, T(\cdot)\}$ are defined up to an additive constant, we may assume $T(0) = 0$ without loss of generality. For the time being, let us restrict attention to linear coverage schedule, i.e., $T(y) = \alpha y + \beta$. Our normalization rule gives $\beta = 0$. Assume also that the falsification costs borne by the policyholder depend upon the absolute amount of misrepresentation ($y - x$) and, for the sake of simplicity, assume $C = \gamma(y - x)^2/2$, where γ is an exogenous cost parameter. Equation (13.10) then gives

$$y(x) \equiv x + \frac{\alpha}{\gamma}. \quad (13.11)$$

Hence the amount of falsification $y(x) - x$ is increasing in the slope of the coverage schedule and decreasing in the falsification cost parameter. The optimal coverage schedule will trade off two conflicting objectives: providing more insurance to the policyholder, which requires increasing α , and mitigating the incentives to claims falsification by lowering α .

¹²See also [Maggi and Rodriguez-Clare \(1995\)](#).

¹³[Hau \(2008\)](#) analyzes costly state verification and costly state falsification in a unified model. See [Crocker and Tennyson \(1999, 2002\)](#), and [Dionne and Gagné \(2001\)](#) on econometric testing of the theoretical predictions of models involving costly state falsification.

The insurer's participation constraint (13.9) is binding at the optimum, which gives

$$P = \int_0^{\bar{x}} \left(\alpha x + \frac{\alpha^2}{\gamma} \right) dF(x) = \alpha E x + \frac{\alpha^2}{\gamma}.$$

Equation (13.8) then gives

$$W_f(x) = W - (1 - \alpha)x - \alpha E x + \frac{\alpha^2}{2\gamma}.$$

Maximizing $EU(W_f(x))$ with respect to α leads to the following first-order condition:

$$\frac{\partial EU}{\partial \alpha} = E \left\{ \left(x - E x - \frac{\alpha}{\gamma} \right) U'(W_f(x)) \right\} = 0, \tag{13.12}$$

and thus

$$\frac{\partial EU}{\partial \alpha} \Big|_{\alpha=1} = -\frac{1}{\gamma} U' \left(W - E x - \frac{1}{2\gamma} \right) < 0, \tag{13.13}$$

$$\frac{\partial EU}{\partial \alpha} \Big|_{\alpha=0} = E \{ (x - E x) U'(W - x) \} > 0. \tag{13.14}$$

We also have

$$\frac{\partial^2 EU}{\partial \alpha^2} = -\frac{1}{\gamma} EU'(W_f(x)) + E \left\{ \left(x - E x - \frac{\alpha}{\gamma} \right)^2 U''(W_f(x)) \right\} < 0, \tag{13.15}$$

which implies that $0 < \alpha < 1$ at the optimum. Hence, under costly state falsification, the optimal linear coverage schedule entails some degree of coinsurance and (13.11) shows that there exists a certain amount of claims falsification at equilibrium. This characterization results from the trade-off between the above-mentioned conflicting objectives: providing insurance to the policyholder and deterring him from engaging in costly claims falsification activities.

This trade-off is particularly obvious when $U(\cdot)$ is quadratic. In that case, we may write

$$EU(W_f) = E W_f - \eta \text{Var}(W_f) \text{ with } \eta > 0, \tag{13.16}$$

and straightforward calculations give

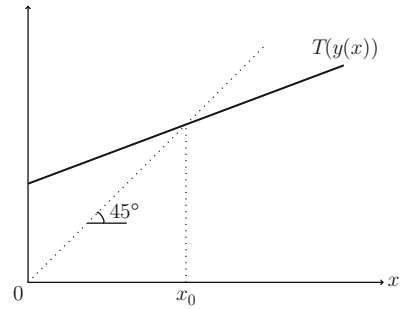
$$\alpha = \frac{2\eta\gamma\sigma^2}{1 + 2\eta\gamma\sigma^2} \tag{13.17}$$

at the optimum, where $\sigma^2 \equiv \text{Var}(x)$.

Hence, the coinsurance coefficient α is an increasing function of the cost parameter γ , of the risk aversion index η , and of the variance of the loss. We have

$$T(y(x)) = \alpha x + \frac{\alpha^2}{\gamma},$$

Fig. 13.6 Equilibrium indemnification under costly state falsification



which give $T(y(x)) > x$ if $x < x_0$ and $T(y(x)) < x$ if $x > x_0$ with $x_0 = \alpha^2/\gamma(1 - \alpha)$. Hence, in this case, the optimal indemnification rule overcompensates small losses and it overpays larger ones. This is depicted in Fig. 13.6.

Assume now that the insurer observes whether a loss occurred or not, as in the paper by Crocker and Morgan (1997). Then an insurance contract is defined by a premium P , an insurance payment t_0 if $x = 0$ and an insurance coverage schedule $T(y)$ to be enforced if $x > 0$. In that case, a natural normalization rule is $t_0 = 0$. We still assume that $T(y)$ is linear: $T(y) = \alpha y + \beta$. For the sake of simplicity, we also assume that $U(\cdot)$ is quadratic.

The insurer's participation constraint and (13.11) give

$$P = \alpha Ex + [1 - f(0)] \left(\frac{\alpha^2}{\gamma} + \beta \right), \tag{13.18}$$

which implies

$$W_f = W - \alpha Ex - [1 - f(0)] \left(\frac{\alpha^2}{\gamma} + \beta \right) \text{ if } x = 0$$

$$W_f = W - \alpha Ex - [1 - f(0)] \left(\frac{\alpha^2}{\gamma} + \beta \right) - (1 - \alpha)x + \beta + \frac{\alpha^2}{2\gamma} \text{ if } x > 0,$$

and we obtain

$$EW_f = W - Ex - \frac{\alpha^2}{2\gamma} [1 - f(0)], \tag{13.19}$$

and

$$\text{Var}(W_f) = f(0)[1 - f(0)] \left(\beta + \frac{\alpha^2}{2\gamma} \right)^2 + (1 - \alpha)^2 \sigma^2 - 2f(0)(1 - \alpha) \left(\beta + \frac{\alpha^2}{2\gamma} \right) Ex. \tag{13.20}$$

Maximizing $EU(W_f)$ defined by (13.16) with respect to α and β gives the following result:

$$\alpha = \frac{2\eta\gamma\tilde{\sigma}^2}{1 + 2\eta\gamma\tilde{\sigma}^2}, \tag{13.21}$$

$$\beta = (1 - \alpha)\bar{x} - \frac{\alpha^2}{2\gamma}, \tag{13.22}$$

where $\tilde{\sigma}^2 = \text{Var}(x \mid x > 0)$ and $\bar{x} = E(x \mid x > 0)$, i.e., $\tilde{\sigma}^2$ and \bar{x} are, respectively, the variance and the expected value of the magnitude of damages conditional on a loss occurring.

Equation (13.21) is similar to (13.17), and it may be interpreted in the same way. The fact that α is strictly positive (and less than one) means that some degree of insurance is provided but also that there is claims falsification at equilibrium. β may be positive or negative, but the insurance payment $T(y(x))$ is always positive.¹⁴ As in the previous case, small losses are overcompensated, and there is undercompensation for more severe losses.

Crocker and Morgan (1997) obtain a similar characterization without restricting themselves to a linear-quadratic model. They characterize the allocations, $\{t(\cdot), y(\cdot), P\}$, with $t(\cdot) : [0, \bar{x}] \rightarrow R_+$ and $y(\cdot) : (0, \bar{x}] \rightarrow R_+$, that may be implemented by a coverage schedule $T(y)$.¹⁵ For such an allocation, there exists $T(\cdot) : R_+ \rightarrow R_+$ such that

$$y(x) \in \text{Arg max}_{y'} \{T(y') - C(y', x)\},$$

and

$$t(x) = T(y(x)) \text{ for all } x.$$

The Revelation Principle (Myerson 1979) applies in such a context, which means that implementable allocations may be obtained as the outcome of a revelation game in which

1. The insurance payment t and the action y are defined as functions of a message $\tilde{x} \in [0, \bar{x}]$ of the policyholder, i.e., $t = t(\tilde{x}), y = y(\tilde{x})$.
2. Truthtelling is an optimal strategy for the policyholder, i.e.,

$$x \in \text{Arg Max}_{\tilde{x}} \{t(\tilde{x}) - C(y(\tilde{x}), x)\} \tag{13.23}$$

for all x in $(0, \bar{x}]$.

Such an allocation $\{t(\cdot), y(\cdot)\}$ is said to be incentive compatible. The optimal allocation maximizes the policyholder's expected utility $EU(W_t(x))$ with respect to $t(\cdot), y(\cdot)$ and P subject to the insurer's participation constraint and to incentive compatibility constraints. Using a standard technique of incentives theory, Crocker and Morgan characterize the optimal solution of a less constrained problem in which a first-order truthtelling condition is substituted to (13.23). They obtain the following result.^{16,17}

Proposition 6. *The optimal solution to the insurance problem under claims falsification satisfies*

$$\begin{aligned} y(0_+) &= 0, y(\bar{x}) = \bar{x} \text{ and } y(x) > x \text{ if } 0 < x < \bar{x}, \\ t'(0_+) &= t'(\bar{x}) = 0 \text{ and } t'(x) > 0 \text{ if } 0 < x < \bar{x}, \\ t(0_+) &> 0 \text{ and } t(\bar{x}) < \bar{x}. \end{aligned}$$

¹⁴When β is negative, the optimal coverage schedule is equivalent to a deductible $m = -\beta/\alpha$ with a coinsurance provision for larger losses, i.e., $T(y(x)) = \text{Sup}\{0, \alpha(y - m)\}$.

¹⁵Crocker and Morgan assume that the insurer can observe whether a loss occurred or not. Hence, there may be falsification only if $x > 0$.

¹⁶There are some minor differences between the Crocker–Morgan setting and ours. They are not mentioned for the sake of brevity.

¹⁷The second-order condition for incentive compatibility requires $y(x)$ to be monotonically increasing. If the solution to the less constrained problem satisfies this monotonicity condition, then the optimal allocation is characterized as in Proposition 6. See Crocker and Morgan (1997) for a numerical example. If this is not the case, then the optimal allocation entails bunching on (at least) an interval $(x', x'') \subset [0, \bar{x}]$, i.e., $y(x) = \hat{y}, t(x) = \hat{t}$ for all x in (x', x'') . In such a case, the coverage schedule $T(y)$ that sustains the optimal allocation is not differentiable at $y = \hat{y}$.

Proposition 6 extends the results already obtained in this section to a more general setting, with a nonlinear coverage schedule. The optimal solution always entails some degree of falsification except at the top (when $x = \bar{x}$) and at the bottom (when $x \rightarrow 0_+$). The insurance payment is increasing in the magnitude of the actual damages, and it provides overinsurance (respect. underinsurance) for small (respect. large) losses.

13.5 Costly State Verification: The Case of Random Auditing

We now come back to the costly state verification setting. Under *random auditing*, the insurer verifies the claims with a probability that depends upon the magnitude of damages. The insurance payment may differ depending on whether the claim has been verified or not. A policyholder who suffers a loss x files a claim \hat{x} that will be audited with probability $p(\hat{x})$. If there is an audit, the true damages are observed by the insurer and the policyholder receives an insurance payment $t_A(x, \hat{x})$. If there is no audit, the insurance payment is denoted $t_N(\hat{x})$.

When a policyholder with damages x files a claim \hat{x} , is expected utility is

$$[1 - p(\hat{x})]U(W - P - x + t_N(\hat{x})) + p(\hat{x})U(W - P - x + t_A(x, \hat{x})).$$

The *Revelation Principle* applies to this setting, and we can restrict attention to incentive compatible insurance contracts, that is, to contracts where the policyholder is given incentives to report his loss truthfully. Such incentive compatible contracts are such that

$$\begin{aligned} & [1 - p(x)]U(W - P - x + t_N(x)) + p(x)U(W - P - x + t_A(x, x)) \\ & \geq [1 - p(\hat{x})]U(W - P - x + t_N(\hat{x})) + p(\hat{x})U(W - P - x + t_A(x, \hat{x})), \end{aligned} \quad (13.24)$$

for all $x, \hat{x} \neq x$.

Let us assume that the net payment from the policyholder to the insurer $P - t_A(x, \hat{x})$ is bounded by a maximal penalty that can be imposed in case of misrepresentation of damages (i.e., when $x \neq \hat{x}$). This maximal penalty¹⁸ may depend on the true level of damages x and will be denoted $B(x)$. Hence, we have

$$P - t_A(x, \hat{x}) \leq B(x) \text{ if } x \neq \hat{x}. \quad (13.25)$$

For instance, [Mookherjee and Png \(1989\)](#) assume that the wealth of the policyholder is perfectly liquid and that his final wealth can be at most set equal to zero in case of false claim detected by audit. We have $B(x) \equiv W - x$ in that case. [Fagart and Picard \(1999\)](#) assume that the policyholder is affected by a liquidity constraint and that the liquid assets of the policyholder have a given value B . The maximal penalty is then $B(x) = B$ for all x . Another interpretation of (13.25) is that $B(x) \equiv B$ is an exogenously given parameter that represents the cost (in monetary terms) incurred by a policyholder who is prosecuted after he filed a fraudulent claim detected by audit.¹⁹

¹⁸The Revelation Principle does not apply anymore if the maximal penalty also depends on the claim \hat{x} . In such a case, there may be false report at equilibrium.

¹⁹Under this interpretation, it may be more natural to assume that the policyholder should pay the penalty B in addition to the premium P , since the latter is usually paid at the beginning of the time period during which the insurance policy is enforced. In fact, both assumptions are equivalent when the policyholder is affected by a liquidity constraint. Indeed, in such a case, it would be optimal to fix the insurance premium P at the largest possible level (say $P = \bar{P}$) and to compensate adequately the policyholder by providing large insurance payments t_N and t_A unless a fraudulent claim is detected by audit. This strategy provides the highest penalty in case of fraud, without affecting equilibrium net payments

This upper bound on the penalty plays a crucial role in the analysis of optimal insurance contracts under random auditing. Indeed, by increasing the penalty, the insurer could induce truthtelling by the policyholder with a lower probability of auditing, which, since auditing is costly, reduces the cost of the private information. Consequently, if there were no bound on the penalty, first best optimality could be approximated with very large fines and a very low probability of auditing. Asymmetry of information would not be a problem in such a case.

In equilibrium, the policyholder always reports his loss truthfully. Hence, it is optimal to make the penalty as large as possible since this provides maximum incentive to tell the truth without affecting the equilibrium payoffs.²⁰ We thus have

$$t_A(x, \hat{x}) = P - B(x) \text{ if } x \neq \hat{x}.$$

Finally, we assume that the policyholder’s final wealth W_f should be larger than a lower bound denoted $A(x)$. This bound on the policyholder’s final wealth may simply result from a feasibility condition on consumption. In particular, we may have $W_f \geq 0$ which gives $A(x) = 0$ for all x . The lower bound on final wealth may also be logically linked to the upper bound on the penalty: when $B(x)$ corresponds to the value of liquid assets of the policyholder, we have $P - t_N(x) \leq B(x)$ and $P - t_A(x, x) \leq B(x)$ for all x which implies $W_f \geq W - x - B(x) \equiv A(x)$. Mookherjee and Png (1989) assume $B(x) = W - x$, which gives $A(x) = 0$. Fagart and Picard (1999) assume $B(x) = B$, which gives $A(x) = W - x - B$.

Let $t_A(x) \equiv t_A(x, x)$. Under random auditing, a contract will be denoted $\delta = \{t_A(\cdot), t_N(\cdot), p(\cdot), P\}$. An optimal contract maximizes

$$EU = \int_0^{\bar{x}} \{[1 - p(x)]U(W - P - x + t_N(x)) + p(x)U(W - P - x + t_A(x))\}dF(x) \tag{13.26}$$

with respect to $P, t_A(\cdot), t_N(\cdot)$, and $p(\cdot)$ subject to the following constraints:

$$E\Pi = P - \int_0^{\bar{x}} \{[1 - p(x)]t_N(x) + p(x)[t_A(x) + c]\}dF(x) \geq 0, \tag{13.27}$$

$$\begin{aligned} & [1 - p(x)]U(W - P - x + t_N(x)) + p(x)U(W - P - x + t_A(x)) \\ & \geq \\ & [1 - p(\hat{x})]U(W - P - x + t_N(\hat{x})) + p(\hat{x})U(W - x - B(x)) \end{aligned} \tag{13.28}$$

for all $x, \hat{x} \neq x$,

$$W - P - x + t_N(x) \geq A(x) \text{ for all } x, \tag{13.29}$$

$$W - P - x + t_A(x) \geq A(x) \text{ for all } x, \tag{13.30}$$

$$0 \leq p(x) \leq 1 \text{ for all } x. \tag{13.31}$$

$t_N - P$ and $t_A - P$. If the law of insurance contracts specifies a penalty \hat{B} to be paid in case of fraudulent claim, we have $P - t_A(x, \hat{x}) \leq \bar{P} + \hat{B}$ which corresponds to (13.25) with $B(x) \equiv \bar{P} + \hat{B}$.

²⁰In a more realistic setting, there would be several reasons for which imposing maximal penalties on defrauders may not be optimal. In particular, audit may be imperfect so that innocent individuals may be falsely accused. Furthermore, a policyholder may overestimate his damages in good faith. Lastly, very large fines may create incentives for policyholders caught cheating to bribe the auditor to overlook their violation.

Equation (13.27) is the insurer’s participation constraint. Inequalities (13.28) are the incentive compatibility constraints that require the policyholder to be willing to report his level of loss truthfully. Equations (13.29)–(13.31) are feasibility constraints.²¹

Mookherjee and Png (1989) have established a number of properties of an optimal contract. They are synthesized in Proposition 7 hereafter. In this proposition, $v(x)$ denotes the expected utility of the policyholder when his loss is x , i.e.,

$$v(x) = [1 - p(x)]U(W - P - x + t_N(x)) + p(x)U(W - P - x + t_A(x)).$$

Proposition 7. *Under random auditing, an optimal insurance contract $\delta = \{t_A(\cdot), t_N(\cdot), p(\cdot), P\}$, has the following properties:*

- (i) $p(x) < 1$ for all x if $v(x) > U(W - x - B(x))$ for all x .
- (ii) $t_A(x) > t_N(x)$ for all x such that $p(x) > 0$.
- (iii) If $p(\hat{x}) > 0$ for some \hat{x} then there exists x such that $v(x) = [1 - p(\hat{x})]U(W - x - P + t_N(\hat{x})) + p(\hat{x})U(W - x - B(x))$.
- (iv) If $v(x) > u(W - x - B(x))$ for all x and $t_N(\hat{x}) = \text{Min}\{t_N(x), x \in [0, \bar{x}]\}$, then $p(\hat{x}) = 0$ and $p(x'') > p(x')$ if $t_N(x'') > t_N(x')$.

In Proposition 7, the condition “ $v(x) > U(W - x - B(x))$ for all x ” means that nontrivial penalties can be imposed on those detected to have filed a fraudulent claim. Let us call it “condition C”. Mookherjee and Png (1989) assume $B(x) = W - x$, which means that the final wealth can be set equal to zero if the policyholder is detected to have lied. In such a case, C means that the final wealth is always positive at the optimum and a sufficient condition for C to hold is $U'(0_+) = +\infty$. If we assume $B(x) = B$, i.e., the penalty is upward bounded either because of a liquidity constraint or because of statutory provisions, then C holds if B is large enough.²² If C does not hold at equilibrium, then the optimal audit policy is deterministic and we are back to the characterization of Sect. 13.2. In particular, the $B = 0$ case reverts to deterministic auditing.

From (i) in Proposition 4, all audits must be random if C holds. The intuition for this result is that under C, the policyholder would always strictly prefer not to lie if his claim were audited with probability one. In such a case, decreasing slightly the audit probability reduces the insurer’s expected cost. This permits a decrease in the premium P and thus an increase in the expected utility of the policyholder, without inducing the latter to lie. (ii) shows that the policyholder who has been verified to have reported his damages truthfully should be rewarded. The intuition is as follows. Assume $t_A(x) < t_N(x)$ for some x . Let $t_A(x)$ —respect. $t_N(x)$ —be increased (respect. decreased) slightly so that the expected cost $p(x)t_A(x) + [1 - p(x)]t_N(x)$ is unchanged. This change does not disturb the incentive compatibility constraints and it increases the expected utility which contradicts the optimality of the initial contract. If $t_A(x) = t_N(x)$, the same variation exerts no first-order effect on the expected utility (since we start from a full insurance position) and it allows the insurer to reduce $p(x)$ without disturbing any incentive compatibility constraint. The expected cost decreases, which enables a decrease in the premium P and thus generates an increase in the expected utility. This also contradicts the optimality of the initial contract. (iii) shows that for any level of loss \hat{x} audited with positive probability, there exists a level of loss x such that the policyholder who suffers the loss x is

²¹Deterministic auditing may be considered as a particular case of random auditing where $p(x) = 1$ if $x \in M$ and $p(x) = 0$ if $x \in M^c$, and Lemma 1 may be obtained as a consequence of the incentive compatibility conditions (13.28). If $x, \hat{x} \in M^c$, (13.28) gives $t_N(x) \geq t_N(\hat{x})$. Interverting x and \hat{x} gives $t_N(\hat{x}) \geq t_N(x)$. We thus have $t_N(x) = t_0$ for all x in M^c . If $x \in M$ and $x \in M^c$, (13.28) gives $t_A(x) \geq t_N(\hat{x}) = t_0$. If $t_A(x) = t_0$ for $x \in [a, b] \subset M$, then it is possible to choose $p(x) = 0$ if $x \in [a, b]$, and to decrease P , the other elements of the optimal contract being unchanged. The policyholder’s expected utility would increase, which is a contradiction. Hence $t_A(x) > t_0$ if $x \in M$.

²²See Fagart and Picard (1999).

indifferent between filing a truthful claim and reporting \hat{x} . In other words, when a claim \hat{x} is audited with positive probability, a decrease in the probability of audit $p(\hat{x})$ would induce misreporting by the policyholder for (at least) one level of loss x . Indeed, if this were not the case, then one could lower $p(\hat{x})$ without disturbing any incentive compatibility constraint. This variation allows the insurer to save on audit cost and it enables a decrease in the premium. The policyholder’s expected utility increases which contradicts the optimality of the initial contract. Finally, (iv) shows that, under **C**, the claim corresponding to the lowest indemnity payment in the absence of audit should not be audited. All other claims should be audited and the larger the indemnity payment in the absence of audit, the larger the probability of audit. Once again, the intuition is rather straightforward. A policyholder who files a fraudulent claim \hat{x} may be seen as a gambler who wins the prize $t_N(\hat{x})$ if he has the luck not to be audited and who will pay $B(x)$ if he gets caught. The larger the prize, the larger the audit probability should be for fraudulent claiming to be deterred. Furthermore it is useless to verify the claims corresponding to the lowest prize since it always provides a lower expected utility than truthtelling.

The main difficulty if one wants to further characterize the optimal contract under random auditing is to identify the incentive compatibility constraints that are binding at the optimum and those that are not binding. In particular, it may be that, for some levels of damages, many (and even all) incentive constraints are binding and, for other levels of damages, none of them are binding.²³ Fagart and Picard (1999) provide a full characterization of the optimal coverage schedule and of the audit policy when the policyholder has constant absolute risk aversion and the penalty is constant (i.e., $B(x) \equiv B$).

Proposition 8. *Assume $U(\cdot)$ exhibits constant absolute risk aversion and **C** holds at the optimum. Then there exist $m > 0$ and $k \in (0, m)$ such that*

$$t_A(x) = x - k \text{ and } t_N(x) = x - k - \eta(x) \text{ if } x > m$$

$$t_A(x) = t_N(x) = 0 \text{ if } x \leq m$$

with $\eta(x) > 0, \eta'(x) < 0, \eta(m) = m - k, \eta(x) \rightarrow 0$ when $x \rightarrow \infty$.

Furthermore, we have

$$0 < p(x) < 1, p'(x) > 0, p''(x) < 0 \text{ when } x > m$$

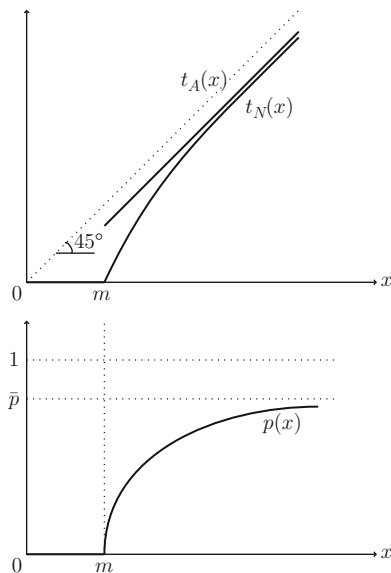
$$p(m) = 0$$

$$p(x) \rightarrow \bar{p} \in (0, 1) \text{ when } x \rightarrow \infty.$$

The optimal contract characterized in Proposition 8 is depicted in Fig. 13.7. No claim is filed, when the magnitude of damages is less than m . When the damages exceed the threshold, then the insurance payment is positive and it is larger when the claim is audited than when it is not—which confirms Proposition 7-(ii). However the difference is decreasing when the magnitude of damages is increasing and this difference goes to zero when the damages go to infinity (when $\bar{x} = +\infty$). Marginal damages are fully covered in case of audit, i.e., $t'_A(x) = 1$ if $x > m$. In other words, the insurance coverage includes a constant deductible k if the claim is verified. If the claim is not verified, then there is also an additional deductible that disappears when the damages become infinitely large. Furthermore the probability of audit is a concave increasing function of the damages and this probability goes to a limit $\bar{p} < 1$ when x goes to infinity.

²³Technically, this rules out the possibility of taking up the differential approach initially developed by Guesnerie and Laffont (1984) and widely used in the literature on incentives contracts under adverse selection.

Fig. 13.7 Optimal insurance contract under random auditing when $U(\cdot)$ is CARA



To understand the logic of these results, observe that any variation in insurance payment (with a compensating change in the premium) entails two effects. Firstly, it affects the risk sharing between the insurer and the policyholder and, of course, this is the *raison d'être* of any insurance contract. Secondly, it may also modify the audit policy for incentive compatibility constraints not to be disturbed. This second effect is more difficult to analyze because the effects of variations in insurance payment on the incentive to tell the truth are intricate. As above, we may describe the decision-making of the policyholder as if he were a gambler. When the true level of damages is x , filing a fraudulent claim $\hat{x} \neq x$ amounts to choose the lottery “earning $t_N(\hat{x})$ with probability $1 - p(\hat{x})$ or losing B with probability $p(\hat{x})$ ” in preference to the lottery “earning $t_N(x)$ with probability $1 - p(x)$ or earning $t_A(x)$ with probability $p(x)$.” If the incentive compatibility constraint corresponding to x and \hat{x} is tight, then any increase in $t_N(\hat{x})$ should be accompanied by an increase in $p(\hat{x})$ for fraudulent claiming to be deterred. However, simultaneously, the increase in $t_N(\hat{x})$ may also affect the optimal strategy of a policyholder who has actually experienced a loss \hat{x} and who (for instance) intended to file another fraudulent claim, say $\hat{x}' \neq \hat{x}$. This policyholder may come back to truthfulling after the increase in $t_N(\hat{x})$, even if $t_N(\hat{x}')$ is slightly increased. This sequence is possible if the preferences of our gambler over lotteries depend upon his wealth, i.e., upon the magnitude of his loss. This suggests that, without simplifying assumptions, analyzing the consequences of a variation in the coverage schedule on the policyholder’s strategy may be quite intricate.

The problem is much more simple under constant absolute risk aversion since wealth effects disappear from the incentive constraints when utility is exponential. [Fagart and Picard \(1999\)](#) have considered this case. They show that, when $U(\cdot)$ is CARA, the only incentive constraints that may be binding at the optimum correspond to loss levels $x \in I \subset [0, \bar{x}]$ for which the policyholder receives the smallest indemnity payment. This results from the fact that, when $U(\cdot)$ is CARA, the loss x disappears from (13.28). We know from Proposition 7-(ii) and (iv) that the claim is not audited in that case, which allows us to assume $t_N(x) = t_A(x) = 0$ if $x \in I$ since, as before, the optimal insurance coverage schedule $\{t_N(\cdot), t_A(\cdot), P\}$ is defined up to an additive constant. The best risk sharing is reached when $I = [0, m]$, with $m > 0$. Under constant absolute risk aversion, the fact that small claims should not be audited can thus be extended to the case of random auditing.

When the loss exceeds m , it is optimal to provide a positive insurance payment. Any increase in $t_N(x)$ should be accompanied by an increase in $p(x)$ for fraudulent claiming to be deterred. Let

$\Phi(t_N)$ be the probability of audit for which the lottery “earning $t_N(x)$ with probability $1 - p(x)$ or losing B with the probability $p(x)$ ” and the status quo (i.e., a zero certain gain) are equivalent for the policyholder when his true loss level \tilde{x} is in I . The probability $\Phi(t_N)$ does not depend on \tilde{x} when $U(\cdot)$ is CARA and we have $\Phi' > 0$, $\Phi'' < 0$. The optimal audit probability is such that $p(x) = \Phi(t_N(x))$ for all $x > m$.

Let $c\Phi'(t_N(x))dt_N(x)$ be the additional expected audit cost induced by a marginal increase in the insurance payment $dt_N(x)$. Adding this additional expected audit cost to the variation in the insurance payment itself gives the additional expected total cost $[1 + c\Phi'(t_N(x))]dt_N(x)$. When a claim is audited, the additional cost induced by an increase in the insurance payment is just $dt_A(x)$. The difference in additional cost per \$ paid as coverage explains why a larger payment should be promised in case of audit—i.e., $t_A(x) > t_N(x)$. More precisely, $\Phi'' < 0$ implies that $1 + c\Phi'(t_N(x))$ is decreasing when $t_N(x)$ is increasing. Hence, the difference in the additional expected cost per \$ paid as coverage decreases when $t_N(x)$ increases. This explains why the additional deductible $t_A(x) - t_N(x) \equiv \eta(x)$ is decreasing and disappears when x is large.²⁴

13.6 Moral Standards and Adverse Selection

Thus far we have assumed that the policyholders are guided only by self-interest and that they did not feel any moral cost after filing a fraudulent claim. In other words, there was no intrinsic value of honesty to policyholders. In the real world, thank God, dishonesty creates moral problems, and a lot of people are deterred to file fraudulent claim even if the probability of being caught is small and the fine is moderate. However, more often than not, the insurers are unable to observe the moral cost incurred by their customers which lead to an adverse selection problem.²⁵ In such a situation, the optimal audit policy as well as the competitive equilibrium in the insurance market (in terms of coverage and premium) may be strongly affected by the distribution of moral costs in the population of policyholders. In particular, the consequences of insurance fraud will be all the more severe that the proportion of purely opportunistic policyholders (i.e., individuals without any moral cost) is large.

We will approach this issue in the following setting, drawn from Picard (1996).²⁶ Assume that the insurance buyers face the possibility of a loss L with probability $\delta \in (0, 1)$. Hence, for the sake of simplicity, the size of the loss is now given. The insurance contract involves a premium P and a level of coverage t . The insurer audits claims with a probability $p \in [0, 1]$ at cost c . To simplify further the analysis, we assume that the insurance payment t is the same, whether the claim is audited or not. The reservation utility is $\bar{U} = \delta U(W - L) + (1 - \delta)U(W)$. The policyholders may be either opportunist, with probability θ or honest with probability $1 - \theta$, with $0 < \theta < 1$. Honest policyholders truthfully report losses to their insurer: they would suffer very large moral cost when cheating. Opportunists may choose to fraudulently report a loss. Let α be the (endogenously determined) probability for an opportunist to file a fraudulent claim when no loss has been incurred. The insurers cannot distinguish honest policyholders from opportunists.

Law exogenously defines the fine, denoted B , that has to be paid by a policyholder who is detected to have lied. Let \tilde{p} denote the audit probability that makes an opportunist (who has not experienced any loss) indifferent between honesty and fraud. Honesty gives $W_f = W - P$ where W (respect. W_f) still denotes the initial (respect. final) wealth of the policyholder. Fraud gives $W_f = W - P - B$ if the

²⁴Let $\bar{U}(x) = [1 - p(x)]U(W - P - x + t_N(x)) + p(x)U(W - P - x + t_A(x))$ be the expected utility of a policyholder who has incurred a loss x . Using $p(m) = 0$ shows that $\bar{U}(x)$ is continuous at $x = m$.

²⁵This asymmetric information problem may be mitigated in a repeated relationship framework.

²⁶See also Boyer (1999) for a similar model.

claim is audited and $W_f = W - P + t$ otherwise. Hence \tilde{p} is given by

$$U(W - P) = \tilde{p}U(W - P - B) + (1 - \tilde{p})U(W - P + t),$$

which implies

$$\tilde{p} = \frac{U(W - P + t) - U(W - P)}{U(W - P + t) - U(W - P - B)} \equiv \tilde{p}(t, P) \in (0, 1).$$

Consider a contract (t, P) chosen by a population of individuals that includes a proportion $\sigma \in [0, 1]$ of opportunists. Note that σ may conceivably differ from θ if various contracts are offered on the market. Given (q, P, σ) , the relationship between a policyholder and his insurer is described by the following three-stage game:

- At stage 1, *nature* determines whether the policyholder is honest or opportunist, with probabilities $1 - \sigma$ and σ , respectively. Nature also determines whether the policyholder experiences a loss with probability δ .
- At stage 2, the *policyholder* decides to file a claim or not. Honest customers always tell the truth. When no loss has been incurred, opportunists defraud with probability α .
- At stage 3, when a loss has been reported at stage 2, the insurer audits with probability p .

Opportunists who do not experience any loss choose α to maximize

$$EU = \alpha[pU(W - P - B) + (1 - p)U(W - P + t)] + (1 - \alpha)U(W - P),$$

which gives

$$\left. \begin{aligned} \alpha &= 0 && \text{if } p > \tilde{p}(t, P), \\ \alpha &\in [0, 1] && \text{if } p = \tilde{p}(t, P), \\ \alpha &= 1 && \text{if } p < \tilde{p}(t, P). \end{aligned} \right\} \quad (13.32)$$

The insurer chooses p to maximize its expected profit $E\Pi$ or equivalently to minimize the expected cost C defined by

$$C = IC + AC,$$

with

$$E\Pi = P - C,$$

where IC and AC are, respectively, the expected insurance coverage and the expected audit cost.²⁷

Insurance coverage is paid to the policyholders who actually experience a loss and to the opportunists who fraudulently report a loss and are not audited. We have

$$IC = t[\delta + \alpha\sigma(1 - \delta)(1 - p)] \quad (13.33)$$

$$AC = pc[\delta + \alpha\sigma(1 - \delta)] \quad (13.34)$$

As in the previous sections, we assume that the insurer can commit to his audit policy which means that he has a Stackelberg advantage in the audit game: the audit probability p is chosen to minimize C given the reaction function of opportunists. Since in the next section we want to contrast

²⁷For the sake of simplicity, we assume that no award is paid to the insurer when an opportunist is caught cheating. The fine B is entirely paid to the government.

such an equilibrium with a situation where the insurer cannot commit to its audit policy, we refer to this commitment equilibrium with the upper index c . Let $\alpha^c(t, P, \sigma)$, $p^c(t, P, \sigma)$, and $C^c(t, P, \sigma)$ be, respectively, the equilibrium strategies of opportunists and insurers and the equilibrium expected cost in an audit game (q, P, σ) under commitment to audit policy. Proposition 9 characterizes these functions.

Proposition 9. *Under commitment to audit policy, the equilibrium of an audit game (t, P, σ) is characterized by*

$$\begin{aligned}
 p^c(t, P, \sigma) &= 0 \text{ and } \alpha^c(t, P, \sigma) = 1 \text{ if } c > c_0(t, P, \sigma), \\
 p^c(t, P, \sigma) &= \tilde{p}(q, P) \text{ and } \alpha^c(t, P, \sigma) = 0 \text{ if } c \leq c_0(t, P, \sigma), \\
 C^c(t, P, \sigma) &= \min\{\delta + \sigma(1 - \delta)\}, \delta[t + \tilde{p}(t, P)c\},
 \end{aligned}$$

where

$$c_0(t, P, \sigma) = \frac{(1 - \delta)\sigma t}{\sigma \tilde{p}(t, P)}.$$

The proof of Proposition 9 is straightforward. Only two strategies may be optimal for the insurer: either fully preventing fraud by auditing claims with probability $p = \tilde{p}(t, P)$ which gives $\alpha = 0$ ²⁸ or abstaining from any audit ($p = 0$) which gives $\alpha = 1$. The optimal audit strategy is chosen so as to maximize C . Using (13.33) and (13.34) gives the result. Proposition 9 shows in particular that, given the contract (t, P) , preventing fraud through an audit policy is optimal if the audit cost c is low enough and the proportion of opportunists σ is large enough.

We now consider a competitive insurance market with free entry, where insurers compete by offering policies. An adverse selection feature is brought in the model because the insurers cannot distinguish opportunists from honest policyholders. Following the approach of Wilson (1977), a market equilibrium is defined as a set of profitable contracts such that no insurer can offer another contract which remains profitable after the other insurers have withdrawn all non-profitable contracts in reaction to the offer. Picard (1996) characterizes the market equilibrium by assuming that honest individuals are uniformly distributed among the best contracts, likewise for opportunists. This assumption will be called **A**. Let²⁹

$$\begin{aligned}
 (t^c, P^c) &= \text{Arg Max}_{t, P} \{ \delta U(W - L + t - P) + (1 - \delta)U(W - P) \\
 &\quad \text{s.t. } P \geq C^c(t, P, \theta) \}.
 \end{aligned}$$

Proposition 10. *Under **A**, (t^c, P^c) is the unique market equilibrium when the insurers can commit to their audit policy.*

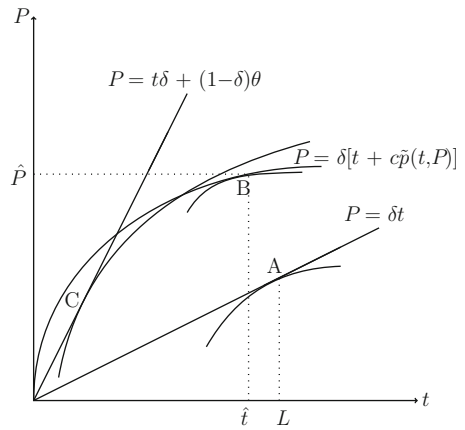
According to Proposition 10, a market equilibrium is defined by a unique contract (t^c, P^c) that maximizes the expected utility of honest policyholders under the constraint that opportunists cannot be set aside.³⁰ The arguments at work in the proof of Proposition 10 can be summarized

²⁸ $\alpha = 0$ is an optimal strategy for opportunists when $p = \tilde{p}(t, P)$ and it is the *only* optimal strategy if $p = \tilde{p}(t, P) + \varepsilon, \varepsilon > 0$.

²⁹We assume that (t^c, P^c) is a singleton.

³⁰Proposition 10 shows that a pooling contract is offered at equilibrium: there does not exist any separating equilibrium where honest and opportunist individuals would choose different contracts. This result is also obtained by Boyer (1999) in a similar framework.

Fig. 13.8 The market equilibrium is at point B when $\theta > \hat{\theta}$



as follows. Let us first note that all contracts offered at equilibrium are necessarily equivalent for honest customers; otherwise some equilibrium contracts would only attract opportunists. Given **A**, this would imply that $\alpha = 1$ is the equilibrium strategy of opportunists for such contract and these contracts could not be profitable. Equilibrium contracts are also equivalent for opportunists. Assume *a contrario* that opportunists concentrate on a subset of equilibrium contracts. For these contracts, the proportion of opportunists is larger than θ , and honest individuals prefer (t^c, P^c) to these contracts. A contract $(t^c - \varepsilon, P^c)$, $\varepsilon > 0$ would attract all honest individuals for ε small and would remain profitable even if opportunists finally also opt for this new contract. This contradicts the definition of a market equilibrium. Hence, for any contract (t, P) offered at the equilibrium, the insurers' participation constraint is $P \geq C^c(t, P, \theta)$. If (t^c, P^c) is not offered, then another contract could be proposed that would be strictly preferred by honest individuals and that would remain profitable whatever the reaction of opportunists. Hence (t^c, P^c) is the only possible market equilibrium. Another contract (\tilde{t}, \tilde{P}) offered in addition to (t^c, P^c) will be profitable if it attracts honest individuals only³¹ and if $\tilde{P} > \delta\tilde{t}$. If (\tilde{t}, \tilde{P}) were offered, the insurers that go on offering (t^c, P^c) lose money. Indeed in such a case we necessarily have $\alpha^c(t^c, P^c, \tilde{\sigma}) = 1$ where $\tilde{\sigma}$ is the proportion of opportunists in the population of insureds who still choose (t^c, P^c) after (\tilde{t}, \tilde{P}) has been offered with $\tilde{\sigma} > \theta$.³²

We then have

$$C^c(t^c, P^c, \sigma^c) = t^c[\delta + \tilde{\sigma}(1 - \delta)] > t^c[\delta + \theta(1 - \delta)] \geq C^c(t^c, P^c, \theta) = P^c,$$

which proves that (t^c, P^c) becomes nonprofitable. Hence (t^c, P^c) will be withdrawn and all individuals will turn toward the new contract (\tilde{t}, \tilde{P}) . This new contract will show a deficit and it will not be offered, which establishes that (t^c, P^c) is the market equilibrium.

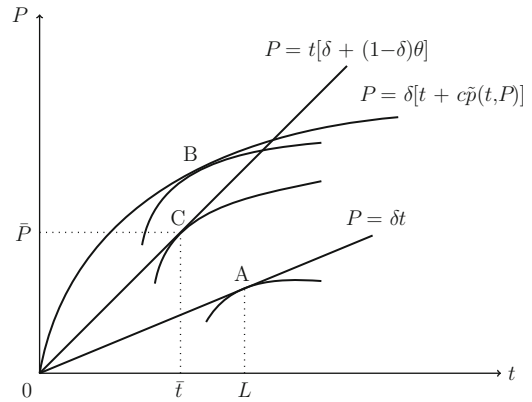
The market equilibrium is depicted in Figs. 13.8 and 13.9. The perfect information market equilibrium is **A** with full insurance offered at fair premium.

Maximizing $EU = \delta U(W - L - P + t) + (1 - \delta)U(W - P)$ with respect to $t \geq 0, P \geq 0$ subject to $P = \delta[t + c\tilde{p}(t, P)]$ gives $t = \hat{t}$ and $P = \hat{P}$ at point **B**. We denote η_B the expected utility at **B** and we assume $\eta_B > \bar{U}$, i.e., the origin of the axis is over the indifference curve that

³¹Opportunists cannot benefit from separating and (t^c, P^c) is the best pooling contract for honest individuals.

³²We have $\tilde{\sigma} = 1$ if all honest policyholders choose (\tilde{t}, \tilde{P}) and $\tilde{\sigma} = \frac{2\theta}{\theta+1}$ if (\tilde{t}, \tilde{P}) and (t^c, P^c) are equivalent for honest policyholders.

Fig. 13.9 The market equilibrium is at point C when $\theta < \hat{\theta}$



goes through B . This assumption is satisfied if the audit cost c is not too large. Maximizing EU with respect to $t \geq 0, P \geq 0$ subject to $P = t[\delta + (1 - \delta)\theta]$ gives $t = \bar{t}$ and $P = \bar{P}$ at point C . We denote $\eta_C(\theta)$ the expected utility at C , with $\eta'_C(\theta) < 0$. Let $\hat{\theta} \in (0, 1)$ such that $\eta_B = \eta_C(\hat{\theta})$. When $\theta > \hat{\theta}$, the market equilibrium is at B : the insurers audit claims with probability $\tilde{p}(\hat{t}, \hat{P})$ and the opportunists are deterred from defrauding. When $\theta < \hat{\theta}$, the market equilibrium is at C : the insurers do not audit claims because the proportion of opportunists is too small for verifying claims to be profitable and the opportunists systematically defraud. Hence, when $\theta < \hat{\theta}$, there is fraud at equilibrium.

Here, we have assumed that the proportion of opportunistic individuals in the population is exogenously given. Note however that moral standards may be affected by the perception of insurers' honesty and also by beliefs about the prevalence of fraud among policyholders.³³ It has been widely documented in the business ethics literature that insurance defrauders often do not perceive insurance claim padding as an unethical behavior and even tend to practice some kind of self-justification. In particular, a common view among consumers holds that insurance fraud would just be the rational response to the unfair behavior of insurance companies. Tennyson (1997, 2002) emphasizes that the psychological attitude toward insurance fraud is related to the perception of the fairness of insurance firms by policyholders. She shows that negative perceptions of insurance institutions are related to attitudes toward filing exaggerated claims. For instance, Tennyson (2002) shows that consumers who are not confident of the financial stability of their insurer and those who find auto insurance premiums to be burdensomely high are more likely than others to find fraud acceptable. Thus, consumers would tend to rationalize and justify their fraudulent claims through their negative perceptions of insurance companies.³⁴

Fukukawa et al. (2007) substantiate this approach of the psychology of insurance defrauders.³⁵ They use a questionnaire to examine the factors that influence the decision-making of "aberrant consumer behaviors" (ACB) such as not only exaggerating an insurance claim but also changing a price tag, returning a stained suit, copying software from a friend, and taking a quality towel from a hotel. Four factors emerged from a Principal Component Analysis, with among them the perception of unfairness relating to business practice.³⁶ Fukukawa et al. (2007) show that the perceived unfairness

³³Poverty may also affect morality. In particular, moral standards may decrease when the economic situation worsens. Dionne and Wang (2013) analyze the empirical relationship between opportunistic fraud and the business cycle in the Taiwan automobile theft insurance market. They show that fraud is stimulated during periods of recession and mitigated during periods of expansion.

³⁴See also Dean (2004) on the perception of the ethicality of insurance claim fraud.

³⁵See also Strutton et al. (1994) on how consumers may justify inappropriate behavior in market settings.

³⁶The *perceived unfairness* factor is comprised of items related to the perception of unfair business practice, for instance, because the insurer is overcharging or because ACB is nothing but retaliation against some inadequate practice or

factor is dominant in characterizing the occurrence of the scenario where individuals exaggerate claims and that its effect on insurance fraud is significantly larger than on the other aberrant behavior scenarios.³⁷ Likewise, individuals' moral standards may depend on their perception of ethics heterogeneity: a policyholder may choose to be honest if he thinks this is the standard behavior in the society around him, but he may start cheating if he thinks "everybody does it." Such perceptions of social ethical standards would affect the proportion θ of opportunistic policyholders.

13.7 The Credibility Issue

In a situation where there are many opportunist policyholders, it is essential for insurers to credibly announce that a tough monitoring policy will be enforced, with a high probability of claim verification and a high level of scrutiny for suspected fraud. In the model introduced in the previous section, this was reached by announcing that claims are audited with probability $\tilde{p}(t, P)$. However, since auditing is costly to the insurer, a commitment to such a tough audit policy may not be credible.

In the absence of commitment, i.e., when the insurer has no Stackelberg advantage in the audit game, the auditing strategy of the insurer is constrained to be a best response to opportunists' fraud strategy, in a way similar to tax compliance games³⁸ studied by Graetz et al. (1986) and Melumad and Mookherjee (1989).³⁹ In the model introduced in the previous section, under no commitment to audit policy, the outcome of an audit game (t, P, σ) corresponds to a perfect Bayesian equilibrium, where (a) the fraud strategy is optimal for an opportunist given the audit policy, (b) the audit policy is optimal for the insurer given beliefs about the probability of a claim to be fraudulent, and (c) the insurer's beliefs are obtained from the probability of loss and opportunist's strategy using Bayes' rule.

Let $\alpha^n(t, P, \sigma)$ and $p^n(t, P, \sigma)$ be the equilibrium strategy of opportunists and of insurers, respectively, in an audit game in the absence of commitment to an audit policy and let $C^n(t, P, \sigma)$ be the corresponding expected cost.

Proposition 11. *Without commitment to an audit policy, the equilibrium of an audit game (t, P, σ) is characterized by⁴⁰*

$$p^n(t, P, \sigma) = 0 \text{ and } \alpha^n(t, P, \sigma) = 1 \text{ if } c > c_1(t, \sigma),$$

$$p^n(t, P, \sigma) = \tilde{p}(t, P) \text{ and } \alpha^n(t, P, \sigma) = \frac{\delta c}{\sigma(1 - \delta)(t - c)} \text{ if } c > c_1(t, \sigma),$$

$$C^n(t, \sigma) = \min \left\{ t[\delta + \sigma(1 - \delta)], \frac{\delta t^2}{t - c} \right\},$$

because of weak business performance. Other factors are labeled *evaluation* (loading variables relating to the easiness to engage in ACB or to the general attitude toward ACB), *social participation* (with variables representing the social external encouragement to ACB), and *consequence* (measuring the extent to which the outcomes of ACB are seen as beneficial or harmful).

³⁷See Bourgeon and Picard (2012) for a model where policyholder's moral standards depend on the attitude of insurers who may nitpick claims and sometimes deny them if possible.

³⁸See Andreoni et al. (1998) for a survey on tax compliance.

³⁹Cummins and Tennyson (1994) analyze liability claims fraud within a model without Stackelberg advantage for insurers: each insurer chooses his fraud control level to minimize the costs induced by fraudulent claims.

⁴⁰We assume $t > c$ and we neglect the case $c = c_1(t, \sigma)$. See Picard (1996) for details.

where

$$c_1(t, \sigma) = \frac{\sigma(1 - \sigma)t}{\sigma(1 - \sigma) + \delta}.$$

The proof of Proposition 11 may be sketched as follows. Let π be the probability for a claim to be fraudulent. Bayes' rule gives

$$\pi = \frac{\alpha\sigma(1 - \delta)}{\alpha\sigma(1 - \delta) + \delta}. \tag{13.35}$$

Once a policyholder puts in a claim, the (conditional) insurer's expected cost is

$$\bar{C} = p[c + (1 - \pi)t] + (1 - p)t. \tag{13.36}$$

The equilibrium audit policy minimizes \bar{C} with respect to p which gives

$$\left. \begin{aligned} p &= 0 && \text{if } \pi t < c, \\ p &\in [0, 1] && \text{if } \pi t = c, \\ p &= 1 && \text{if } \pi t > c. \end{aligned} \right\} \tag{13.37}$$

The equilibrium of the no-commitment audit game is a solution (α, p, π) to (13.32), (13.35), and (13.37). Let us compare Proposition 11–Proposition 9. At a no-commitment equilibrium, there is always some degree of fraud: $\alpha = 0$ cannot be an equilibrium strategy since any audit policy that totally prevents fraud is not credible. Furthermore, we have $c_1(t, \sigma) < c_0(t, P, \sigma)$ for all t, P, σ which means that the optimal audit strategy $p = \tilde{p}(t, P, \sigma)$ that discourages fraud is optimal for a larger set of contracts in the commitment game than in the no-commitment game. Lastly, we have $C^n(t, \sigma) \geq C^c(t, P, \sigma)$ with a strong inequality when the no-commitment game involves $p > 0$ at equilibrium. Indeed, at a no-commitment equilibrium, there must be some degree of fraud for an audit policy to be credible which increases insurance expected cost.⁴¹

The analysis of market equilibrium follows the name logic as in the commitment case. Let

$$\begin{aligned} (t^n, P^n) &= \text{Arg Max}_{t, P} \{ \delta U(W - L + t - P) + (1 - \delta)U(W - P) \\ &\text{s.t. } P \geq C^n(t, P, \theta) \end{aligned}$$

be the pooling contract that maximizes the expected utility of honest policyholders.⁴²

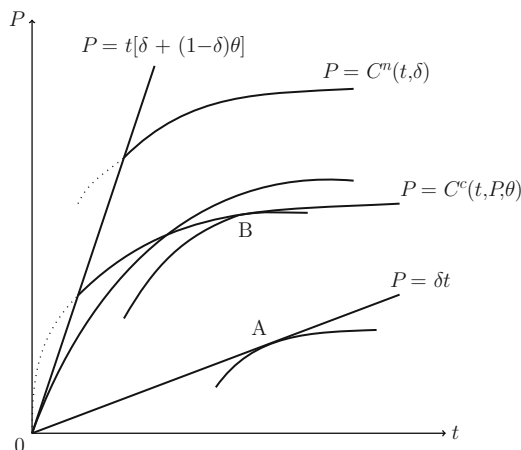
Proposition 12. *Under A, (t^n, P^n) is the unique market equilibrium when the insurers cannot commit to their audit policy.*

The expected utility of honest policyholders is higher at the commitment equilibrium than at the no-commitment equilibrium. To highlight the welfare costs of the no-commitment constraint, let us focus attention on the case where θ is sufficiently large so that, in the absence of claims' verification, honest customers would prefer not to take out an insurance policy than to pay high premiums that cover the cost of systematic fraud by opportunists. This means that point C is at the origin of the axis in Figs. 13.8 and 13.9, which occurs if $\theta \geq \theta^*$, with

⁴¹As shown by Boyer (1999), when the probability of auditing is strictly positive at equilibrium (which occurs when θ is large enough), then the amount of fraud $(1 - \delta) \theta \alpha^n(t^n, P^n, \theta) = \delta c / (t^n - c)$ does not depend on θ . Note that t^n does not (locally) depend on θ when $c < c_1(t^n, \theta)$.

⁴²We assume that (t^n, P^n) is a singleton.

Fig. 13.10 Case where the market shuts down at no-commitment equilibrium



$$\theta^* = \frac{\delta[U'(W - L) - U'(W)]}{\delta U'(W - L) + (1 - \delta)U'(W)} \in (0, 1).$$

In Fig. 13.10, the commitment equilibrium is at point *B* (i.e., $\theta < \theta^*$) and the no-commitment equilibrium is at the origin of the axis: the market shuts down completely at $t = t^n = 0$.⁴³

Hence, besides the inevitable market inefficiency induced by the cost of auditing (i.e., going from *A* to *B* in Fig. 13.10), the inability of insurers to commit to an audit policy induces an additional welfare loss (from *B* to 0). How can this particular inefficiency be overcome? Several solutions have been put forward in the literature. A first solution, developed by [Melumad and Mookherjee \(1989\)](#) in the case of income tax audits, is to delegate authority over an audit policy to an independent agent in charge of investigating claims. An incentive contract offered by the insurer to the investigator could induce a tough monitoring strategy, and precommitment effects would be obtained by publicly announcing that such incentives have been given to the investigator. Secondly, [Picard \(1996\)](#) shows that transferring audit costs to a budget balanced common agency may help to solve the commitment problem. The common agency takes charge of part of the audit expenditures decided by insurers and is financed by lump-sum participation fees. This mechanism mitigates the commitment problem and may even settle it completely if there is no asymmetric information between the agency and the insurers about audit costs. See also [Boyer \(2000\)](#) on the centralization of insurance fraud investigation. Thirdly, [Krawczyk \(2009\)](#) shows that putting the insurer–policyholder interaction in a dynamic context reduces the intensity of the commitment problem. More specifically, he nests insurer–policyholder encounters into a supergame with a sequence of customers. Using the folk theorem for repeated games with many short-lived agents (see [Fudenberg et al. 1990](#)), he shows that the capacity of an insurer to develop its reputation for “toughness” and deter fraud depends on the observability of its auditing strategy. Under full observability of the mixed auditing strategy, fraud can be fully deterred, provided the insurers’ discount factor is large enough, i.e., they are sufficiently patient. More realistically, if policyholders base their decisions on sampling information from the past period, then only partial efficiency gains are possible, and the larger the size of the sample of observed insurer–policyholder interactions, the lower the frequency and thus the cost of fraud. Hence, signalling claims monitoring effort to policyholders should be part and parcel of the struggle against insurance fraud.

⁴³It can be shown that $t^n > L$ when there is some audit at equilibrium, that is, when $\theta > \theta^*$. [Boyer \(2004\)](#) establishes this result in a slightly different model. Intuitively, increasing t over L maintains the audit incentives at the right level for a lower fraud rate π , because we should have $\pi t = c$ for $p = \tilde{p}(t, P) \in (0, 1)$ to be an optimal choice of insurers. In the neighborhood of $t = L$, an increase in t only induces second-order risk-sharing effects, and ultimately that will be favorable to the insured.

13.8 Using Fraud Signals

When there is a risk of fraud, it is in the interest of insurers to use signals on agents’ losses when deciding whether a costly verification should be performed. This leads us to make a connection between optimal auditing and scoring techniques.

We will start with the simple case where the insurer perceives a binary signal $s \in \{s_1, s_2\}$ when a policyholder files a claim. The signal s is observed by the insurer and it cannot be controlled by defrauders. Let q_i^f and q_i^n be, respectively, the probability of $s = s_i$ when the claim is fraudulent (i.e., when no loss occurred) and when it corresponds to a true loss, with $0 < q_2^n < q_2^f$ and $q_1^n + q_2^n = q_1^f + q_2^f = 1$. Thus, we assume that s_2 is more frequently observed when the claim is fraudulent than when it corresponds to a true loss: s_2 may be interpreted as a fraud signal that should make the insurer more suspicious. The decision to audit can now be conditioned on the perceived fraud signal. Let us first assume that the insurer can commit to its auditing strategy. $\hat{p}_i \in [0, 1]$ denotes the audit probability when signal s_i is perceived, with $\hat{p} = (\hat{p}_1, \hat{p}_2)$. $\tilde{p}(t, P)$ still denotes the audit probability that deters opportunistic individuals from filing fraudulent claims. If $q_2^f \geq \tilde{p}(t, P)$, then fraud is deterred if $\hat{p}_2 \geq \tilde{p}(t, P)/q_2^f$ and $\hat{p}_1 = 0$. If $q_2^f < \tilde{p}(t, P)$, the fraud is deterred if $\hat{p}_2 = 1$ and $\hat{p}_1 = [\tilde{p}(t, P) - q_2^f]/(1 - q_2^f) < 1$. In other words, we here assume that the insurer’s auditing strategy prioritizes the claims with signal s_2 . If auditing these claims with probability one is not enough for fraud to be deterred, then a proportion of the claims with signal s_1 are also audited. We will check later that such a strategy is optimal. For the sake of brevity, let us consider here the case where the optimal contract is such that $q_2^f > \tilde{p}(t, P)$. Expected insurance cost IC and expected audit cost AC are now written as

$$\begin{aligned} \text{IC} &= t[\delta + \alpha\sigma(1 - \delta)(1 - \hat{p}_2q_2^f)], \\ \text{AC} &= \hat{p}_2c[q_2^n\delta + \alpha\sigma(1 - \delta)q_2^f], \end{aligned}$$

with unchanged definitions of $\delta, \alpha, \sigma, c$, and t . As in Sect. 13.6, the insurer may decide either to deter fraud by opportunistic individuals—he would choose $\hat{p}_1 = 0, \hat{p}_2 = \tilde{p}(t, P)/q_2^f \in (0, 1)$ —or not ($\hat{p}_1 = \hat{p}_2 = 0$). When fraud is deterred, we have $\alpha = 0$ and the cost of a claim is

$$C = \delta(t + \hat{p}_2cq_2^n) = \delta \left[t + \tilde{p}(t, P)c \frac{q_2^n}{q_2^f} \right].$$

Thus, under commitment to audit policy with fraud signal s , the expected cost in an audit game (t, P, σ) is

$$\hat{C}^c(t, P, \sigma) = \min \left\{ t[\delta + \sigma(1 - \delta)], \delta \left[t + \tilde{p}(t, P)c \frac{q_2^n}{q_2^f} \right] \right\}.$$

$q_2^n/q_2^f < 1$ implies $\hat{C}^c(t, P, \sigma) \leq C^c(t, P, \sigma)$, with a strong inequality when deterring fraud is optimal. We deduce that conditioning auditing on the fraud signal reduces the claims cost, and ultimately it increases the expected utility of honest individuals for the optimal contract.⁴⁴

⁴⁴As before, the optimal contract maximizes the expected utility of honest policyholders under the constraint $P \geq \hat{C}^c(t, P, \theta)$, where θ still denotes the proportion of opportunist individuals in the population. If the optimal contract without fraud signal is such that $\delta[t + \tilde{p}(t, P)c \frac{q_2^n}{q_2^f}] < t[\delta + \theta(1 - \delta)] < \delta[t + \tilde{p}(t, P)c]$, then auditing claims is optimal only if the insurer can condition his decision on the fraud signal.

The previous reasoning may easily be extended to the more general case where the insurer perceives a signal $s \in \{s_1, \dots, s_\ell\}$ with $\ell \geq 2$, following [Dionne et al. \(2009\)](#).⁴⁵ Let q_i^f and q_i^n be, respectively, the probability of the signal vector s taking on value s_i when the claim is fraudulent and when it corresponds to a true loss, with $\sum_{i=1}^\ell q_i^f = \sum_{i=1}^\ell q_i^n = 1$. Without loss of generality, we assume $q_i^n > 0$ for all i and we rank the possible signals in such a way that⁴⁶

$$\frac{q_1^f}{q_1^n} < \frac{q_2^f}{q_2^n} < \dots < \frac{q_\ell^f}{q_\ell^n}.$$

With this ranking, we can interpret $i=1, \dots, \ell$ as an index of fraud suspicion. Indeed, assume that the insurer consider that a claim may be fraudulent with (ex ante) probability π^a . Then, using Bayes' law allows us to write the probability of fraud (fraud score) conditional on signal s_i as

$$\Pr(\text{Fraud} | s_i) = \frac{q_i^f \pi^a}{q_i^f \pi^a + q_i^n (1 - \pi^a)},$$

which is increasing with i . Thus, as index i increases, so does the probability of fraud.⁴⁷

Now the insurers auditing strategy is written as $\hat{p} = (\hat{p}_1, \hat{p}_2, \dots, \hat{p}_\ell)$ where $\hat{p}_i \in [0, 1]$ denotes the audit probability when signal s_i is perceived. Fraudulent and non-fraudulent claims are audited with probability $\sum_{i=1}^\ell q_i^f \hat{p}_i$ and $\sum_{i=1}^\ell q_i^n \hat{p}_i$, respectively. Opportunistic individuals are deterred from defrauding if $\sum_{i=1}^\ell q_i^f \hat{p}_i \geq \tilde{p}(t, P)$ and in that case the expected cost of a claim is written as the sum of the indemnity t and the expected audit cost $c \sum_{i=1}^\ell q_i^n \hat{p}_i$. Thus, the optimal fraud deterring audit strategy $\hat{p} = (\hat{p}_1, \hat{p}_2, \dots, \hat{p}_\ell)$ minimizes the expected cost of claims

$$t + c \sum_{i=1}^\ell q_i^n \hat{p}_i,$$

subject to

$$\begin{aligned} \sum_{i=1}^\ell q_i^f \hat{p}_i &\geq \tilde{p}(t, P), \\ 0 \leq \hat{p}_i &\leq 1 \text{ for all } i = 1, \dots, \ell. \end{aligned}$$

This is a simple linear programming problem, whose optimal solution is characterized in the following proposition:

⁴⁵As in [Dionne et al. \(2009\)](#), s may be a k -dimensional signal, with k the number of fraud indicators (or red flags) observed by the insurer. Fraud indicators cannot be controlled by defrauders and they may make the insurer more suspicious about fraud. For instance, when all indicators are binary, then $\ell = 2^k$ and s may be written as a vector of dimension k with components 0 or 1: component j is equal to 1 when indicator j is “on,” and it is equal to 0 when it is “off.”

⁴⁶Of course if $q_i^n = 0$ and $q_i^f > 0$, then it is optimal to trigger an audit when $s = s_i$ because the claim is definitely fraudulent in that case.

⁴⁷In the present model, insurers fully deter fraud when they can commit to their auditing strategy and the proportion of opportunist individuals is large enough. This is no longer true when there is a continuum of types for individuals. [Dionne et al. \(2009\)](#) consider such a model, with a continuum of individuals and moral costs that may be more or less important. In their model, there is a positive rate of fraud even if insurers can commit to their audit strategy. π^a would then correspond to the equilibrium fraud rate, which is positive, but lower than the equilibrium fraud rate under the no-commitment hypothesis.

Proposition 13. *An optimal auditing strategy is such that*

$$\begin{aligned} \hat{p}_i &= 0 \text{ if } i < i^*, \\ \hat{p}_i &\in (0, 1] \text{ if } i = i^*, \\ \hat{p}_i &= 1 \text{ if } i > i^*, \end{aligned}$$

where $i^* \in \{1, \dots, \ell\}$, and when fraud is deterred the audit probability is

$$p^c(t, P) \equiv \sum_{i=1}^{\ell} q_i^n \hat{p}_i < \tilde{p}(t, P).$$

Proposition 13 says that an optimal verification strategy consists in auditing claims when the suspicion index i exceeds the critical threshold i^* . Thus, the insurer plays a “red flags strategy”: for some signals—those with $i > i^*$ —claims are systematically audited, whereas there is no audit when $i < i^*$ and audit is random when $i = i^*$.⁴⁸ Choosing $\hat{p}_i = \tilde{p}(t, P)$ for all $i = 1, \dots, \ell$ is a suboptimal fraud deterring strategy. Thus, using fraud signals allows to audit a smaller fraction of claims while deterring fraud. The expected cost per policyholder is

$$\hat{C}^c(t, P, \sigma) = \min\{t[\delta + \sigma(1 - \delta)], \delta[t + cp^c(t, P)]\}$$

with $p^c(t, P) < \tilde{p}(t, P)$. Thus, we have $\hat{C}^c(t, P, \sigma) \leq C^c(t, P, \sigma)$, with a strong inequality when it is optimal to deter fraud, which shows that insurers can reduce the cost of claims by triggering audit on the basis of fraud signals.

Let us turn to the case where insurers cannot commit to their auditing strategy, and once again let us start with a binary signal $s \in \{s_1, s_2\}$ with $0 < q_2^n < q_2^f$.⁴⁹ The insurers’ auditing strategy should then be the best response to the opportunistic policyholders’ fraud strategy. α still denotes the fraud rate of opportunistic individuals and the proportion of fraudulent claims π is still given by (13.35). Let us focus once again on the case where $q_2^f > \tilde{p}(t, P)$, so that it is possible to deter fraud by auditing claims under signal s_2 , with $\hat{p}_1 = 0$. Assume first $\hat{p}_2 > 0$. The expected cost of a claim is

$$\bar{C} = (1 - \pi)(t + cq_2^n \hat{p}_2) + \pi(t - (t - c)q_2^f \hat{p}_2),$$

which extends (13.36) to the case where the audit probability differs between fraudulent claims and non-fraudulent claims. As in Sect. 13.7, there cannot exist an equilibrium where fraud would be fully deterred: indeed $\alpha = 0$ would give $\pi = 0$ and $\hat{p}_2 = 0$ and then $\alpha = 1$ would be an optimal fraud strategy of opportunistic individuals, hence a contradiction. When $\alpha = 1$, we necessarily have $q_2^f \hat{p}_2 \leq \tilde{p}(t, P)$, and (13.35) then gives

$$\pi = \frac{\sigma(1 - \delta)}{\sigma(1 - \delta) + \delta} \equiv \bar{\pi}.$$

Assume $q_2^f/q_2^n > c(1 - \bar{\pi})/\bar{\pi}(t - c)$. In that case, minimizing \bar{C} with respect to $\hat{p}_2 \in [0, 1]$, with $\pi = \bar{\pi}$, would give $\hat{p}_2 = 1$, and thus $q_2^f \hat{p}_2 > \tilde{p}(t, P)$ which contradicts $\alpha = 1$. Thus $\alpha \in (0, 1)$ is the only possible case, which implies $\hat{p}_2 = \tilde{p}(t, P)/q_2^f \in (0, 1)$ and $\pi \in (0, \bar{\pi})$. For \bar{C} to be minimized at $\hat{p}_2 = \tilde{p}(t, P)/q_2^f \in (0, 1)$, we need to have

⁴⁸If $\ell = 2$ and deterring fraud is optimal, then we have $i^* = 2$ if $q_2^f \geq \tilde{p}(t, P)$ and $i^* = 1$ if $q_2^f < \tilde{p}(t, P)$.

⁴⁹This case has been studied by Schiller (2006).

$$\pi = \frac{cq_2^n}{cq_2^n + (t-c)q_2^f},$$

which implies $\bar{C} = t$ and

$$\begin{aligned} C &= \frac{\delta \bar{C}}{1-\pi} \\ &= \frac{\delta t [cq_2^n + (t-c)q_2^f]}{(t-c)q_2^f}. \end{aligned}$$

When $\hat{p}_2 = 0$, we have $C = t[\delta + \sigma(1-\delta)]$. Thus, when the insurer cannot commit to its audit strategy, the expected cost in an audit game (t, P, σ) is

$$\hat{C}^n(t, \sigma) = \min \left\{ t[\delta + \sigma(1-\delta)], \frac{\delta t [cq_2^n + (t-c)q_2^f]}{(t-c)q_2^f} \right\}.$$

Using $q_2^n < q_2^f$ yields $\hat{C}^n(t, \sigma) \leq C^n(t, \sigma)$, with a strong inequality when it is optimal to audit claims with positive probability. Thus, conditioning audit on fraud signals reduces the cost of claims even if the insurer cannot commit to its verification strategy.

If the insurer perceives a signal $s \in \{s_1, \dots, s_\ell\}$ with q_i^f/q_i^n increasing in i , then the expected cost of a claim is

$$\bar{C} = (1-\pi) \left(t + c \sum_{i=1}^{\ell} q_i^n \hat{p}_i \right) + \pi \left(t - (t-c) \sum_{i=1}^{\ell} q_i^f \hat{p}_i \right).$$

The optimal auditing strategy minimizes \bar{C} with respect to $\hat{p} = (\hat{p}_1, \hat{p}_2, \dots, \hat{p}_\ell)$ subject to $0 \leq \hat{p}_i \leq 1$ for all $i = 1, \dots, \ell$. We deduce that $\hat{p}_i = 0$ for all i if $\pi = 0$. If $\pi > 0$, then we have

$$\begin{aligned} \hat{p}_i &= 0 \text{ if } \frac{q_i^f}{q_i^n} < \frac{c(1-\pi)}{\pi(t-c)}, \\ \hat{p}_i &\in [0, 1] \text{ if } \frac{q_i^f}{q_i^n} = \frac{c(1-\pi)}{\pi(t-c)}, \\ \hat{p}_i &= 1 \text{ if } \frac{q_i^f}{q_i^n} > \frac{c(1-\pi)}{\pi(t-c)}. \end{aligned}$$

Since q_i^f/q_i^n is increasing in i , we deduce that the characterization given in Proposition 13 is also valid in the no-commitment case. Audit is triggered when a suspicion index i^* is reached, where i^* is the smallest index i such that $q_i^f/q_i^n \geq c(1-\pi)/\pi(t-c)$. As in the case of a binary signal, there cannot exist an equilibrium where fraud would be fully deterred. Thus, we have $\alpha > 0$, and there is some fraud at equilibrium. The ex ante fraud probability π^a coincides with the proportion of fraudulent claims π . The larger the suspicion index, the larger the fraud score $\Pr(\text{Fraud} | s_i) = q_i^f \pi / (q_i^f \pi + q_i^n (1-\pi))$, and audit should be triggered when this fraud score is larger than c/t .

13.9 Some Indirect Effects of Insurance Contracts on Fraud

As mentioned in Sect. 13.6, the intensity of insurance fraud may depend on the perception of unfair behavior on the part of insurance companies, in relation to some stipulations of insurance contracts. For instance [Dionne and Gagné \(2001\)](#) have shown with data from Québec that the amount of the deductible in automobile insurance is a significant determinant of the reported loss, at least when no other vehicle is involved in the accident, and thus when the presence of witnesses is less likely. This suggests that the larger the deductible, the larger the propensity of drivers to file fraudulent claims. Although a deductible is a clause of the insurance contract that cannot be interpreted as a bad faith attitude of the insurer, the result of [Dionne and Gagné](#) sustains the idea that the larger the part of an accident cost born by a policyholder, the larger the incentives he feels to defraud. In the same vein, the results of an experimental study by [Miyazaki \(2009\)](#) show that higher deductibles result in weaker perception that claim padding is an unethical behavior, with the conclusion that the results indicate “some degree of perceived corporate unfairness, wherein consumers feel that the imbalance in favor of the firm has to be balanced by awarding the claimant a higher dollar amount.”

Independently of induced effects on moral standards, some contractual insurance provisions may prompt dishonest policyholders to defraud and in that case, the risk of fraud should be taken into account in the design of optimal insurance policies. An example is provided by [Dionne and Gagné \(2002\)](#) through their analysis of replacement cost endorsement in automobile insurance. A replacement cost endorsement allows the policyholder to get a new car in the case of a theft or if the car has been totally destroyed in a road accident, usually if the theft or the collision occurred in the first 2 years of ownership of a new car. Such endorsements increase the protection of the insureds against depreciation, but they also increase the incentives to defraud, for instance, by framing a fraudulent theft. Note that, in an adverse selection setting, an individual may choose to include a replacement cost endorsement in his coverage because he knows he will be more at risk. Furthermore, individuals may decide to drive less carefully or pay less attention to the risk of theft when their coverage is complete than when it is partial, and thus, replacement cost endorsements may increase the insurance losses because of moral hazard. Thus, the fact that policyholders with a replacement cost endorsement have more frequent accidents or thefts may be the consequence of fraud, but it may also reflect adverse selection or moral hazard. [Dionne and Gagné \(2002\)](#) use data from Québec to disentangle these three effects. They show that holders of car insurance policies with a replacement cost endorsement have a higher probability of theft near the end of this additional protection (which usually lasts for 2 years after the acquisition of a new car). Their statistical tests rule out (ex ante) moral hazard and adverse selection⁵⁰ and they interpret their result as the effect of replacement cost endorsement on the propensity to defraud.

Another example of induced effects of contracts on the propensity to defraud occurs in the case of corporate property insurance. Following the accidental destruction of productive assets (e.g., buildings, plant, inventories), a firm must decide whether to restore those assets to their previous state and the contractual indemnity usually differs according to whether there is restoration or insurance payment. In such a setting, [Bourgeon and Picard \(1999\)](#) characterize the optimal corporate fire insurance contract when the insured firm has private information about the economic value of the damaged productive assets. They show that the indemnity should be larger in case of restoration than when the firm receives insurance money, but there should be partial coverage as well when restoration is chosen. The structure of indemnity payments is chosen to minimize the rent the firms enjoy when the

⁵⁰Moral hazard is ruled out because there is no significant effect of replacement cost endorsements on partial thefts (i.e., thefts where only a part of the car is stolen: hubcaps, wheels, radio, etc.) although the same self-protection activities affect the claims distribution of total and partial thefts. [Dionne and Gagné \(2002\)](#) also rule out adverse selection because the effect is significant for only 1 year of ownership and not for all years.

(unverifiable) economic losses are smaller than the insurance payment, but also to prevent the firm from inefficient restoration (i.e., restoration when the economic value of the damaged capital is low). In this context, fraud may take the form of arson: arson may be decided on by dishonest firms that are in a position to set unprofitable equipment on fire to obtain insurance money. The possibility of arson is an additional motive for lowering insurance money under the restoration indemnity. [Bourgeon and Picard \(1999\)](#) show that, because of the risk of arson, the insurer may be led not to offer any insurance money to the firm but only to reimburse restoration costs.⁵¹

Experience rating, and particularly bonus-malus rules, may alleviate the propensity of opportunistic policyholders to defraud. Bonus-malus pricing in automobile insurance is usually viewed either as a risk-type learning process under adverse selection or as an incentive device under moral hazard. However bonus-malus also affects the propensity to defraud when the mere fact of filing a claim, be it fraudulent or not, leads the insurer to charge higher rates in future periods. Bonus-malus rules may thus be of aid for reducing insurance fraud. This intuition has been developed by [Moreno et al. \(2006\)](#). The key ingredient of their model is the intertemporal choice of policyholders. For simplicity, they assume that at period t , individuals only care about their utility during the current and following period t and $t + 1$, and not about subsequent periods $t + 2, \dots$ (which is an extreme form of non-exponential discounting) and at each period a loss of a given size may occur. An opportunity for fraud exists when no loss occurs and the policyholder may fraudulently report a loss to the insurer. The insurer does not audit claims but simply pays out on any filed claim. However the period following a claim, the insurer adjusts the premium according to whether or not a claim was filed. Thus, filing a fraudulent claim results in a present benefit to the policyholder at the cost of a higher future premium. [Moreno et al. \(2006\)](#) show that this trade-off may tip in favor of honesty, in the cases of a monopolist insurer and of a perfectly competitive markets, and they exhibit a condition for the bonus-malus antifraud mechanism to Pareto dominate the audit mechanism.

13.10 Collusion with Agents

In many cases, insurance fraud goes through collusion between policyholders and a third party. For instance, collusion with automechanics, physicians, or attorneys is a channel through which an opportunist policyholder may manage to falsify his claims. Falsification costs—taken as exogenous in Sects. 13.3 and 13.4—then are the outcome of hidden agreement between policyholders and such agents.

In this section, we focus on collusion between policyholders and agents in charge of marketing insurance contracts. We also consider another type of fraud, namely the fact that policyholders may lie or not disclose relevant information when they take out their policy.⁵² We will assume that the agent observes a number of characteristics of the customer that allow him to estimate correctly the risks and to price the policy. These characteristics cannot be verified by the insurer. Agents also provide promotional services that affect the demand for the policies offered by the insurer, but promotional

⁵¹[Bourgeon and Picard \(1999\)](#) also consider stochastic mechanisms in which the restoration of damaged assets is an option given by the insurance contract to the insurer but not always carried out at equilibrium. The (randomly exercised) restoration option is used as a screening device: larger indemnity payments require larger probabilities of restoration, which prevents firms with low economic losses from building up their claims.

⁵²On this kind of fraud where insurers can (at some cost) verify the policyholders' types, see [Dixit \(2000\)](#), [Dixit and Picard \(2003\)](#), and [Picard \(2009\)](#).

effort cannot either be verified by the insurer.⁵³ The insurer only observes two signals of his agent’s activity, namely net premiums written and indemnity payments.

The key element we want to focus on is the fact that agents may be willing to offer unduly advantageous contracts to some policyholders in order to compensate low promotional efforts. This possibility should lead the insurer to condition his agents’ commissions at the same time on cashed premiums and on indemnity payments. Of course, the issue of how an insurer should provide incentives to his selling agents—be they exclusive or independent—is important independently of insurance fraud. However, in a situation where the insurer does not perfectly monitor his agents, there is some scope for collusion between agents and policyholders which facilitates insurance fraud. The agent may be aware of the fact that the customer tells lies or that he conceals relevant information, but he overlooks this violation in order not to miss an opportunity to sell one more insurance policy. Hence, in such a case, the defrauder is in fact the policyholder-agent coalition itself. In what follows, we sketch a model that captures some consequences of insurance fraud through collusion between policyholders and agents.

Consider an insurance market with n risk-neutral firms of equal size. Each firm employs ℓ exclusive agents to sell insurance contracts.⁵⁴ Let e be the promotional effort expended by an agent. Let k be the loading factor used to price the policies written by the agent. For any customer, the agent is supposed to be able to correctly estimate the expected indemnity payments Et . Let \hat{k} be the loading factor decided upon by the insurer. Hence, if expected indemnity payments are truthfully reported by the selling agent to the insurer, the pricing rule should lead the agent to charge a premium $(1 + \hat{k})Et$. However, by misreporting expected indemnity payments, the agent is able to write policies with an actual loading factor lower than \hat{k} . In what follows, e and k are the decision variables of the agent.

Let P and Q be, respectively, the aggregate premiums collected by a given agent and the aggregate indemnity payments made to his customers during a period of time. We assume

$$P = \frac{1}{n\ell} [g(e, k) + \varepsilon_1] \text{ with } g'_e > 0 \text{ and } g'_k < 0, \tag{13.38}$$

where ε_1 is an idiosyncratic random parameter that varies among agents, with $E\varepsilon_1 = 0$. ε_1 is unknown when the selling agent chooses e and k and cannot be observed by the insurer. Larger promotional efforts increase the amount of collected premiums. Furthermore, we assume that the elasticity of demand for coverage (in terms of expected insurance demand) with respect to loading $1 + k$ is larger than one. Hence, a higher loading factor—or, equivalently, less downward misreporting of expected insurance payments by the agent to the insurer—decreases the premiums cashed. Note that the coefficient $1/n\ell$ in (13.38) reflects the market share of each agent. We also have

$$Q = \frac{1}{n\ell} \left[h(e, k) + \frac{\varepsilon_1}{1+k} + \varepsilon_2 \right], \tag{13.39}$$

where $h(e, k) \equiv g(e, k)/\ell + k$, with $h'_e > 0$, $h'_k < 0$ and where ε_2 is another idiosyncratic random parameter, uncorrelated with ε_1 , such that $E\varepsilon_2 = 0$.

⁵³The choice of distribution system affects the cost to the insurers of eliciting additional promotional effort of their sales force. For instance, exclusive representation prevents the agents from diverting potential customers to other insurers who pay larger commissions. Likewise giving independent agents ownership of policy expirations provides incentives for agents to expend effort to attract and retain customers—see [Kim et al. \(1996\)](#).

⁵⁴Modelling promotional effort in an independent agency system would be more complex since, in such a system, the agent’s decisions are simultaneously affected by several insurers.

Let $\Psi(e)$ be the cost to the agent of providing promotional effort at level e , with $\Psi' > 0$, $\Psi'' > 0$. The agents are supposed to be risk averse.

If insurers were able to monitor the promotional effort and to verify the expected indemnity payments of the policies written by their agents, they would be in position to choose e and k so as to maximize their expected profit written as

$$E\Pi = \ell[EP - EQ - EC]$$

where C denotes the commission paid to each agent. Under perfect information about the agent's behavior it is optimal to pay fixed commissions so that net earnings $C - \Psi(e)$ are equal to a given reservation payment normalized at zero. We thus have $C = \Psi(e)$, which gives

$$E\Pi = \frac{1}{n}[g(e, k) - h(e, k)] - \ell\Psi(e). \quad (13.40)$$

Maximizing $E\Pi$ with respect to e and k gives the first best solution $e = e^*$ and $k = k^*$. A free entry perfect information equilibrium is defined by $E\Pi = 0$ which gives an endogenously determined number of firms $n = n^*$.

Assume now that the insurers do not observe the promotional effort expended by the agents. They can neither verify the expected indemnity payments associated with the policies written by their agent. Opportunist policyholders would like to purchase insurance priced at a loading factor lower than \hat{k} by not disclosing relevant information about the risks incurred to the insurer. It is assumed that this hidden information cannot be revealed to the insurer if an accident occurs. The agent observes the risks of the customers, but he may choose not to report this information truthfully to the insurer in order to get larger sales commissions. The insurer may control the agent opportunism by conditioning his commissions both on cashed premiums and on indemnity payments. However, because of the uncertainty that affects premiums and losses, risk premiums will have to be paid to selling agents which will ultimately affect the firm's profitability.

Assume that the commission paid to an agent depends linearly on P and Q , i.e.,

$$C = \alpha P - \beta Q + \gamma.$$

Assume also that the agents' utility function V is quadratic, which allows us to write

$$EV = EC - \rho\text{Var}(C) - \Psi(e) \text{ with } \rho > 0.$$

The agent's participation constraint $EV \geq 0$ is binding at the optimum, which gives

$$\begin{aligned} EC &= \rho\text{Var}(C) + \Psi(e) \\ &= \frac{\rho}{(n\ell)^2} \left[\alpha^2\sigma_1^2 + \beta^2 \frac{(\sigma_1)^2}{(1+k)^2} + \beta^2\sigma_2^2 \right] \end{aligned}$$

where $\sigma_1^2 = \text{Var}(\varepsilon_1)$ and $\sigma_2^2 = \text{Var}(\varepsilon_2)$. We obtain

$$E\Pi = \frac{1}{n}[g(e, k) - h(e, k)] - \ell\Psi(e) - \frac{\rho}{n^2\ell} \left[\alpha^2\sigma_1^2 + \beta^2 \frac{\sigma_1^2}{(1+k)^2} + \beta^2\sigma_2^2 \right].$$

The insurer maximizes $E\Pi$ with respect to $e \geq 0, k \geq 0, \alpha$, and β subject to the agent's incentive compatibility constraint

$$(e, k) \in \text{Arg Max}_{e', k'} EV = \frac{\alpha}{n\ell} g(e', k') - \frac{\beta}{n\ell} h(e', k') + \gamma - \Psi(e') \\ - \frac{\rho}{(n\ell)^2} \left[\alpha^2 \sigma_1^2 + \beta^2 \frac{\sigma_1^2}{(1+k')^2} + \beta^2 \sigma_2^2 \right].$$

If there is some positive level of promotional effort at the optimum, the incentive compatibility constraint implies $\alpha > 0$ and $\beta > 0$. In words, the insurers should condition the sales commissions at the same time on collected premiums and on indemnity payments. Because of the risk premium paid to the agent, the expected profit of the insurer is lower than when he observes e and k . The equilibrium levels of e and k also differ from their perfect information levels e^* and k^* . Lastly, at a free entry equilibrium, the number of firms in the market is lower than when the insurer has perfect information about his agent's activity.

Insurance fraud through collusion between policyholders and agents may also occur in the claims settlement phase, particularly in an independent agency system. As emphasized by [Mayers and Smith \(1981\)](#), independent agents usually are given more discretion in claims administration than exclusive agents and they may intercede on the policyholder's behalf with the company's claims adjuster. Influencing claims settlement in the interest of their customers is all the more likely that independent agents may credibly threaten to switch their business to another insurer.

Claims fraud at the claims settlement stage may also go through more complex collusion schemes involving policyholders, agents, and adjusters. [Rejesus et al. \(2004\)](#) have analyzed such collusion patterns in the US Federal Crop Insurance Program. Here the policyholders are farmers and the loss is the difference between the actual yield at harvest and the guaranteed yield specified in the insurance contract. Farmers may collude with agents and adjusters to manipulate the size of the loss in order to increase the indemnity. An agent is paid a percentage of the premiums from all insurance policies he sells. An adjuster is paid on the basis of the number of acres he adjusts. Farmers, agents, and adjusters have two possible types: they may be honest or dishonest. Only dishonest individuals may collude. Dishonest agents can potentially have customers from two populations (honest and dishonest farmers), while honest agents only sell policies to honest producers. Thus, the main benefit of collusion to dishonest agents is the chance to have a larger customer pool. Both honest and dishonest adjusters can work for honest and dishonest agents. However, a dishonest adjuster can work for a dishonest agent on all of his policyholders (both honest and dishonest). On the contrary, an honest adjuster can only work on the dishonest agent's honest policyholders, but not the dishonest policyholders. Therefore, a dishonest adjuster has a larger customer base. Thus the opportunity to adjust more acres and earn more money is the main benefit of collusion to adjusters.

[Rejesus et al. \(2004\)](#) consider various patterns of collusion, including "collusion with intermediary," nonrecursive collusion, and bilateral collusion. The "cartwheel" model of collusion is an example of collusion with intermediaries. It is based on the principle of linked actions going from a central group of conspirators (the "cartwheel" hub) to many actors (the "rim") through a network of conspiracy intermediaries (the "spokes" in the wheel). [Rejesus et al. \(2004\)](#) report that, according to compliance investigators of the United States Department of Agriculture (USDA), the structure of collusion in the Federal Crop Insurance Program is configured as such a cartwheel conspiracy, where agents may be the hub, adjusters may be the spokes, and farmers may be the rim. Agents, adjusters, and farmers may also be linked to one another nonrecursively, contrary to the cartwheel model where there is an intermediary that links the two other actors. Furthermore, collusion may also exist between two individuals rather than three.

The authors use data of the USDA's Risk Management Agency (RMA) to flag anomalous individuals.⁵⁵ They show that the pattern of collusion that best fits the data is the nonrecursive scheme. Hence, coordinated behavior between the three entities seems to be the most likely pattern of collusion. The second best pattern of collusion is the collusion with intermediary, where the farmer is the link to both the agent and the adjuster. An example of this type of collusion pattern is the "kickback" scheme, in which a farmer initiates two separate side contracts with the adjuster and the agent and where he promises them kickbacks from fraudulent claims. The results of [Rejesus et al. \(2004\)](#) are in contrast to the RMA investigators' belief that the most prevalent pattern of collusion is where the adjuster is the one who initiates and coordinates the collusion as in the above description of the cartwheel pattern.

13.11 Collusion with Service Providers

Claims fraud may go through collusion between policyholders and service providers (e.g., car repairers, hospitals). During the two last decades, concentration in the insurance market and in the markets for related services went along with the creation of affiliated service providers networks. This includes managed care organizations for health insurance (such as HMO and PPO in the USA) or Direct Repair Programs (DRP) for automobile insurance. Insurance companies may choose to have a restrained set of affiliated service providers for various reasons, including decreasing claims handling costs, monitoring providers more efficiently, or offering more efficient incentive schemes to providers; see particularly [Gal-Or \(1997\)](#) and [Ma and McGuire \(1997, 2002\)](#) in the case of managed health care.

[Bourgeon et al. \(2008\)](#) have analyzed how service providers networks may act as a device to fight claims fraud, when there is a risk of collusion between providers and policyholders.⁵⁶ They limit attention to a simple setup of a double vertical duopoly with two insurance companies and two service repairers. Providers compete on a horizontally differentiated market modelled as the Hotelling line (providers are not valued the same by policyholders) where they have some market power because of the imperfect substitutability of their service. Insurers are perceived as potentially perfectly substitutable by individuals, but they may require their customers to call in a specific provider (say a car repairer) in case of an accident. Two main affiliation structures are considered. In the case of nonexclusive affiliation (Fig. 13.11), customers of both insurance companies are free to choose their providers, while under exclusive affiliation (Fig. 13.12), insurance companies are attached to their own providers.⁵⁷ When there is no risk of collusion between providers, exclusive affiliation allows to transfer some market power from the differentiated providers to the undifferentiated insurers, and that transfer will be a disadvantage for the customers. In this case, [Bourgeon et al. \(2008\)](#) show that exclusive affiliation is the most likely structure that may emerge in such a setting, with a negative effect on the customers' welfare and higher insurers' profit. Hence, if the government gives more social value to the insured's welfare (in terms of wealth certainty equivalent) than to insurers' profit, then it should prevent insurers to restrict access to providers.

⁵⁵[Rejesus et al. \(2004\)](#) use indicators of anomalous outcomes. Some of them are applicable to the three types of agents (e.g., the indemnity/premium ratio); others are specific to agents (e.g., the fraction of policies with loss in the total number of policies sold by the agent) or to adjusters (e.g., the indemnity per claim for the adjuster divided by average adjusted claims in the county).

⁵⁶See also [Brundin and Salanié \(1997\)](#).

⁵⁷[Bourgeon et al. \(2008\)](#) also consider the case of common affiliation in which insurers choose the same provider as their unique referral, and the case of asymmetric affiliation in which one insurer is affiliated with one single provider while customers of the other insurer are free to call in the provider they prefer.

Fig. 13.11 No affiliation

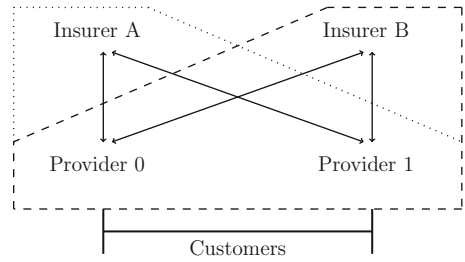
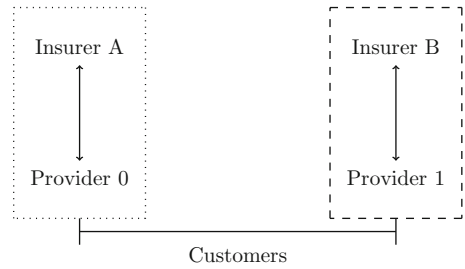


Fig. 13.12 Exclusive affiliation



Providers and policyholders may collude to file fraudulent claims. We may, for instance, think of a car repairer who would facilitate fraudulent claiming by certifying that a policyholder actually needed a repair, although that was not the case. Such a collusion may be deterred through auditing. Let us assume that providers are risk neutral. Collusion will be deterred if the expected gains obtained by a provider from a collusive deal (i.e., the fraction of the insurance indemnity he would receive) are lower than the expected fines he would have to pay if audit reveals collusion. Thus, collusion proofness may lead insurers to reduce their coverage in order to decrease the collusion stake, hence a welfare loss for risk-averse policyholders. Bourgeon et al. (2008) show that in a one-shot setting this collusion-proofness condition does not modify the previous conclusion: the defense of the policyholders’ interests may still legitimately lead the government to prohibit exclusive affiliation regimes. Matters are different when insurers and providers are engaged in a repeated relationship. In such a setting, a provider is deterred from colluding with a customer if his loss in case of an audit is sufficiently large and the threat of retaliation is credible. Assume insurers offer insurance contracts that would not be collusion proof in a one-period framework. Under nonexclusive affiliation, retaliation against a malevolent provider is possible only if insurers agree to punish him simultaneously in the future periods, say by excluding him from their networks or by switching to collusion-proof insurance contracts for all policyholders who would choose this provider.⁵⁸ This would require a high degree of coordination between insurers. The situation is different under exclusive affiliation. In particular, if an insurer comes back to collusion-proof contracts after a fraud has been detected (while its competitor does not modifies its offer), then its provider’s future profit is reduced. When providers put sufficiently large a weight on future profits, i.e., when their discount factor is large enough, this threat destroys the incentives to collude, even if the probability of detecting collusion is low or when the fines imposed on revealed defrauders are low. In other words, exclusive affiliation may complement imperfect auditing.

⁵⁸Indeed, under nonexclusive affiliation, if there is only one insurance company (the one that has detected collusion) that excludes the defrauder from its network or that switches to collusion-proof contracts, then insureds will move to its competitor and the malevolent provider will not be affected.

It may also supplement an inefficient judicial system, where defrauders can easily avoid being strongly fined because insurers have difficulty providing strong evidence in court.

Note finally that deterring collusion between policyholders and service providers may not be optimal if some providers are collusive while some are honest. Indeed, if insurers cannot distinguish collusive providers from honest ones, they must either separate them through self-selection contracts or offer collusion-proof contracts to all providers. Both solutions involve distortions in resource allocation. [Alger and Ma \(2003\)](#) consider such a model, with two types of providers. If the insurer is unable to screen providers by offering them a menu of self-selection contracts, then collusion is tolerated if and only if the provider is collusive with a sufficiently low probability.⁵⁹

13.12 Conclusion

Although the theory of insurance fraud is far from being complete, this survey allows us to draw some tentative conclusions. Firstly, insurance fraud affects the design of optimal insurance policies in several ways. On the one hand, because of claims' monitoring costs, an optimal contract exhibits non-verification with constant net payouts to insureds in the lower loss states and (possibly random) verification for some severe losses. In some cases, a straight deductible contract is optimal. On the other hand, the possibility for policyholders either to manipulate audit costs or to falsify claims should lead insurers to offer contracts that exhibit some degree of coinsurance at the margin. The precise form of coinsurance depends on the specification of the model. For instance, it may go through a ceiling on coverage or through overcompensation for small losses and undercompensation for large losses. However, the fact that insurers should not be offered policies with full insurance at the margin seems a fairly robust result as soon as they may engage in costly activities that affect the insurer's information about damages. Secondly, insurance fraud calls for some cooperation among insurance companies. This may go through the development of common agencies that build databases about past suspicious claims, that develop quantitative method for better detecting fraudulent claims,⁶⁰ and that spread information among insurers. In particular, databases may help to mitigate the inefficiency associated with adverse selection, that is, with the fact that insurers are unable to distinguish potential defrauders from honest policyholders. Cooperation among insurers may also reduce the intensity of the credibility constraints that affect antifraud policies. Free-riding in antifraud policies could be analyzed along the same lines and it also calls for more cooperation among insurers. Thirdly, insurance fraud frequently goes through collusion with a third party, be it an insurance agent or a service provider. Contractual relationships between insurers and these third parties strongly affect the propensity of policyholders to engage in insurance fraud activities. In particular, conditioning sales commissions paid to agents on a loss-premium ratio results from a compromise between two objectives: providing incentives to make promotional effort and deterring collusion with customers. Risk premiums borne by agents are then an additional cost of the distribution system, which ultimately affects the efficiency of insurance industry. Preventing collusion between a policyholder and his own agent is a still more difficult challenge. Vertical integration of these agents by insurance companies (for instance through affiliated automechanic networks) is likely to mitigate the intensity of collusion in such cases.

⁵⁹ [Alger and Ma \(2003\)](#) do not obtain the same result when the insurer can use menus of contracts.

⁶⁰ See [Derrig and Ostaszewski \(1995\)](#), [Artis et al. \(1999\)](#), and [Viaene et al. \(2002\)](#).

Appendix

Proof of Lemma 1

Let

$$\begin{aligned}\tilde{t}(x) &= \text{Sup}\{t(x), t(y), y \in M^c\}, \\ t_0 &= \text{Inf}\{\tilde{t}(x), x \in [0, \bar{x}]\}, \\ \tilde{M} &= \{x \mid \tilde{t}(x) > t_0\}, \\ \tilde{P} &= P.\end{aligned}$$

Obviously, the contract $\tilde{\delta} = \{\tilde{t}(\cdot), \tilde{M}, \tilde{P}\}$ is incentive compatible. Hence $\tilde{\delta}$ and δ yield the same insurance payment.

Let $\hat{x}(x)$ be an optimal claim of the policyholder under δ when he suffers a loss x . Let $x_0 \in \tilde{M}$. We then have $\tilde{t}(x_0) > \tilde{t}(x_1)$ for some x_1 in $[0, \bar{x}]$. This gives $\hat{x}(x_0) \in M$; otherwise $\hat{x}(x_0)$ would be a better claim than $\hat{x}(x_1)$ under δ when $x = x_1$. Audit costs are thus lower under $\tilde{\delta}$ than under δ .

Proof of Lemma 2⁶¹

Let

$$\mathcal{L} = U(W - P - x + t(x))f(x) + \lambda[t(x) + c] \text{ if } x \in M$$

be the Lagrangian, with λ a multiplier associated with the nonnegative expected profit constraint. When P, t_0 , and M are fixed optimally, the schedule $t(\cdot) : M \rightarrow R_+$ is such that

$$\frac{\partial \mathcal{L}}{\partial t} = U'(W - P - x + t(x))f(x) - \lambda f(x) = 0.$$

This allows us to write

$$t(x) = x - k \text{ for all } x \in M,$$

where k is a constant.

Assume there exist $0 \leq a_1 < a_2 < a_3 < a_4 \leq \bar{x}$ such that

$$\begin{aligned}[a_1, a_2] \cup (a_3, a_4] &\subset M, \\ (a_2, a_3) &\subset M^c.\end{aligned}$$

Let

$$\begin{aligned}M_* &= M - \{[a_1, a_2] \cup (a_3, a_4]\}, \\ M_*^c &= M^c - [a_2, a_3].\end{aligned}$$

⁶¹This proof follows [Bond and Crocker \(1997\)](#).

We have

$$\begin{aligned}
 EU &= \int_{M_*} U(W - P - k) dF(x) + \int_{M_*} U(W - P - k + t_0) dF(x) \\
 &+ \int_{a_1}^{a_2} U(W - P - k) dF(x) + \int_{a_2}^{a_3} U(W - P - k + t_0) dF(x) \\
 &+ \int_{a_3}^{a_4} U(W - P - k) dF(x)
 \end{aligned} \tag{13.41}$$

and

$$\begin{aligned}
 E\Pi &= P - \int_{M_*} (x - k + c) dF(x) - \int_{M_*^c} t_0 dF(x) \\
 &- \int_{a_1}^{a_2} (x - k + c) dF(x) - \int_{a_2}^{a_3} t_0 dF(x) \\
 &- \int_{a_3}^{a_4} (x - k + c) dF(x) = 0.
 \end{aligned} \tag{13.42}$$

Differentiating (13.42) with respect to a_2 and a_4 gives

$$da_3 = \frac{(a_2 - k + c - t_0) f(a_2) da_2}{a_3 - k + c - t_0}$$

which implies

$$dEU = f(a_2) \Delta (t_0 - a_2 + k - c) da_2$$

with

$$\Delta = \frac{U(W - k - P) - U(W - P - a_3 + t_0)}{a_3 - k - t_0 + c} - \frac{U(W - k - P) - U(W - P - a_2 + t_0)}{a_2 - k - t_0 - c}.$$

The concavity of U guarantees that $\Delta > 0$. Furthermore $a_2 - k \geq t_0$ since $[a_1, a_2] \subset M$. We thus have $dEU > 0$ if $da_2 < 0$.

Proof of Proposition 1

Let us delete the constraint (13.6). We may check that it is satisfied by the optimal solution of this less constrained problem. Assigning a multiplier $\lambda \geq 0$ to the nonnegative profit constraint, the first-order optimality conditions on k , P , and m are, respectively,

$$[1 - F(m)][U'(W - P - k) - \lambda] = 0 \tag{13.43}$$

$$\int_0^m U'(W - x - P) dF(x) + [1 - F(m)]U'(W - P - k) = \lambda \tag{13.44}$$

$$\begin{aligned}
 &U(W - m - P) f(m_+) - U(W - P - k) f(m_+) + \lambda(c + m - k) f(m_+) \\
 &\leq 0 \\
 &= 0 \text{ if } m > 0.
 \end{aligned} \tag{13.45}$$

Equations (13.43), (13.44), and $F(m) \geq f(0) > 0$ for all $m \geq 0$ give

$$U'(W - P - k) = \frac{1}{F(m)} \int_0^m U'(W - x - P) dF(x)$$

which implies $0 < k < m$ if $m > 0$ and $k = 0$ if $m = 0$.

Assume $m = 0$. Substituting $k = m = 0$ in (13.45) then gives $\lambda c f(0_+) \leq 0$, hence a contradiction.

Proof of Proposition 2

The first-order optimality conditions on k , P , and t_0 are, respectively,

$$[1 - F(m)][U'(W - P - k) - \lambda] \tag{13.46}$$

$$f(0)U'(W - P) + \int_{0_+}^m U'(W - x - P + t_0) dF(x) + [1 - F(m)]U'(W - P - k) = \lambda \tag{13.47}$$

$$\int_{0_+}^m U'(W - x - P + t_0) dF(x) = \lambda[F(m) - f(0)] \tag{13.48}$$

Equations (13.46)–(13.48), and $F(m) \geq f(0) > 0$ for all $m \geq 0$ give $k = 0$ and $\lambda = U'(W - P)$. Using (13.48) then yields

$$[F(m) - f(0)]U'(W - P) = \int_{0_+}^m U(W - x - P + t_0) dF(x)$$

which implies $0 < t_0 < m$ if $m > 0$.

Consider m as a fixed parameter. Let $\Phi(m)$ be the optimal expected utility as a function of m . The envelope theorem gives

$$\begin{aligned} \Phi'(m) &= U'(W - m - P + t_0)f(m) - U(W - P - k)f(m) \\ &\quad + \lambda(t_0 + c + m - k)f(m) \end{aligned}$$

if $m > 0$. When $m \rightarrow 0$, then $t_0 \rightarrow 0$. Using $k = 0$ then gives

$$\lim_{m \rightarrow 0} \Phi'(m) = \lambda c f(0_+) > 0$$

which implies $m > 0$ at the optimum.

Proofs of Propositions 3 and 5. See Picard (2000).

Proof of Propositions 4 and 6. See Bond and Crocker (1997).

Proof of Proposition 7. See Mookherjee and Png (1989) and Fagart and Picard (1999).

Proof of Proposition 8. See Fagart and Picard (1999).

Proof of Propositions 9–12. See Picard (1996)

Proof of Proposition 13. Optimality conditions are written as

$$\hat{p}_i = 1 \text{ if } cq_i^n - \lambda q_i^f < 0,$$

$$\hat{p}_i \in [0, 1] \text{ if } cq_i^n - \lambda q_i^f = 0,$$

$$\hat{p}_i = 0 \text{ if } cq_i^n - \lambda q_i^f > 0,$$

where λ is a Lagrange multiplier. i^* is the smallest index i in $\{1, \dots, \ell\}$ such that $q_i^f/q_i^n \geq c/\lambda$.

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Chapter 14

Asymmetric Information in Insurance Markets: Predictions and Tests

Pierre-André Chiappori and Bernard Salanié

Abstract This chapter surveys a number of recent empirical studies that test for or evaluate the importance of asymmetric information in insurance relationships. Our focus throughout is on the methodology rather than on the empirical results. We first discuss the main conclusions reached by insurance theory in both a static and a dynamic framework for exclusive as well as nonexclusive insurance. We put particular emphasis on the testable consequences that can be derived from very general models of exclusive insurance. We show that these models generate an inequality that, in simple settings, boils down to a positive correlation of risk and coverage conditional on all public information. We then discuss how one can disentangle moral hazard and adverse selection and the additional tests that can be run using dynamic data.

Keywords Insurance • Adverse selection • Moral hazard • Contract Theory • Tests

14.1 Introduction

Modern insurance economics has been deeply influenced by the developments of contract theory. Our understanding of several crucial aspects, such as the design of optimal insurance contracts, the form of competition on insurance markets, or the role of public regulation, just to name a few, systematically refers to the basic concepts of contract theory—moral hazard, adverse selection, commitment, renegotiation, and others. Conversely, it is fair to say that insurance has been, and to a large extent still remains, one of the most important and promising fields of empirical application for contract theory.

It can even be argued that, by their very nature, insurance data provide nearly ideal material for testing the predictions of contract theory. [Chiappori \(1994\)](#) and [Chiappori and Salanié \(1997\)](#) remark that most predictions of contract theory are expressed in terms of a relationship between the form of the contract, a “performance” that characterizes the outcome of the relationship under consideration, and the resulting transfers between the parties. Under moral hazard, for instance, transfers will be positively correlated to but less volatile than outcomes in order to conjugate incentives and risk sharing; under adverse selection, the informed party will typically be asked to choose a particular relationship between transfer and performance within a menu. The exact translation of the notions of

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“performance” and “transfer” varies with the particular field at stake. Depending on the context, the “performance” may be a production or profit level, the performance of a given task, or the occurrence of an accident, whereas the transfer can take the form of a wage, a dividend, an insurance premium, and others.

In all cases, empirical estimation of the underlying theoretical model would ideally require a precise recording of (i) the contract, (ii) the information available to both parties, (iii) the performance, and (iv) the transfers. In addition, the contracts should be to a large extent standardized, and large samples should be considered, so that the usual tools of econometric analysis can apply. As it turns out, data of this kind are quite scarce. In some contexts, the contract is essentially implicit, and its detailed features are not observed by the econometrician. More frequently, contracts do not present a standardized form because of the complexity of the information required either to characterize the various (and possibly numerous) states of the world that should be considered or to precisely describe available information. In many cases, part of the information at the parties’ disposal is simply not observed by the econometrician, so that it is *de facto* impossible to condition on it as required by the theory. Last but not least, the “performance” is often not recorded, and even not precisely defined. In the case of labor contracts, for instance, the employee’s “performance” often is the product of a supervisor’s subjective evaluation, which is very rarely recorded in the data that the firm makes available to the econometrician.

In contrast, most insurance contracts fulfill all of the previous requirements. Individual insurance contracts (automobile, housing, health, life, etc.) are largely standardized. The insurer’s information is accessible and can generally be summarized through a reasonably small number of quantitative or qualitative indicators. The “performance”—whether it represents the occurrence of an accident, its cost, or some level of expenditure—is very precisely recorded in the firms’ files. Finally, insurance companies frequently use databases containing several millions of contracts, which is as close to asymptotic properties as one can probably be. It should thus be no surprise that empirical tests of adverse selection, moral hazard, or repeated contract theory on insurance data have attracted renewed attention.

In what follows, we shall concentrate on empirical models that explicitly aim at testing for or evaluating the importance of asymmetric information in insurance relationships. This obviously excludes huge parts of the empirical literature on insurance that are covered by other chapters of this volume. Some recent research has focused on evaluating the welfare consequences of asymmetric information, “beyond testing” to use the title of the survey by [Einav et al. \(2010\)](#). For lack of space we will not cover it here. Also, we will leave aside the important literature on fraud—a topic that is explicitly addressed by Picard in this volume. Similarly, since the major field of health insurance is comprehensively surveyed by Morrissey in another chapter, we shall only allude to a few studies relating to information asymmetries in this context.

Finally, we chose to focus on the methodological aspects of the topic. In the past 15 years, a large volume of empirical work has evaluated the importance of asymmetric information in various insurance markets. There are excellent surveys that present their results, such as Cohen–Siegelman (2010), and we will limit ourselves to the broad conclusions we draw from these many studies.

The structure of this contribution is as follows. Section 14.2 discusses the main conclusions reached by the economic theory of insurance. We place particular emphasis on the testable consequences that can be derived from existing models. Section 14.3 reviews a few studies that exploit these theoretical insights in a static context. Section 14.4 briefly considers the dynamic aspects of the issue. We conclude with some ideas for future research.

14.2 Empirical Tests of Information Asymmetries: The Theoretical Background

It is by now customary to outline two polar cases of asymmetric information, namely adverse selection and moral hazard. Each case exhibits specific features that must be understood before any attempt at quantifying their empirical importance.¹

14.2.1 *Asymmetric Information in Insurance: What Does Theory Predict?*

14.2.1.1 Adverse Selection

The Basic Story and Its Interpretations

At a very general level, adverse selection arises when one party has a better information than other parties about some parameters that are relevant for the relationship. In most theoretical models of insurance under adverse selection, the subscriber is taken to have superior information. The presumption is usually that the insuree has better information than her insurer on her accident probability and/or on the (conditional) distribution of losses incurred in case of accident. A key feature is that, in such cases, the agent's informational advantage bears on a variable (risk) that directly impacts the insurer's expected costs. Agents who know that they face a higher level of risk will buy more coverage, introducing a correlation between the agents' contract choice and the unobservable component of their risk. The insurer's profit will suffer since the cost of providing coverage is higher for higher-risk agents. In the terminology of contract theory, this is a model of *common values*, and this feature is what creates problems with competitive equilibrium.

This general definition may however be qualified in several ways. First, a finding that agents who buy more insurance have riskier outcomes is consistent not only with the standard story (they bought more insurance *because* they realized that they were more likely to have an accident) but also with alternative, observationally equivalent interpretations. To give but a simple example, assume that insurees are of two types, green and red, and that insurees know their types, but the insurer does not—or at least that he does not use this information for risk-rating purposes. Assume, furthermore, that red agents have two characteristics: their risk is larger *and* they have a higher predisposition to buy insurance (or contracts offering a more extensive coverage). These two characteristics could be linked by a causal relationship: agents want more coverage because they realize they are more accident prone; or they could just be caused by some third factor—say, wealthier agents have a longer life expectancy and can also better afford to buy annuities. The distinction is irrelevant for most theoretical predictions, at least as long as the putative third factor is not observed by the insurance company.² As we shall discuss below, the important feature is the existence of an exogenous correlation between the agent's risk and her demand for insurance, not the source of this correlation.

Secondly, the focus in most theoretical models on one particular source of adverse selection—the agent's better knowledge of her risk—is very restrictive. In many real-life applications, risk is not the only possible source of informational asymmetry and arguably not the most important one. Individuals also have a better knowledge of their own preferences and particularly their level of risk aversion—an aspect that is often disregarded in theoretical models. A possible justification for this lack of interest

¹We refer the reader to [Salanié \(2005\)](#) for a comprehensive presentation of the various theoretical models.

²Indeed, the underwriting of standard annuity contracts is not contingent on the client's wealth or income.

is that if adverse selection only bears on preferences, it should have negligible consequences upon the form and the outcome of the relationship in competitive markets. Pure competition typically imposes that companies charge a fair premium, at least whenever the latter can be directly computed (which is precisely the case when the agent's risk is known.) The insurer's costs do not directly depend on the insuree's preferences: values are private. Then the equilibrium contract should not depend on whether the subscriber's preferences are public or private information. To be a little more specific, in a model of frictionless, perfectly competitive insurance markets with symmetric information, the introduction of hidden information on preferences only will not alter the equilibrium outcome.³

This conclusion should however be qualified for at least two reasons. First, perfect competition does not approximate insurance markets that well. Fixed costs, product differentiation, price stickiness, switching costs, and cross-subsidization are common; oligopoly is probably the rule rather than the exception. In such a context, firms are able to make positive profits; their profitability depends on the agents' demand elasticity, which is related to their risk aversion. Take the extreme case of a monopoly insurer, which corresponds to the principal–agent framework: it is well known that adverse selection on risk aversion does matter for the form of the optimal contract, as more rent can be extracted from more risk-averse buyers.

A second caveat is that even when adverse selection on preferences *alone* does not matter, when added to asymmetric information of a more standard form, it may considerably alter the properties of equilibria. In a standard Rothschild–Stiglitz context, for instance, heterogeneity in risk aversion may result in violations of the classical, “Spence–Mirrlees” single-crossing property of indifference curves, which in turn generates new types of competitive equilibria.⁴ More generally, situations of bi- or multidimensional adverse selection are much more complex than the standard ones and may require more sophisticated policies.⁵

The previous remarks only illustrate a basic conclusion: when it comes to empirical testing, one should carefully check the robustness of the conclusions under consideration to various natural extensions of the theoretical background. Now, what are the main robust predictions emerging from the theoretical models?

The Exclusivity Issue

A first and crucial distinction, at this stage, must be made between *exclusive* and *nonexclusive* contracts. The issue, here, is whether the insurer can impose an exclusive relationship or individuals are free to buy an arbitrary number of contracts from different insurance companies. Both situations coexist in insurance markets; for instance, automobile insurance contracts are almost always exclusive, whereas annuities or life insurance contracts are typically sold without exclusivity.⁶ The distinction is not always watertight, and since it is often driven by regulations it may vary over time and across countries. In health care, for instance, insurance is nonexclusive, but sometimes regulation caps the total amount of coverage that can be bought. We neglect these important issues in this survey: for

³See Pouyet–Salanié–Salanié (2008) for a general proof that adverse selection does not change the set of competitive equilibria when values are private.

⁴See, for instance, Villeneuve (2003). The same remark applies to models with adverse selection and moral hazard, whether adverse selection is relative to risk, as in Chassagnon and Chiappori (1997), or to risk aversion, as in Jullien et al. (2007).

⁵Typically, they may require more instruments than in the standard models. In addition, one may have to introduce randomized contracts, and bunching may take specific forms. See Rochet and Stole (2003) for a survey.

⁶A different but related issue is whether, in a nonexclusive setting, each insurer is informed of the agent's relationships with other insurers. Jaynes (1978) showed how crucial this can be for the existence of equilibrium.

us, “nonexclusive” means that the insuree can buy as much coverage as she wants from as many insurers as she wants. But applications clearly need to come to terms with real-world limitations to nonexclusivity.

Nonexclusive Contracts and Price Competition

Nonexclusivity strongly restricts the set of possible contracts. For instance, no convex price schedule can be implemented: if unit prices rise with quantities (which is typically what adverse selection requires), agents can always “linearize” the schedule by buying a large number of small contracts from different insurers.⁷ This limits the ability of insurers to screen different types of agents, compared to the exclusive case: an agent cannot commit anymore to buying a partial coverage, and instruments like quantity constraints are less effective. In fact, competition between non exclusive insurers is shown in Attar, Mariotti and Salanié (2011a, b) to yield linear pricing of coverage.

In this context, since all agents face the same (unit) price, high-risk individuals are de facto subsidized (with respect to fair pricing), whereas low-risk agents are taxed. The latter are likely to buy less insurance or even to leave the market (the ‘Akerlof effect’). A first prediction of the theory is precisely that, in the presence of adverse selection, the market typically shrinks, and the high-risk agents are overrepresented among buyers. In addition, purchased quantities should be positively correlated with risk, i.e., high-risk agents should, everything equal, buy more insurance. Both predictions are testable using insurers’ data, insofar—and this is an important reservation—that the data reports the total amount of coverage bought by any insuree, not only his purchase from one insurer.

The presence of adverse selection will also have an impact on prices. Because of the overrepresentation (in number and in quantity purchased) of high-risk agents in the insurers’ portfolios, unit prices will, at equilibrium, exceed the level that would obtain in the absence of adverse selection. Although the latter is not observable, it may in general be computed from the average characteristics of the general population. A typical example is provided by annuities, since the distribution of life expectancy conditional on age is well documented. It is in principle possible to compute the fair price of a given annuity and to compare it to actual market price. A difference that exceeds the “normal” loading can be considered as indirect evidence of adverse selection (provided, of course, that the normal level of loading can be precisely defined).

Exclusive Contracts

In the alternative situation of exclusivity, the set of available contracts is much larger. In particular, price schedules may be convex, and ceilings over insurance purchases can be imposed. Theoretical predictions regarding outcomes depend, among other things, on the particular definition of an equilibrium that is adopted—an issue on which it is fair to say that no general agreement has been reached. Using Rothschild and Stiglitz’s concept, equilibrium may fail to exist and cannot be pooling. However, an equilibrium à la Riley always exists. The same property holds for equilibria à la Wilson; in addition, the latter can be pooling or separating, depending on the parameters. Recent contributions, that consider game-theoretic frameworks with several stages (in the line of earlier work by Hellwig 1987), tend to emphasize the relevance of the Miyazaki-Spence-Wilson equilibrium concept, although

⁷The benefits of linearization can be mitigated by the presence of fixed contracting costs. For large amounts of coverage, however, this limitation is likely to be negligible.

the analysis may be sensitive to the detailed structure of the game (for instance, the exact timing of the moves, the exact strategy spaces, . . .); see for instance Netzer and Scheuer (2011) or Mimra and Wambach (2011).

These remarks again suggest that empirically testing the predictions coming from the theory is a delicate exercise; it is important to select properties that can be expected to hold in very general settings. Here, the distinction between exclusive and nonexclusive contracts is crucial. For instance, convex pricing—whereby the unit price of insurance increases with the purchased quantity—is a common prediction of most models involving exclusive contracts, but it cannot be expected to hold in a nonexclusive framework.

A particularly important feature, emphasized in particular by Chiappori and Salanié (2000), is the so-called *positive correlation property*, whereby an increasing relationship exists, conditional on all variables used for underwriting, between an agent's risk and the amount of insurance she purchases. Prior to any empirical test, however, it is crucial to clearly understand the scope and limits of this prediction; we analyze this issue in Sect. 14.2.2.

14.2.1.2 Moral Hazard

Moral hazard occurs when the probability of a claim is not exogenous but depends on some decision made by the subscriber (e.g., effort of prevention). When the latter is observable and contractible, then the optimal decision will be an explicit part of the contractual agreement. For instance, an insurance contract covering a fire peril may impose some minimal level of firefighting capability or alternatively adjust the rate to the existing devices. When, on the contrary, the decision is not observable or not verifiable, then one has to examine the incentives the subscriber is facing. The curse of insurance contracts is that their mere existence tends to weaken incentives to reduce risk. Different contracts provide different incentives, hence result in different observed accident rates. This is the bottom line of most empirical tests of moral hazard.

Ex ante Versus Ex post

An additional distinction that is specific to insurance economics is between an *accident* and a *claim*. The textbook definition of moral hazard is *ex ante*: the consequence of the agent's effort is a reduction in *accident* probability or severity, as one would expect of unobservable self-insurance or self-protection efforts. But insurance companies are interested in claims, not in accidents. Whether an accident results in a claim is at least in part the agent's decision, and as such, it is influenced by the form of the insurance contract—a phenomenon usually called *ex post* moral hazard. Of course, the previous argument holds for both notions: more comprehensive coverage discourages accident prevention *and* increases incentives to file a claim for small accidents. However, the econometrician will in general be eager to separate “true” moral hazard, which results in changes in the accident rates, from *ex post* moral hazard. Their welfare implications are indeed very different. For instance, a deductible is more likely to be welfare increasing when it reduces accident probability than when its only effect is to discourage victims from filing a claim. The latter only results in a transfer between insurer and insured, and this matters much less for welfare.⁸

⁸A related problem is fraud, defined as any situation where a subscriber files a claim for a false accident or overstates its severity in order to obtain a more generous compensation. The optimal contract, in that case, typically requires selective auditing procedures (see the chapter by Picard in this volume).

The distinction between claims and accidents has two consequences. One is that the incentives to file a claim should be (and indeed are) monitored by the insurance company, particularly when the processing of a small claim involves important fixed costs for the company. A deductible, for instance, is often seen by insurance companies as a simple and efficient way of avoiding small claims; so are experience rating provisions, whereby the premium paid at any given period depends on past claims filed by the insuree. Secondly and from a more empirical perspective, the empirical distribution of claims will in general be a truncation of that of accidents—since “small” accidents are typically not declared. However, the truncation is endogenous; it depends on the contract (typically, on the size of the deductible or the form of experience rating) and also on the individual characteristics of the insured (if only because the cost of higher future premia is related to the expected frequency of future accidents). This can potentially generate severe biases. If a high deductible discourages small claims, a (spurious) correlation will appear between the choice of the contract and the number of filed claims, even in the absence of adverse selection or ex ante moral hazard. The obvious conclusion is that any empirical estimation must very carefully control for potential biases due to the distinction between accidents and claims.

Moral Hazard and Adverse Selection

Quite interestingly, moral hazard and adverse selection have similar empirical implications but with an inverted causality. Under adverse selection, people are characterized by different levels of ex ante risk, which translate into different ex post risk (accident rates), and, (possibly) being aware of these differences in risk, insurees choose different contracts. In a context of moral hazard, agents first choose different contracts; they are therefore faced with different incentive schemes and adopt more or less cautious behavior, which ultimately results in heterogeneous accident probabilities. In both cases, controlling for observables, the choice of a contract will be correlated with the accident probability: more comprehensive coverage is associated with higher risk.

This suggests that it may be difficult to distinguish between adverse selection and moral hazard in the static framework (i.e., using cross-sectional data). An econometrician may find out that, conditionally on observables, agents covered by a comprehensive automobile insurance contract are more likely to have an accident. But this could be because the comprehensive contract they chose (for some exogenous and independent reason) reduced their incentives to drive safely or because they chose full coverage knowing that their risk was higher or because both contract choice and risk were determined by some exogenous, third factor. Discriminating between these explanations is a difficult problem, to which we return in Sect. 14.3.4.

14.2.2 *The Positive Correlation Property: General Results*

The argument that in the presence of asymmetric information and with exclusive contracts, ex post risk and coverage should be positively correlated is quite intuitive, and in fact such tests were used in the health insurance literature⁹ before they were formally analyzed by Chiappori and Salanié (1997, 2000) and by Chiappori et al. (2006). In practice, however, it raises a host of technical issues: Which variables are expected to be correlated? What are the appropriate measures? How should the conditioning set be taken into account? Answering these questions can be particularly delicate when the form of the contracts and/or the distribution of outcomes (the “loss distribution”) are complex:

⁹See for instance the surveys by Cutler and Zeckhauser (2000) and Glied (2000).

precisely defining the mere notions of “more coverage” or “higher risk” may be problematic. Often-used pricing schemes, such as experience rating, or regulation may also complicate the picture, not to mention ex post moral hazard (when insurees may not file low-value claims so as to preserve their risk rating).

In addition, there are a priori appealing objections to the intuitive argument. The one that comes up most frequently may be that insurers attempt to “cherry-pick” insurees: more risk-averse insurees may both buy higher coverage and behave more cautiously, generating fewer claims. Such a “propitious” or “advantageous” selection¹⁰ suggests that the correlation of risk and coverage may in fact be negative. As it turns out, this counterargument is much less convincing than it seems, but it does require proper analysis.

Before we proceed with the formal analysis, it is important to note that all of the arguments below assume an observably homogeneous population of insurees: more precisely, we focus on a subpopulation whose pricing-relevant characteristics are identical. What is “pricing-relevant” depends on what insurers can observe, but also on regulation (e.g., rules that forbid discrimination). We will assume that the econometrician also observes all pricing-relevant characteristics, which is typically true if he has access to the insurer’s data.

A Simple Counterexample

We may start with a simple but basic remark—namely that the positive correlation property is, broadly speaking, typical of a *competitive* environment. While we will be more precise below, it is easy to see that in a monopoly context, the correlation between coverage and accidents may take any sign, at least when the analyst cannot fully control for risk aversion. An intuitive argument goes as follows. Start from a monopoly situation in which agents have the same risk but different risk aversions; to keep things simple, assume there exist two types of agents, some very risk averse and the others much less. The monopoly outcome is easy to characterize. Two contracts are offered; one, with full insurance and a larger unit premium, will attract more risk-averse agents, while the other entails a smaller premium but partial coverage and targets the less risk-averse ones. Now, slightly modify individual risks in a way that is perfectly correlated with risk aversion. By continuity, the features just described will remain valid, whether more risk-averse agents become slightly riskier or slightly less risky. In the first case, we are back to the positive correlation situation; in the second case, we reach an opposite, *negative* correlation conclusion.

The logic underlying this example is clear. When agents differ in several characteristics—say, risk and risk aversion—contract choices reflect not only relative riskiness but also these alternative characteristics. The structure of the equilibrium may well be mostly driven by the latter (risk aversion in the example above), leading to arbitrary correlations with risk.¹¹

However, and somewhat surprisingly, this intuition does *not* hold in a competitive context. Unlike other differences, riskiness *directly* impacts the insurer’s profit; under competition, this fact implies that the correlation can only be positive (or zero), but never negative, provided that it is calculated in an adequate way. To see why, let us first come back to our simple example, this time in a perfectly competitive context. Again, we start from the benchmark of agents with identical risk but different risk aversions, and we marginally modify this benchmark by slightly altering riskiness. If more risk-averse agents are riskier, any Rothschild–Stiglitz (from now RS) equilibrium will take the usual form—namely, a full insurance contract attracting high-risk/high-risk aversion agents and a partial coverage one targeting the remaining low-risk/low-risk aversion ones. In particular, the positive

¹⁰See Hemenway (1990) and de Meza and Webb (2001) for a recent analysis.

¹¹The analysis in Jullien et al. (2007) also illustrates it, with risk-averse agents and moral hazard in a principal–agent model of adverse selection.

correlation property is satisfied. Assume, now, that risk-averse agents are *less* risky. Then a separating contract cannot exist. Indeed, under the standard, zero-profit condition, the comprehensive coverage contract, which attracts the more risk-averse agents, should now have a *lower* unit price, because of their lower risk. But then the revelation constraint cannot be satisfied, since all agents—including the less risk-averse ones—prefer more coverage and a cheaper price.

Of course, this example cannot by itself be fully conclusive. For one thing, it assumes perfect correlation between risk and risk aversion; in real life, much more complex patterns may exist. Also, we are disregarding moral hazard, which could in principle reverse our conclusions. Finally, RS is not the only equilibrium concept; whether our example would survive a change in equilibrium concept is not clear a priori. We now proceed to show that, in fact, the conclusion is surprisingly robust. For that purpose, we turn to the formal arguments in [Chiappori et al. \(2006\)](#), which show how combining a simple revealed preference argument and a weak assumption on the structure of equilibrium profits yields a testable inequality. Readers who are not interested in the technical argument can skip it and go directly to Sect. 14.3.

The Formal Model

Consider a competitive context in which several contracts coexist. Suppose that each contract C_i offers a coverage $R_i(L)$: if the total size of the claims over a contract period is L , then the insuree will be reimbursed $R_i(L)$. For instance, $R_i(L) = \max(L - d_i, 0)$ for a straight deductible contract with deductible d_i . We say that contract C_2 “covers more” than contract C_1 if $R_2 - R_1$ (which is zero in $L = 0$) is a non-decreasing function of L ; this is a natural generalization of $d_2 \leq d_1$ for straight deductible contracts. To keep our framework fully general, we allow the probability distribution of losses to be chosen by the insuree in some set, which may be a singleton (then risk is fully exogenous) or not (as in a moral hazard context).

Now consider an insuree who chose a contract C_1 , when a contract C_2 with more coverage was also available to him. Intuitively, it must be that contract C_1 had a more attractive premium. Let P_1 and P_2 denote the premia of C_1 and C_2 . Now suppose that the insuree anticipates that under contract C_1 , he will generate a distribution of claims G . Note that the insuree could always buy contract C_2 and otherwise behave as he does under contract C_1 , generating the same distribution G of claims L that he anticipates under contract C_1 . If the insuree is risk neutral, his expected utility under contract C_1 is

$$\int R_1(L)dG(L) - P_1$$

and he knows that he could obtain

$$\int R_2(L)dG(L) - P_2$$

by buying contract C_2 and otherwise behaving as he does under contract C_1 , generating the same distribution G of claims L that he anticipates under contract C_1 . By revealed preferences, it must be that

$$\int R_1(L)dG(L) - P_1 \geq \int R_2(L)dG(L) - P_2.$$

Now let the insuree be risk averse, in the very weak sense that he is averse to mean-preserving spreads. Then given that contract C_2 covers more than contract C_1 , it is easy to see that $R_1 - \int R_1 dG$ is a mean-preserving spread of $R_2 - \int R_2 dG$, which makes the inequality even stronger. To summarize this step of the argument

Lemma 1. *Assume that an insuree prefers a contract C_1 to a contract C_2 that covers more than C_1 . Let G be the distribution of claims as anticipated by the agent under C_1 . Then if the insuree dislikes mean-preserving spreads,*

$$P_2 - P_1 \geq \int (R_2(L) - R_1(L)) dG(L).$$

The Main Result

We now consider the properties of the equilibrium. As mentioned above, under adverse selection, the mere definition of an equilibrium is not totally clear. For instance, a Rothschild–Stiglitz equilibrium requires that each contract makes nonnegative profit and no new contract could be introduced and make a positive profit. As is well known, such an equilibrium may fail to exist or to be (second best) efficient. Alternatively, equilibria à la Miyazaki–Spence–Wilson allow for cross subsidies (insurance companies may lose on the full insurance contract and gain on the partial insurance ones). We certainly want to avoid taking a stand on which notion should be preferred; actually, we do not even want to rule out imperfectly competitive equilibria.

Therefore, we shall simply make one assumption on the equilibrium—namely, that *the profit made on contracts entailing more comprehensive coverage cannot strictly exceed those made on contract involving partial insurance*. Note that this “nonincreasing profits” property (Chiappori et al. 2006) is satisfied by the two concepts just described (profit is zero for all contracts in a Rothschild–Stiglitz equilibrium; in a Miyazaki–Spence–Wilson context, more comprehensive coverage contracts typically make losses that are compensated by the positive profits generated by partial coverage ones). As a matter of fact, most (if not all) concepts of competitive equilibrium under adverse selection proposed so far satisfy the nonincreasing profit condition.

Formally, define the profit of the insurer on a contract C as the premium¹² minus the reimbursement, allowing for a proportional cost λ and a fixed cost K :

$$\pi = P - (1 + \lambda) \int R(L)dF(L) - K$$

if the average buyer of contract C generates a distribution of claims F . Under the nonincreasing profits assumption, we have that $\pi_2 \geq \pi_1$; therefore,

$$P_2 - P_1 \leq (1 + \lambda_2) \int R_2(L)dF_2(L) - (1 + \lambda_1) \int R_1(L)dF_1(L) + K_2 - K_1,$$

which gives us a bound on $P_2 - P_1$ in the other direction than in Lemma 1. Remember that the inequality in the lemma contains the distribution of claims G that the insuree expects to prevail under contract C_1 . Assume that there is at least one insuree who is not optimistic,¹³ in the sense that his expectations G satisfy

$$\int (R_2(L) - R_1(L)) (dG(L) - dF_1(L)) \geq 0.$$

Combining with Lemma 1 and rearranging terms to eliminate $P_2 - P_1$, we obtain

¹²Premia are often taxed, but this is easy to incorporate in the analysis.

¹³Since $R_2 - R_1$ is nondecreasing, this inequality holds, for instance, if G first-order stochastically dominates F_1 , hence our choice of the term “not optimistic.” Chiappori et al. (2006) assumed that no insuree was optimistic. The much weaker condition stated here is in fact sufficient.

$$\int R_2(L) ((1 + \lambda_2)dF_2(L) - dF_1(L)) \geq \lambda_1 \int R_1(L)dF_1(L) + K_1 - K_2. \quad (14.1)$$

While it may not be obvious from this expression, this inequality is the positive correlation property. To see this, assume that the proportional costs are zero and that $K_2 \leq K_1$. Then we have

Theorem 1. *Consider a contract C_1 and a contract C_2 that covers more than C_1 . Assume that:*

1. *At least one of the insurees who prefers C_1 to C_2 is not optimistic, has increasing preferences, and is averse to mean-preserving spreads.*
2. *Profits are nonincreasing in coverage.*

Then if C_1 and C_2 have zero proportional costs and their fixed costs are ordered by $K_2 \leq K_1$,

$$\int R_2(L) (dF_2(L) - dF_1(L)) \geq 0.$$

As an illustration, take the simplest possible case, in which claims can either be 0 or \bar{L} , and the average buyer of contract C_i faces a claim \bar{L} with probability p_i ; then

$$\int R_2(L) (dF_2(L) - dF_1(L)) = (p_2 - p_1) R_2(\bar{L}),$$

and Theorem 1 implies that $p_2 \geq p_1$: contracts with more coverage have higher ex post risk, in the sense used in the earlier literature. In more complex settings, inequality (14.1) could be used directly if the econometrician observes the reimbursement schemes R_i and distributions of claim sizes F_i and has reliable estimates of contract costs λ_i and K_i .

Note that while we assume some weak forms of risk aversion and rationality in Assumption 1, we have introduced no assumption at all on the correlation of risk and risk aversion: it does not matter whether more risk-averse agents are more or less risky, insofar as it does not invalidate our assumption that profits do not increase in coverage and if we apply the general version of the inequality (14.1). Take the advantageous selection story in [de Meza and Webb \(2001\)](#), for instance. They assume no proportional costs, zero profits (which of course fits our Assumption 2), and a $\{0, \bar{L}\}$ model of claim sizes, but they allow for administrative fixed costs, so that (14.1) becomes

$$(p_2 - p_1)R_2(\bar{L}) \geq K_1 - K_2.$$

In the equilibrium they consider, contract C_1 is no-insurance, which by definition has zero administrative costs. Thus their result that p_2 may be lower than p_1 does not contradict Theorem 1.

Let us stress again that in imperfectly competitive markets Assumption 2 may fail when agents have different risk aversions and sometimes negative correlations will obtain, but it should be possible to check Assumption 2 directly on the data.¹⁴

Inequality (14.1) is also useful as an organizing framework to understand when simpler versions like $p_2 \geq p_1$ may *not* hold. Assume again that claims can only be 0 or some (now contract-dependent) \bar{L}_i and reintroduce costs. Then (14.1) is

$$(1 + \lambda_2)p_2R_2(\bar{L}_2) - (R_2(\bar{L}_1) + \lambda_1R_1(\bar{L}_1))p_1 + K_2 - K_1 \geq 0.$$

¹⁴[Chiappori et al. \(2006\)](#) do it in their empirical application.

Proportional costs, even if equal across contracts, may make this consistent with $p_2 < p_1$. Even if the proportional costs are zero, $p_2 \geq p_1$ may fail if $\bar{L}_2 > \bar{L}_1$, so that higher coverage generates larger claims, or as we saw above, if $K_2 > K_1$ —higher coverage entails larger fixed costs. We would argue that in such cases, the positive correlation property does not fail; but it must be applied adequately, as described by our results, and may not (does not in this example) boil down to the simplest form $p_2 \geq p_1$.

Finally, Theorem 1 abstracts from experience rating. With experience rating the cost of a claim to the insuree is not only $(L - R_i(L))$; it also includes the expected increase in future premia, along with their consequences on future behavior. If switching to a new contract is costless (admittedly a strong assumption in view of the evidence collected by [Handel 2011](#) and others), then the discounted cost of a claim $c(L)$ is the same for both contracts. It is easy to see that experience rating then does not overturn the inequality $p_2 \geq p_1$ in the simpler cases. [Chiappori et al. \(2006\)](#) have a more detailed discussion.

As a final remark, note that, as argued in Sect. 14.2.1.2, tests of the positive correlation property, at least in the static version, cannot distinguish between moral hazard and adverse selection: both phenomena generate a positive correlation, albeit with opposite causal interpretations. Still, such a distinction is quite important, if only because moral hazard and adverse selection have different (and sometimes opposite) welfare consequences. For instance, a deductible—or, for that matter, any limitation in coverage—that reduces accident probabilities through its impact on incentives may well be welfare increasing, but if the same limitation is used as a separating device, the conclusion is less clear. Distinguishing empirically between moral hazard and adverse selection requires more structure or more data; we survey several approaches in Sect. 14.3.4.

14.3 Empirical Tests of Asymmetric Information

While the theoretical analysis of contracts under asymmetric information began in the 1970s, the empirical estimation of insurance models entailing either adverse selection or moral hazard is more recent.¹⁵ Much of this work revolves around the positive correlation property, as will our discussion.

We will focus here on the methodological aspects. We start with insurance markets involving nonexclusive contracts. Next, we discuss the most common specifications used to evaluate and test the correlation of risk and coverage under exclusivity. Then we give a brief discussion of the results; the survey by [Cohen and Siegelman \(2010\)](#) provides a very thorough review of empirical studies on various markets, and we refer the reader to it for more detail. Finally, we discuss the various approaches that have been used to try to disentangle moral hazard and adverse selection.

14.3.1 Nonexclusive Insurance

A first remark is that tests of asymmetric information in nonexclusive insurance markets must deal with a basic difficulty—namely, the relevant data for each insuree should include *all* of her insurance contracts. Indeed, if an insuree buys insurance from several insurers, then her final wealth and the risk she bears cannot be evaluated using data from her relationship with only one insurer. Some of the tests that have been published in this setting are immune to this criticism; we give examples below.

¹⁵Among early contributions, one may mention [Boyer and Dionne \(1989\)](#) and [Dahlby \(1983\)](#).

14.3.1.1 Annuities

Annuities provide a typical example of nonexclusive contracts, in which moreover the information used by the insurance company is rather sparse. Despite the similarities between annuities and life insurances (in both cases, the underlying risk is related to mortality), it is striking to remark that while the underwriting of life insurance contracts (at least above some minimum amount) typically requires detailed information upon the subscriber's health state, the price of an annuity only depends on the buyer's age and gender. One may expect that this parsimony leaves a lot of room for adverse selection; empirical research largely confirms this intuition.

A first line of research has focused on prices. In an important contribution, [Friedman and Warshawski \(1990\)](#) compute the difference between the implicit contingent yield on annuities and the available yield on alternative forms of wealth holding (in that case, US government bonds). Even when using longevity data compiled from company files, they find the yield of annuities to be about 3% lower than that of US bonds of comparable maturity, which they interpret as evidence of adverse selection in the company's portfolio. Similar calculations on UK data by [Brugiavini \(1990\)](#) also find a 3% difference, but only when longevity is estimated on the general population.

A related but more direct approach studies the distribution of mortality rates in the subpopulation of subscribers and compares it to available data on the total population in the country under consideration. [Brugiavini \(1990\)](#) documents the differences in life expectancy between the general population and the subpopulation actually purchasing annuities. For instance, the probability, at age 55, to survive till age 80 is 25% in the general population but close to 40% among subscribers. In a similar way, the yield difference computed by [Friedman and Warshawski \(1990\)](#) is 2% larger when computed from data relative to the general population.

The most convincing evidence of adverse selection on the annuity market is probably that provided by [Finkelstein and Poterba \(2004\)](#). They use a data base from a UK annuity firm; the data covers both a compulsory market (representing tax-deferred retirement saving accounts that must be transformed into annuities to preserve the tax exemption) and a voluntary market. The key element of their empirical strategy is the existence of different products, involving different degrees of back-loading. At one extreme, nominal annuities pay a constant nominal amount; the real value of annual payments therefore declines with inflation. Alternatively, agents may opt for escalating annuities, in which an initially lower annual payment rises with time at a predetermined rate (in practice, 3 to 8%), or for real annuities, which pay an annual amount indexed on inflation. Under adverse selection on mortality risks, one would expect agents with superior life expectancy to adopt more back-loaded products (escalating or real). Finkelstein and Poterba's results confirm this intuition; using a proportional hazard model they find that buyers of these products have a significantly smaller death hazard rate. The most striking conclusion is the magnitude of this effect. The differential impact, on the hazard rate, of indexed or escalating products versus nominal ones dominates that of gender, the standard indicator used in underwriting; for the voluntary market, the impact of contract choice is actually several times larger.

These results teach two lessons. First, adverse selection does exist in real life and particularly affects markets in which insurers collect little information during the underwriting process—a salient characteristic of annuity markets. Second, the form taken by adverse selection on such markets goes beyond the standard correlation between risk and quantity purchased; the type of product demanded is also affected by the agent's private information, and that effect may in some cases be dominant.¹⁶

¹⁶While Finkelstein and Poterba do find a significant relationship between risk and quantity purchased, the sign of the correlation, quite interestingly, differs between the compulsory and voluntary markets.

14.3.1.2 Life Insurance

Life insurance contracts provide another typical example of nonexclusive contracts, although adverse selection might in this case be less prevailing. In an early paper, [Cawley and Philipson \(1999\)](#) used direct evidence on the (self-perceived and actual) mortality risk of individuals, as well as the price and quantity of their life insurance. They found that unit prices fall with quantities, indicative of the presence of bulk discounts. More surprisingly, quantities purchased appeared to be *negatively* correlated with risk, even when controlling for wealth. They argued that this indicated that the market for life insurance may not be affected by adverse selection. This conclusion is however challenged in a recent article by [He \(2009\)](#), who points to a serious sample selection problem in the Cawley–Philipson approach: agents with a higher, initial mortality risk are more likely to have died *before* the beginning of the observation window, in which case they are not included in the observed sample.

To avoid this bias, He suggests to concentrate on a sample of potential *new* buyers (as opposed to the entire cross section). Using the Health and Retirement Study (HRS) dataset, he does find evidence for the presence of asymmetric information, taking the form of a significant and positive correlation between the decision to purchase life insurance and subsequent mortality (conditional on risk classification). The effect is actually quite strong; for instance, individuals who died within a 12-year time window after a base year were 19% more likely to have taken up life insurance in that base year than were those who survived the time window. In summary, the existence of adverse selection effects is well documented in several nonexclusive markets.

14.3.2 Evaluating the Correlation of Risk and Coverage in Exclusive Markets

We now turn to exclusive markets. To measure the correlation of risk and coverage, we of course need to measure them first. Since risk here means “ex post risk,” it can be proxied by realized risk: the occurrence of a claim (a binary variable), the number of claims (an integer), or the cumulative value of claims (a nonnegative number) could all be used, depending on the specific application. Let y_i denote the chosen measure of ex post risk for insuree i . Coverage D_i could be the value of the deductible, or some other indicator (e.g., a binary variable distinguishing between compulsory and complementary insurance) could be used.

Finally, a (hopefully complete) set of pricing-relevant variables X_i will be found in the insurer’s files. As emphasized by [Chiappori and Salanié \(1997, 2000\)](#), it is very important to account for all publicly observed pricing-relevant covariates. Failure to do so can lead to very misleading results: [Dionne et al. \(2001\)](#) provide a striking illustration on the early study by [Puelz and Snow \(1994\)](#). Even so, it is not always obvious which variables are “pricing-relevant”; we will return to this issue in Sect. 14.3.3.

14.3.2.1 Basic Approaches

Let us focus first the simplest (and very common) case in which both y and D are 0–1 variables. Then one straightforward measure of the relevant correlation¹⁷ is

$$\rho_1(X) = \Pr(y = 1|D = 1, X) - \Pr(y = 1|D = 0, X); \quad (14.2)$$

¹⁷Recall however from Sect. 14.2.2 that given the results of [Chiappori et al. \(2006\)](#), the positive correlation property may bear on a more complicated object.

and a second one is

$$\rho_2(X) = \text{cov}(y, D|X) = \Pr(y = D = 1|X) - \Pr(y = 1|X)\Pr(D = 1|X). \quad (14.3)$$

It is easy to see that

$$\rho_2(X) = \rho_1(X)V(D|X)$$

since $V(D|X) = \Pr(D = 1|X)(1 - \Pr(D = 1|X))$; it follows that the two measures have the same sign.

In [Chiappori and Salanié \(1997, 2000\)](#) we proposed to simultaneously estimate two binary choice models. The first one describes the choice of coverage:

$$y = \mathbf{1}(f(X) + \varepsilon > 0); \quad (14.4)$$

and the second one regresses coverage on covariates:

$$D = \mathbf{1}(g(X) + \eta > 0). \quad (14.5)$$

We argued that the correlation can be estimated by running a bivariate probit for (y, D) and allowing for correlated ε and η or by estimating two separate probits and then measuring the correlation of the generalized residuals $\hat{\varepsilon}$ and $\hat{\eta}$. By construction the probit assumes that ε and η are independent of X , so that a test that they are uncorrelated is equivalent to a test that ρ_1 and ρ_2 are identically zero.

According to standard theory, asymmetric information should result in a positive correlation under the convention that $D = 1$ (resp. $y = 1$) corresponds to more comprehensive coverage (resp. the occurrence of an accident). One obvious advantage of this setting is that it does not require the estimation of the pricing policy followed by the firm, which is an extremely difficult task and a potential source of severe bias.

An alternative way to proceed when D is a 0–1 variable is to run a linear regression of y on D :

$$E(y|X, D) = a(X) + b(X)D + u. \quad (14.6)$$

Given that D only takes the two values 0 and 1, the linear form is not restrictive, and it is easy to see that the estimator of $b(X)$ in (14.6) converges to

$$\rho(X) = E(y|D = 1, X) - E(y|D = 0, X),$$

which equals $\rho_1(X)$ if y is also a 0–1 variable; if it is not, then $\rho(X)$ is a useful measure of correlation but may not be the appropriate one.

Given the often large set of covariates X used by insurers for pricing, it may be hard to find the correct functional forms for f and g or alternatively for a and b . We also proposed a nonparametric test that relies upon the construction of a large number of “cells,” each cell being defined by a particular profile of exogenous variables. Under the null (in the absence of asymmetric information), within each cell, the choice of contract and the occurrence of an accident should be independent, which can easily be checked using a χ^2 test. Constructing the cells requires some prior knowledge of the context, and it is useful to restrict the analysis to relatively homogeneous classes of drivers.

Finally, while much of the literature has focused on a discrete outcome (the occurrence of a claim or sometimes a coarse classification), we have shown in Sect. 14.2.2 that there is no need to do so. For a more general implementation of the test, we refer the reader to Chiappori et al. (2006, Sect. 5) who use data on the size of claims to test the more general positive correlation property of Theorem 1.

14.3.2 Accidents Versus Claims

These methods can easily be generalized to the case when coverage D takes more than two values (see, for instance, Dionne et al. (1997), Richaudeau (1999) and Gouriéroux (1999) for early contributions). However, the issues raised in Sect. 14.2.2 then may become important. If, for instance, D is the choice of deductibles, then we need to take into account differences in per-contract and per-claim costs for the insurer. A regression using claims as the dependent variable may generate misleading results, because a larger deductible automatically discourages reporting small accidents, hence reduces the number of claims even when the accident rate remains constant.

As shown in the Appendix of Chiappori et al. (2006), if insurees follow simple, contract-independent strategies when deciding to report a loss as a claim, then under fairly weak assumptions, Theorem 1 is still valid. However, the positive correlation test then becomes conservative: positive correlations can be found even without asymmetric information. In any case, we know very little about the reporting behavior of insurees and other approaches are still useful. Chiappori and Salanié (2000) discarded all accidents where one vehicle only is involved. Whenever two automobiles are involved, a claim is much more likely to be filed in any case.¹⁸ A more restrictive version is to exclusively consider accidents involving bodily injuries, since reporting is mandatory in that case, but this implies a drastic reduction in the number of accidents in the data.

Alternatively, one can explicitly model the filing decision as part of the accident process. For any accident, the agent computes the net benefit of filing a claim and reports the accident only when this benefit is positive (or above some threshold). Although accidents involving no claims are generally not observed,¹⁹ adequate econometric techniques can be used. Note, however, that these require estimating a complete structural model.

14.3.3 Is the Correlation Positive?

The existence of a positive correlation between risk and coverage (appropriately measured) cannot be interpreted as establishing the presence of asymmetric information without some precautions: any misspecification can indeed lead to a spurious correlation. Parametric approaches, in particular, are highly vulnerable to this type of flaws, especially when they rely upon some simple, linear form. But the argument is not symmetric. Suppose, indeed, that some empirical study does *not* reject the null hypothesis of zero correlation. In principle, this result might also be due to a misspecification bias, but this explanation is not very credible as it would require that while (fully conditional) residuals are actually positively correlated, the bias goes in the opposite direction with the *same* magnitude—so

¹⁸In principle, the two drivers may agree on some bilateral transfer and thus avoid the penalties arising from experience rating. Such a “street-settled” deal is however quite difficult to implement between agents who meet randomly, will probably never meet again, and cannot commit in any legally enforceable way (since declaration is in general compulsory according to insurance contracts). We follow the general opinion in the profession that such bilateral agreements can be neglected.

¹⁹Some datasets do, however, record accidents that did not result in claims. Usually, such datasets have been collected independently of insurance companies. See Richaudeau (1999).

that it exactly offsets the correlation. In other words, misspecifications are much more likely to bias the results *in favor* of a finding of asymmetric information.

Moreover, a positive correlation may come from variables that are observed by insurers but not used in pricing. There are many instances of such “unused observables”: regulation may forbid price discrimination based on some easily observed characteristics such as race, or insurers may voluntarily forgo using some variables for pricing. [Finkelstein and McGarry \(2006\)](#) show, for instance, that British insurers do not use residential address in pricing annuities, even though it is clearly informative on mortality risk. The theoretical arguments that led us to the positive correlation property of Theorem 1 extend to such cases, as long as the list of “pricing-relevant” variables excludes unused unobservables. A positive correlation then may be entirely due to these unused observables.

Given these remarks, it may come as a surprise that the estimated correlation is often close to zero. The case of automobile insurance is emblematic. Using three different empirical approaches, [Chiappori and Salanié \(1997, 2000\)](#) could not find evidence of a nonzero correlation, and most later work has confirmed their findings. A few studies of automobile insurance have estimated a positive correlation, but it was often due to special features of a local market. As an example, [Cohen \(2005\)](#) found that Israeli drivers who learned that they were bad risks tended to change insurers and buy underpriced coverage, an opportunistic behavior that was facilitated at the time by local regulations concerning information on past driver records.

The evidence on health insurance is more mixed, with some papers finding positive correlation, zero correlation, or negative correlation. The Medigap insurance market²⁰ is especially interesting since [Fang et al. \(2008\)](#) found robust evidence that risk and coverage are negatively correlated. They show that individuals with higher cognitive ability are both more likely to purchase Medigap and have lower expected claims.

This points towards the fact that asymmetric information may bear on several dimensions—not only risk. As we explained in Sect. 14.2.2, with perfectly competitive markets, the positive correlation property should hold irrespective of the dimensionality of privately known characteristics. This is often misunderstood. For instance, [Cutler et al. \(2008\)](#) argue that much of the variation in test results across markets can be explained by the role of heterogeneous risk aversion, but variations in the market power of insurers are also necessary and can be evaluated using the variation of profits with coverage. In [Chiappori et al. \(2006\)](#), we used this approach and we found clear deviations from perfect competition.

The findings by [Fang et al. \(2008\)](#) stress the importance of taking into account the cognitive limitations of insurees; we return to this in the Conclusion.

14.3.4 Adverse Selection Versus Moral Hazard: The Static Context

As argued above, the previous tests are not specific of adverse selection. Moral hazard would typically lead to the same kind of correlation, although with a different causality. In order to distinguish between adverse selection and moral hazard, one needs some additional structure.

In some cases, one explanation may seem more plausible. For instance, it has often been argued that asymmetric information in annuity contracts was mostly due to selection: individuals are unlikely to die younger *because* of a lower annuity payment. Sometimes the data contain variables that can be used to directly assess adverse selection. For instance, [Finkelstein and McGarry \(2006\)](#), studying the long-term care insurance market, use individual-level survey data from the Asset and Health Dynamics (AHEAD) cohort of the HRS. A crucial feature of this data is that it provides a measure of individual

²⁰Medigap insurance is private, supplementary insurance targeted at Medicare recipients in the USA.

beliefs about future nursing home use—an information to which insurers have obviously no access. They find that these self-assessed risk estimates are indeed informative of actual, subsequent nursing home utilization and also of the person's long-term care insurance holdings—a clear indicator of adverse selection. In addition, they can then analyze the determinants of the demand for long-term care insurance; they conclude that these determinants are typically multidimensional.

Other papers have relied either on natural or quasi-natural experiments or on the fact that moral hazard and adverse selection generate different predictions for the dynamics of contracts and claims. We discuss here the natural experiments approach, reserving dynamics for Sect. 14.4.

14.3.4.1 Natural Experiments

Assume that, for some exogenous reason (say, a change in regulation), a given, exogenously selected set of agents experience a modification in the incentive structure they are facing. Then the changes in the incentives that agents are facing can reasonably be assumed exogenous in the statistical sense (i.e., uncorrelated with unobserved heterogeneity.) The resulting changes in their behavior can be directly studied, and adverse selection is no longer a problem, since it is possible to concentrate upon agents that remained insured throughout the process.²¹

The first and arguably most influential study of moral hazard is the celebrated Rand study on medical expenditures (Manning et al., 1987), in which individuals were randomly allocated to different coverage schemes. While such examples, involving explicit randomization, are actually quite rare (if only because of their cost), the basic idea may in some occasions apply even in the absence of an actual experiment of this kind. Any context where similar individuals are facing different incentive schemes can do, provided one can be sure that the selection into the various schemes is not related to risk-relevant characteristics. Clearly, the key issue in this literature is the validity of this exogeneity assumption.

A typical example is provided by the changes in automobile insurance regulation in Québec, where a “no fault” system was introduced in 1978, then deeply modified in 1992. Dionne and Vanasse (1997) provide a careful investigation of the effects of these changes. They show that the new system introduced strong incentives to increase prevention and that the average accident frequency dropped significantly during the years that followed its introduction. Given both the magnitude of the drop in accident rate and the absence of other major changes that could account for it during the period under consideration, they conclude that the reduction in claims is indeed due to the change in incentives.²²

An ideal experiment would also have a randomly assigned control group that is not affected by the change, allowing for a differences-of-differences approach. A paper by Dionne and St-Michel (1991) provides a good illustration of this idea. They study the impact of a regulatory variation of coinsurance level in the Quebec public insurance plan on the demand for days of compensation. Now it is much easier for a physician to detect a fracture than, say, lower back pain. If moral hazard is more prevalent when the information asymmetry is larger, theory predicts that the regulatory change will have more significant effects on the number of days of compensation for those cases where the diagnosis is more problematic. This prediction is clearly confirmed by empirical evidence. Note that the effect thus identified is *ex post* moral hazard. The reform is unlikely to have triggered significant changes in prevention, and, in any case, such changes would have affected all types of accidents.

Additional evidence is provided by Fortin et al. (1995), who examine how the Canadian Workers' Compensation (WC) and the Unemployment Insurance (UI) programs interact to influence the

²¹In addition, analyzing the resulting attrition (if any) may in some cases convey interesting information on selection issues.

²²See Browne and Puelz (1998) for a similar study on US data.

duration of workplace accidents. Here, the duration is estimated from a mixed proportional hazard model, where the baseline hazard is estimated nonparametrically, and unobserved heterogeneity is taken into account using a gamma distribution. They show that an increase in the generosity of Workers' Compensation in Quebec leads to an increase in the duration of accidents. In addition, a reduction in the generosity of Unemployment Insurance is, as in Dionne and St-Michel, associated with an increase in the duration of accidents that are difficult to diagnose. The underlying intuition is that workers' compensation can be used as a substitute to unemployment insurance. When a worker goes back to the labor market, he may be unemployed and entitled to UI payments for a certain period. Whenever workers' compensation is more generous than unemployment insurance, there will be strong incentives to delay the return to the market. In particular, the authors show that the hazard of leaving WC is 27% lower when an accident occurs at the end of the construction season, when unemployment is seasonally maximum.²³

Chiappori et al. (1998) use data on health insurance that display similar features. Following a change in regulation in 1993, French health insurance companies modified the coverage offered by their contracts in a nonuniform way. Some of them increased the level of deductible, while others did not. The tests use a panel of clients belonging to different companies, who were faced with different changes in coverage and whose demand for health services are observed before and after the change in regulation. In order to concentrate upon those decisions that are essentially made by consumers themselves (as opposed to those partially induced by the physician), the authors study the occurrence of a physician visit, distinguishing between general practitioner (GP) office visits, GP home visits, and specialist visits. They find that the number of GP home visits significantly decreased for the agents who experienced a change of coverage, but not for those for which the coverage remained constant. They argue that this difference is unlikely to result from selection, since the two populations are employed by similar firms, display similar characteristics, and participation in the health insurance scheme was mandatory.

Finally, a recent paper by Weisburd (2011) uses an intriguing quasi-experiment in which a large Israeli firm covered car insurance premia for some of its employees. These lucky employees only had to pay the deductible if they filed a claim, and the firm would also cover the increase in premia that resulted from experience rating. As a result, those employees who did not benefit from the scheme faced steeper incentives, and to the extent that employees were randomly assigned between the two groups, differences in claims isolate the incidence of moral hazard. Weisburd argues that this is indeed the case; she finds that as expected, employer-paid premia are associated with more claims.

14.3.4.2 Quasi-natural Experiments

Natural experiments are valuable but scarce. In some cases, however, one finds situations that keep the flavor of a natural experiment, although no exogenous *change* of the incentive structure can be observed. The key remark is that any situation where identical agents are, for *exogenous* reasons, faced with different incentive schemes can be used for testing for moral hazard. The problem, of course, is to check that the differences in schemes are purely exogenous and do not reflect some hidden characteristics of the agents. For instance, Chiappori and Salanié (2000) consider the case of French automobile insurance, where young drivers whose parents have low past accident rates can benefit from a reduction in premium. Given the particular properties of the French experience rating system, it turns out that the marginal cost of accident is reduced for these drivers. In a moral hazard context, this should result in less cautious behavior and higher accident probabilities. If, on the contrary, the parents' and children's driving abilities are (positively) correlated, a lower premium should signal

²³See also Fortin and Lanoie (1992), Bolduc et al. (1997), and the survey by Fortin and Lanoie (2000).

a better driver, hence translate into less accidents. The specific features of the French situation thus allow to distinguish between the two types of effects. Chiappori and Salanié find evidence in favor of the second explanation: other things equal, “favored” young drivers have slightly fewer claims.

A contribution by Cardon and Hendel (1998) uses similar ideas in a very stimulating way. They consider a set of individuals who face different menus of employer-based health insurance policies, under the assumption that there is no selection bias in the allocation of individuals across employers. Two types of behavior can then be observed. First, agents choose one particular policy within the menu at their disposal; second, they decide on the level of health expenditures. The authors identify a fully structural model, which allows them to simultaneously estimate a selection equation that describes the policy choice and estimate the price elasticity of demand controlling for selection bias. The key ingredient for identifying the specific effects of moral hazard is that while people are free to choose any contract in the menu they face, they cannot choose the menu itself, and different menus involve different coinsurance levels. The “quasi-experimental” features stem precisely from this random assignment of people to different choice sets. Even if less risky people always choose the contract with minimum coinsurance, the corresponding coinsurance rates will differ across firms. In other words, it is still the case that identical people in different firms face different contracts (i.e., different coinsurance rates) for exogenous reasons (i.e., because of the choice made by their employer). Interestingly enough, the authors find no evidence of adverse selection, while price elasticities are negative and very close to those obtained in the Rand HIE survey. This suggests that moral hazard, rather than adverse selection, may be the main source of asymmetric information in that case.

14.4 Dynamic Models of Information Asymmetries

Tests based on the dynamics of the contractual relationship can throw light on the predictions of models of asymmetric information. In addition, moral hazard and adverse selection models have quite different predictions in dynamic situations; therefore dynamic studies offer an opportunity to disentangle them.

Empirical studies exploiting dynamics can be gathered into two broad categories. First, some work assumes that observed contracts are optimal and compares their qualitative features with theoretical predictions in both a moral hazard and an adverse selection framework. While the derivation of diverging predictions is not always easy in a static context, the introduction of dynamic considerations greatly improves the picture.

Natural as it seems, the assumption that contracts are always optimal may not be warranted in some applications. For one thing, theory is often inconclusive. Little is known, for instance, on the form of optimal contracts in a repeated moral hazard framework, at least in the (realistic) case where the agent can freely save. And the few results we have either require utterly restrictive assumptions (CARA utilities, monetary cost of effort) or exhibit features (randomized contracts, for instance) that sharply contrast with real-life observations. Even skeptics of bounded rationality theories may accept that such very sophisticated constructs, which can hardly be understood by the average insurance salesman (let alone the average consumer), are unlikely to be implemented on a large scale.²⁴

²⁴A more technical problem with the optimality assumption is that it tends to generate complex endogeneity problems. Typically, one would like to compare the features of the various existing contracts. The optimality approach requires that each contract is understood as the optimal response to a specific context, so that differences in contracts simply reflect differences between the “environments” of the various firms. In econometric terms, contracts are thus, by assumption, endogenous to some (probably unobserved) heterogeneity across firms, a fact that may, if not corrected, generate biases in the estimations.

Another potential deviation from optimality comes from the existence of regulations, if only because regulations often impose very simple rules that fail to reproduce the complexity of optimal contracts. An interesting example is provided by the regulation on experience rating by automobile insurance companies, as implemented in some countries. A very popular rule is the “bonus/malus” scheme, whereby the premium is multiplied by some constant larger (resp. smaller) than one for each year with (resp. without) accident. Theory strongly suggests that this scheme is too simple in a number of ways. In principle, the malus coefficient should not be uniform but should vary with the current premium and the driver’s characteristics; the deductible should vary as well; etc.²⁵

14.4.1 Tests Assuming Optimal Contracts

Only a few empirical studies consider the dynamics of insurance relationships. An important contribution is due to [Dionne and Doherty \(1994\)](#), who use a model of repeated adverse selection with one-sided commitment. Their main purpose is to test the “highballing” prediction, according to which the insurance company should make positive profits in the first period, compensated by low, below-cost second-period prices. They test this property on Californian automobile insurance data. According to the theory, when various types of contracts are available, low-risk agents are more likely to choose the experience-rated policies. Since these are characterized by highballing, the loss to premium ratio should rise with the cohort age. If insurance companies are classified according to their average loss per vehicle (which reflects the “quality” of their portfolio), one expects the premium growth to be negative for the best quality portfolios; in addition, the corresponding slope should be larger for firms with higher average loss ratios. This prediction is confirmed by the data: the “highballing” prediction is not rejected. Interestingly, this prediction contrasts with those of a standard model involving switching costs, in which insurers would actively compete in the first period, typically resulting in below-cost initial premium, and overcharge the clients thus acquired in the following periods.

[Hendel and Lizzeri \(2003\)](#) have provided very convincing tests of a symmetric learning model à la [Harris and Holmstrom \(1982\)](#) on life insurance data. Theory tells us that contracts involving commitment from the insurer, in the sense that the dynamics of future premium is fixed in advance and cannot depend on the evolution of the insuree’s situation, should entail front loading, representing the cost of the insurance against the classification risk. Some contracts involve commitment from the insurer, in the sense that the dynamics of future premium is fixed in advance and cannot depend on the evolution of the insuree’s health. For other contracts, however, future premia are contingent on health. Specifically, the premium increases sharply unless the insured is still in good health (as certified, for instance, by a medical examination). In this context, the symmetric learning model generates very precise predictions on the comparison between contracts with and without commitment. Contracts with noncontingent future premia should entail front loading, representing the cost of the insurance against the classification risk. They should also lock-in a larger fraction of the consumers, hence exhibit a lower lapsation rate; in addition, only better risk types are likely to lapse, so that the average quality of the insurer’s client portfolio should be worse, which implies a higher present value of premia for a fixed period of coverage. Hendel and Lizzeri show that all of these predictions are satisfied by existing contracts.²⁶ Finally, the authors study accidental death contracts, i.e., life insurance contracts

²⁵Of course, the precise form of the optimal scheme depends on the type of model. It is however basically impossible to find a model for which the existing scheme is optimal.

²⁶The main puzzle raised by these findings is that a significant fraction of the population does not choose commitment contracts, i.e., does not insure against the classification risk. The natural explanation suggested by theory (credit

that only pay if death is accidental. Strikingly enough, these contracts, where learning is probably much less prevalent, exhibit none of the above features.

Another characteristic feature of the symmetric learning model is that any friction reducing the clients' mobility, although ex post inefficient, is often ex ante beneficial, because it increases the agents' ability to (implicitly) commit and allow for a larger coverage of the classification risk. Using this result, Crocker and Moran (2003) study employment-based health insurance contracts. They derive and test two main predictions. One is that when employers offer the same contract to all of their workers, the coverage limitation should be inversely proportional to the degree of worker commitment, as measured by his level of firm-specific human capital. Secondly, some contracts offer "cafeteria plans," whereby the employee can choose among a menu of options. This self-selection device allows the contract to change in response to interim heterogeneity of insurees. In this case, the authors show that the optimal (separating) contract should exhibit more complete coverage but that the premia should partially reflect the health status. Both predictions turn out to be confirmed by the data. Together with the results obtained by Hendel and Lizzeri, this fact that strongly suggests the symmetric learning model is particularly adequate in this context.

14.4.2 Behavioral Dynamics Under Existing Contracts

Another branch of research investigates, for given (not necessarily optimal) insurance contracts, the joint *dynamics* of contractual choices and accident occurrence. This approach is based on the insight that these properties are largely different under moral hazard and that these differences lead to powerful tests. A classical example involves the type of experience rating typical of automobile insurance, whereby the occurrence of an accident at date t has an impact on future premia (at date $t + 1$ and beyond). In general, existing experience rating schedules are highly nonlinear; the cost of the marginal accident in terms of future increases in premium is not constant and often actually nonmonotonic.²⁷ In a moral hazard framework, these changes in costs result in changes in incentives and ultimately in variations in accident probabilities; under pure adverse selection, on the contrary, the accident probabilities should either remain constant or change in a systematic way (e.g., through aging), irrespective of the accident history.

One idea, therefore, is to use theory to derive the main testable features of individual behavior for the various models at stake. Abbring et al. (2003a,b) develop a test of this type. The test is based on the so-called "negative contagion" effect. With many experience rating schemes, the occurrence of an accident increases the cost of the next one, therefore the insuree's incentives to avoid it. Under moral hazard, a reduction of its probability of occurrence should result. In principle, the variations in individual accident probabilities that follow the occurrence of an accident can be statistically detected using adequate techniques. The main empirical challenge, however, is to disentangle such fairly small fluctuations from the general, background noise due to unobserved heterogeneity. Should one simply look at the intertemporal correlation of accident occurrences among agents, the dominant phenomenon by far reflects some time-invariant (or time-correlated) unobserved heterogeneity: good drivers are less likely both to have had an accident in the past and to have one in the future. Technically, the "negative

rationing) is not very convincing in that case, since differences in premia between commitment and no commitment contracts are small (less than \$300 per year), especially for a client pool that includes executives, doctors, businessmen, and other high-income individuals. Heterogeneous risk perception across individuals is a better story, but formal tests still have to be developed. Obviously, more research is needed on this issue.

²⁷Typically, the cost of the first accident is low; marginal costs then increase, peak, and drop sharply. See, for instance, Abbring et al. (2008).

contagion” property holds only *conditionally* on agents’ characteristics, including unobserved ones; any empirical test must therefore control for the latter.

This problem, which is quite similar to the distinction between state dependence and unobserved heterogeneity in the labor literature (see Heckman 1981, Heckman and Borjas 1980), can in principle be solved when panel data are available. In practice, the authors use French data, for which regulation imposes that insurers increase the premium by 25% in case an accident occurs; conversely, in the absence of any accident during one year, the premium drops by 5%. The technique they suggest can be intuitively summarized as follows. Assume the system is malus only (i.e., the premium increases after each accident but does not decrease subsequently), and consider two sequences of 4-year records, $A = (1, 0, 0, 0)$ and $B = (0, 0, 0, 1)$, where 1 (resp. 0) corresponds to the occurrence of an accident (resp. no accident) during the year. In the absence of moral hazard and assuming away learning phenomena, the probability of the two sequences should be exactly identical; in both cases, the observed accident frequency is 25%. Under moral hazard, however, the first sequence is more probable than the second: in A , the sequence of three years without accident happens after an accident, hence when the premium and consequently the marginal cost of future accidents and the incentives to take care are maximum.

One can actually exploit this idea to construct general, nonparametric tests of the presence of moral hazard. The intuition goes as follows. Take a population of drivers observed over a given period; some drivers have no accident over the period; others have one, two, or more. Assume for simplicity a proportional hazard model, and let H_1 be the distribution of the first claim time T_1 in the subpopulation with exactly one claim over the period. Note that H_1 need not be uniform; with learning, for instance, claims are more likely to occur sooner than later. Similarly, define H_2 to be the distribution of the second claim time T_2 in the subpopulation with exactly two claims in the contract year. In the absence of moral hazard, it must be the case that

$$H_1(t)^2 = H_2(t),$$

a property that can readily be tested non-parametrically.

These initial ideas have recently been extended by Abbring et al. (2008), and Dionne et al. (2013). The first paper, in particular, explicitly models the forward-looking behavior of an agent in the Dutch automobile insurance market, which exhibits a highly nonlinear bonus-malus scheme; they then use this model to compute the dynamic incentives faced by an agent and to construct a structural test that exploits these computations in detail. Their framework explicitly distinguishes ex ante and ex post moral hazard and models both claim occurrences and claim sizes. Interestingly, all three papers (using, respectively, Dutch, Canadian, and French data) find evidence of (ex ante and ex post) moral hazard, at least for part of the population, and compute the magnitude of the resulting effect.

14.5 Conclusion

As argued in the introduction, empirical applications of contract theory have become a *bona fide* subfield, and insurance data has played a leading role in these developments. This literature has already contributed to a better knowledge of the impact of adverse selection and moral hazard in various markets. The practical importance of information asymmetries has been found to vary considerably across markets. In particular, there exists clear and convincing evidence that some insurance markets are indeed affected by asymmetric information problems and that the magnitude of these problems may in some cases be significant.

There exist a number of crucial normative issues where our theoretical and empirical knowledge of asymmetric information are likely to play a central role. To take but one example, a critical feature of the recent reform of the US health insurance system (PPACA, <http://www.ncsl.org/documents/health/ppaca-consolidated.pdf>) is the prohibition of the use of preexisting conditions in the underwriting process. While the benefits of such a measure are clear in terms of ex ante welfare and coverage of the “classification risk,” some of its potential costs have been largely underanalyzed. In particular, the prohibition would introduce a massive amount of adverse selection (since agents have a detailed knowledge of the preexisting conditions that insurers are not allowed to use) into a system that remains essentially market-oriented. From a theoretical viewpoint, the consequences may (but need not) be dramatic. After all, any RS equilibrium exhibits de facto price discrimination (based on self-selection), coupled with significant welfare losses due to severe restrictions of coverage for low-risk individuals.²⁸ The law addresses these issues by introducing penalties for absence of coverage, and by limiting the set of contractual options that can be offered to subscribers. Still, the long term consequences of the new regulation for the health insurance market remain a largely unexplored empirical question; even the basic information needed to attempt a preliminary welfare evaluation (e.g., the joint distribution of income, health risk, and risk aversion) is only very partially known. Some pioneering studies have taken steps in this direction however (see [Einav et al. 2010](#)), and one can only hope that our ability to simulate the effect of such reforms will improve in the near future.

Finally, a better understanding of actual behavior is likely to require new theoretical tools. The perception of accident probabilities by the insurees, for instance, is a very difficult problem on which little is known presently. Existing results, however, strongly suggest that standard theoretical models relying on expected utility maximization using the “true” probability distribution may fail to capture some key aspects of many real-life situations. Our analysis in Sect. 14.2.2 shows that the positive correlation property should hold on perfectly competitive markets under fairly weak conditions on the rationality of agents, but with market power there is much we still need to learn. The confrontation of new ideas from behavioral economics with insurance data is likely to be a very promising research direction in the coming years.

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²⁸See Chiappori (2006) for a preliminary investigation of these effects.

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Chapter 15

The Empirical Measure of Information Problems with Emphasis on Insurance Fraud and Dynamic Data

Georges Dionne

Abstract We discuss the difficult question of measuring the effects of asymmetric information problems on resource allocation. Three problems are examined: moral hazard, adverse selection, and asymmetric learning. One theoretical conclusion, drawn by many authors, is that information problems may introduce significant distortions into the economy. However, we verify, in different markets, that efficient mechanisms have been introduced in order to reduce these distortions and even eliminate, at the margin, some residual information problems. This conclusion is stronger for pure adverse selection. One explanation is that adverse selection is related to exogenous characteristics, while asymmetric learning and moral hazard are due to endogenous actions that may change at any point in time. Dynamic data help to identify the three information problems by permitting causality tests.

Keywords Empirical measure • Information problem • Moral hazard • Adverse selection • Learning • Insurance fraud • Causality test • Dynamic data

15.1 Introduction

The study of information problems in economics began in the early 1960s. The two best known problems, moral hazard and adverse selection, were introduced in the literature in 1963 by Kenneth Arrow in a classic article published in the *American Economic Review*. In 1970, Akerlof came up with the first analysis of market equilibrium in the presence of adverse selection. Optimal contracts were first characterized endogenously for adverse selection in articles by Pauly (1974), Rothschild and Stiglitz (1976), and Wilson (1977), and for ex ante moral hazard by Holmstrom (1979) and Shavell (1979a, b). Ex post moral hazard was defined early on by Pauly (1968) and was later formalized by Townsend 1979 and Gale and Hellwig (1985).

In the early 1980s, several theoretical developments were advanced to account for different facts observed in several markets. Specifically, dealing with models of two-party contracts, multi-period contractual relations were introduced; the renegotiation of contracts was formalized; the problem of contractual commitments was analyzed; and simultaneous treatment of several information problems became a consideration. Other noteworthy proposals were developed to explain hierarchical relations in firms and in organizations, often involving multi-party participants and contracts.

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The economic relationships most often studied were insurance contracts, banking contracts, work and sharecropping contracts, and auctions. Several forms of contracts observed in these markets were catalogued in various theoretical contributions. The best known are partial insurance coverage (co-insurance and deductibles), compensation based on hours worked and performance, executive compensation with stock options, debt with collateral, bonus-malus schemes, temporal deductibles, and venture capital contracts with warrants. There was also rationalization of several corporate organizational practices such as the use of foremen, internal and external controls, auditing, decentralization of certain decisions, and the centralization of more difficult-to-control decisions.

The empirical study of information problems began much later. The main motivation was to distinguish the stylized (qualitative) facts used to construct certain models from real or more quantitative facts. For example, in classroom and theoretical journals, different automobile insurance deductibles can very well be used to justify adverse selection, but there is no evidence that insurers established this partial coverage for that reason. It can also be argued that labor contracts with performance compensation are used to reduce moral hazard in firms, but it has not necessarily been conclusively empirically demonstrated that there is less moral hazard in firms with this form of compensation than in other firms that use fixed compensation, combined with other incentives or control mechanisms to deal with this information problem.

Another strong motivation for empirically verifying the effects of information problems is the search for ways to reduce their negative impact on resource allocation. For example, we know that partial insurance is effective in reducing ex ante moral hazard, as it exposes the insured person to risk. Yet this mechanism is ineffective against ex post moral hazard, because the accident has already occurred. Partial insurance may even have pernicious effects and encourage the padding of costs. The audit of files seems to be the most effective instrument against ex post moral hazard. This shows the importance of identifying the real problem when attempting to correct imperfections and improve resource allocation.

When it comes to empirically measuring information problems and assessing the effectiveness of mechanisms set up to correct them (relationship between the nature of contracts and their performance), numerous complications soon arise. For one, several information problems may be present, simultaneously, in the database studied; the theoretical predictions must then be carefully defined to distinguish the effects of different information problems on the parameters of the models to be estimated. Moreover, firms have a wide range of mechanisms (substitutes or complementary) at their disposal and they may be selected for reasons other than information problems or for information problems other than those investigated in a particular study. In other words, the information problems under consideration are often neither a necessary nor a sufficient condition to justify the existence of certain mechanisms.

Treating several information problems simultaneously is difficult: the literature does not yet offer strong theoretical predictions, even when all available contributions are reviewed. If we simply verify whether a market contains any residual information asymmetry, regardless of its origin, it is easier to demonstrate its absence, because there is no need to distinguish between the different forms of information asymmetry. Otherwise, we have to ascertain which form is still present and document its cause to analyze the instruments that could mitigate or eliminate it.

As a rule, the distinction between moral hazard and adverse selection can be reduced to a problem of causality (Chiappori 1994, 1999). With moral hazard, the non-observable actions of individuals that affect the way contracts work are consequences of the forms of contracts. For example, a contract may increase the risk of the activity, because it reduces the incentives to act safely.¹ With pure adverse

¹On the choice of insurance contracts by employees and their anticipated behavioral response to insurance (moral hazard), see the recent study of Einav et al. (2013). On optimal contracting in presence of asymmetric information, see Laffont (1997, 1985) and Laffont and Martimort (1997).

selection, the nature of different risks already exists before the contract is written. The contracts selected appear from the risks present. There is thus a form of reverse causality between the two information problems. When an exogenous change occurs in an insurance contract, we can limit our test to the way it affects existing policy holders and isolate a moral hazard effect. Alternatively, we could make comparisons to see whether the chance of accident differs between new and old policy holders and check for any bias caused by adverse selection. Another way is to use panel data and develop causality tests. However, these tests must consider that other information asymmetries may be present such as the learning of the contract parties over time (Dionne et al. 2013a). This learning can be symmetrical or not. Dynamic data are also useful for separating moral hazard from unobserved heterogeneity (Abbring et al. 2003; Dionne et al. 2005, 2011).

Another difficulty in the empirical measurement of information problems is the fact that researchers are not privy to more information than decision makers. Two solutions have been adopted to make up for that difficulty: (1) use of confidential surveys and (2) development of econometric strategies that can isolate the desired effect. The experimental approach is a third avenue that I shall not deal with in detail.

The survey method has the advantage of providing direct access to private information not available to one party to the contract, such as accidents not claimed or risk perception. Such information makes it possible to measure motivations for choosing specific contractual clauses directly, along with agents' behavior. The drawback of this method is that it is very costly. It can also be biased, because it is very difficult to explain the complexity of the problem studied to respondents, and because several alternative explanations might have been overlooked in the questionnaires. Another source of bias is related to the selection of representative samples.

The development of econometric strategies requires knowledge of the theoretical problem under study and of the econometric methods suitable for the project. This is why the most productive research teams are composed of theoreticians and econometricians. The objective is to isolate effects that are not directly observable by both parties to the contract but that are taken into account by certain variables or combination of variables. As discussed by Chiappori et al. (1994) and Gouriéroux (1999), econometric work consists in distinguishing between two sources of information. The first type is composed of variables observable by the two parties to the contract. These variables can be used to make estimates conditional on the characteristics observed. The second type is linked to the information not observable by econometricians (and by at least one contractual party), but that may explain choices of contracts or behaviors. In the case of adverse selection, choices of contracts can be interpreted by econometricians as being a bias of endogenous selection. One way of taking this into account is to estimate agents' decisions simultaneously by introducing hidden connections (or informational asymmetries) between the decisions. One known form is the non-null correlation between the random terms of the different equations (contract choice and accident distributions; Chiappori and Salanié 2000). Another form entails estimating the parameters of contract choice on contract result (Dionne et al. 2001).

Quality of data is a determining factor in the measurement of desired effects. The data must correspond directly to the contractual relations studied and to the duration of the contractual periods. There must also be access to data broken down contract by contract. The effort involved in formulating raw data for research purposes should not be underestimated. Raw data are used in the day-to-day operations of firms that are not concerned with research problems, and do not always contain direct information on variables needed for the problem studied.

Econometric specifications must correspond to the theoretical models under consideration, if erroneous conclusions are to be avoided. Often, researchers choose (or are forced) to use only part of the information available to decision-makers, and thus bias the effects of certain variables so that they capture the effects of other forgotten or inaccessible variables and obtain false conclusions.

Finally, the agents to different contracts are often risk averse to varying degrees. This characteristic is also difficult to observe and can be a source of asymmetric information. Some authors have recently

proposed models taking into account the varying degrees of risk aversion, but very few predictions can isolate the effects of information problems as they relate to varying degrees of risk aversion among agents. These difficulties will be discussed in detail below (see [Dionne et al. 2014](#), for a longer theoretical discussion of adverse selection).

The rest of the chapter will look at examples of the empirical verification of the presence or absence of a residual information problem in different markets with an emphasis on insurance markets. These examples highlight various difficulties that are not always well understood by those who tackle the empirical measurement of information problems. The first is a test for the presence of asymmetric information in an insurer's portfolio. One should ask: Is risk classification sufficient to rule out residual asymmetric information or do we need self-selection mechanisms inside risk classes? We also treat the separation issue between moral hazard and adverse selection and how dynamic data can be used to develop tests for the presence of moral hazard when adverse selection is not a significant factor, as in public insurance regimes with compulsory insurance coverage.

The second example deals with labor contracts and compensation methods. Such methods are often observable by econometricians, whereas individual effort is not. Furthermore, individual output can hardly be used to deduce effort, because it depends on several other factors, such as the outcome of a random variable or other non-observable staffing practices.

We next treat ex post moral hazard in insurance markets covering work accidents and medical services. The main difficulty is attributing variations in demand to one of three factors: price variations, moral hazard, and adverse selection. Many studies show that a change in coverage will affect consumption, but few determine whether the cause is moral hazard, for example. The estimated variation may simply be due to the price and wealth effects of insurance. A section on insurance fraud will also be presented. We will see how parameters of standard insurance contracts may affect incentives to defraud and how the development of optimal audit strategies can reduce the presence of fraud.

Finally, we shall discuss price differences in reference to adverse selection in markets for various transactions such as used cars, slaves, and mergers and acquisitions. Can the price differences observed be explained by asymmetric information, and specifically by adverse selection? We will see how adequate data can point to a sequence in the tests to separate adverse selection from asymmetric information.

15.2 Measurement of Residual Asymmetric Information in Insurance Data²

The objective of this section is to present various tests for the presence of residual asymmetric information in insurance markets. From the theoretical literature ([Dionne et al. 2014](#); [Picard 2014](#); [Winter 2013](#)), we know that the potential presence of asymmetric information between insured and insurers regarding individual risks motivates partial insurance, risk classification, and auditing of claims. It is also well known from the insurance literature that risk classification is due, in part, to asymmetric information between the insurer and the insured ([Crocker and Snow 1985, 1986](#)). Full efficiency in risk classification should separate individual risks and generate different actuarial insurance premiums that reflect these risks ([Dionne and Rothschild 2011](#); [Crocker and Snow 2013](#)). This means there should not be any residual asymmetric information between the insurer and the insured inside the risk classes. With actuarial premiums, full insurance should be the optimal contract, and there should be no correlation between insurance coverage and individual risk. However, in

²Based on [Dionne and Rothschild \(2011\)](#) and [Dionne et al. \(2013b\)](#).

the real world of insurance contracting, there may be numerous constraints that limit efficiency in risk classification. Incentive contracting thus becomes important, and the empirical question is: how efficiently does this mechanism reduce asymmetric information in insurers' portfolios?

Cohen and Siegelman (2010) present a survey of empirical studies of adverse selection in insurance markets. They argue that the coverage-risk correlation is particular to each market. Accordingly, the presence of a significant coverage-risk correlation has different meanings in different markets, and even in different risk pools in a given market, depending on the type of insured service, the participants' characteristics, institutional factors, and regulation. This means that when testing for the presence of residual asymmetric information, one must also control for these factors. What characteristics and factors explain the absence of coverage-risk correlation in automobile insurance markets? Some studies using the conditional correlation approach on cross-sectional data find evidence of asymmetric information (Dahlby 1983, 1992; Devlin 1992; Puelz and Snow 1994; Richaudeau 1999; Cohen 2005; Kim et al. 2009) while others did not (Chiappori and Salanié 2000; Dionne et al. 2001; Saito 2006). One major criticism of the conditional correlation approach with cross-sectional data is that it does not allow separation of adverse selection from moral hazard.

Many theoretical contributions were published in the 1970s to account for stylized facts observed in insurance markets. The first models developed were with one-period or static contracts. Partial insurance, such as deductible and co-insurance contracts, can be justified by asymmetric information (Rothschild and Stiglitz 1976; Shavell 1979a, b; Holmstrom 1979). However, a deductible can be optimal for moral hazard, adverse selection, or proportional administrative costs (Fluet 1992). As mentioned above, risk classification based on observable characteristics and multi-period relationships between principal and agent are other mechanisms associated with the presence of asymmetric information.

The first empirical question in insurance markets can be summarized as follows: Is there any residual correlation between chosen insurance coverage and risk within risk classes? The second question is how to identify which information problem remains when the first test rejects the null hypothesis that there is no residual information problem. This step is important for the insurer because it must implement the appropriate instruments to improve resource allocation. A deductible efficiently reduces *ex ante* moral hazard, but not necessarily *ex post* moral hazard because often, the accident has already occurred when the action is taken. A high deductible can even have an adverse effect and encourage accident cost building (Dionne and Gagné 2001). As is well known in the empirical literature, a positive correlation between insurance coverage and risk is a necessary condition for the presence of asymmetric residual information, but it does not shed light on the nature of the information problem. The third question is how improving the contracts can reduce the negative impact of asymmetric information on resource allocation. These resource allocation objectives must take into account other issues such as risk aversion, fairness, and accessibility of insurance. This last issue is particularly important in many insurance markets. A decrease in insurance coverage may reduce *ex ante* moral hazard because it exposes the insured person to risk, but it also significantly reduces accessibility to insurance protection for risky and poor people who are not always responsible for their risk type and financial conditions.

Econometricians analyze two types of information when studying insurers' data (Lemaire 1985, 1995; Boyer and Dionne 1989; Boyer et al. 1992; Dionne and Vanasse 1989, 1992; Chiappori et al. 1994; Puelz and Snow 1994; Gouriéroux 1999; Richaudeau 1999; Dionne and Ghali 2005; Dionne et al. 2006; Gouriéroux et al. 1984a, b; Hausman et al. 1984; Pinquet 1999, 2013; Saito 2006). The first type contains variables that are observable by both parties to the insurance contract. Risk classification variables are one example.

Econometricians/insurers combine these variables to create risk classes when estimating accident distributions. Observed variables can be used to make estimates conditional on the risk classes or within the risk classes. The second type of information is related to what is not observed by the insurer or the econometrician during contract duration and at contract renegotiations, but can explain

the insured's choice of contracts or actions. If we limit our interpretation to asymmetric information (either moral hazard or adverse selection), we can test the conditional residual presence of asymmetric information in an insurer's portfolio; or look for a correlation between the contract coverage and the realization of the risk variable during a contract period. Two parametric tests have been proposed in the literature (Chiappori and Salanié 2000; Dionne et al. 2001; see Chiappori and Salanié 2003, 2013, for detailed analyses). One parametric test (Dionne et al. 2001) estimates the following relationship:

$$y_i = g(\alpha + \beta X_i + \gamma d_i + \delta E(d_i | X_i)) + \varepsilon_i, \quad (15.1)$$

where y_i is the contract choice by individual i (level of deductible, for example), X_i is a vector of control variables such as the observable characteristics used in risk classification and control variables for risk aversion, β is a vector of parameters to be estimated, d_i is the realization of the random variable observed at the end of the contract period (accident or not, for example), $E(d_i | X_i)$ is the conditional expected value of the random variable obtained from the estimation of the accident distribution, and ε_i is the residual of the regression. A positive sign is usually anticipated for the coefficient of d_i (γ) when residual asymmetric information remains (higher coverage is related to more accidents or higher risk). The seminal theories of Rothschild and Stiglitz (1976) and Wilson (1977) strongly predict that such a correlation should be observed in the data in the presence of adverse selection, while Holmstrom 1979 and Shavell (1979a, b) strongly predict that the correlation is due to moral hazard. Note that the dependent variable in the above regression can be the risk variable d_i while the coverage y_i is an independent variable. This symmetry is discussed in detail in Dionne et al. (2006). The presence of the variable d_i is not necessarily exogenous in (15.1). It is often better to instrument this variable (see Dionne et al. 2009b, 2010, and Rowell 2011, for more details).

The presence of $E(d_i | X_i)$ is necessary to control for specification errors (missing variables) or for potential nonlinearity not modeled in the equation. Without this control, the coefficient of d_i can be significant for reasons other than the presence of residual asymmetric information in the risk classes.

If the coefficient of d_i is not significant, one can reject the presence of residual asymmetric information in the risk classes when all other factors are well controlled. This does not mean that there is no asymmetric information in this market; rather, it means that the insurer's risk classification system eliminates asymmetric information efficiently, and that there is no *residual* asymmetric information within the risk classes. In other words, when risk classification is done properly, it is not necessary to choose the contract form within the risk classes to reduce asymmetric information.

An equivalent parametric model was proposed by Chiappori and Salanié (2000). Here, two equations are estimated simultaneously, one for contract choice and the other for accident distribution. An example is the bivariate probit model:

$$y_i = f(X_i, \beta) + \varepsilon_i \quad (15.2)$$

$$d_i = g(X_i, \beta) + \eta_i. \quad (15.3)$$

The test consists in verifying whether there is dependence between the residuals of the two equations. An absence of conditional correlation is interpreted as an absence of residual asymmetric information in the data. The authors present an additional non-parametric test that is independent of the functional forms of the above models. It is based on a Chi-square test of independence. However their test seems to be limited to discrete variables, contrary to the two parametric tests presented above. (See Su and Spindler 2013, for a longer discussion.)

Many extensions of these models were presented in the literature. Chiappori et al. (2006) presents conditions to obtain robustness of the test when insured may have different degrees of risk aversion. They show that if insurers maximize profits in competitive markets, the results of the above test are

robust to heterogeneity in preferences. Such robustness is less evident in noncompetitive insurance markets.

Fang et al. (2008) do not reject asymmetric information in the medical insurance market, but do not find evidence of adverse selection. Their results are consistent with multidimensional private information along with advantageous selection (De Meza and Webb 2001). They obtain a *negative* correlation between risk and insurance coverage. Risk aversion is not a source of advantageous selection in their data. The significant sources are income, education, longevity expectations, financial planning horizons, and most importantly, cognitive ability. (See also Finkelstein and McGarry 2006, on this issue.)

To separate moral hazard from adverse selection, econometricians need a supplementary step. An additional market relationship can be estimated to look for adverse selection (conditional on the fact that the null hypothesis of no asymmetric information was rejected), as Dionne et al. (2009b) did for auctions. In insurance markets, dynamic data are often available. Time adds an additional degree of freedom to test for asymmetric information (Dionne and Lasserre 1985, 1987; Dionne and Vanasse 1989, 1992; D'Arcy and Doherty 1990; Dionne and Doherty 1994; Chiappori et al. 1994; Hendel and Lizzeri 2003). This information can be used in many insurance markets where past experience information is available and when it is possible to use it. For ethical reasons, this information is not utilized on an individual basis in health insurance and for bodily injury insurance in many countries. Experience rating works at two levels in insurance. Past accidents implicitly reflect unobservable characteristics of the insured (adverse selection) and introduce additional incentives for prevention (moral hazard). Experience rating can therefore directly mitigate problems of adverse selection and moral hazard, which often hinder risk allocation in the insurance market.

Experience rating not only provides additional information on risk, but may also play an important role in the dynamic relationship between policyholders' insurance claims and contract choice. The theoretical literature on repeated insurance contracting over time clearly indicates that these features may help overcome problems of moral hazard when risks known to the policyholder (endogenous) are unobservable by the insurer (moral hazard, Winter 2013) or when exogenous characteristics are unobservable (adverse selection, Dionne et al. 2014). Contract choice is influenced by the evolution of the premium, which is closely linked to the insured's risk or past experience. Because increased insurance coverage tends to lower the expected cost of accidents for the insured, incentives for safe behavior are weakened for all risks. Under experience rating, the subsequent rise in accidents increases the marginal costs of future accidents when experience rating is taken into account. Experience rating may therefore offset the disincentive effect created by single-period insurance coverage.

The above empirical tests are conducted in a static framework, which fails to recognize the dynamics that experience rating introduces in contractual relationships. Chiappori and Salanié (2000) discuss in detail how the omission of the experience-rating variable, even in tests with one-period data, must plausibly explain the failure to detect asymmetric information.

Abbring et al. (2003) apply a multi-period incentive mechanism by focusing on the dynamics of claims, but not on the dynamics of contract choice (because of data limitations). Proposing specific assumptions about the wealth effects of accidents to policyholders who differ only in their claim records (thus their experience rating), their model predicts that subjects with the worst claims records should try harder to increase safety, and thereby, *ceteris paribus*, file fewer claims in the future. However, their data do not support the presence of moral hazard. Dionne et al. (2011) extend their model and do not reject the presence of moral hazard, using a different data set. The potential presence of adverse selection in their data was not a real problem because all drivers must be insured for bodily injuries (see also Abbring et al. 2008, and Rowell 2011, for other tests of moral hazard).

Dionne et al. (2013a) show that failure to detect residual asymmetric information, and more specifically, moral hazard and adverse selection in insurance data, is due to the failure of previous econometric approaches to model the dynamic relationship between contract choice and claims adequately and simultaneously when looking at experience rating. Intuitively, because there are at least

two potential information problems in the data, an additional relationship to the correlation between risk and insurance coverage is necessary to test for the causality between risk and insurance coverage. Using a unique longitudinal survey of policyholders from France, they propose a methodology to disentangle the historical pathways in claims and premiums. They show how causality tests can be used to differentiate moral hazard from asymmetric learning (and eventually adverse selection). They do not reject moral hazard for a given group of policyholders, and do not reject asymmetric learning for younger drivers. The empirical methodologies of [Dionne et al. \(2011\)](#) and [Dionne et al. \(2013a\)](#) are reviewed in detail below.

15.3 Ex Ante Moral Hazard and Choices of Work Contracts

There is, by definition, ex ante moral hazard if one of the parties to a contract can affect the results of the contractual relation by non-observable actions before realization of the random variables ([Holmstrom 1979](#); [Shavell 1979a, b](#); [Caillaud et al. 2000](#)) (see [Arnott 1992](#) and [Winter 2013](#), for reviews of the insurance literature with moral hazard). In the simple model that we shall now evaluate, the realized output is observable but we do not know whether its value is due to the agent's effort or to the outcome of a random variable. We thus have a problem of identification to solve, if we want to check for the presence of residual moral hazard.

One useful prediction that models with moral hazard have made for the labor market is that forms of compensation can influence work incentive: a worker paid based on performance should work harder than a worker paid an hourly wage. In other words, there should be less moral hazard when workers are paid based on performance, because their compensation is exposed to risks whose impact they can vary by their efforts.

Empirically, the hardest factor to measure in the model is the worker's effort, as this means gaining access to a variable the employer cannot observe, and which can still be used to see whether methods of compensation have any impact on effort. [Foster and Rosenzweig \(1993, 1994\)](#) used calories consumed by workers as an approximation of the effort they expend.

They propose a simple theoretical model of workers' health in which body mass (kg/m^2) is affected by food intake, illness, and work effort. They show that it is possible, for the types of jobs studied, to make a direct connection between forms of compensation and the calories consumed. More specifically, in periods where workers have access to methods of compensation that reward more high powered performance, they work harder and consume more calories, thus justifying the direct theoretical link between method of compensation and consumption of calories.

To test their model, they used panel data containing information on 448 farming families in the Philippines; the members of these families may work either for themselves or for outsiders, under different forms of compensation. These individuals were interviewed four times concerning their wages, their modes of compensation, the type of work done, and the quantity of calories consumed over the previous 24 h. A period of 4 months separated the interviews.

The results from estimation of the health function indicate that self-employment and piece work significantly reduce the body mass index compared with unemployment, whereas work compensated on an hourly basis shows no significant effect. This seems to indicate either less effort or a measurable presence of moral hazard in those who are paid with an hourly rate.

What about the link between methods of payment and the performance rate per calorie consumed? They found that the calories consumed are associated with higher pay and performance in self-employment and piece work. Consequently, workers receiving these modes of payment consume more calories and, thus, can be said to work harder.

The next important question is: Is this a test for moral hazard or for adverse selection? In other words, do workers themselves choose their type of work and mode of compensation?

The authors tried to answer this question by checking whether their data contained any sample selection effect. They used two methods to do this: Heckman's two-step Probit selection (1979) and Lee's multinomial Logit selection (1983). Both models render identical results. It should be pointed out that 47.1% of the subjects worked under different regimes during the same period. However, this statistic does not suffice to qualify the choices as random, because only 28% worked for hourly wages in all four periods.

Taking workers' choices of types of compensation explicitly into account tends to strengthen rather than weaken the results. Modes of compensation actually have a bigger impact on the use of calories with the selection model. This implies that those who choose incentive pay at the margin do so because they truly want to work harder. Unlike what the authors suggest, the model tested is not a pure moral-hazard model. It is rather a mixed model containing aspects of adverse selection and moral hazard. The best physically endowed and most highly motivated will choose the highest paying but most demanding work.

In fact, to isolate a pure moral-hazard effect without dynamic data, it practically takes an exogenous change in a compensation regime or in some other parameter impinging on all the agents (Dionne et al. 1997). We will now study changes of this nature as we turn to ex post moral hazard.

15.4 Ex Post Moral Hazard, Demand for Medical Services, and Duration of Work Leaves

In our applications, ex post moral hazard deals with non-observable actions on the part of agents, actions that occur during or after the outcome of the random variable or accident (Townsend 1979; Gale and Hellwig 1985). For example, an accident can be falsified to obtain better insurance compensation. This form of moral hazard is often associated with fraud or falsification (Crocker and Morgan 1998; Crocker and Tennyson 1999; Bujold et al. 1997; Picard 2013). Partial insurance of agents is not optimal in reducing this form of moral hazard, because agents often know the state of the world when they make decisions. Claims auditing is more appropriate, but it is costly, resulting in the potential presence of this moral hazard in different markets.

The main difficulty in isolating the ex post moral hazard effect in different levels of insurance coverage is separating the effects of price and income variations from the effects of asymmetric information. Contrary to what is often stated in the literature (especially that of health insurance), not every variation in consumption following a variation in insurance coverage can be tied to ex post moral hazard. When compared with full-coverage regimes, it is perfectly conceivable that a health insurance regime with partial coverage might be explained by transaction costs and patients' decision to curtail consumption of certain services because they must share the cost. If for some reason the transaction costs drop and the insurance coverage expands, the consumption of medical services will increase, because their price will be cheaper. Yet this increase will not be due to moral hazard. It will simply be a classic effect of price on demand. There are still too many contributions in the literature that confuse variations in demand with moral hazard (see, however, the discussion in Lo Sasso et al. 2010, and the contributions of Manning et al. 1987; Chiappori et al. 1998; Dionne and St-Michel 1991).

Another big difficulty in isolating moral hazard is linked to the possibility that potential policyholders, who are better informed than the insurer about the state of their health over the next period of the contract, will make an endogenous choice of insurance regime. As a rule, those expecting health problems choose more generous insurance regimes, even if the per unit cost is higher. This is a well-known adverse selection effect.

In the famous Rand corporation study (Manning et al. 1987; Newhouse 1987) dealing with the effects of changes in insurance coverage on the demand for medical services, the experimental method used was capable of isolating the elasticity of the demand from the effects of adverse selection by random selection of families who might be subject to exogenous changes in insurance coverage but who were not free to choose their insurance coverage ex ante. They thus successfully calculated elasticities of demand much lower than those obtained in other studies that did not screen for the effect of endogenous choices of insurance regimes (adverse selection).

Their measurement of the elasticity of demand for medical services is not a measurement of ex post moral hazard. It is, in fact, very unlikely that there is any moral hazard in their data, considering the extensive screening done (see Dionne and Rothschild 2011, for a longer discussion on health care insurance).

Let us now consider work accidents. As indicated above, using an exogenous change in an insurance regime can isolate moral hazard. An exogenous change in an insurance regime can be interpreted as a laboratory experiment, if certain conditions are met. Similar to studies of laboratory animals, it is possible to restrict choice sets: here we restrict the choices of insurance available to the subjects.

It is also important to have a control group who undergoes the same insurance changes, but who does not have the same information problems as those expected. For example, if we suspect that some workers with specific medical diagnoses (hard to diagnose and verify) have greater information asymmetry with the insurer, there have to be other workers having undergone the same insurance changes at the same time but whose information asymmetry is weaker (easy to diagnose and verify). The reason for this is that it is hard to isolate an absolute effect with real economic data, because other factors not screened for may lead to changes in behavior. The control group allows us to isolate a relative effect arising from the information problem, all things being equal. To simplify the analysis, it is preferable that the period under study should be short enough to avoid having to screen for several changes at once.

Dionne and St-Michel (1991) managed to bring together all these conditions in a study of change in coverage for salary losses associated with work accidents (see Fortin and Lanoie 1992, 2000, for similar studies and for a survey of different issues associated with workers' compensation; see also the recent survey of Butler et al. 2013).

The change in insurance coverage studied was exogenous for all the workers. Other forms of insurance were not readily available, even if, in theory, it is always possible to buy extra insurance in the private sector if one is not satisfied with the public regime. Very few individuals do so in Quebec for this type of compensation. The fact that there are state monopolies over several types of insurance coverage in Quebec makes it easier for Dionne and St-Michel (1991) to meet this condition.

Dionne and St-Michel (1991) showed, first, that the increase in insurance coverage had a significant positive effect on the duration of absence from work. This effect cannot be interpreted as being moral hazard; it may simply be associated with an increase in demand for days off due to their lower cost. Next, the authors checked to see whether this effect was significant only for diagnoses with greater information asymmetry (hard to diagnose) between the worker and the insurer as represented by a doctor. This second finding confirms that the only effect observed on the duration of absences was that of moral hazard, because the workers of the control group (those without information asymmetry, easy to diagnose) did not modify their behavior. In addition, the change-of-regime variable without interaction with diagnoses is no longer significant when the diagnosis-change-of-insurance variables are adjusted. This implies that there is no demand effect. However, the change of regime achieved the desired redistribution effects by allowing poorer workers to have access to more insurance.

Arguably, Dionne and St-Michel isolated an ex post moral hazard effect (see Cummins and Tennyson 1996; Butler et al. 1996a; Ruser 1998; Dionne et al. 1995; Butler and Worall 1983, 1991; Krueger 1990; Lanoie 1991; Leigh 1985; Meyer et al. 1995; Ruser 1991; Thomason 1993, for similar results). Nonetheless, it is highly unlikely that the change in regime studied had an impact on ex ante

prevention activities that might affect the severity of work accidents. There is no reason to think that the average worker can practice selective prevention to influence diagnoses *ex ante*. *Ex post*, however, when workers know their diagnosis, they can take undue advantage of the situation of asymmetric information. Some workers might be more tempted to provoke accidents or to falsely claim that they had an accident to receive more compensation when the rates are more generous. These activities were not distinguished from other forms of moral hazard by Dionne and St-Michel, because they can be interpreted as *ex post* moral hazard.

It is also difficult to find the link between this result and adverse selection. On the one hand, workers could not choose their insurance coverage in this market and, on the other hand, it is highly unlikely that the change in insurance regime had any short-term effect on workers' choice of more or less risky jobs.

Fortin and Lanoie (2000) review the literature on the incentive effects of work accident compensation. They use the classification of different forms of moral hazard proposed by Viscusi (1992). The form of *ex post* moral hazard we just described is linked to the duration of claims, which they distinguish from moral hazard in the form of substitution hazard. This distinction can be explained, for example, by the fact that compensation for work accidents is more generous than that for unemployment insurance. Activities resulting in accidents are called causality moral hazard, which is *ex post* moral hazard (bordering on *ex ante* moral hazard), because the action takes place at the time of the accident. The result obtained by Dionne and St-Michel captures these three forms of *ex post* moral hazard. In fact, workers may have substituted workers' compensation for unemployment insurance.

To deepen the analysis, one must attempt to distinguish between the three forms of *ex post* moral hazard: incentives provoking hard-to-verify accidents; decisions to prolong length of absence in hard-to-check diagnoses; or decisions to substitute accident compensation for unemployment insurance, or even falsification. This distinction would be important because the mechanisms for correcting the situation would not necessarily be the same for each of these forms of asymmetric information.

The last three forms are difficult to distinguish, because they belong to the same market. However, it is possible to separate new accidents from older ones using indicative variables. We know, for example, that the accidents provoked occur early on Monday mornings (see also Fortin and Lanoie 2000; Derrig 2002) and that, among seasonal workers, requests to extend work absences increase with the approach of unemployment insurance periods. Further research is needed on this subject.

15.5 Testing for Moral Hazard in the Automobile Insurance Market³

15.5.1 Moral Hazard as a Function of Accumulated Demerit Points

Below, I analyze moral hazard as a function of demerit points. Because no-fault environments are common in the North American continent, traffic violations are events likely to be used in experience rating schemes. Increases in premiums are often triggered by claims at fault in the vehicle insurance sector.

In Quebec, the public insurer in charge of the compensation of bodily injuries uses an experience rating scheme based on demerit points.⁴ The same public enterprise is also in charge of the point-record license system. Dionne et al. (2011) show that the new insurance pricing scheme introduced

³This section is based on Dionne et al. (2013b).

⁴On point-record driver's license, see Bourgeon and Picard (2007).

in 1992 reduced the number of traffic violations by 15%. They also verified that there is residual *ex ante* moral hazard in road safety management. The discussion below focuses on the methodology they developed for obtaining this result.

The methodology extends the empirical model of [Abbring et al. \(2003\)](#). Over time, a driver's observed demerit points informs on two effects: an unobserved heterogeneity effect and an incentive effect. Drivers with more demerit points accumulated during a period are riskier with respect to hidden features in risk distributions. Hence, unobserved heterogeneity is a form of risk reassessment in the sense that those who accumulate demerit points represent higher risks over time. This effect is in the opposite direction of the incentive effect. For the incentive effects, accumulating demerit points should increase the incentive for safe driving to reduce the probability of receiving a higher penalty. The time effect of unobserved heterogeneity is also converse to that of the incentive effect.

The model proposed by [Dionne et al. \(2011\)](#) tests for an increasing link between traffic violations and the number of accumulated demerit points over time. Rejecting the positive link is evidence of moral hazard. They estimate the following hazard function ([Cox 1972](#)):

$$\lambda_i(t) = \exp(x_i(t)\beta) + g(\text{adp}_i(t)) \times h(c_i(t)), \quad (15.4)$$

where $\lambda_i(t)$ is the hazard function for driver i at date t , $x_i(t)$ is a vector of control variables, β represents the corresponding coefficients, $\text{adp}_i(t)$ is the number of demerit points accumulated over the two previous years at time t , and $c_i(t)$ is contract time at date t .

In the absence of moral hazard, g should be increasing because of unobserved heterogeneity. They found that g is decreasing when drivers have accumulated more than seven demerit points. This means that beyond seven demerit points, drivers become safer if they do not want to lose their driver's license. This is evidence of the presence of moral hazard in the data: these drivers were negligent when the accumulated record was below seven demerit points.

15.5.2 *Separating Moral Hazard from Learning and Adverse Selection with Dynamic Data*

To separate learning leading to adverse selection (asymmetric learning) from moral hazard, [Dionne et al. \(2013a\)](#) consider the case where information on contracts and accidents is available for multiple years in the form of panel data. They exploit dynamics in accidents and insurance coverage controlling for dynamic selection due to unobserved heterogeneity. They construct two additional tests based on changes in insurance coverage. Coupled with the negative occurrence test of [Abbring et al. \(2003\)](#) and [Dionne et al. \(2011\)](#), these tests allow them to separate moral hazard from asymmetric learning (which should become adverse selection in the long run).

They analyze the identification of asymmetric learning and moral hazard within the context of a tractable structural dynamic insurance model. From the solution of their theoretical model, they simulate a panel of drivers behaving under different information regimes or data generating processes (with or without both moral hazard and asymmetric learning). They validate their empirical tests on simulated data generated from these different information regimes. They then apply these tests to longitudinal data on accidents, contract choice, and experience rating for the period 1995–1997 in France ([Dionne 2001](#)). They find no evidence of information problems among experienced drivers (more than 15 years of experience). For drivers with less than 15 years of experience, they find strong evidence of moral hazard but little evidence of asymmetric learning. They obtain evidence of asymmetric learning, despite the small sample size, when focusing on drivers with less than 5 years of experience. To obtain these results, they estimated the following model.

They consider a joint parametric model for the probabilities of accidents and contract choice. Each equation corresponds to a dynamic binary choice model with predetermined regressors and an error component structure. The error component structure is important given the likelihood of serial correlation in contract and accident outcomes. They use the solution proposed by [Wooldridge \(2005\)](#) to take the potential left censoring effect into account.

More specifically, the process for accidents is specified as:

$$\begin{aligned} n_{it} &= I(x_{it}\beta_n + \phi_{nd}d_{it-1} + \phi_{mn}n_{it-1} + \phi_{nb}b_{it} + \varepsilon_{n,it} > 0) \\ i &= 1, \dots, N, t = 1, \dots, T \end{aligned} \quad (15.5)$$

where $\varepsilon_{n,it}$ has an error component structure $\varepsilon_{n,it} = \alpha_{ni} + v_{n,it}$, n_{it} is a binary variable for the number of accidents of individual i at time t , d_{it-1} is his contract choice in period $t - 1$, n_{it-1} is his number of accidents in period $t - 1$, and b_{it} is his bonus-malus score at period t . The presence of moral hazard would be confirmed by a positive sign for ϕ_{nd} (more insurance coverage-more accidents) and a negative sign for ϕ_{nb} (a higher malus creates more incentives for safe driving, similar to the test presented in the previous section with accumulated demerit points.) Here a high malus means an accumulation of accidents over the previous periods. They specify a similar equation for contract choice:

$$\begin{aligned} d_{it} &= I(x_{it}\beta_d + \phi_{dd}d_{it-1} + \phi_{dn}n_{it-1} + \phi_{db}b_{it} + \varepsilon_{d,it} > 0) \\ i &= 1, \dots, N, t = 1, \dots, T \end{aligned} \quad (15.6)$$

where again $\varepsilon_{d,it} = \alpha_{di} + v_{d,it}$. The asymmetric learning test is a test of whether an accident in the last period, conditional on the bonus-malus, leads to an increase in coverage of this period. Drivers thus learn that they are riskier than anticipated and increase their insurance coverage accordingly. It is a test of whether $\phi_{dn} > 0$ or not.

15.6 Insurance Fraud

Insurance fraud (or ex post moral hazard) has become an important economic problem in the insurance industry (see [Derrig 2002](#), for a survey). Early empirical evaluations include the reports from the Florida Insurance Research Center (1991) and the Automobile Insurers Bureau of Massachusetts (1990), the contributions of [Weisberg and Derrig \(1991, 1992, 1993, 1995\)](#), [Fopper \(1994\)](#), [Derrig and Zicko \(2002\)](#) in the USA and the [Dionne and Belhadji \(1996\)](#), [Belhadji et al. \(2000\)](#), and [Caron and Dionne \(1997\)](#) studies for the Insurance Bureau of Canada ([Medza 1999](#)). As for ex ante moral hazard, insurance fraud does not necessary imply a criminal act. It ranges from simple buildup to criminal fraud ([Picard 2014](#)).

[Townsend \(1979\)](#) studied the optimal contract form under a costly state verification setting. He obtains that a straight deductible is optimal under deterministic auditing while [Mookherjee and Png \(1989\)](#) do not obtain such a simple contract form when auditing costs are random. This last result is explained in part by the fact that random auditing introduces a supplemental source of uncertainty to the risk averse insured. [Bond and Crocker \(1997\)](#), [Picard \(1996\)](#), and [Fagart and Picard \(1999\)](#) extend this theoretical framework to insurance fraud, and design the optimal insurance contracting form when the policy holder can manipulate auditing costs. The optimal contract is not a straight deductible as is often observed in practice, and can have very complicated forms that may even be nonlinear (see [Picard 2014](#), for details and [Hau 2008](#), for the consideration of costly state verification and costly state falsification in a single model). [Schiller \(2006\)](#) asserts that the efficiency of audit

could be improved through conditioning the information from the detection system under costly state verification. Interventions other than optimal contract design can be used by insurers for limiting insurance fraud. [Dionne et al. \(2009a\)](#) theoretically and empirically investigate the optimal audit strategies when the scoring methodology is used by insurers or when fraud signals (or red flags) serve to evaluate the probability that a file is fraudulent. Their results are related to the credibility issue of auditing that is also analyzed in detail in [Picard \(1996\)](#) and [Boyer \(2004\)](#) (see also [Pinquet et al. 2007](#), on the use of fraud signals).

[Lacker and Weinberg \(1989\)](#) and [Crocker and Morgan \(1998\)](#) theoretically investigate optimal insurance contracting under costly state falsification by the insured. They obtain that the solution always involves some level of manipulation and the optimal insurance payment includes overinsurance. [Crocker and Tennyson \(1999, 2002\)](#) have empirically tested the link between insurance fraud and optimal insurance contracting under costly state falsification.

Insurance fraud has been analyzed empirically in automobile insurance markets by, among others, [Cummins and Tennyson \(1996\)](#), [Tennyson \(1997\)](#), [Abrahamse and Carroll \(1999\)](#), [Carroll and Abrahamse \(2001\)](#), [Bujold et al. \(1997\)](#), [Dionne and Gagné \(2001, 2002\)](#), [Derrig \(2002, 2006\)](#), [Dionne and Wang \(2013\)](#), [Artis et al. \(2002\)](#), [Brockett et al. \(2002\)](#), [Pao et al. \(2012\)](#). Other researchers investigated the workers' compensation insurance market ([Dionne and St-Michel 1991](#); [Butler et al. 1996a, b](#)) and the health care insurance market ([Dionne 1984](#); [Hyman 2001, 2002](#)).

[Derrig \(2002\)](#), [Artis et al. \(2002\)](#), [Brockett et al. \(2002\)](#), [Major and Riedinger \(2002\)](#), [Viaene et al. \(2002\)](#), [Caudill et al. \(2005\)](#), and [Loughran \(2005\)](#) have also explored many techniques of fraud detection. [Tennyson and Salsas-Forn \(2002\)](#) investigated the concept of fraud detection and deterrence while [Moreno et al. \(2006\)](#) verified how an optimal bonus malus scheme can affect the level of fraud.

The causes of the rapid growth of insurance fraud are numerous⁵: changes in morality, increased poverty, modifications in the behavior of the intermediaries (medical doctors or mechanics, for instance), insurers' attitudes, etc. ([Dionne 1984](#); [Dionne et al. 1993](#); [Bourgeon and Picard 2012](#)) and variation of economic activity ([Dionne and Wang 2013](#)). In two articles, [Dionne and Gagné \(2001, 2002\)](#) highlight the nature of insurance contracts. In both articles, they use the theoretical model proposed by [Picard \(1996\)](#) to obtain equilibrium without the parties' commitment. In the 2002 article, they test whether the presence of a replacement cost endorsement can be a cause of fraudulent claims for automobile theft. This endorsement was introduced in the automobile insurance market to increase the insured's protection against depreciation.

Traditional insurance markets do not offer protection against the replacement value of an automobile. Rather, they cover current market value, and when a theft occurs, the insurance coverage is partial with respect to the market value of a new automobile. A replacement cost endorsement covers the cost of a new vehicle in the case of theft or in the case of total destruction of the car in a collision, usually if the theft or the collision occurs in the first 2 years of ownership of a new automobile. In case of total theft, there is no deductible. Ex ante and without asymmetric information, this type of contract can be optimal. The only major difference with standard insurance contracts is the higher expected coverage cost, which can easily be reflected in the insurance premium.

Intuitively, a replacement cost endorsement may decrease the incentives toward self-protection because it can be interpreted as more than full insurance when the market value of the insured car is lower than the market value of a new car. The presence of a replacement cost endorsement in the insurance contract may also increase the incentives to defraud for the same reason. For example, the insured may have an incentive to set up a fraudulent theft because of the additional protection given by the replacement cost endorsement. This particular type of fraud is known as opportunistic fraud because it occurs when an opportunity occurs and usually not when an insurance contract for

⁵For a recent analysis of insurance fraud in the unemployment insurance market, see [Fuller et al. 2012](#).

a new vehicle is signed. Alternatively, under adverse selection, individuals may choose to include a replacement cost endorsement in their coverage because they know they will be more at risk.

The first objective of the study by [Dionne and Gagné \(2002\)](#) was to test how the introduction of a replacement cost endorsement affects the distribution of thefts in the automobile insurance market. Another significant objective was to propose an empirical procedure allowing the distinction between the two forms of moral hazard. In other words, they seek to determine whether an increase in the probability of theft may be explained by a decrease in self-protection activities or by an increase in opportunistic fraud. They also took into account the adverse selection possibility because the insured ex ante decision to add a replacement cost endorsement to the insurance policy might be explained by unobservable characteristics that also explain higher risks.

As discussed above, [Dionne et al. \(2001, 2006\)](#) proposed a parametric model that was applied to test for the presence of asymmetric information. In their article, [Dionne and Gagné \(2002\)](#) extend this method to consider both forms of moral hazard simultaneously. Their approach also makes it possible to isolate adverse selection.

Let us first consider y , an endogenous binary variable indicating the occurrence of a theft. The decision or contract choice variable z (in this case the presence of a replacement cost endorsement) will provide no additional information on the distribution of y if the prediction of y based on z and other initial exogenous variables x coincides with that based on x alone. Under this condition, the conditional distribution of y can be written as

$$\phi_y(y|x, z) = \phi_y(y|x), \quad (15.7)$$

where $\phi(\cdot|\cdot)$ denotes a conditional probability density function. Another appropriate but equivalent form for other applications is

$$\phi_z(z|x, y) = \phi_z(z|x). \quad (15.8)$$

In that case, the distribution of z is estimated and when condition (15.8) holds, this distribution is independent of y , which means that the distribution of theft is independent of the decision variable z , here the replacement cost endorsement, because (15.7) and (15.8) are equivalent. The empirical investigation of [Dionne and Gagné \(2002\)](#) relies on the indirect characterization as defined by (15.8). It can be interpreted as the description of how individuals' decisions affect their future risks (moral hazard) or of what their decisions would be if they knew their future risks (adverse selection).

This type of conditional dependence analysis is usually performed in a parametric framework where the model is a priori constrained by a linear function of x and y , that is:

$$\phi_z(z|x, y) = \phi_z(z|x'a + by).$$

This practice may induce spurious conclusions, because it is difficult to distinguish between the informational content of a decision variable and an omitted nonlinear effect of the initial exogenous variables. A simple and pragmatic way of taking these potential nonlinear effects of x into account is to consider a more general form:

$$\phi_z(z|x, y) = \phi_z(z|x'a + by + cE(y|x)), \quad (15.9)$$

where $E(y|x)$ is an approximated regressor of the expected value of y computed from the initial exogenous information. Assuming normality, $E(y|x)$ is computed with the parameters obtained from the estimation of y using the *Probit* method.

The above framework can be applied to test for different types of information asymmetries. The failure of condition (15.8) to hold may allow a distinction between different types of information

problems depending on how y is defined. [Dionne and Gagné \(2002\)](#) defined y using five different contexts or subsamples (s):

- $s = 0$ when no theft occurred;
- $s = 1$ if a partial theft occurred at the beginning of the cost endorsement contract;
- $s = 2$ if a partial theft occurred near the end of the cost endorsement contract;
- $s = 3$ if a total theft occurred at the beginning of the cost endorsement contract;
- $s = 4$ if a total theft occurred near the end of the cost endorsement contract.

Using such a categorization, they identified the different types of information problems: adverse selection, ex ante moral hazard and ex post moral hazard or opportunistic fraud.

If a pure adverse selection effect exists, the time dimension (i.e., the proximity of the expiration of the replacement cost endorsement in the contract, which is valid for only 2 years after a new car is bought) would be irrelevant. In other words, the effect of pure adverse selection would be significant and of approximately the same size regardless of the age of the contract. However, the effects may not be of the same magnitude. Therefore, with a pure adverse selection effect, condition (15.8) should not hold in all subsamples considered (i.e., $s = 1, 2, 3$, and 4).

Assuming that the same self-protection activities are involved in the reduction of the probabilities of both types of theft (partial and total), condition (15.8) should not hold under ex ante moral hazard for both types of theft. In that case, the presence of a replacement cost endorsement in the insurance contract reduces self-protection activities leading to an increase in the probabilities of partial and total theft. In addition, because the benefits of prevention are decreasing over time, ex ante moral hazard increases over time. Thus, as for adverse selection, ex ante moral hazard implies that condition (15.8) does not hold in all subsamples considered, but has a stronger effect near the end of the contract (i.e., subsamples 2 and 4) than at the beginning (i.e., subsamples 1 and 3).

In the case of opportunistic fraud, the pattern of effects is different. Because the incentives to defraud are very small or even nil in the case of a partial theft, condition (15.8) should hold in both subsamples 1 and 2. Also, because the benefits of fraud for total theft are few at the beginning of the contract but increasing over time with a replacement cost endorsement, condition (15.8) should also hold in the case of a total theft at the beginning of the contract ($s = 3$). However, near the end of the contract, the incentives to defraud reach a maximum only in the case of a total theft when the insurance contract includes a replacement cost endorsement. It follows that with a fraud effect, condition (15.8) would not be verified in subsample 4.

[Dionne and Gagné \(2002\)](#) empirical results show that the total theft occurrence is a significant factor in the explanation of the presence of a replacement cost endorsement in an automobile insurance contract only when this endorsement is about to expire. The total theft occurrence is insignificant at both the beginning of the contract and during the middle stage.

As suggested by [Chiappori \(1999\)](#), one way to separate insurance problems from claim data is to use a dynamic model. The data of [Dionne and Gagné \(2002\)](#) did not allow them to do so. The originality of their methodology, although in the spirit of [Chiappori \(1999\)](#), was to use different contracting dates for the replacement cost endorsement but claims over one period. Consequently, [Dionne and Gagné \(2002\)](#) were first able to separate moral hazard from adverse selection because the latter should have the same effect at each period according to the theory. They distinguished the two forms of moral hazard by using partial and total thefts and by assuming that the same preventive actions affect both distributions. Their results do not reject the presence of opportunistic fraud in the data, which means that the endorsement has a direct significant effect on the total number of car thefts in the market analyzed.

More recently, [Dionne and Wang \(2013\)](#) extended the methodology to analyze the empirical relationship between opportunistic fraud and business cycle ([Boyer 2001](#)). They find that residual opportunistic fraud exists both in the contract with replacement cost endorsement and the contract

with no-deductible endorsement in the Taiwan automobile theft insurance market. They also show that the severity of opportunistic fraud is counter-cyclical. Opportunistic fraud is stimulated during periods of recession and mitigated during periods of expansion.

To respond to the view of [Picard \(1996\)](#) and [Schiller and Lammers \(2010\)](#) that individuals' characteristics could affect the incentive to engage in fraud, [Huang et al. \(2012\)](#) find that individuals who properly maintain their vehicles do not commit opportunistic fraud induced by the replacement cost endorsement. This conclusion is robust regardless of whether they consider the endogeneity problem for maintenance behavior and of the threshold used to define proper car maintenance.

In their 2001 article, [Dionne and Gagné](#) discuss the effect of a higher deductible on the costs of claims explained by falsification. Since the significant contribution of [Townsend \(1979\)](#), an insurance contract with a deductible has been described as an optimal contract in the presence of costly state verification problems. To minimize auditing costs and guarantee insurance protection against large losses to risk-averse policy-holders, this optimal contract reimburses the total reported loss less than the deductible when the reported loss is above the deductible, and pays nothing otherwise. The contract specifies that the insurer commits itself to audit all claims with probability one. This deductible contract is optimal only for the class of deterministic mechanisms. Consequently, we should not observe any fraud, notably in the form of build-up, in markets with deductible contracts, because the benefits of such activity are nil. However, fraud is now a significant problem in automobile insurance markets for property damage where deductible contracts prevail.

The recent literature on security design has proposed extensions to take into account different issues regarding the optimal insurance contracts. Three main issues related to the empirical model of [Dionne and Gagné \(2001\)](#) are discussed in this literature. First, the deductible model implies that the principal fully commits to the contract in the sense that it will always audit all claims (above the deductible) even if the perceived probability of lying is nil. It is clear that this contract is not renegotiation proof: at least for small claims above the deductible, the insurer has an incentive to save the auditing cost by not auditing the claim. However, if the clients anticipate that the insurer will behave this way, they will not necessarily tell the truth when filing the claim!

One extension to the basic model was to suggest that random audits are more appropriate to reduce auditing costs. However, the optimal insurance contract is no longer a deductible contract and the above commitment issue remains relevant. Another extension is to suggest that costly state falsification is more pertinent than costly state verification for insurance contracting with ex post moral hazard. The optimal contract under costly state falsification leads to insurance overpayments for small losses and under-compensation for severe accidents. We do not yet observe such contracts for property damage in automobile insurance markets, although they seem to be present for bodily injuries in some states or provinces ([Crocker and Tennyson 1999, 2002](#)).

The empirical hypothesis of [Dionne and Gagné \(2001\)](#) is as follows: when there is a sufficient high probability that the fraud will succeed, the observed loss following an accident is higher when the deductible of the insurance contract is higher. Because they have access to reported losses only, a higher deductible also implies a lower probability of reporting small losses to the insurer. To isolate the fraud effect related to the presence of a deductible in the contract, they introduce some corrections in the data to eliminate the potential bias explained by incomplete information.

Their results are quite significant. They imply that when there are no witnesses (other than the driver and passengers) on the site of the accident, the losses reported to the insurance companies are between 24.6 and 31.8% higher for those insured with a \$500 deductible relative to those with a \$250 deductible. Furthermore, they are confident that this increase corresponds to build-up, because their result is closely related to the presence of witnesses. Given the mean loss reported in their sample of \$2552.65, the corresponding increases in the reported losses range from \$628 to \$812, which is far more than the difference between the two deductibles (\$250). Thus, it seems that when insured decide to defraud, not only do they try to recover the deductible, but also to increase their net wealth.

The choice of deductible is arguably the consequence of an extension of the traditional adverse selection problem because the insured anticipates higher expected losses. However, if this *ex ante* argument was right, we should observe a significant effect of the deductible on reported losses even when the presence of witnesses is more likely, which was not the case. It would be surprising to obtain such an *ex ante* effect only in the case of accidents without witnesses, because it is difficult to anticipate the type of accident and its severity when choosing the deductible *ex ante*.

Insurers may also affect the probability of successful falsification by increasing the frequency of audits in the case of claims for which no witnesses are involved and for which the policy bears a high deductible. In other words, insurers may use the presence of witnesses as a fraud indicator. In this case, the results show that insurers are not fully efficient in their investigations because there is still a significant effect associated with the deductible in the reported loss equation. This interpretation is supported by the fact that insurers detect only 33% of fraud when they audit (Caron and Dionne 1997).

Other contributions (Crocker and Morgan 1998; Crocker and Tennyson 2002) show that other types of contracts are more effective than deductible contracts in reducing this type of *ex post* moral hazard when falsification activities are potentially present. However, they limit the insurer's behavior to full commitment. The full characterization of an optimal contract in the presence of *ex post* moral hazard is still an open question in the literature (see Picard 2014, for more details).

15.7 Adverse Selection and the Quality of the Transaction in a Market

Akerlof (1970) was the first to propose a model with asymmetric information on the quality of products. This pathbreaking article has motivated many researchers to study second-hand markets for durable goods. In general, owners of used goods know the quality of their good better than a potential buyer does. Kim (1985) proposed a model suggesting that traded used cars should be of higher quality. Bond (1982) tested a similar proposition but did not find evidence of adverse selection in the market for used pickup trucks. However Lacko (1986) reported evidence for older cars only, a result also obtained by Genesove (1993).⁶ Below, Genesove's contribution is reviewed in detail.

The main hypotheses related to testing for the presence of adverse selection are:

- During the transaction, one party is better informed than the other about the product's quality: usually the seller.
- Both of the parties involved in the transaction value quality.
- The price is not determined by either party but by the market.
- There is no market mechanism such as guarantees or reputation to eliminate adverse selection.

To test for residual adverse selection, Genesove (1993) analyzed the market for used cars sold by auction in the USA, where buyers have only a few moments to look at the cars and cannot take them for a test drive before purchase. The auction is simple: a series of ascending bids where the seller has the option of accepting or rejecting the second highest bid. Sixty percent of the sellers agree to relinquish their cars. The auction lasts 1½ min, including the time to put the car up for auction and the time to remove it once the last bid is made! As a rule, the second price should correspond to the average quality of the cars offered, and buyers are supposed to be aware of this level of quality.

Genesove wanted to test whether any observable characteristic of the seller could be used to predict the average quality of the cars sold. In the presence of perfect information on the quality of the product,

⁶On double-sided adverse selection in the presence of insurance, see Seog (2010); on adverse selection in the labor market, see Greenwald (1986).

the seller's characteristics would be of no importance. Only the quality of the product would count in explaining the price equilibrium.

He thus considered two types of sellers participating in these auctions: those who sold only used cars (UC) and those who sold both used and new cars (NC). Each seller participates in two markets: the auction market where the buyer makes no distinction in quality and a more traditional market where the real quality is more likely to be observed by the buyer.

It can be shown that the equilibrium price will be equal to the price matching the average quality each type of seller will offer. Thus, a seller whose cars are of superior quality to the average quality offered by this type will not put them up for auction unless there is a surplus in stock. In this case, it may offer some for auction, starting with those of lower quality. Moreover, the average quality of the two types may vary, because sellers may have different stock management systems. The author shows that those who offer the two types of cars (used and new) have cars whose average quality is higher.

The motive behind stock management is important in finding an equilibrium. If the only motive for putting used cars up for auction is to take advantage of information asymmetry as shown in Akerlof's model, it is hard to obtain an equilibrium in a market where buyers are ready to pay for average quality and sellers are motivated to offer cars of only inferior or average quality. However, during a period of surplus stock, some sellers may have cars worth less than market value that they may be motivated to sell at the average-quality price, to gain a bonus. In other words, buyers in this type of market would have to value cars more highly than sellers to obtain equilibrium. [Gibbons and Katz \(1991\)](#) have used this type of argument to obtain equilibrium in the work market with specific human capital. They argue, however, that this equilibrium can be explained either by adverse selection or by learning of the participants in the market.

Empirically, according to [Genesove \(1993\)](#), a positive bonus in an auction market is possible only in a situation of asymmetric information where the buyer pays the average-quality price associated with the type of seller. Thus a seller who is more likely to sell in this market because he often has surpluses will usually sell better quality cars and obtain, at the equilibrium, a higher average price for the same quality of car.

The author finds that, though the data covered cars from 1988 to 1984 and earlier, there is a significant bonus only for 1984 cars. He consequently concludes that residual adverse selection is weak in this kind of market. Hence, enough information circulates by other mechanisms, i.e., reputation and guarantees, to reduce the informational bonus to zero. Sellers are not truly anonymous in the auction market. The seller must be present to accept or refuse the second price. There are also limited guarantees protecting buyers during the first hour following the auction. As in the automobile insurance example, in Sect. 15.2, private markets use effective mechanisms to reduce residual adverse selection.

Many extensions have been presented in the literature. We discuss four of them. The first one proposes to use price and quantity profiles over time across brands of cars to isolate evidence of adverse selection ([Hendel and Lizzeri 1999](#)). There will be evidence of adverse selection if the car that has a steeper price decline over time also has lower trade volume. This contrasts with the depreciation story, where the faster price decline should correspond to a larger volume of trade. The second extension is to show that leasing can solve the lemons problem ([Guha and Waldman 1996](#); [Hendel and Lizzeri 2002](#)).

The next two extensions go back to the methodology to distinguish adverse selection from other information problems in these markets. As [Dionne et al. \(2009b\)](#) argue, information asymmetry is a necessary prerequisite for testing adverse selection. Otherwise a statistical relationship can be interpreted as a learning phenomenon or any other market relationship. [Dionne et al. \(2009b\)](#) apply a sequence of tests to Mauritian slave auctions to separate adverse selection from learning.

Information asymmetry is a necessary condition for adverse selection to take place. If information is asymmetric, then adverse selection is possible, but remains to be proven. This suggests a sequential procedure whereby information asymmetry is tested before adverse selection. [Dionne et al. \(2009b\)](#)

apply this procedure in the particular context of nineteenth century Mauritian slavery. They ask (a) how the behavior of better informed bidders might have affected that of the less informed slave auction participants, and (b) what the impact of such inter-dependent bidding on slave prices would have been. If the second effect is negligible, then information was either symmetric or it was asymmetric but inconsequential. In contrast, if information is found to be asymmetric, then adverse selection is possible and additional tests can be performed.

To test for adverse selection after having verified the presence of asymmetric information in succession auctions using (15.1), the authors compare prices in succession sales with those in voluntary auctions. Again controlling for observable characteristics as well as the presence of informed bidders, they obtain that the succession sale premium is positive and statistically significant, meaning that adverse selection is present because the presence of asymmetric information was already proven in the succession market.

Another contribution of [Dionne et al. \(2009b\)](#) to the literature on the asymmetric information test is to verify if the independent variable of interest (d_i) in (15.1) is correlated with the unobservable factors. If this correlation exists, ordinary least square estimates may be biased. One way to reduce potential bias is to instrument the variable by adding exogenous variables to the vector of explanatory variables and by using (for example) the 2SLS method of estimation for the two equations. They used an instrument that reduces the potential bias but could not test the exogeneity of the instrument because they had only one instrument.

More recently, [Dionne et al. \(2010\)](#) extended the above analysis using three instrumental variables. Their application tests the influence of information asymmetry between potential buyers on the premium paid for a firm acquisition. They analyze mergers and acquisitions as English auctions. The theory of dynamic auctions with private values exclusively predicts that more informed bidders should pay a lower price. They test that prediction with a sample of 1,026 acquisitions in the USA between 1990 and 2007. They hypothesize that blockholders of the target's shares are better informed than other bidders because they possess privileged information. Information asymmetry is shown to influence the premium paid, in that blockholders pay a much lower premium than do other buyers.

To obtain this result, they estimate the influence of determinants of the premium identified in the literature using the ordinary least squares method. Their model is expressed as in (15.1). Again the test for the null hypothesis of no information asymmetry is that the gamma parameter is not statistically significant. The instrumental variables must be correlated with Blockholders; rather than with the error term in (15.1).

The three variables to instrument the presence of blockholders in the target are: (1) Intrastate; (2) Regulated industry; (3) An interaction variable between Intrastate and performance of the target. As pointed out above, these three variables must be correlated with the probability that blockholders are present in the auction but should neither directly affect the premium nor be correlated with the residuals of the premium equation. Because three instruments are examined, the authors can apply two formal tests to verify the desired result: the Sargan test for the over-identifying restrictions (the instruments are truly exogenous) and the Durbin–Wu–Hausman test for the relevance of instrumental variables method (or the endogeneity test).

They obtain that the presence of blockholders influences the equilibrium price of an acquisition and that their three instruments are exogenous and significant to explain the presence of blockholders.

15.8 Conclusion

We have explored the difficult question of the empirical measurement of the effects of information problems on the allocation of resources. The problems drew our attention: moral hazard, asymmetric learning, and adverse selection.

One conclusion that seems to be accepted by many authors is that information problems may create considerable distortions in the economy, in contrast with a situation of full and perfect information. Indeed, effective mechanisms have been established to reduce these distortions and to eliminate residual problems at the margin. In this new version of our survey, we have emphasized the role of dynamic data to identify different information problems. We have shown that dynamic data can be used to separate unobserved heterogeneity from moral hazard and to apply causality tests to separate moral hazard from adverse selection and asymmetric learning.

This conclusion seems stronger for adverse selection than for moral hazard, at least in the markets studied. One possible explanation, which should be investigated in detail, is that adverse selection concerns exogenous factors, whereas moral hazard and asymmetric learning hinge on endogenous actions that are always modifiable.

Finally, given the specific nature of the problems studied—lack of information—conclusions must be drawn prudently, because the effect measured cannot be fully verified. There will always be a lingering *doubt!*

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Chapter 16

Workers' Compensation: Occupational Injury Insurance's Influence on the Workplace

Richard J. Butler, Harold H. Gardner, and Nathan L. Kleinman

Abstract Worker's compensation provides health care and partial wage loss replacement to workers injured on the job. It is more complex in its scope and impact on workers than other social insurance both because it is a system of diverse state-based laws funded through private, public, and self-insuring entities, and because it has significant overlap with health insurance, unemployment insurance, and other employer-provided benefits. While research indicates strong incentive responses to the structure of indemnity benefits and medical reimbursements, future research will benefit from employing a *worker-centric* (rather than a program-centric) orientation using integrated databases that ultimately link workplace productivity to program characteristics.

16.1 Social Insurance for Occupational Injury and Disease

16.1.1 Workers' Compensation in North America

If John Q. Public is injured on the job or acquires a job-related disease, all his medical expenses and possibly some of his lost wages, are covered in the USA and Canada by Workers' Compensation. Workers' Compensation (WC) is a system of no-fault laws implemented, state by state, and province by province, about 100 years ago. While the system is fragmented, it is large: in 2008, \$58.3 billion of WC benefits were paid out to workers in the USA, over half going for health care expenditures and slightly less than half for lost work time pay. The cost to US firms of the system in 2009 was \$74 billion (Sengupta et al. 2011).

While we describe in this chapter some institutional details of the US system, Canada and many developed nations have similar systems for workplace injuries. Because each state dictates how wages are to be replaced (with "indemnity benefits"), who can initially direct the health care of the injured worker, and what mechanisms the firm can employ to provide for this insurance coverage, this is

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considered “social insurance.” Though each state has its own WC system, (and a Federal law to cover Federal employees), the institutional characteristics of WC are broadly consistent across states and similar to many systems outside the United States. Hence, the medical, redistributive, and incentive issues applicable to the WC system in the USA carry over to other countries.

16.1.1.1 Benefits

With respect to employee benefits under WC, all state laws require nearly 100% coverage of medical expenses and some minimum cash benefits related to lost earnings for those out of work longer than the state-specific waiting period (2–7 days, with modal waiting periods of 3 and 7 days). Though WC benefits are more generous than unemployment insurance benefits, the structure of reimbursements is similar. John Q. Public receives no lost workday compensation (i.e., no indemnity compensation), unless his claim exceeds the state’s waiting period.

Once past this waiting period, he is classified as a temporary total injury and receives approximately 67% of usual weekly wages as a benefit, subject to a state-wide weekly maximum payment, often set equal to the average wage for the state. After the injured worker’s medical condition has stabilized (called the point of “maximal medical improvement”), his injuries are evaluated for the permanency of the condition. Depending upon the state, he may be paid a lump-sum for things such as an amputated finger (scheduled benefits) or receive a weekly payment (benefits not stipulated for specific injury types by state legislation, such as low back pain, are “unscheduled”). In some states, there are time limits on the duration that a worker can receive benefits, though the most severe injuries generally have no time limits.

If the injury lasts longer than the retroactive period, the associated benefits withheld during the initial waiting period are reimbursed to the worker. Medical costs associated with a workplace injury are compensated on a fee-for-service basis, employing the “usual and customary” fees for the local health care market. Whether chiropractic care is reimbursed depends on state statutes regulating WC claims. WC policies are occurrence policies, so that if the injury happens when the insurance is in force, all associated payments for lost time or medical costs are incurred immediately and continue even if the worker doesn’t return to work or the firm changes insurance coverage. The laws also provide for rehabilitation services and the payment of income benefits to dependents in the case of a workplace fatality.

16.1.1.2 Insuring Workplace Risk

Except for domestic servants, agricultural workers in some states, and some very small employers, WC laws make employers liable for all medical expenses and a portion of lost wages for their injured workers. The employer pays these benefits for injuries arising “out of and in the course of employment,” regardless of who is at fault, except under certain exclusions, such as when the worker is under the influence of alcohol or drugs. The liability imposed on the employer is exclusive: the injured worker cannot sue for additional compensation nor is there compensation for pain and suffering.

Some large firms and groups of moderately sized firms are able to self-insure their liabilities. Generally, however, employers are required to purchase insurance to cover their potential liabilities. In four states—North Dakota, Ohio, Washington, and Wyoming—the insurance for those not self-insuring is provided by monopoly state funds. The remaining 46 states provide that insurance be purchased from private insurance carriers or, in 20 states, from a state fund that competes with the private carriers.

The procedures for calculating insurance premiums are similar across states. To calculate the firm’s insurance premium, the firm’s workers are placed into one or more of approximately 600 industrial–

occupational classifications. On the basis of these classifications, the firm is assigned "manual rates" which are premium rates reflecting the average losses found in each classification. "Manual premiums" are then calculated by multiplying the manual rate by the payroll of workers in the classification. These manual premiums are summed for all employee classifications to arrive at the manual premium for the firm.

The actual premiums paid by the smallest firms are these manual premiums. The vast majority of all employers in the USA pay unmodified manual premiums, though these employers have relatively few employees and only account for a small fraction of all employment covered by WC.

If the manual premium exceeds a given amount, then premiums are "experience-rated." In this case, the manual premium is modified to reflect the firm's own past injury loss experience: if the firm experiences fewer than expected WC claims in one of their classifications, the manual rate is adjusted downward to reflect the firm's better than average experience. If the firm is worse than average, rates go up. In the USA, the premium of an experience-rated firm is a weighted average of the manual premium and the firm's actual loss experience, where the weight placed on actual loss experience grows with firm size. That is, the extent to which a firm's actual premium reflects its own injury losses depends on the size of the firm. Small firms pay experience-rated premiums largely reflecting the manual premiums. In contrast, large experience-rated firms pay premiums largely reflecting their own loss experience rather than the average loss experience. The weight placed on the firm's own loss experience is termed the "degree of experience-rating." The greater the degree of experience rating, the more strongly the firm's incentives are tied to loss prevention, including incentives to invest in workplace safety and claims management. Firms that self-insure bear all of the costs of WC benefits directly, resembling full experience-rating. However, simulations by Victor (1982) have shown that fully experience-rated premiums can provide stronger incentives for safety than self-insurance.

16.2 Direct Financial Incentives (Intra-Program Responses): Safety and Reporting Incentives

16.2.1 Moral Hazard

"Moral hazard" occurs when individuals change behavior as insurance coverage changes. For example, employees have a tendency to take more days off work when sick leave benefits are expanded (made more generous). As another example, firms have more incentive to prevent WC claims when they are fully experience rated, and when they have large deductible policies in which they bear all the costs of initial injuries.

Numerous economic analyses have considered the effects of such *intra-program* moral hazard responses, where the change in benefits coverage affects the use of benefits in that program. From the perspective of the experience-rated firm, higher benefits increase the cost of an accident, and so increase the benefits from providing a safer workplace environment. More generous benefits weaken workers' incentives to self-protect (take care on the job and take care while recuperating from an injury), resulting in an increase in the incidence and severity of resulting injuries. Conversely, more generous benefits may increase incentives for firms to invest in safety, as these more generous benefits are passed along to firms in the form of higher premiums. Again, this firm incentive depends on the extent that premiums are tied to a firm's own loss experience. If a firm simply pays a manual premium that is not tied to its own loss experience, then higher WC benefits provide no additional incentive to avoid injuries (of course, other factors will provide this incentive, particularly, the firm-specific human capital of its skilled workers).

Workers' incentives are the opposite to firm's incentives: as WC benefits increase, the opportunity cost of being gone from active employment falls for the workers, increasing the tendency to file a claim or stay out on an extant claim longer than they otherwise would in the absence of an increase in benefits. Disability/health insurance changes (including the institution of such programs where they did not exist before) generate moral hazard potential to workers in general because such insurance expansion raises the benefits of claimants directly, but shifts the cost of program participation to the entire risk pool of the insured.

Ruser and Butler (2010) present formal models of firm and worker behavior when WC benefits, and experience rating changes, and find offsetting incentive effects influence the tendency to take care or provide safety. Hence, economic theory is ambiguous about the impact of WC on the level of workplace risk. While it weakens workers' incentives to avoid injury, it strengthens the incentives of experience-rated firms to invest in safety. Butler and Worrall (1991) termed such changes in risk, related to incentive changes, "risk bearing moral hazard."

Workers' compensation may also alter incentives for reporting injuries without changing the true level of safety. Like the safety incentives, the reporting incentives work in opposite directions for workers and firms. Specifically, more generous benefits may increase workers' incentives to report off-the-job injuries as occurring on-the-job, to report injuries that they wouldn't report in the absence of insurance coverage, and to possibly exaggerate the severity of injuries. Both changes in the true safety level and changes in the propensity to file claims for any given level of safety increase the reported incidence and severity of injuries in terms of lost weeks of employment.

Conversely, more generous benefits may cause firms to resist filing claims for injuries that have occurred. They may also cause firms to place injured workers on light duty either to avoid WC claims or to bring workers back to work earlier. These firm incentives decrease the reported incidence and severity of injuries. Like the firm's true safety effect, the extent to which firms resist filing claims and bring workers back to work earlier will depend on the extent to which premiums are experience-rated. Butler and Worrall (1991) termed these reporting effects "claims-reporting moral hazard."

16.2.2 Workers' Compensation and Occupational Injury Frequency

Empirical studies have measured the effect of WC on the incidence of occupational injuries and claims, analyzing both WC claims data and injury rate data. Earlier reviews of these studies are found in Worrall and Butler (1986) and Smith (1992). Research finds that increases in benefits are generally associated with an increase in the incidence of claims and injuries. This supports the contention that the incentive effects for workers tend to dominate those for firms, though a recent analysis finds that the (implied) frequency response has fallen closer to zero (Guo and Burton 2010), which may be the result of the recent expansion of large deductible insurance policies offered to firms, as large deductibles increase the importance of cost containment for the firm (Durbin and Butler 1998). However, Bronchetti and McInerney (2012) find that estimates of benefit elasticities have not changed from pre- and post-1990 periods in their analysis of CPS data using a quadratic specification for wages (Table 6, without higher order wage moments in the specification).

Some studies analyzed the injury rate data collected by the Bureau of Labor Statistics (measuring the annual number of new injury cases per 100 full-time workers). These data distinguish between injuries that involve lost workdays and injuries that have no lost workdays. The results from studies using these data generally showed that higher benefits increased the rate of lost-workday injuries more than the rate of injuries without lost workdays. Chelius (1982) reports that a 10% increase in benefits increased the rate of lost workday cases by 1.2%, while increasing the rate of cases (those not involving lost workdays) by only 0.7% (an effect that was not statistically significant). Ruser (1985) found that a 10% increase in benefits increased the rate of lost workday cases between 1.2 and 3.1%

depending on the model specification, while the increase for all cases (including those without lost workdays) was between 0.6 and 2.8%.

Butler and Worrall (1983) found comparable results for workers' compensation claims data: using aggregate data for 35 states in the 1970s, they estimated that a 10% increase in benefits was associated with a 4% increase in claims (a claims rate/benefit elasticity of 0.4). Butler and Worrall (1988) fit generalized loss distributions on 11 manual-rate risk categories (roughly, occupations) for 38 states using detailed WC losses (insured firm level data), for 2 years, and found a benefit elasticity of 0.47. Chelius and Kavanaugh (1988) examined a particular case where WC benefits were reduced and found that this resulted in a decline in WC claims, so the positive claims elasticity was symmetric in that claims went down when benefits dropped.

Butler (1983), using aggregate claims for 15 industries over a 32-year period in South Carolina, estimates benefit to claim frequency elasticities generally from 0.13 to 1.1. Butler et al. (1997) use a difference-in-difference estimator for WC claims from a single large inter-state employer, identifying the benefit elasticity from four large increases in the WC maximum weekly benefit for different states, and one state with a large decrease in the WC maximum benefit. The logistic, difference-in-difference estimators implied claims rate/benefit elasticities from .4 to 1.1, even for the state with the large decrease in the maximum benefits (in that state, claim rates went down substantially following the decrease—again, suggesting a symmetric impact of benefit changes). While Butler et al. (1997) used data from just one employer, examining before and after changes in benefit utilization for several states with large increases (or decreases) in the maximum benefits in the 1990s (including California), Neuhauser and Raphael (2004) focus exclusively on the changes in the maximum benefits just for California using administrative WC data across several employers and arrive at similar benefit elasticities.

Barring the quasi-experimental design employed by Meyer et al. (1995), Butler et al. (1997), or Neuhauser and Raphael (2004), the identification of benefit effects in micro-data sets hinges on the nonlinearity between benefits and wages induced by maximum benefits. The findings of Bronchetti and McInerney (2012, Tables 4–6) suggest that including higher order moments of the wage distribution in the specification significantly reduce the estimated benefit effects. As Bronchetti and McInerney don't discuss the variance inflation factors (VIF) for expected benefits and the higher order moments for the wage distribution in their results (expected benefits are just a nonlinear transformation of the worker's wage), future research should look at the VIFs when using anything other than just the individual worker's wage rate in the specification, or just the replacement rate, as historically been employed in WC research.

16.2.3 Experience Rating

Beyond these overall results, further research has focused on a variety of issues, including whether experience-rating strengthens firms' incentives for safety and whether it is possible to separate reporting and true safety incentives.

Evidence tends to support the hypothesis that experience-rating strengthens firms' economic incentives for safety, but not all research is conclusive. Among the stronger results, Ruser (1985, 1991) showed that higher benefits raised injury rates less in larger, more experience-rated firms. Ruser (1991) analyzed BLS injury rates for separate establishments (individual businesses or plants). Depending on the statistical model, he found that a 10% increase in weekly benefits increased injury rates by 3.8–7.7% in establishments with fewer than 100 employees. In contrast, this benefit increases raised injury rates by at most 1.8% in establishments with more than 500 workers. Ruser interpreted this as evidence that experience rating in larger firms strengthens incentives for safety, counterbalancing the worker disincentive effect.

Utilizing the same basic methodology as [Ruser \(1985\)](#), [Worrall and Butler \(1988\)](#) also found confirming evidence that “experience-rating matters” in WC data from the state of South Carolina. They obtained stronger evidence for permanent partial disabilities than for temporary total disabilities. More recent empirical evidence indicating that self-insured firms having lower injury risks than partially experience-rated firms comes from [Asfaw and Pana-Cryan \(2009\)](#).

Besides experience rating, another mechanism that strengthens the link between a firm’s WC benefits paid to its workers and its insurance costs is the use of large deductibles in insurance policies. The larger the deductible, the greater the incentive to reduce costs: if deductibles exceed expected WC benefits consumed by the workers, the “insurance” would be essentially the same as being fully experience rated or self-insured. [Durbin and Butler \(1998\)](#) regress state level fatal workplace injury rates on the introduction of large deductible insurance policies during the 1980s and find a significance decrease in fatalities associated with larger deductibles, and also significant decreases in fatal workplace injury rates associated with increases in experience rating coverage among firms. [Guo and Burton \(2010\)](#) report that injury frequency elasticities have become essentially zero recently. If this unusual finding proves to be robust, it may be the result of the introduction of large deductible policies offered by WC carriers to firms as additional incentive to avoid workplace injuries.

Not all researchers find that experience-rating provides incentives for safety. In two studies, [Chelius and Smith \(1983, 1993\)](#) failed to find empirical support that experience-rating increased workplace safety. They provided a variety of explanations for their negative results. Among these, they noted that the premium adjustments due to experience rating tend to be relatively small and, owing to the way that premiums are calculated, premium savings from safety appear several years in the future. Also, since the formula for calculating experience-rating is complicated, they questioned whether employers understand the financial incentives.

A potential shortcoming of the studies of Ruser and others is that they analyze outcomes such as injury or claims incidence that are influenced both by changes in safety and in reporting ([Durbin and Butler \(1998\)](#) analysis of fatal injury rates avoids this criticism, as discussed above). Critics of the experience-rating hypothesis argue that, even when supported by evidence, it may result not from reductions in true safety, but merely from firm’s activities to reduce reported injuries. In an interesting study of experience-rating, [Thomason and Pozzebon \(2002\)](#) analyzed data they collected from 450 firms in the Canadian province of Quebec. These data provided information directly about firms’ activities both to improve the safety and health conditions at the workplace and to manage claims. Variables to measure health and safety practices included presence of in-house safety personnel, hiring of a safety consultant, safety duties performed by safety personnel, presence of a worker–employer safety committee and the number of meetings held by that committee, safety training time provided to employees, and firm expenditures on personal protective equipment.

Claims management involves activities that can reduce the cost of injury and disease to the firm without necessarily affecting workplace health and safety. Claims management practices in their study consist of the following standard practices: presence of in-house claims management personnel or the hiring of a claims management consultant, the extent to which the firm has placed disabled workers on temporary assignments, the number of compensation claims resulting in a formal dispute. These included activities that increased the injured worker’s return to work and challenged the worker’s claim for benefits. In general, the statistical analysis of [Thomason and Pozzebon \(2002\)](#) supported the hypothesis that experience-rating causes employers both to improve workplace health and safety and to engage in more aggressive claims management.

16.2.4 Incentives and Types of Claims

Attempts to address empirically the distinction between true safety incentives and claims-reporting moral hazard have also focused on differences in possible reporting of different types of injuries.

One strain of the literature focuses on the impact of WC on fatalities as compared to nonfatal injuries. The rationale is that it is more difficult to misreport a work-related fatality as opposed to a nonfatal injury. In contrast to the bulk of the literature on nonfatal injuries, [Moore and Viscusi \(1990\)](#) and [Ruser \(1993\)](#), using data from a census of death certificates and the BLS injury data respectively, found that death rates generally declined with benefits. They inferred that this reflected a true safety effect since there would be no claims-reporting effect.

Others, noting that worker-generated claims-reporting moral hazard is more likely to occur for injuries that are hard to diagnose or whose work-relatedness is hard to establish, have hypothesized that more generous benefits increase the frequency of hard-to-diagnose injuries such as back sprains, relative to easier-to-diagnose injuries like fractures and cuts. An implicit assumption needed to empirically test this hypothesis is that the effects of WC on true safety incentives and on *firm*-generated claims-reporting moral hazard are the same for all types of injuries.

The evidence on a differential effect of higher benefits on hard-to-diagnose injuries is not unanimous, but tends to support the hypothesis of worker-generated claims-reporting moral hazard. In three manufacturing plants, [Robertson and Keeve \(1983\)](#) found that a higher maximum benefit increased the number of subjectively verified injuries and claims such as back sprains and pain, but there was no effect of higher benefits on lacerations and fractures. [Johnson et al. \(1997\)](#) also found that low back claims are more responsive to benefit increases than other types of more readily monitored injuries. [Welland \(1986\)](#), on the other hand, studying WC claims data for six states in 1976, found that more generous weekly benefits decreased the proportions of sprains and contusions, but increased the proportions of easily diagnosed amputations, burns, fractures, and scratches.

In state level WC claims data, [Butler et al. \(1996\)](#) found that higher benefits increased the relative frequency of sprains and strains and decreased the frequency of cuts. Anomalously, they also found that the proportion of fractures increased with benefits. Finally, in BLS injury rate data, [Ruser \(1998\)](#) found that more generous benefits increased hard-to-diagnose back sprains and carpal tunnel syndrome relative to cuts and fractures.

The empirical literature generally supports the hypothesis that more generous WC benefits induce more reported injuries and claims, particularly, for injuries that are hard to diagnose or relate to the workplace. Workers' incentives tend to dominate those of firms. However, experience-rating does tend to enhance firms' incentives both to invest in safety and to engage in claims management to reduce claims.

16.2.5 Workers' Compensation Benefits and WC Claim Duration

Besides many analyses of claims' incidence as benefits increase, or as the extent of experience rating increases, claim duration (number of lost workdays) would also be expected to vary with changes in benefits or experience rating. The empirical research generally finds that higher benefits are associated with longer time away from work. The earliest published study of claim duration is [Butler and Worrall \(1985\)](#), who examined variations in the duration of low back claims with respect to socio-economic characteristics and the wage replacement ratio. They found a benefits/duration elasticity of about 0.4: for each 10% increase in benefits, the duration of the claim increased by about 4%. In a related study using a different empirical approach, [Worrall and Butler \(1985\)](#) find benefits/duration elasticities of about the same magnitude.

Using a difference-in-difference specification, [Meyer et al. \(1995\)](#) analyzed the impact of an increase in the maximum income benefit in two states. They found that a 10% increase in benefits was associated with a 3–4% increase in the duration of an out of work spell, similar to [Butler and Worrall \(1985\)](#). Other researchers have found larger impacts, including [Gardner \(1991\)](#) who found that a 10% increase in benefits in Connecticut led to a nearly 10% increase in duration and [Krueger \(1990a,b\)](#),

who found that this benefit increase resulted in an over 16% increase in duration in Minnesota. [Johnson and Ondrich \(1990\)](#) also estimate relatively high benefits/duration elasticities, around 1.1 and 1.2.

Even if all existing claims increase in duration with a rise in WC benefits, so that workers' incentives to remain off the job dominate firms' incentives to bring workers back to work, it is not a priori certain that more generous benefits will result in longer average durations. [Smith \(1992\)](#), [Meyer et al. \(1995\)](#), [Butler et al. \(1997, footnote 1\)](#), and [Ruser and Pergamit \(2004\)](#) argued that offsetting effects lead to ambiguity. On the one hand, more generous benefits provide incentives for workers to remain off the job longer, but on the other hand, more generous benefits may induce workers to report more injuries and claims. If these new injuries tend to be minor, then more generous benefits result in a larger number of short duration injuries and claims. This "compositional" effect—the addition of more short term claims in the mix—would tend to reduce average measured duration.

[Ruser and Pergamit \(2004\)](#) found evidence supporting the compositional effect. Counter to most results, they found that a 10% increase in the weekly benefit lowered the duration of all WC claims by over 5%. However, when claims of 7 days or longer were examined, there was no effect of higher benefits, suggesting that "compositional" effects were weaker than the incentives for those with more serious injuries to stay out longer on a claim.

Like the analyses of claims incidence, experience-rating seems to strengthen firms' incentives to shorten out-of-work durations. [Chelius and Kavanaugh \(1988\)](#) found that the severity of injuries declined in a particular college after that institution switched to self-insurance. In a broader set of Minnesota data, [Krueger \(1990a,b\)](#) found that the duration of temporary total spells was about 10% shorter in self-insured firms than in privately insured firms. Krueger noted, however, that this result was consistent with the possibility that the group of firms that self-insure might have injuries that are less severe than privately insured firms, even after controlling for observable covariates.

Benefits also seem to have different effects on duration depending on the type of injury. [Dionne and St-Michel \(1991\)](#) found in their analysis of Quebec data that higher benefits increased the duration of hard-to-diagnose back injury cases but had no effect on durations of objectively determined contusions, amputations, and fractures.

Needed in the research on WC duration effects, is a panel data analysis of effect of benefits on the relative wage path of injured workers following an injury. [Ehrenberg and Oaxaca \(1976\)](#) did such an analysis for receipt of unemployment insurance benefits by looking at the duration of work loss and subsequent wage gain. By analogy with that study, in the WC case, if WC benefits represent a pure moral hazard response, longer durations induced by higher benefits will not increase workers' relative wages. However, if WC benefits increase duration because of improved recovery of human capital, then the longer duration should be associated with relatively higher productivity (and hence, higher wages or lower absenteeism) after the employees' return to work.

16.3 Indemnification: How Complete is Workers' Compensation Coverage?

As indicated above, WC benefits and experience rating have been found to generate moral hazard responses by firms and workers. In the absence of moral hazard responses in safety and reporting behavior induced by the insurance coverage, full coverage is optimal with risk averse workers. With moral hazard responses, optimal insurance is less than 100% wage replacement—hence, the standard cost sharing WC insurance mechanisms of partial wage replacement and waiting periods. Moreover, hard-to-monitor claims such as low back claims seem to exhibit more moral hazard response than other claims ([Dionne and St-Michel 1991](#)), so one Pareto-improving adjustment to the benefit structure (that could be cost neutral within the WC system) would raise the replacement rate of easy to monitor

injuries (such as lacerations and broken bones) while lowering the replacement rate of hard-to-monitor injuries (such as low back claims). Finding such patterns of benefit response in their data, [Johnson et al. \(1997\)](#) suggest such a change in the WC benefits structure.

[Bronchetti and McInerney \(2012\)](#) estimate that WC benefits significantly smooth consumption lost to workplace injuries, even in the presence of potentially low take-up rates, and given the moral hazard responses historically measured (given in the previous two sections above), finds that WC benefits may be slightly higher than is socially optimal (weighing the importance of consumption smoothing against moral hazard response).

In conjunction with these considerations of the optimal structure of WC payments by moral hazard potential, there is a small literature on how fully WC benefits replace lost wages of workers injured on the job. These estimates have to be made with care, particularly for inter-temporal comparisons. For example, some workers with long-term back pain may not be eligible for WC benefits if the back pain is not related to their current job. Modern sedentary life may change the incidence of back pain in uncertain directions. Moreover, firms are increasingly using restricted work for injured workers ([Ruser 1999](#); [Wahrer and Miller 2003](#)), as benefits increase and waiting periods shorten, changing the estimated dynamic of days away from work and benefits (and hence, lost wages).

Partial wage replacement mechanisms that guard against moral hazard response also bias the estimates of lost earnings. Waiting periods guarantee that most minor workplace injuries will end up being medical only claims, and hence, there will be no wage replacement even in the absence of work-origin or "take-up" rate problems. Using countrywide data on claims, [Appel and Borba \(1988, p. 4\)](#) report that 81.2% of all claims are medical only claims (using an ultimate report basis). This high fraction of medical only claims is also apparent in more recent data (New Mexico Workers Compensation Research Department reports that 76% of their claims were medical only in 2010). Even so, evidence suggests that not all claim-eligible workers get WC benefits, both because the take-up rate for claims is less than 100% even past the waiting period and because some claims are denied by the employer/insurer.

Most studies of WC take-up rates compare administrative WC data with some alternative measure of injured workers. For their alternative measure of work injuries, [Biddle and Roberts \(2003\)](#) employ a sample of workers with shoulder, back, wrist, or hand sprains/strains whose injuries were deemed work related by physicians. The advantage of these injuries is that they cover a relatively large fraction of WC claims and so are fairly representative of typical claims; the disadvantage is the specific work origin of a soft tissue injury may be difficult to determine, even by a worker if they have more than one job for any length of time. In comparing their sample of injured workers with Michigan administrative WC data, they find that up to 60% of their injured workers never filed a WC claims, primarily because workers self-report that they did not think the condition was sufficiently serious. Even among those with more than 1 week of lost work (beyond the Michigan waiting period), 40% did not file for wage-loss benefits. An earlier analysis suggests that the low take-up rate is not just a strain/sprains problem as they find acute conditions just as likely to be under-reported as chronic conditions ([Biddle et al. 1998](#)).

As WC insurance is purchased by the employer and WC claims are filed by workers, Coase theorem outcomes are less likely to be obtained between firms and workers with respect to claiming behavior and wages (expect perhaps between large, self-insuring firms and long-tenured skilled employees). Hence, it is feasible that higher denial rates could lower claims filing, particularly, for hard to monitor injuries like low-back pain. [Biddle \(2001\)](#) finds such a result in an Oregon sample.

[Boden and Galizzi \(2003, 1999\)](#) find that evidence that women receive lower loss-wage reimbursements than men, which may reflect discriminatory differences in injury benefits. Using a sample of injured men and women from Wisconsin in 1989–1990, they find significant differences in loss-wage reimbursements 3 years after the injury, even after observable labor supply factors are taken into account.

Clearly there are a lot of unresolved problems with estimating wage-loss in WC, and future research—perhaps along the lines of [Bronchetti and McInerney \(2012\)](#)—will be welcome in this literature.

16.4 “Indirect” Financial Incentives: Workers’ Compensation Program Overlap

In this section, we extend the moral hazard discussion to responses in two other empirical directions: (1) how insurance changes in one program affect employee participation in other programs at a point in time (*inter-program moral hazard*) and (2) how the consumption of program benefits now tends to affect employees behavior over time (*benefits consumption capital*). This section draws heavily on the models and results developed in [Butler and Gardner \(2011\)](#).

Moral hazard across programs: inter-program moral hazard. Though a lot of research has been directed to estimating intra-program moral hazard, such as how benefit increases in WC affect the incidence of WC claims, incentive responses can occur *between* programs as well. Changes in one type of insurance coverage, say compensable health conditions covered by WC, may affect use of other program benefits, such as health insurance, sick leave benefits, employer-provided short- and long-term disability benefits, or unemployment insurance. For example, states may change whether mental stress claims are compensable under WC, affecting the use of counseling services under employers’ health insurance policies. We call these cross program effects *inter-program moral hazard* to distinguish it from the *intra-program moral hazard* usually analyzed in the literature ([Gardner 2006](#); [Gardner et al. 1999](#)).

The WC literature’s narrow, single-program outcome focus has overlooked how program overlap with WC (especially health insurance, sick leave, employer provided disability insurance, and unemployment insurance) may yield contradictory incentive structures. For example, cost sharing in WC to help control moral hazard response through waiting periods and partial wage replacement may not be effective in reducing moral hazard when another program compensates for WC cost-sharing features. Paid sick leave frequently replaces wages lost during the waiting period for WC, or tops off WC benefits to 100% wage replacement, mitigating cost sharing in WC that is aimed at limiting moral hazard.

16.4.1 WC and Health Insurance

Program overlap is most likely to appear in “health” conditions that are difficult to monitor as to place and activity of origin, and which can possibly be reimbursed under alternative programs. The difficult-to-diagnosis health events include strains and sprains, particularly for low back pain, mental stress claims, carpal tunnel syndrome, etc. Though the medical costs of injuries that “arise in the course of and out of employment” are meant to be paid under the WC insurance policy, an employer may prefer to have these expenses paid out under the health insurance contract, particularly if the employer is experience-rated and wishes to avoid future premium increases by artificially lowering their WC costs now.

As noted above, [Dionne and St-Michel \(1991\)](#) examined increases in WC benefits in Quebec and subsequent WC claim durations by injury type (in a multivariate duration model) and found that increases in expected benefits significantly increased claim duration for hard-to-diagnosis conditions relative to easy-to-diagnosis conditions. The authors attribute the differential result to

more information asymmetry for the hard-to-diagnosis conditions, and hence, greater moral hazard response. Ruser's (1998) multinomial logit analyses indicate an increase in the wage-replacement rate and a decrease in the benefit-waiting period increase the fraction of carpal tunnel syndrome cases relative to cuts and fractures, while a decrease in the waiting period increases back sprains relative to fractures, as expected.

Johnson et al. (1997) find WC back pain claims (back pain information comes from self-reports) behave differently than non-back claims (where the degree of injury, for say cuts or fractures, is readily measured). Their multivariate analysis indicates back pain cases are twice as elastic as other accident cases to increases in benefits when it comes to returns to work after an injury. That is, back pain cases are less likely to return to work given the same benefit increase as lacerations or broken bones. Bolduc et al. (2002) find a similar pattern of increased hard-to-diagnosis claim frequency for a sample of construction workers in Quebec, using a random effects multinomial probit model.

The easiest health event to monitor, one with minimal diagnostic problems, and whose work origin is clearly defined, is a fatal workplace injury. So workers' claim-reporting moral hazard response should be minimal for these types of injuries relative to nonfatal injuries in that the moral hazard response would be different for fatal and nonfatal injuries. Moore and Viscusi (1990) and Ruser (1993) find that fatal injuries generally decline with increases in WC benefits, suggesting that for fatal injuries the firms' safety incentives under WC dominate the workers claim-reporting responses.

Inter-program moral hazard may affect health care providers as well as workers. Few health care providers receive training in occupational medicine and hence, have no scientific basis for distinguishing the work origin and impact of a given health condition. Butler (2000) and Park and Butler (2000) employ worker specific data on severe low back injury claims under WC to regress physician's impairment ratings (which can be viewed as a measure of loss of human capital earnings potential) on subsequent wage loss (they constructed worker specific wages from matched state unemployment insurance data) for the census workers receiving impairment ratings. They find that in a regression of subsequent wage loss on a polynomial in impairment ratings that less than 1% of subsequent wage loss is explained and is statistically insignificant, under several alternative specifications. This indicates that physicians' assessment of potential wage loss from back injuries is virtually useless.

But it is not just the asymmetric information between doctors and WC claimants that is a problem; incentives are also a problem. Ducatman (1986) examined WC claims for workers in shipyards, who had health insurance either under a Health Maintenance Organization (HMO), or a standard fee-for-service type of coverage. Ducatman found higher WC costs for those with HMO coverage, and he attributes that to moral hazard: HMOs increased their income by classifying health conditions as work related. Treating physicians are paid either on a fee-for-service basis or a salary. HMOs at the plan level are capitated payment programs, treating all the health care needs for an individual (or family) for a fixed annual fee. Since all WC programs reimburse on a fee-for-service basis, HMO plans can increase their revenues by encouraging their staff physicians to classify as many conditions as work-related as possible so that they will receive the WC fee-for-service payment on top of the already contracted annual fee. In particular, since the work origin of soft tissue injuries is difficult to determine, there are incentives for HMOs to classify as many soft tissue health conditions as work-related as possible.

There is some evidence that a similar sort of cost-shifting occurred during the 1980s as HMOs expanded rapidly in the US, a time during which WC as a percent of the payroll increased markedly as did fraction of sprain and strain claims under WC. Butler et al. (1996, 1997) provide evidence that most of the shift in claims was due to moral hazard, rather than changes in the composition of workplace risk or reduction in traumatic injuries such as broken bones, lacerations, and crushing injuries. They found, both in their analyses of longitudinal claims and individual WC claims from a large employer, that most of the increase in soft tissue claims was explained by the expansion of HMOs, likely via the Ducatman "misclassification" effect discussed above.

16.4.2 *WC and Sick Leave: “Cascade of Coverage” Effects*

A traditional insurance mechanism to control moral hazard is cost sharing through deductibles or copayments. Health insurance research indicates when cost sharing reduces usage. In a randomized experimental study, when deductibles were reduced, health care expenditures rose more than proportionally (Manning et al. 1987). In addition, the presence of “Medigap” insurance policies that cover the deductibles in Medicare insurance has been shown to substantially increase the cost of Medicare (Link et al. 1980; McCall et al. 1991; Cartwright et al. 1992; Chulius et al. 1993).

Like Medigap policies, when employers provide “gap” coverage for those on WC claims, it removes the cost sharing arrangements designed to help limit moral hazard. Under the WC system, disability copayments for workers take the form of partial wage replacement and maximum benefit restrictions, while deductibles take the form of waiting periods. However, such cost-sharing deductibles have been substantially reduced by trends in employer-provided disability insurance policies that effectively eliminate all the costs from being on a WC claim.

WC studies have generally shown that waiting periods effectively reduce the amount of lost time experienced on WC or group disability claims. Butler and Worrall (1983) found that a 10% increase in the waiting period reduces temporary total claims by 3.3% and reduces permanent partial injuries by 1.5%, holding constant WC benefits, wages, union status, and geographical location in a longitudinal analysis of states’ WC systems during the 1970s. Krueger (1990a,b) estimated that (holding benefits and workers’ socio-demographic characteristics constant) longer waiting periods significantly decrease the likelihood of becoming a WC recipient in an analysis of individual data from the Current Population Survey. He reports, “If the waiting period were increased from 3 to 7 days, the WC reciprocity rate would fall by 38.7%.” Butler (1994), in a longitudinal analysis of state data from 1954 to 1991, finds that a 10% increase in the waiting period not only lowers claims frequency by 3.5% but also is associated with more severe claims because of the truncation of less severe claims. Both effects were statistically significant.

Using micro-data from three large companies with varying overlap between disability programs (from relatively little in one company to 100% coverage of one insurance waiting period with other benefits in another company), Gardner et al. (2000) find cost differences of over \$600 per employee between the least overlap and greatest overlap companies. Lynch and Gardner (2008, p. 118–120) find, for a sample of over 100,000 workers, that short-term disability (STD) waiting periods affect long-term disability (LTD) claims: a 10% increase in the short-term disability waiting period decreased the likelihood of LTD claim by 5.5%. This suggests that LTD status and STD status may be complements as a longer STD waiting period makes going on a STD claim more expensive to the worker (higher foregone wages with a longer waiting period), probably decreasing the likelihood of a STD, and decreasing the likelihood of a subsequent LTD disability claim.

16.4.3 *WC and Unemployment Insurance*

For health conditions of uncertain work origin, like mental stress conditions or sprains and strains (particularly low back pain conditions), for which severity is difficult to assess except through an employee’s self report, WC is an attractive alternative for workers whose firms are downsizing their workforce. For workers in imminent danger of layoffs, WC benefits are more attractive than unemployment benefits: unemployment benefits are of limited duration, only 50% of wages and subject to taxation whereas WC benefits are often open-ended, usually two-thirds of wages, and not subject to taxation. Hence for those *expecting to be laid off a job*, it’s better to be a WC claimant rather than an unemployment insurance (UI) claimant. If currently in WC claimant status and if employment

status becomes less certain due to possible layoffs, it is financially advantageous to remain on a WC claim as long as possible. Among workers expecting to be laid off, claim frequency and claim duration should increase as part of an inter-program moral hazard response associated with the relative differences in WC compensation and UI compensation.

A good example of incentives for those with uncertain job prospects is contingent workers—generally contractors or those employed through a temporary staffing agency. As they have no formal or even informal expectation of continued employment, they would be expected to experience higher WC costs than regular workers, even in places where the real level of safety risk is held constant. Besides more job insecurity than regular employees, leased-workers' safety precautions are more difficult to monitor by the staffing agency (which is responsible for providing contingent workers WC insurance), compounding the moral hazard problems. As expected, [Park and Butler \(2001\)](#) find that even after controlling for occupation, workers' socio-demographic characteristics, expected benefits, and type of injury, the WC costs of contingent workers are about three times higher than regular full-time workers. Consistent with the notion that this increase is in part due to claims-reporting moral hazard rather than risk bearing moral hazard, the WC denial rate for contingent workers is also much greater than for regular full-time employees.

Another margin of substitution, however, for those expecting to retain their job—i.e., among those not expecting to be laid off in an economic downturn, that may offset the effect outlined above—is the margin for those expecting continued employment and thus receiving wages higher than non-work benefits. Workers *hoping to avoid the reduction in force*, and retain wages from their current job, may actually avoid reporting workplace injuries in order to keep from “rocking the boat” and increasing the likelihood of being laid off. This may take the form of not reporting minor, on-the-job injuries, but also being more careful on the job, reducing work place risk and thus reducing workplace injuries. The implication is that claim frequency may not necessarily be counter-cyclical in the aggregate, either because of a fall in risk bearing moral hazard or a fall in claims-reporting moral hazard. As the aggregate workforces are composed with some workers expecting to be laid off (for whom WC is a better alternative than unemployment insurance) and some workers expecting to survive layoffs in an economic downturn, the net effect of a recession on the frequency of WC claims is indeterminate.

Consistent with the model results given above for those experiencing a reduction in force, [Butler and Park \(2005\)](#) estimate that the duration of non-work spells on WC is 25% higher when a company has experienced a reduction in force during the last year, controlling for occupation, industry, injury type, and company safety policy. [Fortin and Lanoie \(1992\)](#) find, using an industry level sample, that an increase in expected weekly unemployment insurance benefits decreases the average duration of a WC claim with an elasticity from -0.5 to -0.7. That is, as the relative weekly UI/WC benefit ratio goes up, the duration of a WC claim goes down as predicted by the inter-program moral hazard model.

Holding the ratio of UI/WC benefits constant over the business cycle, however, as weekly WC benefits exceed weekly UI benefits, WC claim duration appears to increase during recessions. Using a WC administrative database on more than 30,000 Canadian injury claims among construction employees, [Fortin et al. \(1999\)](#) estimate the effect of claim duration with respect to expected unemployment benefits and find that a reduction in the unemployment benefits to wage ratio (holding WC weekly benefits constant) increases the duration of difficult to diagnosis WC claims. Also, as expected, in December at the beginning of the lay-off season in the Canadian construction sector, claim duration rose significantly. These results are all consistent with WC benefits being more generous than unemployment insurance benefits, and those with tenuous employment, choosing to report more WC claims.

The evidence of accident frequency during recessions has been more mixed, at least until recent research. [Lanoie \(1992a,b\)](#) in an analysis of Quebec accident rates estimates no statistically significant relationship between proxies for the business cycle and the frequency of WC claims. Though this relationship is weak, [Lanoie \(1992a\)](#) finds that as the unemployment rate increases, the frequency of accident claims falls, suggesting that reported compensation claims per employee fall during

a recession. [Boone and van Ours \(2006\)](#) analyze workplace injuries in 16 OECD countries for about 20 years and find that while fatal accident rates remain unchanged over the business cycle, nonfatal accident rates fall as unemployment increases. So while real safety—as proxied by fatal injuries—remains unchanged over the business cycle, reported (nonfatal) accidents fall. This may be a “claims-reporting moral hazard” response where workers are less willing to report injuries when job opportunities are scarce and unemployment high.

The best evidence that injuries are pro-cyclical comes from trends in WC claims and reported accidents during the recent great recession in the US, as examined by [Butler \(2011\)](#). Using multiple US data sets, Butler finds—in models with state and year fixed effects, individual state trend controls, and numerous demographic control variables—that both fatal injuries and nonfatal injuries are pro-cyclical. As unemployment increases, injuries fall. At least for the recent US experience, workers seem to be taking less risk in economic downturns.

16.5 Non-Financial, Behavioral Correlates of Workers’ Compensation Claims

16.5.1 WC Benefits Consumption Capital: “Inter-Temporal Moral Hazard”

Moral hazard over time: benefits consumption capital. Program participation increases program capital—that is, as knowledge of program restrictions, qualifications, and the scope of benefits increases—the cost of future participation is lowered. It also increases knowledge about how to best to present a given health condition as program-qualifying and knowledge of relatively more sympathetic health service providers (doctors, etc) or administrative personnel (company or third party). A worker absent from work for an extended duration not only has human capital depreciate, his/her comfort as a beneficiary may increase, possibly including a greater sense of entitlement under WC. Hence, program participation now may lower the real and psychic costs of WC participation in the future, increasing the likelihood of future WC participation.

This inter-temporal moral hazard relates the program participation per se rather than just a change in the scope of the insurance coverage: we call it benefits consumption capital. The insurance margin that induces benefits consumption capital is the extensive margin, as WC participation lowers future costs of participation and hence affects subsequent non-work spells. Although this is a type of consumption capital response discussed in other contexts ([Becker and Murphy 1988](#)), we also view it is as type of moral hazard in the sense that insurance coverage now affects the likelihood of insurance claims in the future.

Human resource and risk management policies that emphasize early WC claims’ intervention efforts—including various types of job accommodations to encourage early return to work—provide indirect evidence that, from management’s prospective at least, claims may generate benefits consumption capital. Presumably, firms wouldn’t provide job accommodations unless they thought it was cost beneficial. Direct evidence on the benefits of early return to work efforts come chiefly from research of hospital personnel, including various approaches to encourage early return to work: pro-active case management ([Arnetz et al. 2003](#)), functional restoration early intervention protocol ([Gatchel et al. 2003](#)), early intervention with light mobilization ([Molde et al. 2000, 2003](#)), and clinical and/or occupational interventions ([Loisel et al. 1997](#)). However, these “early intervention” studies did not explicitly quantify the “early” aspect of their treatment—for example, days or hours from symptom onset to first treatment or intervention—as a separate independent variable. Studies with more explicit examinations of how early intervention (given in days from symptom onset) affects perceived satisfaction with the firm and health care provider, perceived levels of pain and back

functionality, and return to work include [Yassi et al. \(1995\)](#) and [Cooper et al. \(1996\)](#), and [Butler et al. \(2007\)](#). [Butler et al. \(2007\)](#) focus on corporate workers in a prospective analysis of WC claims for workers with low back pain symptoms. They find that when a nurse contacts a WC claimant within the first week, the likelihood that the worker continues to remain at work without interruption doubles, relative to nurse contacts occurring after the first week.

Direct evidence of benefits consumption capital is found by [Butler and Gardner \(2011\)](#). Following a panel of newly employed workers for a decade, they find that, even after controlling for worker heterogeneity, those who have experienced claims in 2 of the past 5 years are twice as likely to file a claim this year as someone who has not experienced any prior claims. Moreover, the Markov claim transitions indicate that repeat claims are not the result of residual damage from an initial injury: the body-part-injury-type for new claims is virtually uncorrelated with body-part-injury-type for the old claims when tracked across the panel.

16.5.2 The Monday Effect and Changes in Work Shifts

Four studies examine the issue of the timing of reported injuries. [Smith \(1990\)](#) argued that WC creates incentives for workers to report hard-to-diagnose off-the-job injuries as having occurred on the job. Since there are more off-the-job hours preceding Mondays and the days after long weekends (referred to collectively as “Mondays”) than before regular Tuesdays through Fridays, more off-the-job injuries occur prior to Mondays. Then, hard-to-diagnose injuries will be disproportionately reported on Mondays compared to other regular workdays. Consistent with this hypothesis, [Smith](#) showed in WC claims data that a greater proportion of sprains and strains relative to fractures and cuts were reported earlier in the work week and work shift than at other work times.

Contrary to [Smith](#), two other studies failed to find a Monday effect. Using Minnesota WC claims data, [Card and McCall \(1996\)](#) showed that workers who were less likely to have health insurance coverage were not more likely to report injuries on Monday compared to other days, as would be expected if workers' use WC to provide health insurance. They also showed that the wage-replacement rate did not exert an independent effect on the probability of Monday injuries. [Campolieti and Hyatt \(2006\)](#) use Canada's universal government-provided medical insurance to identify if the Monday effect was due to health coverage differentials by comparing the Monday effect in Canada with the Monday effect in the United States. They find no differential Monday filing in the US relative to Canada.

[Butler et al. \(2012\)](#) examine over 200,000 employment days for a single, large national employer, operating across the USA, with uniform human resource policies, to control for firm-specific effects and possible intra-program moral hazard in ways not previously possible in earlier research. They find more soft tissue claims filed for younger workers, union members, for workers with higher expected WC benefits, and workers in non-exempt occupations, but they do NOT find that these factors—nor the absence of health insurance—differentially increases soft tissue filings on Monday. This is consistent with the [Card and McCall \(1996\)](#) and the [Campolieti and Hyatt \(2006\)](#) findings.

But [Butler et al. \(2012\)](#) also find no evidence that the differentially higher frequency of soft tissue claims on Monday are due to risk or ergonomic factors either. There is no differential increase on Monday for fractures and lacerations. Workplace fatalities in the USA are actually lower on Monday than they are other days of the workweek.

So what explains the higher rate of Monday soft-tissue WC claims? They find that work absences are higher on Monday than other days of the week (including Friday) and suggest that the Monday effect may be psychological. If a substantial number of workers do not love their jobs and find it harder to return to work on Monday than continue working Tuesday through Friday, then this Monday

work aversion may translate into more perceived soft tissue pain. When people do things they don't like, they are more susceptible to experiencing (or at least, being aware of) pain (Moon and Sauter 1996).

There are no conclusive studies examining the effect of shift work or a change in the working schedule (say from day to night shift) on the incidence or costs of claims, though there is some evidence that long hours of work increases the likelihood of claims (Iwasaki et al. 2006, for Japan).

16.5.3 Other Correlates of Return to Work

Ostbye et al. (2007) find that obese employees had more claims, and among those filing WC indemnity claims, BMI is associated with a significant increase in days on a claim, using retrospective data from Duke University Health Care system, even after controlling for occupation and socio-demographic variables. The effect of obesity on WC claim reporting may partly be the effect of increased willingness to file a claim among those who are overweight: Fan et al. (2006) report that obese (and married) workers are more likely to file a WC claim given that a workplace injury has occurred than other workers.

Return-to-work expectations have a large and statistically significant impact on the length of a WC claim. Early research is reported in Butler and Johnson for a prospective sample of low back claims. Turner et al. (2006) also find that poor job expectations are associated with poor disability outcomes 6 months later, using a prospective sample of low back pain patients from Washington state. Gross and Battié (2005b) come to similar conclusions for their prospective analysis of Alberta, Canada data.

Perceptions of pain at time of injury (Johnson et al. 2011; Butler and Johnson 2008; Baldwin et al. 2007) reduce the likelihood of a speedy return to work given a low back WC claim. Gross and Battié (2005a) also find that increases in the perceived level of pain reduce functionality among low back WC claimants, though the study is retrospective and hence fraught with interpretation difficulties. Greater satisfaction with health care for low back pain increases the likelihood of a quick return to work (Butler and Johnson 2008). Holding pain at time of injury constant and satisfaction with health care treatment constant, greater job satisfaction increases return to work (Butler et al. 2007).

16.6 Some Concluding Observations

Our review of WC has been largely limited to economic/insurance perspective issues. We have not considered the largely macro-economic issues associated with 50 different state systems, and the incentives these differentiated payment structures provide for firm migration across states: the limited evidence we have suggests that such migration is not significant (Edmiston 2006), probably due to the offsetting wage differentials required in states with less coverage. Nor did we examine the large literature on WC injury risk (and loss) by industry and occupation, though that literature's findings are intuitive: riskier work environments generate more WC costs (see, for example, Breslin et al. 2007). Neither did we summarize a large strain of literature that examines the relationship between opioid prescriptions (particularly for low back pain) and long-term WC costs, though the positive correlation has been well documented in the literature (Franklin et al. 2008; Lipton et al. 2009). Modes of treatment of low back pain in WC, whether it was chiropractic care or the care of physicians, did not make much difference in terms of long term recovery (Butler and Johnson 2010; Baldwin et al. 2006), though satisfaction with the care did make a difference (Butler and Johnson 2008).

The findings of this chapter—that changes in WC insurance coverage and those programs with significant overlap: employee health benefits, employer-provided sick pay/disability benefits, and the

unemployment insurance system do affect one another in significant ways—have substantial relevance to the cost of doing business for every organization providing non-wage benefits to their North American workforces. Further, ignoring the economic incentives embedded in benefits design that predictably drive worker behavior does not necessarily lead to the desired improvements in health and safety performance. Part of these interactions may simply reflect the overall workplace environment, as suggested by Lakdawalla et al. 2005 analysis of the interaction of employer-provided health insurance and WC claims. Butler and Park (2005) more directly estimate such an effect: management safety culture and employee participation in the firm's financial outcomes significantly reduced claims filings in their sample of Minnesota firms (similar results were reported in Hunt et al. (1993), for a large sample of Michigan employers).

Future research on cost drivers under WC has several avenues to explore. On the indemnity side of compensation (lost workdays), it is not well understood why surgical outcomes tend to be worse for WC claimants. That is, while it is well known that surgical or clinical interventions, both in the short run and long run are far worse for those receiving WC indemnity benefits than those with no WC benefits (Hou et al. 2008; Atlas et al. 2006, 2010; Landers et al. 2007; Zelle et al. 2005; DeBerard et al. 2009; Carreon et al. 2010; Scuderi et al. 2005; De Beer et al. 2005), the mechanism for this important phenomenon is poorly understood. Without understanding why, it is hard to assess the source of this externality of receipt of WC benefits on injury treatment outcomes, but research to date indicates that the extra health care costs associated with the receipt of WC indemnity pay are substantial.

With respect to medical costs in WC, a relatively unexplored issue is whether cost increases under WC medical costs are different than cost increases under health insurance generally. As medical costs under WC have become at least as large as indemnity costs, and medical cost inflation is a principle driver of WC cost increases, another potentially important research topic is explaining medical cost inflation under WC, to the extent that it differs from medical care cost inflation. It is not clear that medical care under WC is much different from medical care cost inflation in the rest of the economy. Durbin et al. (1996) find some evidence that suggests higher medical costs under WC result from more intensive treatments to promote earlier returns to work (so that medical costs substitute for indemnity costs). Shuford et al. (2009) claim that the cost inflation is the result of increased medical billing (rather than an increase in the itemized costs of specific procedures or the promotion of earlier return-to-work treatment modalities), but do not quantify how increased medical billing differs from health care more generally. Robertson and Corro (2006), in the spirit of the original Johnson et al. (1993) analysis, attribute the cost differences to several factors.

We think, however, that the most cost effective improvements in the productivity of workers injured on-the-job can only be understood and implemented with a fundamental re-conceptualization of employee benefits, one that does not treat one program (like WC) in isolation of other programs, and one that provides insurance that promotes workers' human capital while reducing workplace risk. Successful programs will take into account the need for a *worker-centric* rather than our current *program-centric* risk management system. The impact on every business of current health insurance and health care reforms has fundamentally ignored this information and therefore likely underestimated the cost impact of these forms of (benefits consumption and inter-program) moral hazard.

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Chapter 17

Experience Rating in Nonlife Insurance

Jean Pinquet

Abstract This chapter presents statistical models which lead to experience rating in insurance. Serial correlation for risk variables can receive endogenous or exogenous explanations. The interpretation retained by actuarial models is exogenous and reflects the positive contagion usually observed for the number of claims. This positive contagion can be explained by the revelation throughout time of a hidden features in the risk distributions. These features are represented by fixed effects which are predicted with a random effects model. This chapter discusses identification issues on the nature of the dynamics of nonlife insurance data. Examples of predictions are given for count data models with a constant or time-varying random effects, one or several equations, and for cost-number models on events.

Keywords Observed and real contagion • Overdispersion • Fixed and random effects models • Heterogeneity and state dependence • Poisson models with random effects • Experience rating with an expected value principle or a linear credibility approach

17.1 Introduction

The assessment of individual risks in nonlife insurance raises problems which occur in any statistical analysis of longitudinal data. An insurance rating model computes risk premiums, which are estimations of risk levels, themselves expectations of risk variables. These variables are either numbers of claims or are related to their severity (the cost of the claim or the duration of a compensation). The risk levels assessed in this chapter are the frequency of claims and the pure premium, which refers to the expected loss or to its estimation.

Experience rating in nonlife insurance is almost systematic and can be justified with two arguments:

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- The first argument is actuarial neutrality. For nonlife insurance data, a claimless period usually implies a reduction in frequency premium for the next periods, whereas an accident triggers an increase in the premium. Hence bonus-malus systems (i.e., no-claim discounts and increases in premium after a claim) can be justified with an actuarial neutrality argument.
- The second argument is the incentives to risk prevention created by experience rating. There is a short-term efficiency of effort in reducing nonlife insurance risks,¹ and experience rating may create these incentives under conditions which are recalled later in this chapter. Things are different for health and life risks. These risks are related to a capital, the depletion of which is partly irreversible. Prevention efforts are inefficient in the short run, and there is a reclassification risk which makes experience rating very uncommon.²

The predictive ability on risks of individual histories reflects two possible interpretations. On the one hand, histories reveal an unobserved heterogeneity, which has a residual status with respect to observable information on the risk units. On the other hand, histories modify risk levels, either through incentives or through psychological effects. [Tversky and Kahneman \(1973\)](#) proposed an “availability bias” theory, where the subjective estimation of the frequency of an event is based on how easily a related outcome can be brought to mind. An accident may then increase the perceived risk level and consequently prevention activities. At the opposite, the “gambler’s fallacy” argument ([Tversky and Kahneman 1974](#)) suggests that individuals will feel protected from a risk after the occurrence of a related event. In that case, prevention activities decrease after an accident, which entails an increase in risk as for the revelation effect of unobserved heterogeneity.

Experience rating is performed in the actuarial literature through a revelation principle. Unobserved heterogeneity on risks is taken into account with mixture models, where the mixing distribution reflects the weight of unobserved information. Individual fixed effects reflect the relative risk between an individual and his peers (i.e., with the same regression components). Experience rating is obtained through the prediction of this fixed effect, which is performed from a demixing derivation. Parametric approaches can be used (see [Lemaire 1995](#) for a survey of frequency risk models), but semiparametric derivations pioneered by [Bühlmann \(1967\)](#) in the actuarial literature are also very popular. Nonlife insurance is thus one of the domains that has offered to Karl Pearson a posthumous revenge on Ronald Fisher.

This chapter is organized as follows: Sect. 17.2 describes experience rating schemes in the nonlife insurance business as well as cross subsidies between periods. Section 17.3 recalls the usual representations of unobserved heterogeneity by fixed and random effects models and the experience rating strategies in relation with the type of specification of the mixing distribution (whether parametric, semiparametric, and nonparametric). Section 17.4 presents the “generalized linear models” ([Nelder and Wedderburn 1972](#); [Zeger et al. 1986](#)) of current use in nonlife insurance rating. Section 17.5 discusses the nature of the dynamics in nonlife insurance, a point developed in more detail by [Chiappori and Salanié \(2014\)](#) in connection with economic theory. Lastly, Sect. 17.6 presents examples of frequency and pure premium risk models.

¹Risk reduction applies on frequency rather than severity in most of the economic literature. Hence prevention is of the “self-protection” rather than of the “self-insurance” type, with the Ehrlich–Becker ([1972](#)) terminology.

²[Hendel and Lizzeri \(2003\)](#) mention however term-life insurance contracts in the USA that offer state contingent prices, where low premiums are contingent on the insured showing he is still in good health.

17.2 Experience Rating Schemes and Cross Subsidies in the Nonlife Insurance Industry

There is a trend towards deregulation in the automobile insurance industry, but bonus-malus systems are still in force in the world (either compulsory as in France or not but used by most of the competitors as in Belgium). A bonus-malus system summarizes an event history, where events are most often claims at fault. This coefficient is updated each year, decreases after a claimless year (no-claim discount), and increases if events are reported during the year. The insurance premium is the product of the bonus-malus coefficient and of a basic premium. A bonus-malus system enforces the experience rating policy if the basic premium does not depend on the individual history. This is not the case any more in France, but the bonus-malus system provides an information available to all the competitors in the market. Reducing information rents is now the role of bonus-malus systems, more than enforcing experience rating rules.³

Let us consider for instance the updating rules for bonus-malus coefficients in France. A new driver begins with a bonus-malus coefficient equal to one, and this coefficient is equal to 0.95 after 1 year if no claim at fault is reported. The coefficient is equal to $(1.25)^n$ if n claims at fault are reported during the first year and is bounded by 3.5. The same rules are applied later to the new coefficient. Besides, there is a lower bound of 0.5 for the coefficient. If the bonus-malus coefficient is equal to 0.95, you have a 5% bonus, whereas a claim at fault entails a 25% malus. In this example, the bonus-malus coefficient is roughly an exponential function of the number of claims at fault. In other countries, the average coefficient after a given number of years is usually a convex function of the number of claims. As the bonus-malus coefficient is updated from the preceding value and from the claim history in the last year, bonus-malus systems can be expressed as Markov chains (see [Lemaire 1995](#)).

Actual bonus-malus systems always have a “crime and punishment” flavor. The events which trigger a malus are usually claims at fault. If a no-fault system is in force as in several states of the United States and in Quebec, claims at fault are often replaced in the experience rating scheme by offenses against the highway safety code. You can also think of mixing the history of claims and offenses in the rating structure. In the USA, insurers have direct access to records of the Motor Vehicles Division. In states with a tort compensation system (i.e., fault is determined if the accident involves a third party), insurance companies use both types of events in their experience rating schemes. A speeding ticket related to more than 15 m.p.h. above the speed limit entails the same penalty as an accident at fault and so does failure to stop at a traffic light or failure to respect a stop sign. The worst offense consists in overtaking a school bus while its red lights are blinking. It is worth nine points, instead of five for the aforementioned events.

Fairness in the rating structure is made necessary because of the difficulty to maintain cross subsidies between different risk levels in a competitive setting. Hence, risk premiums are usually seen as estimations of expectations of risk variables conditional on an information available to the insurance company. A question is raised about the private or public nature of this information. Insurance companies are not forced by competition to use private information on their policyholders in their rating structure. A compulsory bonus-malus system makes this information partly public, since it provides a summary of the policyholder’s behavior which can be shown to every competitor of the insurance company.

Cross subsidies between the periods of a contract are termed as either “back-loading” or “front-loading,” depending on whether the first periods are subsidized by the following ones or the contrary. “Back-loading” in insurance contracts may occur when the insurer extracts a rent from

³Ten years ago, the European Commission sued France, arguing that the bonus-malus system distorted competition. As an answer, French authorities argued that the bonus-malus system did not enforce experience rating. They finally won the case.

the policyholder based on its use of private information (Kunreuther and Pauly 1985) or from the maximization of a customer's value derived from an estimated lapse behavior (Taylor 1986).⁴ In a recent study of an Australian automobile insurance portfolio, Nini and Kofman (2011) find that average risk decreases with policyholder tenure but that the effect is entirely due to the impact of observable information. This result contradicts the theory of informational monopoly power.⁵

17.3 Allowance for Unobserved Heterogeneity by Random Effects Models

This section does not provide a self-content presentation of such models and of their applications to experience rating. A more detailed exposition is given in Pinquet (2000). Classic references are Lemaire (1995) for parametric models and Bühlmann and Gisler (2005) for semiparametric approaches.⁶ Denuit et al. (2007) provide a comprehensive presentation on count data models applied to nonlife insurance. We recall later the main features of fixed and random effects models applied to experience rating, and we illustrate with a basic example in nonlife insurance (i.e., a frequency risk model on a single type of event). We consider a sample of risk units, and we interpret data dynamics within these units (e.g., between different periods of time series) with a revelation principle. Three levels are used in the rating model:

- The first level is an a priori rating model which does not allow for unobserved heterogeneity. An important assumption is that the risk variables defined within a statistical unit are independent. Hence data dynamics are only explained by the revelation of unobserved heterogeneity.
- A second level includes individual fixed effects in the a priori rating model. These fixed effects reflect idiosyncratic features of risk distributions that are not represented by the regression components. The independence assumption is not challenged at this level.
- The third level is the random effects model. The fixed effects are assumed to be outcomes of random effects. The distributions of the random effects model are mixtures of those of the a priori rating model. These distributions are those of a class of real individuals with the same observable information, represented by the regression components.

Experience rating is obtained from a prediction of the fixed effect (plugged multiplicatively into the expectation of the risk variable) for the next period. This prediction can either be obtained from a posterior likelihood in a parametric setting or from constraining the shape of the predictor in a semiparametric setting. In the latter case, this shape must be affine in order to make derivations tractable, and this type of risk prediction is usually termed as the linear credibility approach. Risk prediction with the random effects model implicitly supposes that the dynamics observed on the data are only due to a revelation mechanism. To what extent this approach limits risk description is discussed later.

⁴Kunreuther and Pauly's model is derived in a no-commitment setting, with myopic consumers (i.e., those who take decisions based on the current contract). Taylor uses a multiperiod approach where the premium is the control variable in the maximization of the customer value. The model also includes an elasticity between the lapse rate and relative prices between the incumbent insurer and its competitors.

⁵At the opposite, life and health insurance products are often front-loaded and sometimes heavily without any surrender value as is the case for long-term care insurance. Hendel and Lizzeri (2003) provide an economic analysis of front-loading in term-life insurance in the USA.

⁶In most statistical problems, a parameter set has a much smaller dimension than that of the probability set it aims at describing. A parametric approach is a one-to-one map from the parameter set to the probability set. In a semiparametric setting, the parameters are related to constraints on the probabilities.

Let us describe a basic example of frequency risk model. The statistical units are indexed by $i = 1, \dots, n$, and the dependent variable is a sequence of claims numbers. We denote it as

$$Y_i = (Y_{i,t})_{t=1,\dots,T_i}; Y_{i,t} \sim P(\lambda_{i,t}), \lambda_{i,t} = \exp(x_{i,t}\beta).$$

A duration $d_{i,t}$ of risk exposure must be included in the parameter of the Poisson distribution if these durations are not constant on the sample. In the a priori rating model, the variables $Y_{i,t}$ are independent and this property also holds in the fixed effects model

$$Y_{i,t} \sim P(\lambda_{i,t} u_i).$$

The reference value of the time-independent fixed effect u_i is one. If $u_i > 1$, the individual i is riskier than the average of its peers with respect to the regression components.

The random effects model (where the fixed effect u_i is the outcome of U_i) can be defined parametrically, with an explicit distribution for U_i . The distribution of $Y_{i,t}$ is defined by an expectation with respect to U_i , i.e.,

$$P[Y_{i,t} = n] = E [P_{\lambda_{i,t} U_i}(n)] = E \left[\exp(-\lambda_{i,t} U_i) \times \frac{\lambda_{i,t}^n U_i^n}{n!} \right].$$

With Gamma distributions, ($U_i \sim \gamma(a, a) : E(U_i) = 1, V(U_i) = 1/a$), the distributions of the risk variables are negative binomial. Extensions of the negative binomial model to panel data are given in [Hausman et al. \(1984\)](#).

A semiparametric specification stems from the equation

$$E(U_i) = 1 \Rightarrow E(Y_{i,t}) = \lambda_{i,t}; V(Y_{i,t}) = \lambda_{i,t} + (\lambda_{i,t}^2 \times V(U_i)) \tag{17.1}$$

in the random effects model. It appears that the variance σ^2 of the random effect is the natural parameter of the mixing distribution in a semiparametric approach.

The prediction $\widehat{u}_i^{T_i+1}$ of the fixed effect u_i with a linear credibility approach stems from a linear probabilistic regression of U_i with respect to the $Y_{i,t}$ ($t = 1, \dots, T_i$) in the random effects model. The solution is

$$\widehat{u}_i^{T_i+1} = \frac{1 + \left(\widehat{\sigma}^2 \times \sum_{t=1}^{T_i} y_{i,t} \right)}{1 + \left(\widehat{\sigma}^2 \times \sum_{t=1}^{T_i} \widehat{\lambda}_{i,t} \right)}, \tag{17.2}$$

where a consistent estimation of the variance of the random effect is obtained from (17.1) as

$$\widehat{\sigma}^2 = \frac{\sum_{i,t} \left[(y_{i,t} - \widehat{\lambda}_{i,t})^2 - \widehat{\lambda}_{i,t} \right]}{\sum_{i,t} \widehat{\lambda}_{i,t}^2}. \tag{17.3}$$

The predictor of Eq. (17.2) is also obtained with an expected value principle in a Poisson model with Gamma random effects ([Dionne and Vanasse 1989](#)). The semiparametric estimator of the variance is unconstrained and is positive only if there is overdispersion on the data (i.e., if the residual variance is greater than the empirical mean).⁷ A consistent estimation strategy of the parameters of a random effects models is detailed in the next section in a semiparametric framework. This strategy exploits two results that are obtained in this example:

⁷We have $\sum_{i,t} \widehat{\lambda}_{i,t} = \sum_{i,t} y_{i,t}$ from the orthogonality between the residuals and the intercept.

- First, the expectation of the risk variable in the random effects model does not depend on σ^2 . As a consequence, the estimation of β in the Poisson model is consistent in the model with random effects.
- Second, Eq. (17.3) provides an estimator of σ^2 that depends on $\hat{\beta}$. This is due to a separability property in the specification of the variance of the risk variable in the random effects model.

The prediction of the fixed effect u_i obtained from a posterior expectation in the negative binomial model is the same as that obtained with the linear credibility approach. This predictor can be written as a weighted average of $1 = E(U_i)$ and of the ratio $\sum_t y_{i,t} / \sum_t \hat{\lambda}_{i,t}$, which summarizes the individual history and which can be seen as an estimator of the fixed effect u_i . The weight given to this ratio is the credibility

$$cred_i = \frac{\hat{\sigma}^2 \times \sum_t \hat{\lambda}_{i,t}}{1 + (\hat{\sigma}^2 \times \sum_t \hat{\lambda}_{i,t})}, \tag{17.4}$$

which ranges in $[0, 1]$ and increases with risk exposure (represented by the cumulated frequency premium) and the estimated variance $\hat{\sigma}^2$, which represents the weight of unobserved heterogeneity. From the weighted average definition of the predictor, the credibility is the discount on the frequency premium (the “bonus”) if no claims are reported.

The experience-rated premium for the next period is $\hat{\lambda}_{i,T_i+1} \times \hat{u}_i^{T_i+1}$. The predictor $\hat{u}_i^{T_i+1}$ summarizes the individual history and can be interpreted as a “bonus-malus” coefficient. From Eq. (17.2), the estimated variance of the random effect is close to the relative increase in premium after a claim (the “malus”) if risk exposure is close to 0.

The linear shape of the predictor in this example can be challenged. Prediction with a posterior expectation would not be linear in the number of past claims if the mixing distribution was not of the Gamma type. We might want to obtain other shapes as the exponential one in the French bonus-malus system.

The parametric and semiparametric approaches of risk prediction both rely on restrictions. The mixing distribution family is constrained in the parametric approach, whereas the shape of the predictor is constrained in the semiparametric setting. Discarding these restrictions is possible with a nonparametric analysis of the mixing distribution. Such approaches are feasible, but they can be applied only with high-frequency data, which is not the case in nonlife insurance. To see this, consider the moment result on Poisson distributions

$$Y \sim P(\lambda) \Rightarrow E [Y \times (Y - 1) \dots \times (Y - k + 1)] = \lambda^k \quad \forall k \in \mathbb{N}^*. \tag{17.5}$$

If Y follows a mixture of a $P(\lambda u)$ distributions, where u is the outcome of a random effect U , we have that

$$E(U) = 1 \Rightarrow E(U^k) = \frac{E [Y \times (Y - 1) \dots \times (Y - k + 1)]}{\lambda^k = [E(Y)]^k}. \tag{17.6}$$

Then the mixing distribution can be identified from a sequence of moments of increasing order (i.e., going from a semiparametric to a nonparametric approach through a representation of the mixing distribution by moments of increasing order).⁸ However, Eq. (17.6) suggests that the accuracy of the estimation of a high-order moment of the random effect is weak if the frequency risk $E(Y)$ is low. This is the case in nonlife insurance and explains why experience rating models restrict to parametric and semiparametric approaches.

⁸See Zhang (1990) for an approximation of the Fourier transform of the mixing distribution.

17.3.1 Statistical Models on Count Data of the (a, b, k) Type

This chapter deals mostly with frequency risk models, and we present a distribution family on count data that encompasses the usual ones. This distribution family on \mathbb{N} is defined from (a, b, k) , (with $0 < a < 1$, $b > 0$, and $k \in \mathbb{N}$) in the following way (Klugman et al. 2008):

- If p_n is the probability related to $n \in \mathbb{N}$, the $(p_n)_{n < k}$ are defined without any constraints other than their belonging to the simplex of probabilities.
- The tail distribution is defined from the recurrence relation

$$p_n = p_{n-1} \times \left(a + \frac{b}{n} \right), \quad n > k. \quad (17.7)$$

This equation allows to denote the ratio $(\sum_{n > k} p_n) / p_k$ as $M(a, b, k)$. Then the tail distribution is defined from

$$p_k = \frac{1 - \sum_{n < k} p_n}{1 + M(a, b, k)}$$

and from Eq. (17.7).

Let us recover usual distribution families on count data as distributions of the (a, b, k) type:

- A Poisson distribution $P(\lambda)$ is obviously of the $(0, \lambda, 0)$ type.
- A “zero-inflated” distribution linked with a variable $B \times N$, where $B \sim B(1, p)$ and $N \sim P(\lambda)$ are independent variables (see Boucher et al. 2009 for applications to insurance rating), is of the type $(0, \lambda, 1)$, with $p_0 = \exp(-\lambda) + [(1 - p) \times (1 - \exp(-\lambda))] \geq \exp(-\lambda)$.
- Let us consider a negative binomial distribution, obtained as a mixture of $P(\lambda u)$ distributions, where u is the outcome of U , $U \sim \gamma(a, a)$. It is easily seen that this distribution is of the type $\left(\frac{\lambda}{\lambda+a}, \frac{\lambda \times (a-1)}{\lambda+a}, 0 \right)$. Hence, all the distributions of the $(a, b, 0)$ type are either of the Poisson or of the negative binomial type.

Distributions of the (a, b, k) type, with $k > 1$, can be considered if the frequency is not too low.

17.4 Estimation Approaches for Random Effects Models

17.4.1 The Generalized Estimating Equations

Statistical models are designed depending on the nature of the dependent variable. For instance, a binary distribution is defined by its expectation, and the model deals with the link between this expectation (and the related probability) and regression components. Going from the most constrained distribution in terms of support (the binary distributions) to the less constrained (variables that range on the whole real line) allows to disconnect completely the expectation and moments of higher order, including the variance. Between these two polar cases, nonlife insurance models first deal with count variables, where events are insurance claims. The claim frequency per year is usually far less than one, which constrains the design of statistical models as mentioned in the preceding section.

The generalized estimating equations approach (Zeger et al. 1986) proposes an estimation strategy from the a second-order specification of the moments of a dependent risk variable that can be applied for frequency risk and linear models. Let i be a statistical unit in a sample of size n , and let Y_i be a

risk variable ranging in \mathbb{R}^{d_i} . The statistical unit may include time series, strata, and multiple equations related to different guarantees or to a frequency-cost specification. The expectation and the variance of Y_i are denoted as

$$E(Y_i | x_i, \beta), V(Y_i | x_i, \beta, \alpha).$$

The parameters β, α ($\beta \in \mathbb{R}^{k_1}, \alpha \in \mathbb{R}^{k_2}$) of the model are included hierarchically, and the specific parameters of the mixing distribution represented by α do not influence the expectation of the risk variable.⁹ These specific parameters are usually second-order moments of random effects. These random effects are plugged additively in the expectation of Y_i for linear models and multiplicatively for frequency risk models. The independence of $E(Y_i)$ with respect to α is obtained from obvious constraints on the expectation of the random effects in the additive and multiplicative setting. These specifications also yield separability properties which allow to estimate α from β and the observations, using cross-section moment equations. Let us consider a statistic $M(y_i, x_i, \alpha, \beta)$ such as

$$\alpha, M(y_i, x_i, \alpha, \beta) \in \mathbb{R}^{k_2}; E [M(Y_i, x_i, \alpha, \beta) | x_i, \beta, \alpha] \equiv 0; \frac{\partial}{\partial \alpha} M(Y_i, x_i, \alpha, \beta) \text{ is invertible.} \tag{17.8}$$

We have, for instance, $M(y_i, x_i, \alpha, \beta) = \sum_t [(y_{i,t} - \lambda_{i,t})^2 - \lambda_{i,t}] - \sigma^2 \sum_t \lambda_{i,t}^2$ for the basic example developed in the preceding section, where $\alpha = \sigma^2$ is the variance of a scalar random effect. We suppose that

$$\sum_{i=1}^n M(y_i, x_i, \alpha, \beta) = 0 \Leftrightarrow \exists! \alpha, \alpha = \hat{\alpha}(\beta; y_1, \dots, y_n; x_1, \dots, x_n).$$

This condition is linked to the invertibility condition given in (17.8), and the solution α does not necessarily belong to the parameter set, as is the case for the example if there is underdispersion.

The algorithm $\hat{\beta}^m, \hat{\alpha}^m \rightarrow \hat{\beta}^{m+1}, \hat{\alpha}^{m+1}$ is then the following: first, the variances-covariances matrices of risk units

$$\hat{V}_i^m = V(Y_i | x_i, \hat{\beta}^m, \hat{\alpha}^m)$$

are derived from the current estimations of the parameters. Then the estimations at the next step are obtained as follows:

$$\hat{\beta}^{m+1} = \arg \min_{\beta} \sum_i ||y_i - E(Y_i | x_i, \beta)||_{[\hat{V}_i^m]^{-1}}^2 = \arg \min_{\beta} f(\beta, \hat{\beta}^m, \hat{\alpha}^m); \tag{17.9}$$

$$\hat{\alpha}^{m+1} = \hat{\alpha}(\hat{\beta}^{m+1}; y_1, \dots, y_n; x_1, \dots, x_n). \tag{17.10}$$

The algorithm can be initialized at step $m = 0$ with $\hat{\alpha}^0 = 0$, which corresponds to no unobserved heterogeneity, and with $\hat{\beta}^0 = \arg \min_{\beta} f(\beta, \beta, 0)$, with the notations of Eq. (17.9).

⁹The independence of the random effects distribution with respect to the regression components can be challenged. This issue is discussed by Boucher and Denuit (2006) and by Bolancé et al. (2008).

This estimated approach is semiparametric and unconstrained with respect to the parameters of the mixing distribution.¹⁰ An estimation obtained outside the parameter domain is a failure of the model which corresponds to an estimation obtained at the boundary of the parameter set with a constrained estimation approach. In the example studied in this chapter, a negative estimation for the variance σ^2 of the random effect corresponds to a residual underdispersion on the data. A maximum likelihood estimation of a parametric mixture of Poisson distributions would lead to a null-estimated variance. Indeed, the numerator of the ratio which defines the unconstrained estimator of the variance given in (17.3) is equal to twice the Lagrangian of the log-likelihood with respect to σ^2 at the frontier of the parameter set. Then underdispersion leads to a local maximum of the likelihood, which actually is global. When the mixing distribution family is more intricate, a constrained estimation obtained at the boundary of the parameter set may indicate feasible submodels more clearly than an unconstrained approach.

17.4.2 Other Estimating Approaches

Let us consider first a parametric setting. The likelihood of a random effects model is an expectation, which does not have a closed form in most cases. The likelihood can be then approximated, and two types of computation can be investigated:

- Numerical integration of the likelihood. If the likelihood is viewed as a parameter, the approximation is a biased and deterministic estimator. See [Davis and Rabinowitz \(1984\)](#) for methods of numerical integration using Gaussian quadrature rules and [Lillard \(1993\)](#) for empirical results.
- Monte-Carlo methods interpret the likelihood as the expectation of a function of a distribution-free variable. An average derived from independent draws of this variable for each individual leads to a simulation-based estimator. The likelihood is then approximated by a random and unbiased variable. Owing to the concavity of the logarithm, the estimator of the log-likelihood has a negative bias. The asymptotic properties of these estimators are given by [Gouriéroux and Monfort \(1991\)](#). Consistency is obtained if the number of simulations converges towards infinity with the size of the sample.

We come back to a semiparametric setting. In the generalized estimating equations approach presented in Sect. 17.4.1, the first- and second-order moments of the dependent variable have implicitly a closed form in the random effects model. However, this assumption does not hold in most cases for binary variables. Suppose that these moments are approximated by simulations. If the simulation errors are independent across observations and sufficiently regular with respect to the parameters, the simulation-based estimators can be consistent even if the number of draws is fixed for each individual. Consistency is obtained if a linearity property allows the simulation errors to be averaged out over the sample. A proof of these properties and applications to discrete response models are found in [Mac Fadden \(1989\)](#).

17.5 The Nature of the Dynamics on Nonlife Insurance Data

Random effects models reflect the observed dynamics on nonlife insurance data, as estimated risks usually decrease with time and increase with claims. This time-event property fits the “bonus-malus” logic of risk prediction based on random effects models. Two points will be developed further:

¹⁰The parameter set for α is usually a convex cone in \mathbb{R}^{k^2} .

- The first point is the analysis of the data dynamics. The observed dynamics on risks reflect both revelation and modification effects of the individual histories. The revelation effect of unobserved heterogeneity is not intrinsic, as it is defined with respect to the observable information. The individual histories modify the risks levels due to incentive effects (the *homo æconomicus* reacts to the financial implications of his behavior), but also to psychological effects that influence risk perception and tastes. These effects usually counteract the revelation effects, but this is not always true and will be discussed in the next section.
- The second point is the identifiability issue of the two components of the dynamics. The main motivation is to analyze the incentive effects of insurance rating. This point is also analyzed by [Chiappori and Salanié \(2014\)](#).

17.5.1 Incentives Effects of Nonlife Insurance Rating Schemes

The incentive properties of an insurance rating scheme are obtained from the minimization of the lifetime disutility of future premiums. The incentive level is related to the increase in the future premiums after a claim. From the exponential structure of the French bonus-malus system, a claim at fault (which triggers the “malus”) increases the incentives to safe driving (see [Abbring et al. 2003](#)). The risk level decreases after a claim, which counteracts the revelation effect of unobserved heterogeneity. However, an opposite effect could be obtained if the potential penalties did not increase after a claim (i.e., if the premium was not a convex function of the number of past claims, for a given risk exposure).

The time effects of incentives are at the opposite of the event effect, and the relative weights depend on the equilibrium of the rating scheme. Let us consider the French bonus-malus system. A 25% malus balances a 5% bonus if the annual frequency of claims is close to 1/6. The frequency of claims at fault is actually equal to 6%, and the French bonus-malus system is downwards biased, as is the case for most of the experience rating schemes (see [Lemaire 1995](#)). Drivers cluster at the lowest levels of the bonus-malus scale when their seniority increases and are subject on average to decreasing incentives. This means that the time effect of incentives outweighs the event effect in this context. It is worth mentioning that the result also depends on the frequency risk of the driver.

The time effect of incentives can reinforce the revelation effect if the reward for a claimless history consists in canceling the claim record after a given duration. This feature exists in the French bonus-malus system for drivers with a bad claim history. If their bonus-malus coefficient is greater than one (that of a beginner), they are considered as beginners after a 2-year claimless history.¹¹ An informal argument to explain this result is that the date of claim removal does not vary with time and that safe-driving effort increases as this date comes nearer. A more formal argument is that the incentive level increases with the difference between the lifetime disutility of premiums in the state reached after a claim and the disutility in the current state. The time counter is reset to zero after a claim, and the disutility after a claim is constant. As the current disutility decreases with time, the difference increases with time and so does the incentive level. Then risk decreases with time as for the revelation effect of unobserved heterogeneity. Hence incentive effects do not always counteract revelation effects in nonlife insurance.

¹¹The same logic is applied in many point-record driving licenses (where events are traffic violations which are associated to demerit points and where the driving license is suspended once the cumulated demerit points reach a given threshold). In France and in many European countries, all the demerit point is removed after a given period of violation-free driving. In the USA and in Canada, point removal is performed on each traffic offense once a given seniority is reached. The incentive properties of point-record mechanisms are studied by [Bourgeon and Picard \(2007\)](#) and by [Dionne et al. \(2011\)](#).

17.5.2 Identifiability Issues in the Analysis of Nonlife Insurance Data Dynamics

Early statistical literature did not grasp the identification issue raised by the interpretation of individual histories. Discussing a paper written by Neyman (1939), Feller (1943) mentions the two interpretations of the negative binomial model with revelation and modification stories. These two interpretations of data dynamics are also termed as heterogeneity and state dependence. Feller remarks that this twofold interpretation is not understood by most of statisticians, including Neyman.¹² Feller concludes to the impossibility of identifying the nature of the dynamics of longitudinal data. At the end of his article, he suggests that a duration-event analysis could help improve identification.

This article was taken seriously by Neyman, who wrote an article with Bates a decade later (Bates and Neyman 1952) proposing an elimination strategy of unobserved heterogeneity for a point process of the Poisson type. They restrict their analysis to individuals with a single event observed on a given interval. The date distribution of this event is uniform, and a Kolmogorov–Smirnov test of fit to a uniform distribution allows to integrate out unobserved heterogeneity in the test for the absence of state dependence, according to Neyman. Many articles in econometric literature (see Chiappori and Salanié 2014 for a survey) stem from this contribution.

Bates and Neyman’s conclusion is, however, overoptimistic. Indeed, a mixture of Poisson processes can be applied to real individuals and not to a class of individuals sharing the same available information. In that case, the history modifies the individual distributions instead of revealing them, although the null assumption tested for by Bates and Neyman is fulfilled. For instance, a mixture of a Poisson process with a parameter λ and a $\gamma(a, a)$ mixing distribution is associated to a Markov process with integer values, where the only positive transition intensities are those from n to $n + 1$ ($n \in \mathbb{N}$) and equal to

$$\lambda_n(t) = \lambda \frac{a + n}{a + \lambda t}$$

at date t . We obtain a Pólya process, with negative binomial marginal distributions. The date distribution of a unique event in a given interval is also uniform, as we show now. Let us consider an interval $[0, T]$ and N_t the number of events between 0 et t . We denote $\Lambda_n(t) = \int_0^t \lambda_n(u) du$. We have that

$$P [N_T = 1] = \int_0^T \exp(-\Lambda_0(t)) \lambda_0(t) \exp(\Lambda_1(t) - \Lambda_1(T)) dt,$$

where t is the date of the unique event. The density of this date is equal to $\lambda_0(t) \times \exp(\Lambda_1(t) - \Lambda_0(t))$, up to a multiplicative constant. The log-derivative of the density is equal to $(\lambda'_0/\lambda_0) + \lambda_1 - \lambda_0$. The null assumption tested by Bates and Neyman reflects an equilibrium between the time and event components of the data dynamics, i.e.,

$$\frac{\lambda'_0}{\lambda_0} \text{ (time); } \lambda_1 - \lambda_0 \text{ (event).} \tag{17.11}$$

In the Pólya process, we have $\lambda'_0/\lambda_0 < 0$ and $\lambda_1 - \lambda_0 > 0$. But opposite signs can be observed for these components if they are related to incentives derived from a convex rating structure, as discussed

¹²Neyman was far from being a beginner when he wrote this article. He already had published his results on optimal tests with Egon Pearson.

in the preceding section. The time-event psychological effects can also be represented by Eq. (17.11). The “availability effect” is associated to an increasing link between time and risk and to a decreasing event-risk link. Results are at the opposite for the “gambler’s fallacy” effect. As a conclusion, what is eliminated by the Bates–Neyman test is unobserved heterogeneity applied to balanced time-event effects on real individuals.¹³

17.6 Examples of Frequency and Pure Premium Risk Models

17.6.1 Multiple Equations and Stratified Samples

Different types of claims can be used in the prediction of nonlife insurance risks, as for instance claims at fault and not at fault, accidents, and traffic violations (in a framework where traffic violations are used for experience rating and not accidents in a no-fault environment). These different types of claims can be nested (e.g., accidents with bodily injury among accidents of all type in automobile insurance; see Sect. 17.6.3) or overlap partially or not. In a situation where event types (e.g., type A and type B) overlap partially, a random effects model should be applied to nonoverlapping events (e.g., $A - B$, $B - A$, and $A \cap B$). Mixing distributions can be estimated in a semiparametric framework (Pinquet 1998) or with parametric specifications (Frees and Valdez 2008). For small risk exposures, it can be shown that the predictive ability of a given type of event on another type in a frequency risk model is proportional to the product of the frequency risk and of the squared covariance of the random effects related to each type and applied multiplicatively to the frequency.

Stratified samples are, for example, fleets of vehicles (Angers et al. 2006; Desjardins et al. 2001), whether owned by companies or households. The history of a contract should have a greater ability to predict the risk level of this contract than that of the other contracts in the same stratum. The relative efficiencies are obtained from the comparison between the variance of a random effect at the stratum level and the residual variance at the individual level.

17.6.2 Allowance for the Age of Claims in Experience Rating

Real-world experience rating schemes in property-liability insurance mostly depend on numbers of events, which are usually claims at fault. Only in a few publications (Bolancé et al. 2003; Gerber and Jones 1975; Sundt 1981) do frequency risk models take into account the age of events. These contributions use the intuition that the predictive ability for a period of the policyholder’s history should decrease with age. If a stationary specification is retained for time-varying random effects in a Poisson model, the estimated autocorrelation coefficients should be decreasing. This shape is indeed usually obtained from nonlife insurance data.

With time-independent random effects, total credibility converges to one as frequency risk exposure increases (see Eq. (17.4), and remember that credibility is the no-claim discount related to a claimless history). This result does not hold anymore with dynamic random effects. Limit credibility can be much less than one, a result in accordance with real-world rating structures.

A bonus-malus system designed from a model with dynamic random effects and a decreasing autocorrelation function will behave in the following way. For a policyholder with a faultless history,

¹³The test proposed by Abbring et al. (2003) eliminates unobserved heterogeneity in some unbalanced time-event frameworks.

the no-claim discounts induced by a claimless year are smaller after a few years than those obtained from the usual credibility model, but they are more important if claims were reported recently. The explanation is the same in both cases. The credibility granted to a given period of the past decreases rapidly as time goes by, due to the increase of risk exposure but mostly to the diminution of the autocorrelation coefficients. Notice that economic analysis also suggests that optimal insurance contracts with moral hazard should penalize recent claims more than older ones ([Henriet and Rochet 1986](#)).

Dynamics on longitudinal count data can also be obtained from endogenous approaches. The integer autoregressive model of order one (or INAR(1) model) writes as follows for a single time series:

$$N_t = I_t + \sum_{j=1}^{N_{t-1}} B_{j,t}.$$

The number of events at the current period is the sum of two independent variables. The first variable is a number of events without link to those occurred in the past and represents an innovation. The second variable is a sum of Bernoulli variables indexed by the events occurred at the preceding period and provides a causality relationship between events. If I_t and N_{t-1} are Poisson variables and if the Bernoulli variables are i.i.d., N_t is also a Poisson variable. Parameters are retained in order to ensure the stationarity of N_t .

With the INAR model, the predictive ability of past events decreases with seniority, which is in accordance with real-life data. However the autocorrelation structure is similar to that of a linear process, and this feature does not fit the data in nonlife insurance. Let us consider the covariances between a time series of count variables. In a Poisson model with dynamic random effects, these covariances are obtained from the autocorrelation coefficient applied to the overdispersion of the count variable. With the INAR specification, the autocorrelation coefficient is applied to the total variance of the count variable, and data speak in favor of the preceding formulation in nonlife insurance.¹⁴ Considering mixtures of INAR processes can alleviate this shortcoming (see [Gouriéroux and Jasiak 2004](#)).

17.6.3 Allowance for the Severity of Claims in Experience Rating

Multiequation models can be used to allow for the severity of claims involving third-party liability, from the dichotomy between claims with or without bodily injury (see [Lemaire 1995](#); [Picard 1976](#)). The number of claims with bodily injury follows a binomial distribution, indexed by the number of claims and by a probability which follows a beta distribution in the random effects model. Nesting this random effect in a negative binomial model yields a linear predictor based on the number of claims of both types.

For guarantees related to property damage or theft, a cost equation on claims can be considered. Gamma or log-normal distributions provide a good fit to cost data without thick tails.¹⁵ A two-equation model with Poisson distributions for the number of claims and log-normal distributions for their cost admits closed-form estimators for the second-order moments of bivariate random effects ([Pinquet 1997](#)). The correlation between the random effects related to the number and cost equations appears to

¹⁴Also, the prediction derived from the INAR(1) model is derived from the number of events restricted to the last period. This is an unpleasant property if events are claims, as all the claims in the past have some predictive ability.

¹⁵Log-normal distributions have, however, thicker tails than the Gamma, as they are of the subexponential type.

be very low for the sample investigated in the aforementioned article. Because of this low correlation, the bonus-malus coefficients related to pure premium are close to the product of the coefficients for frequency and expected cost per claim.

In a recent publication, [Frees and Valdez \(2008\)](#) propose a three-equation model corresponding to the frequency, type, and cost of claims. The first equation is a random effects Poisson regression model, the second is a multinomial logit model, and the cost component is a Burr XII long-tailed distribution. A t-copula function is used to specify the joint multivariate distribution of the cost of claims arising from these various claims types.

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Chapter 18

On the Demand for Corporate Insurance: Creating Value

Richard MacMinn and James Garven

Abstract Ever since Mayers and Smith first claimed, 30 years ago, that the corporate form provides an effective hedge that allows stockholders to eliminate insurable risk through diversification, the quest to explain the corporate demand for insurance has continued. Their claim is demonstrated here so that the corporate demand for insurance may be distinguished from the individual's demand for insurance. Then some of the determinants of the demand for corporate insurance that exist in the literature are reviewed and generalized. The generalizations show how the corporation may use insurance to solve underinvestment and risk-shifting problems; the analysis includes a new simpler proof of how the risk-shifting problem may be solved with corporate insurance. Management compensation is also introduced here and the analysis shows the conditions which motivate the corporate insurance decision. Finally, some discussion is provided concerning the empirical implications of the extant theory, the tests that have been made, and the tests that should be made going forward.

18.1 Introduction

Insurance contracts are regularly purchased by corporations and play an important role in the management of corporate risk. This role has not been adequately analyzed in finance even though insurance contracts are simply another type of financial contract in the nexus of contracts which is the corporation. The purpose of this chapter is to provide a model which is robust enough to allow for an investigation of the scope of insurance contracts in the management of corporate risk.

In the insurance literature, the incentive to buy insurance is often assumed to be risk aversion. Risk aversion may be a sufficient motivation for the closely held corporation but, as Mayers and Smith observe, not for the publicly held corporation. Mayers and Smith claim that "The corporate form provides an effective hedge since stockholders can eliminate insurable risk through diversification," i.e., see [Mayers and Smith \(1982\)](#). An equivalent claim is that the value of the insured corporation is the same as the value of the uninsured corporation. If this claim holds, then insurance is not a necessary tool in managing corporate risk. A characterization of the market economies in which the claim does and does not hold should be important to corporate managers as well as insurance

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companies. The purpose of this chapter is, first, to characterize the corporate and market environment in which insurance is irrelevant (i.e., establish the claim) and, second, to modify the model in order to characterize the corporate and market environments in which insurance is an important tool in managing corporate risk.

The first step is to establish the claim that corporations need not buy insurance since competitive risk markets already provide sufficient opportunity to diversify corporate risk. To establish or refute this claim requires a model of the economy which includes a stock market as well as an insurance market. Such a market model is provided in the model section of this chapter and does appear in the literature, e.g., see [Mayers and Smith \(1982\)](#) and [MacMinn \(1987\)](#). The model here includes two types of financial contracts and two sources of uncertainty. The analysis demonstrates that any insurance decision made by the corporation may be reversed by any individual on personal account. Equivalently, a no-arbitrage condition guarantees that stock and insurance contracts must be priced the same; then it is a simple matter to show that the net present value of the insurance decision is zero. The basic model incorporates risky debt as well as stock and insurance. The analysis shows that as long as bankruptcy is costless the same reasoning applies. Since the value of the corporation is the sum of the values of its financial contracts and the net present value of the insurance is zero, the claim is established.

In the agency cost section, the model is generalized so that it incorporates the conflicts of interests between corporate management and bondholders. Conflict of interest problems arise when the corporate manager, acting in the interests of stockholders, has the incentive to select actions which are not fully consistent with the interests of bondholders. Two classic examples of the conflict of interest problem are developed. Then the analysis necessary to show how the insurance contract may be used to limit the divergence between the interests of bondholders and management is developed. The first agency conflict considered is usually referred to as the underinvestment problem. In this example, the manager of a levered firm has an incentive to limit the scale of investment because the additional returns from further investment accrue primarily to bondholders. [Mayers and Smith \(1987\)](#) and [Garven and MacMinn \(1993\)](#) discuss this conflict of interest and demonstrate how insurance may be used to solve the underinvestment problem; this initial solution to the underinvestment problem is reviewed here. The analysis is then extended to a more general setting and shows that insurance can be used to protect bondholder and creditor the movement of additional value due to investment to shareholders.

The second agency problem considered is usually referred to as the asset substitution problem, or equivalently, as the risk-shifting problem. Once a corporation has obtained debt financing, it is well known that by switching from a relatively safe investment project to a riskier one, the corporation can increase the value of its equity at the expense of its bondholders. [Mayers and Smith](#) discuss this conflict and note that rational bondholders recognize this incentive to switch and incorporate it into the bond price. As a result, an agency cost is represented in the bond price and a reduction in the corporate value. [Mayers and Smith](#) also note that one role insurance plays, in this corporate environment, is in bonding the corporation's investment decision. They suggest that the incentive to include insurance covenants in bond contracts increases with firm leverage. [MacMinn \(1987\)](#) noted how insurance could be used to solve the risk-shifting problem; a simpler model is developed here which shows how insurance may be used to solve the risk-shifting problem. The analysis is then extended and operating decisions rather than investment decisions are considered; a risk-shifting problem does exist and the analysis shows that insurance can be used to reduce the agency cost associated with the risk-shifting problem.

In addition to the classic agency problems, conflicts of interest can and do occur in a corporate setting. The conflicts do have implications for the demand for corporate insurance. A few examples are considered in the section on management compensation. A management compensation that includes salary and stock options is considered. If management is compensated with salary and stock options and the insurable losses are positively correlated with corporate earnings then management will make

decisions on corporate account to maximize stock option value and purchase insurance to increase that option value. A management compensation that includes salary and bonus is also considered. In this case, the analysis shows that if the losses are negatively correlated with corporate earnings then management will make decisions on corporate account to maximize bonus value and include insurance to increase the probability that the bonus is paid. Some additional work on more complex compensation packages is noted.

After completing our exposition of the demand for corporate insurance, we focus our attention on some important empirical considerations. Specifically, we consider [Smith’s \(2007\)](#) survey of the empirical hedging literature and expand upon it for the purpose of providing a critique of empirical studies of corporate insurance purchases. The final section of this chapter presents some conclusions and comments on the role that insurance contracts play in managing corporate risk.

18.2 Model

Assume that there are many individual investors indexed by i in the set I and that there are many firms indexed by f in the set F . There are two dates, $t = 0$ and $t = 1$, that will be subsequently referred to as *now* and *then*. All decisions are made *now* and all payoffs from those decisions are received *then*. The payoffs depend on the actions taken, e.g., investment or insurance decisions, and on which state of nature in the set occurs *then*. The model is developed with stock, bond, and insurance markets. The Fisher model is used in this setting.¹

Investor i is endowed with income *now* and *then* represented by the pair (m_{i0}, m_{i1}) . Furthermore, investor i has a consumption pair (c_{i0}, c_{i1}) and an increasing concave utility function $u_i : D \rightarrow R$, where D is a subset of $R \times R^n$; u_i expresses the individual’s preferences for consumption *now* versus *then*. In order to introduce uncertainty, let (Ξ, F, Ψ) denote the probability space for individual i , where Ξ is the set of states of nature, F is the event space, and Ψ is the probability measure. If the number of states of nature is finite, i.e., $\Xi = \{\xi_1, \xi_2, \dots, \xi_n\}$ then the event space F is the power set, i.e., the set of all subsets of Ξ . To make the uncertainty operational, suppose that the investor can only transfer dollars between dates by buying or selling stocks, bonds, or insurance. In this complete market setting, suppose that a basis stock of type c is a promise to pay one dollar if state ξ occurs and zero otherwise, and let its price be denoted by $p(\xi)$.² Then the investor’s budget constraint may be expressed as

$$c_{i0} + \sum_{\Xi} p(\xi)c_{i1}(\xi) = m_{i0} + \sum_{\Xi} p(\xi)m_{i1}(\xi) \tag{18.1}$$

The left-hand side of Eq. (18.1) represents the risk-adjusted present value of the consumption plan, while the right-hand side represents the risk-adjusted present value of income. The investor’s constrained maximization problem can be stated as

$$\begin{aligned} & \text{maximize } \int_{\Xi} u_i(c_{i0}, c_{i1}(\xi)) d\Psi(\xi) \\ & \text{subject to } c_{i0} + \sum_{\Xi} p(\xi)c_{i1}(\xi) = m_{i0} + \sum_{\Xi} p(\xi)m_{i1}(\xi) \end{aligned} \tag{18.2}$$

¹ See [Fisher \(1930\)](#). The Fisher model is developed under uncertainty in [MacMinn \(2005\)](#).

² These stock contracts form a basis for the payoff space. This rather dramatic notion of financial market instruments was introduced by [Arrow \(1963\)](#).

This is the classic statement of the investor’s problem; it may also be expressed in terms of a portfolio of financial contracts and more financial contracts can be introduced. As long as any new contracts are spanned by the basis stock, the financial markets remain complete. Any spanned contract has a value equal to that of a portfolio of basis stock that provides the same payoff structure *then*.³ Hence, letting $\Pi(a, \xi)$ denote a corporate payoff *then* that depends on the state of nature and an action taken by management, it follows that the value of the unlevered corporate payoff is $S(a)$ where

$$S(a) = \int_{\Xi} \Pi(a, \xi) dP(\xi) \tag{18.3}$$

and $P(\xi)$ represents the sum of basis stock prices up to state ξ . The action taken by management will take the form of either an investment or production decision in the subsequent analysis. If the action is an investment decision *now*, then the action will be denoted by I and I will be included in the financing constraint. If the firm issues a zero coupon bond with a promised payment of b dollars *then*, the value of the bond issue is $B(a, b)$, where

$$\begin{aligned} B(a, b) &= \int_{\Xi} \min\{\Pi(a, \xi), b\} dP \\ &= \int_B \Pi(a, \xi) dP + \int_{\Xi \setminus B} b dP \end{aligned} \tag{18.4}$$

where B represents the bankruptcy event, i.e., $B = \{\xi | \Pi(a, \xi) < b\}$ and $\Xi \setminus B$ represents the complement of the bankruptcy event relative to Ξ . The stock or equity value in this levered case is $S(a, b)$ where

$$\begin{aligned} S(a, b) &= \int_{\Xi} \max\{0, \Pi(a, \xi) - b\} dP(\xi) \\ &= \int_{\Xi \setminus B} (\Pi(a, \xi) - b) dP \end{aligned} \tag{18.5}$$

In each case the value represents the risk-adjusted present value of the contract payoffs.⁴ Finally, the corporate value is V where

$$\begin{aligned} V &= S(a, b) + B(a, b) \\ &= \int_{\Xi \setminus B} (\Pi(a, \xi) - b) dP + \int_B \Pi(a, \xi) dP + \int_{\Xi \setminus B} b dP \\ &= \int_{\Xi} \Pi(a, \xi) dP \end{aligned} \tag{18.6}$$

Next we introduce insurance. Suppose the corporation faces property risks. Let the corporate payoff be $\Pi^u(a, \xi) = R(a, \xi) - L(a, \xi)$ for the uninsured firm and $\Pi^i = R(a, \xi) - L(a, \xi) + \max\{0, L(a, \xi) - d\}$ for the insured firm where R represents the quasi-rent on the production or investment, L represents the property losses, and d represents the deductible on the insurance; the insurance contract payoff is $\max\{0, L(a, \xi) - d\}$. Suppose that the payoffs Π^u and Π^i are increasing and concave in the action a

³This may be demonstrated by direct calculation, but it also clearly follows by a no-arbitrage argument.

⁴See MacMinn (2005) for more on this interpretation.

and increasing in state, i.e., $D_1\Pi^k > 0$, $D_{11}\Pi^k$ and $D_2\Pi^k > 0$, $k = u, i$. Suppose losses decrease in state and let γ be the boundary of the event that the insurance contract pays $L(a, \gamma) - d$ dollars, i.e., γ is implicitly defined by the condition $L(a, \gamma) - d = 0$.⁵ Let β be the boundary of the insolvency event; then it is implicitly defined by the condition $\max\{R(a, \beta) - d, R(a, \beta) - L(a, \beta)\} - b = 0$. The insured stock value is S^i where

$$\begin{aligned} S(a, b, d) &= \int_{\Xi} \max\{0, \Pi^i - b\} dP \\ &= \begin{cases} \int_{\beta}^{\gamma} (R - d - b) dP + \int_{\gamma}^{\omega} (R - L - b) dP & \text{if } \beta \leq \gamma \\ \int_{\beta}^{\omega} (R - L - b) dP & \text{if } \beta > \gamma \end{cases} \end{aligned} \quad (18.7)$$

while the bond value is B

$$\begin{aligned} B(a, b, d) &= \int_{\Xi} \min\{\Pi^i, b\} dP \\ &= \begin{cases} \int_0^{\beta} (R - d) dP + \int_{\beta}^{\omega} b dP & \text{if } \beta \leq \gamma \\ \int_0^{\gamma} (R - d) dP + \int_{\gamma}^{\beta} (R - L) dP + \int_{\beta}^{\omega} b dP & \text{if } \beta > \gamma \end{cases} \end{aligned} \quad (18.8)$$

Hence, the insured corporate value is

$$\begin{aligned} V^i(a, d) &= S^i(a, b, d) + B(a, b, d) \\ &= \int_0^{\gamma} (R - d) dP + \int_{\gamma}^{\omega} (R - L) dP \end{aligned} \quad (18.9)$$

Let i denote the premium *now* on the insurance contract. In this setting, the premium value is

$$i(a, d) = \int_{\Xi} \max\{0, L - d\} dP \quad (18.10)$$

Finally, the model provides enough structure to allow the derivation of the corporate objective function that incorporates the insurance decision along with the financing and investment decisions.

Suppose the corporate manager is paid a salary *now* and *then* of (y_0, y_1) and is also compensated with m shares of corporate stock. Suppose there are N shares of stock outstanding and let n denote the number of new shares issued to finance the corporate operations. Let S^m be the manager's equity stake and S^n be the value of the issue of new shares of stock. Since $N + m$ denotes the existing shares, note that

$$S^m = \frac{m}{N + m + n} S \text{ and } S^n = \frac{n}{N + m + n} S$$

Similarly, let S^o denote the current shareholder value. Then

$$S^o = \frac{N}{N + m + n} S$$

⁵The losses could also be increasing without affecting the results in this section.

The manager makes an investment decision on corporate account and selects the financing, i.e., debt and equity, necessary to cover the investment. The next theorem shows how the corporate objective function is derived.

Theorem 1. *Suppose the corporate manager receives a salary package (y_0, y_1) and m shares of stock in the corporation. Suppose the manager pursues her own self-interest in making decisions on personal and corporate account. The decisions on personal account may be separated from those on corporate account and the decisions on corporate account are made to maximize shareholder value.*

Proof 1. The pursuit of self-interest yields the following constrained maximization problem:

$$\begin{aligned} & \text{maximize } \int_{\Xi} u(c_0, c_1(\xi))d\Psi(\xi) \\ & \text{subject to } c_0 + \sum_{\Xi} p(\xi)c_1(\xi) = y_0 + \sum_{\Xi} p(\xi)y_1(\xi) + S^m \\ & \text{and } S^n + B = a + i, \end{aligned} \tag{18.11}$$

The constrained maximization function includes the budget constraint and financing constraint, i.e., the personal account and corporate account constraints. Without loss of generality, assume that any new finance is raised with a bond issue, i.e., $n \equiv 0$ here. Letting $c(c_0, c_1(\xi))$, the Lagrange function for this constrained maximization problem is

$$L(a, b, c, d, \lambda, \delta) = \int_{\Xi} ud\Psi + \lambda(m_{i0} + \sum_{\Xi} pm_1 + S^m - c_{i0} - \sum_{\Xi} pc_1) + \delta(B - a - i) \tag{18.12}$$

The first-order conditions are as follows:

$$\frac{\partial L}{\partial a} \equiv D_1L = \lambda D_1S^m = 0 \tag{18.13}$$

$$\frac{\partial L}{\partial b} \equiv D_2L = \lambda D_2S^m + \delta D_2B = 0 \tag{18.14}$$

$$\frac{\partial L}{\partial c_0} \equiv D_3L = \int_{\Xi} D_1ud\Psi - \lambda = 0 \tag{18.15}$$

$$\frac{\partial L}{\partial c_1} \equiv D_4L = D_2u\psi(\xi) - \lambda p(\xi) = 0 \tag{18.16}$$

$$\frac{\partial L}{\partial d} \equiv D_5L = \lambda D_3S^m + \delta(D_3B - D_2i) = 0 \tag{18.17}$$

$$\frac{\partial L}{\partial \lambda} = m_{i0} + \sum_{\Xi} pm_1 + S^m - c_{i0} - \sum_{\Xi} pc_1 = 0 \tag{18.18}$$

$$\frac{\partial L}{\partial \delta} = B - a - i = 0 \tag{18.19}$$

Hence, direct calculation shows that the manager makes decisions on corporate account to maximize $\lambda S^m + \delta(B - a - i)$. Since the financing constraint, i.e., $B(a, b, d) - a - i(a, d) = 0$, yields a function $b(a, d)$, the objective function may also be expressed as $S^m(a, b(a, d), d)$.⁶ *QED*

⁶See the appendix for a derivation of the function $b(a, d)$.

Corollary 1. *Given a debt issue to finance the insurance, the manager selects the action a to maximize the stock value $S(a, b(a, d)d)$ or equivalently the risk-adjusted net present value $V^i(a, d) - a - i(a, d)$.*

Proof 2. Given no new equity issue, the manager's stake in the firm is $m/(m + N)$ which is a constant. Hence, maximization of S^m is equivalent to the maximization of S . Since

$$\begin{aligned} S^i &= V^i - B \\ &= V^i - a - i \end{aligned} \tag{18.20}$$

where the second equality follows due to the financing constraint, the second conclusion follows trivially. *QED*

Theorem 1 and its corollary establish a financial market version of Fisher's separation theorem and the maximization of net present value as the objective function. Like Fisher's result, this theorem and corollary show that decisions made on corporate account are separable from decisions made on personal account. The manager's measure of risk aversion will affect the saving and portfolio decisions made on personal account but not those decisions made on corporate account. The manager will make the finance, insurance, and other corporate decisions to maximize stock value or equivalently risk-adjusted net present value.⁷

18.3 Agency Problems

In this section, the use of insurance contracts in resolving conflict of interest problems between stockholders and bondholders is analyzed. Since the corporate manager represents the interests of stockholders, there is a potential for conflict between the manager and bondholders, or equivalently, between the manager and the bondholders' trustee. This will be the case if it is possible for the manager to take actions that benefit one group but are detrimental to the other. If the bonds represent safe debt then there is no conflict. If not, then an agency problem may exist.

The agency relationship can be thought of as a contract between the principal, i.e., the bondholders' trustee⁸ and an agent, i.e., the corporate manager. The agent acts on behalf of the principal. The contract specifies the bounds on the actions that may be taken by the agent. If the contract covers all possible contingencies then there is no real delegation of authority and therefore no agency problem. If the contract is incomplete so that the agent has some discretion in the selection of actions then there is at least the potential for a conflict of interests. The conflict occurs because the agent behaves in accordance with her own self-interest. The principal can limit the divergence of interests by providing provisions in the contract that give the agent the appropriate incentives to act in the principal's interest;

⁷This statement must be qualified. As long as the manager's compensation is salary and stock, the incentives are aligned with shareholders and the statement holds. We note the qualifications of the statement in a subsequent section on executive compensation.

⁸The legal trustee for the bondholders may be treated as the single principal. It should be added that the trustee acts on behalf of the bondholders. The trustee's problem is the selection of bond covenants that limit the divergence of interests between corporate management and the bondholders. In general, the trustee may have a problem in selecting covenants that provide a solution to the conflict because of the different risk aversion measures of the bondholders. In the two cases considered here, however, the bondholders will unanimously support a covenant that provides management with the incentive to maximize the risk-adjusted net present value of the corporation. It should also be noted that in general there may be an agency problem between the trustee and bondholders, i.e., between the agent and the principals. In the cases considered here that problem does not arise because of the unanimity.

in addition, the principal can monitor the activity of the agent. It is, however, not usually possible to specify the contract in such a way as to completely eliminate a conflict of interest. Hence, it will usually be the case that there is a difference between the action taken by the agent and the action that is in the best interests of the principal. Jensen and Meckling (1976) define agency cost as the sum of the monitoring expenditures of the principal, the bonding expenditures of the agent, and the residual loss; this residual loss is the loss in the market value of the corporation.⁹

18.3.1 Underinvestment

The first agency problem considered here occurs when the manager makes investment decisions. Jensen and Smith (1985) note that one source of conflict is underinvestment. They observe that

... when a substantial portion of the value of the firm is composed of future investment opportunities, a firm with outstanding risky bonds can have incentives to reject positive net present value projects if the benefit from accepting the project accrues to the bondholders (Jensen and Smith 1985, p. 111)

The incentive need not be so extreme that it causes the manager to reject a positive net present value project; the manager may underinvest by limiting the size of the investment. Mayers and Smith (1987) consider the underinvestment problem. They note that property losses create options on corporate assets because value depends on further discretionary investment. If the corporation has a risky debt issue then that creates a conflict of interest between shareholders and bondholders because management, acting in the interests of shareholders, may forgo the investment even though it has a positive net present value. The story is captured in the following figure which shows the potential cash flows with or without the investment.

The story is constructed by considering a firm with assets valued *then* at V dollars. A loss of $L(\xi)$ in state on assets of value V may be realized *then* and yield a cash flow of $V - L(\xi)$. If the corporation invests to reconstitute the assets then the cash flow *then* becomes $V - I(\xi)$ instead. Of course, if the corporation is levered and has a promised bond payment of b *then*, it becomes apparent that no investment in assets is made in states $\xi < \xi^u$ since all cash flows would accrue to bondholders; any investment in those states would make shareholders worse off.¹⁰ The investment is made if $V - I(\xi) \geq b$ or equivalently if state ξ occurs where $\xi^i > \xi \geq \xi^u$. In the absence of a solution to the underinvestment problem, the value of the debt and equity are D^u and S^u where

$$D^u = \int_0^{\xi^u} (V - L(\xi))dP(\xi) + \int_{\xi^u}^{\omega} b dP(\xi) \tag{18.21}$$

and

$$S^u = \int_{\xi^u}^{\xi^i} (V - I(\xi) - b)dP(\xi) + \int_{\xi^i}^{\omega} (V - b)dP \tag{18.22}$$

⁹Jensen and Meckling (1976) also define the residual loss as the dollar equivalent of the loss in expected utility experienced by the principal. Although this notion of residual loss is measurable for a particular principal, this definition poses problems when a trustee represents many principals because the residual loss of any bondholder will depend on the bondholder's measure of risk aversion and on the proportion of the contract owned.

¹⁰It may be noted that if the bond payment is $b \leq VI(0)$ then no underinvestment problem exists

These values are depicted in Fig. 18.1.¹¹ The corporate value given the underinvestment is¹²

$$V^u \equiv D^u + S^u \text{ or } V^u = \int_0^{\xi^u} (V - L(\xi)) dP(\xi) + \int_{\xi^u}^{\xi^i} (V - I(\xi)) dP(\xi) + \int_{\xi^i}^{\omega} V dP(\xi) \quad (18.23)$$

If the corporation did invest in each state then the debt, equity, and corporate values would be D^i , S^i and $V^i \equiv D^i + S^i$ where

$$D^i = \int_0^{\xi^u} (V - I(\xi)) dP(\xi) + \int_{\xi^u}^{\omega} b dP(\xi) \quad (18.24)$$

$$S^i = \int_{\xi^u}^{\xi^i} (V - I(\xi) - b) dP(\xi) + \int_{\xi^i}^{\omega} (V - b) dP(\xi) \quad (18.25)$$

and

$$V^i = \int_0^{\xi^i} (V - I(\xi)) dP(\xi) + \int_{\xi^i}^{\omega} V dP(\xi) \quad (18.26)$$

The agency cost is the difference in corporate value, i.e., $c = V^i - V^u$. Hence, it is easy to show that the agency cost is the c defined in (18.27) and is the risk-adjusted present value of the area depicted in Fig. 18.1.

$$\begin{aligned} c &\equiv V^i - V^u \\ &= \int_0^{\xi^u} (L(\xi) - I(\xi)) dP(\xi) \end{aligned} \quad (18.27)$$

Of course, it is apparent that, *ceteris paribus*, the corporate management does not have the incentive *then* to invest in states $\xi < \xi^u$ because all the gain would go to bondholders rather than shareholders. Thus management cannot simply declare that the investment would always be made to reconstitute the asset; such a claim would not be credible. Management can, however, create a bond that includes a covenant stipulating an insurance contract. In particular, suppose that management packages the bond with a deductible insurance contract with a payoff $\max\{0, I(\xi) - I(\xi^u)\} = \max\{0, I(\xi) - (V - b)\}$. Such an insurance contract would payoff $b - (V - I(\xi))$ in all states $\xi < \xi^u$. This payoff just covers the promised payment on the bond and leaves the shareholders no worse off. Hence, such a contract repairs the conflict in incentives between shareholders and bondholders. This makes any statement made by management that the asset will be reconstituted credible.

The premium for the deductible insurance contract in a competitive market is i where

$$\begin{aligned} i &= \int_0^{\xi^u} (I(\xi) - I(\xi^u)) dP(\xi) \\ &= \int_0^{\xi^u} (b - (V - I(\xi))) dP(\xi) \end{aligned} \quad (18.28)$$

¹¹The risk-adjusted present value of the areas denoted in figure 1 is the value for debt, equity, and agency cost.

¹²This is the stock value without any dividend.

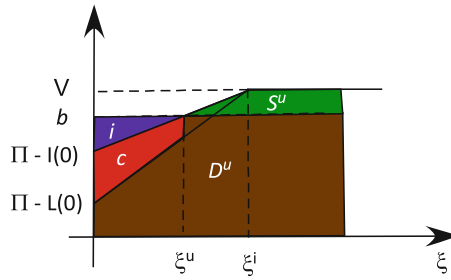


Fig. 18.1

The second equality in (18.28) follows by the choice of the deductible, i.e., $I(\xi^u) = V - b$. The insurance premium is represented by the area labeled i in Fig. 18.1. Now, given the insurance payoff and the investment in all states $\xi < \xi^i$, a bond with the same promised payment b but with the insurance covenant becomes a safe bond and so raises $i + c$ dollars in addition to the D^u dollars. Hence, this bond raises enough to pay for the insurance contract and to pay a dividend *now* to shareholders in the amount of c dollars. Equivalently, the shareholder value *now* given the bond covenant package is S^i where

$$\begin{aligned}
 S^i &= c + \int_{\xi^u}^{\xi^i} (V - I(\xi) - b) dP(\xi) + \int_{\xi^i}^{\omega} (V - b) dP(\xi) \\
 &= S^u + c \\
 &= S^u + (V^i - V^u)
 \end{aligned}
 \tag{18.29}$$

Therefore, the bond covenant package solves the underinvestment problem and fully captures the agency cost for shareholders. It is also possible to reduce the promised repayment and restructure the bond so that no dividend need be paid *now*, but the shareholders capture the entire agency cost that would have been borne without the bond covenant package, e.g., see [Garven and MacMinn \(1993\)](#). It is also apparent that even if the insurance premium includes some loading this bond covenant scheme can still align incentives as long as the loading does not exceed the agency cost, i.e., see [Schnabel and Roumi \(1989\)](#).

18.3.2 Generalized Underinvestment Problem

Suppose the firm's earnings are $\Pi^u = R(I, \xi) - L(I, \xi)$ if it is uninsured and $\Pi^i = R(I, \omega) - L(I, \omega) + \max\{0, L - d\}$ if it is insured, where R represents the quasi-rents from the investment projects, L represents property losses, and d represents the deductible on the insurance. Suppose the firm has fixed obligations from previous periods and debt obligations from financing its current investment; the fixed obligation c may be a commitment on previously issued bonds, but it need not be limited to that. Suppose $D_1 \Pi^k > 0$ and $D_{11} \Pi^k < 0$ for $k = u, i$, so that the corporate payoff is increasing at a decreasing rate in the dollar investment I . Let B^k denote the firm's bankruptcy event. Then, with no corporate taxes, the market value of the firm's equity is $S^k(I, b, d)$, where

$$S^k(I, b, d) = \int_{\Xi} \max\{0, \Pi^k - b - c\} dP
 \tag{18.30}$$

where $\Xi \setminus B^k = \{\xi \in \Xi \mid \Pi^k(I, \xi) - b - c \geq 0\}$. The boundary β^k of the bankruptcy event is implicitly defined by $\Pi^k(I, \beta) - b - c = 0$. The market value of the corporation's creditor stake is $O(I, b, d)$ where

$$C^k(I, b, d) = \int_{B^k} \frac{c}{b+c} \Pi^k dP + \int_{\Xi \setminus B^k} cdP \quad (18.31)$$

Similarly, the value of a new debt issue *now* is

$$D^k(I, b, d) = \int_{B^k} \frac{b}{b+c} \Pi^k dP + \int_{\Xi \setminus B^k} bdP \quad (18.32)$$

Observe that the corporate value is the sum of the values of the stakeholder's interests in the firm. Denote that value as $V(I, d)$ where

$$\begin{aligned} V^k &= S^k + C^k + B^k \\ &= \int_{\Xi \setminus B^k} (\Pi^k - b - c) dP + \int_{B^k} \frac{c}{b+c} \Pi^k dP + \int_{\Xi \setminus B^k} cdP \\ &\quad + \int_{B^k} \frac{b}{b+c} \Pi^k dP + \int_{\Xi \setminus B^k} bdP \\ &= \int_{B^k} \Pi^k dP + \int_{\Xi \setminus B^k} \Pi^k dP \\ &= \int_{\Xi} \Pi^k dP \end{aligned} \quad (18.33)$$

There is a well-known corollary to the 1958 Modigliani–Miller theorem¹³ which says that the value of the uninsured firm equals that of the insured firm, e.g., see [Mayers and Smith \(1982\)](#) and [\(MacMinn 1987\)](#). That corollary may be noted here by observing that $V^i = V^u$ since

$$\begin{aligned} V^i &= -i + \int_{\Xi} \Pi^i dP \\ &= -i + \int_{\Xi} (R(I, \omega) - L(I, \omega) + \max\{0, L - d\}) dP \\ &= -i + \int_{\Xi} (R(I, \omega) - L(I, \omega)) dP + \int_{\Xi} \max\{0, L - d\} dP \\ &= \int_{\Xi} \Pi^u dP \\ &= V^u \end{aligned} \quad (18.34)$$

¹³See [Modigliani and Miller \(1958\)](#).

where as before i is the insurance premium. Suppose that the corporate payoff then is the sum of the payoffs from the corporate projects or operating divisions.¹⁴ It is possible to motivate the underinvestment problem by noting how the creditor value is affected by changing the investment level on a project. Note that the value increases in the scale of the investment if there is a positive probability of insolvency since

$$\begin{aligned} D_1C &= \left(\frac{c}{b+c}(R(I, \beta) - d) - b \right) p(\beta) \frac{\partial \beta}{\partial I} + \frac{c}{b+c} \int_B D_1 R dP \\ &= \frac{c}{b+c} \int_B D_1 R dP \\ &> 0 \end{aligned} \tag{18.35}$$

This inequality provides analytic content for the earlier statement by Jensen and Smith since it shows that the benefits of the insurance coverage accrue, in part, to firm creditors. This will reduce the incentive to invest since not all of the benefits go to current shareholders.

The underinvestment may be relative to either the investment that would maximize the value of an unlevered corporation or the investment that is socially efficient.¹⁵ The socially efficient investment maximizes the value of all the corporate stakeholders; equivalently, the socially efficient investment satisfies the following first-order condition:

$$-1 + \int_{\Xi} D_1 \Pi dP = -1 + \int_{\Xi} (D_1 R - D_1 L) dP = 0 \tag{18.36}$$

This condition implicitly defines an investment level I^v that maximizes the value of all the stakeholders' claims on the firm. The extent of the underinvestment will be measured relative to this.

The corollary to Theorem 1 shows that the corporate manager makes the investment decision to maximize the risk-adjusted net present value. The objective function is

$$V^i - I - i = -I + \int_{\Xi} \Pi^u dP \tag{18.37}$$

$$\begin{aligned} S^{oi} &= -I - i + \int_{\Xi} \max\{0, \Pi^i - b - c\} dP \\ &= -I - i + \int_{\Xi} \max\{0, R - L + \max\{0, L - d\} - b - c\} dP \end{aligned} \tag{18.38}$$

The following first-order condition implicitly defines the optimal investment I^m that is selected by corporate management acting in the interests of current shareholders:

Case I: Let state be the boundary of the insurance event and be implicitly defined by $L(I, \gamma) - d = 0$; similarly let state β_1 be the boundary of the bankruptcy event and be implicitly defined by the condition $R(I, \beta_1) - L(I, \beta_1) + \max\{0, L - d\} = R(I, \beta_1) - d = 0$. Suppose $\beta_1 > \gamma$. Then

$$S^{oi} = -I - i + \int_{\beta_1}^{\omega} (R - d - b - c) dP \tag{18.39}$$

¹⁴Here it suffices to think of the payoff as being the sum of old and new project payoffs, i.e. $\Pi(I, \xi) = \Pi(\xi) + \Pi_v(I, \xi)$.

¹⁵This is efficiency in the Pareto sense. An investment is socially efficient if it is not possible to make one investor better off without making another worse off.

and

$$\begin{aligned}
\left. \frac{\partial S^{oi}}{\partial I} \right|_{I=I^v} &= -1 - \frac{\partial i}{\partial I} + \int_{\beta_1}^{\omega} D_1 R dP \\
&= -1 - \int_{\gamma}^{\beta_1} D_1 L dP + \int_{\beta_1}^{\omega} (D_1 R - D_1 L) dP \\
&< -1 + \int_{\beta_1}^{\omega} (D_1 R - D_1 L) dP \\
&< -1 + \int_0^{\omega} (D_1 R - D_1 L) dP \\
&= 0
\end{aligned} \tag{18.40}$$

The derivative in (18.40) shows that the manager underinvests, equivalently, $I^m < I^v$, where I^m and I^v represent the investment levels that maximize current shareholder value and total stakeholder value, respectively.

Case II: Let the boundary β_2 of the bankruptcy event be implicitly defined by $R(I, \beta_2) - L(I, \beta_2) = 0$ and let $\beta_2 < \gamma$. Then

$$S^{oi} = -I - i + \int_{\beta_2}^{\gamma} (R - L - b - c) dP + \int_{\gamma}^{\omega} (R - d - b - c) dP \tag{18.41}$$

and

$$\begin{aligned}
\left. \frac{\partial S^{oi}}{\partial I} \right|_{I=I^v} &= -1 - \frac{\partial i}{\partial I} + \int_{\beta_2}^{\gamma} (D_1 R - D_1 L) dP + \int_{\gamma}^{\omega} D_1 R dP \\
&= -1 - \int_{\gamma}^{\omega} D_1 L dP + \int_{\beta_2}^{\gamma} (D_1 R - D_1 L) dP + \int_{\gamma}^{\omega} D_1 R dP \\
&= -1 + \int_{\beta_2}^{\omega} (D_1 R - D_1 L) dP \\
&< -1 + \int_0^{\omega} (D_1 R - D_1 L) dP \\
&= 0
\end{aligned} \tag{18.42}$$

As in case I, the derivative in (18.42) again shows that the manager underinvests, i.e., $I^m < I^v$.

Insurance can play an important role in alleviating the underinvestment problem. The decision sequence is critical. To ensure that current shareholders receive the benefit of positive risk-adjusted net present value investment decisions, the insurance contract must precede the investment. If insurance can be used to eliminate insolvency risk then the derivative in (18.40) or (18.42) may be used to show that the underinvestment problem would be eliminated. The next theorem shows that even if insurance cannot eliminate the insolvency risk and so the underinvestment problem, it can be effectively used to reduce the impact of this problem.

Theorem 2. *If the probability of insolvency is positive, i.e., $P\{B\} > 0$, then the optimal investment is non-decreasing in insurance coverage.*

Proof 3. It suffices to show that

$$\frac{\partial I}{\partial d} = -\frac{\frac{\partial^2 S^{oi}}{\partial d \partial I}}{\frac{\partial^2 S^{oi}}{\partial I^2}} \leq 0 \quad (18.43)$$

The concavity of S^{oi} makes the denominator negative and so the optimal investment is decreasing in the deductible if the numerator is negative; equivalently, the optimal investment increases with additional insurance coverage.

Consider case II. Let γ_1 be associated with d_1 and γ_2 with $d_2 > d_1$. Then $\gamma_2 > \gamma_1$. Here an increase in the deductible yields $\beta_2 < \gamma_1 < \gamma_2$ and β_2 does not increase with the deductible. Hence, from (18.42) we have

$$\begin{aligned} \frac{\partial^2 S^{oi}}{\partial d \partial I} &= \frac{\partial}{\partial d} \left(-1 + \int_{\beta_2}^{\omega} (D_1 R - D_1 L) dP \right) \\ &= (D_1 R(I, \beta_2) - D_2 L(I, \beta_2)) p(\beta_2) \frac{\partial \beta_2}{\partial d} \\ &= 0 \end{aligned} \quad (18.44)$$

and the equality follows because β_2 does not increase with the deductible.

Next, consider case I. As above, let γ_1 be associated with d_1 and γ_2 with $d_2 d_1$. Then $\gamma_2 > \gamma_1$. Here an increase in the deductible yields $\gamma_1 < \beta_1 < \beta_2$ and β_2 is non-decreasing in d . Hence, from (18.40), the cross partial is

$$\begin{aligned} \frac{\partial^2 S^{oi}}{\partial d \partial I} &= \frac{\partial}{\partial d} \left(-1 - \int_{\gamma}^{\beta_1} D_1 L dP + \int_{\beta_1}^{\omega} (D_1 R - D_1 L) dP \right) \\ &= D_1 L(I, \gamma) p(\gamma) \frac{\partial \gamma}{\partial d} - D_1 L(I, \beta_1) p(\beta_1) \frac{\partial \beta_1}{\partial d} - (D_1 R(I, \beta_1) - D_1 L(I, \beta_1)) p(\beta_1) \frac{\partial \beta_1}{\partial d} \\ &= D_1 L(I, \gamma) p(\gamma) \frac{\partial \gamma}{\partial d} - D_1 R(I, \beta_1) p(\beta_1) \frac{\partial \beta_1}{\partial d} \\ &< D_1 L(I, \gamma) p(\gamma) \frac{\partial \gamma}{\partial d} - D_1 R(I, \beta_1) p(\gamma) \frac{\partial \beta_1}{\partial d} \\ &< 0 \end{aligned} \quad (18.45)$$

and the sign follows since basis stock prices increase in state, the quasi-rent increases more than the loss in the investment, and, by direct calculation,

$$\frac{\partial \beta_1}{\partial d} = \frac{1}{D_2 R} > \frac{1}{D_2 L} = \frac{\partial \gamma}{\partial d} \quad (18.46)$$

QED

This theorem shows that insuring mitigates the underinvestment problem if it reduces the probability of insolvency. If the firm insures and increases its investment then it protects bond and general creditor values and so facilitates the movement of additional value from investment to existing shareholders. The theorem also suggests that full insurance is optimal if it is feasible.

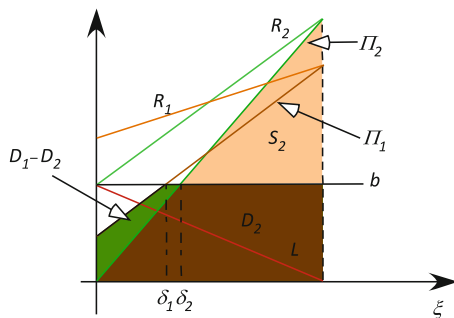


Fig. 18.2

18.3.3 Asset Substitution

The second agency problem considered here is typically referred to as either the asset substitution or risk-shifting problem. It is encountered by the corporation in selecting the set of assets and liabilities that constitute the firm. The problem can occur when the firm selects among mutually exclusive investment projects, e.g., MacMinn (1993), selects a portfolio of investment projects, e.g., Green (1984), or makes operating decisions or restructures, e.g., MacMinn and Brockett (1995). Jensen and Smith (1985) note that

... the value of the stockholders' equity rises and the value of the bondholders' claim is reduced when the firm substitutes high risk for low risk projects (Jensen and Smith 1985, p. 111).¹⁶

Rational bondholders are aware of the incentive to shift risk and so it is reflected in a lower value for the corporation's debt issues, or equivalently, in a higher interest rate on the debt.

Green (1984) and MacMinn (1993) have shown that convertible bonds can be used to solve the risk-shifting problem. In MacMinn (1993) the corporate manager, acting in the interests of shareholders, faces mutually exclusive investment projects and selects either the more or the less risky investment project; more risk was characterized using the notion of a mean preserving spread as in Rothschild and Stiglitz (1970).

18.3.4 The RiskShifting Problem and Insurance

Consider a variant of the Mayer–Smith model introduced in the previous section. Let L denote the random losses and let those losses be the same on projects one and two. Let R_1 and R_2 denote the quasi-rents generated by each project. Suppose that R_2 is riskier than R_1 in the Rothschild–Stiglitz sense and as shown in Fig. 18.2; see Rothschild and Stiglitz (1970) for the notion of an increase in risk. The projects are mutually exclusive and the project payoffs are $\Pi_j = R_j - L$ for $j = 1, 2$. Note that Π_2 is riskier than Π_1 and so the corporate values satisfy the following inequality: $V_1 \equiv D_1 + S_1 > D_2 + S_2 \equiv V_2$.¹⁷ If zero coupon debt is issued to finance the project and b is the promised payment then the value of the debt is

¹⁶See Green (1984) and Hirshleifer (1965) for similar statements.

¹⁷For a demonstration of the relation between values, see MacMinn (1993).

$$D_2(b) = \int_0^{\delta_2} \Pi_2(\xi) dP(\xi) + \int_{\delta_2}^{\omega} b dP(\xi) \quad (18.47)$$

for project two and

$$D_1(b) = \int_0^{\delta_1} \Pi_1(\xi) dP(\xi) + \int_{\delta_1}^{\omega} b dP(\xi) \quad (18.48)$$

for project one. If the firm switches from project one to two then $D_1 - D_2$ represents the devaluation of the debt experienced by bondholders and the devaluation is shown in Fig. 18.2. If the promised payment on the debt issue is sufficiently large, then the levered stock value for project two exceeds that for project one, i.e., $S_2(b) > S_1(b)$, and management acting in the interests of shareholders will switch. Being rationale, bondholders understand this incentive and so the conflict of interests is borne by shareholders in the form of an agency cost $c = V_1 - V_2$.s Equivalently, if b_1 and b_2 represent the promised payments that just finance projects one and two, respectively, then it may be shown that $\frac{S}{2}(b_2) = S_1(b_1) - (V_1 - V_2)$, i.e., see MacMinn (1993). This risk-shifting problem has been solved by Green (1984) and by MacMinn (1993) using a convertible bond. It is also possible, however, to solve the problem with a bond that includes a covenant requiring insurance. Here we will suppose that b is the promised payment on debt that just finances the investment if bondholders believe that project two is selected. That b is shown in the next figure.

It is possible to make three claims that if true suffice to show that insurance can be used to solve the risk-shifting problem. The claims are (1) insurance increases corporate value by the fair insurance premium; (2) the difference between the corporate values of the projects remains the same with as without insurance; (3) the insurance can increase the value of the safer project by the agency cost. Consider the claims.

If the corporation can purchase insurance at a fair premium then the premium is the risk-adjusted present value of the net loss. Given a deductible of d the premium is

$$\begin{aligned} i &= \int_0^{\omega} \max\{0, L(\xi) - d\} dP(\xi) \\ &= \int_0^{\eta} (L(\xi) - d) dP(\xi) \end{aligned} \quad (18.49)$$

where η is the boundary of the event that the loss exceeds the deductible. If the corporation insures part of its losses then the payoff becomes

$$\Pi_j^i = \begin{cases} R_j(\xi) - d & \xi \leq \eta \\ R_j(\xi) - L(\xi) & \xi > \eta \end{cases} \quad (18.50)$$

Suppose that the firm selects a deductible such that $\eta = \delta_2$. The value of the insured corporation with project $j = 1, 2$ is

$$V_j^i = \int_0^{\eta} (R_j(\xi) - d) dP(\xi) + \int_{\eta}^{\omega} (R_j(\xi) - L(\xi)) dP(\xi) \quad (18.51)$$

while the value of the uninsured is

$$V_j^u = \int_0^{\omega} (R_j(\xi) - L(\xi)) dP(\xi) \quad (18.52)$$

It follows that $V_j^i - V_j^u = i$ and so claim one holds. This also shows that

$$\begin{aligned} V_1^i - V_2^i &= V_1^u + i - (V_2^u + i) \\ &= V_1^u - V_2^u \\ &> 0 \end{aligned} \tag{18.53}$$

Recall that the promised payment b suffices to finance an uninsured project two. If the firm insures and bondholders believe that project two will be selected then bond value increases by the value of the insurance premium as shown in Fig. 18.3. If the insurance provides credible evidence that the firm will select project one then bond value increases by more than the insurance premium; the additional amount is denoted by e in Fig. 18.3; then e may be paid as a dividend *now* to shareholders. *The* stock value of the insured firm selecting project one must exceed that of the same firm selecting project two if the insurance provides credible assurance to the bondholders that the firm will indeed select project one. The shaded area i in Fig. 18.3 denotes the fair insurance premium and so the difference in stock values is

$$\begin{aligned} S_1^i - S_2^i &= \int_0^{\delta_2} (R_1 - R_2)dP + \int_{\delta_2}^v ((R_1 - L) - (R_2 - L))dP - \int_v^\omega ((R_2 - L) - (R_1 - L))dP \\ &= \int_0^\omega (R_1 - R_2)dP \\ &= V_1 - V_2 \\ &= c \end{aligned} \tag{18.54}$$

Equivalently, the insured stock value of project one equals that of project two plus the agency cost, i.e., $S_1^i = S_2^i + c$. Hence, the insurance provides credible assurance that corporate management acting in the interests of shareholders will select the safer project.

18.3.5 Risk Shifting, Insurance, and Production Decisions

The literature has been devoted to investment decisions and risk shifting.¹⁸ The corporation can, however, take other actions which affect the risk of its payoff. A production decision is one example. The analysis here shows that a levered firm with a positive probability of insolvency faces a risk-shifting problem in making its production decision. The production decision may increase risk and so shift value from existing debt holders to equity holders. The first step here shows that the agency problem exists. Then an insurance mechanism is constructed to reduce or eliminate the risk-shifting incentive and so another source of the agency cost of debt.

In order to demonstrate the agency problem, suppose the corporation is considering an operating decision after its finance and insurance decisions have been made. Let q denote the operating decision *now* and let denote the random earnings. Suppose earnings are positive for all states.¹⁹ Suppose also that the project satisfies the principle of increasing uncertainty (PIU), e.g., see Leland (1972) and MacMinn and Holtmann (1983); let the random payoff be defined by a function that maps the

¹⁸One known exception to this is theorem three in MacMinn and Garven (2000).

¹⁹The assumption $\Pi > 0$ for all $\xi \in \Xi$ simply allows the result $V^i - V^u$ for any insurance scheme to be used here.

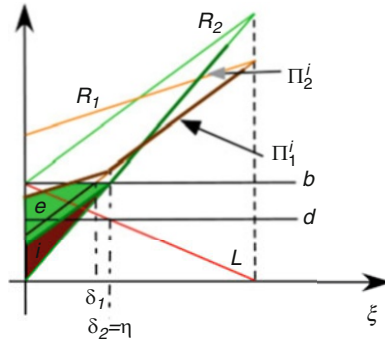


Fig. 18.3

operating decision and state into earnings. Then the payoff is $\Pi(q, \xi)$ and by the PIU, $D_2\Pi > 0$ and $D_{12}\Pi > 0$. These derivative properties say that the payoff increases in state as does the marginal payoff. The PIU also implies that, after correcting for the changes in the expected payoff, an increase in scale increases risk in the Rothschild–Stiglitz sense.²⁰

To establish the existence of the asset substitution problem consider the relationship between the scale of production and the level of debt. If the firm leverages itself to finance the project then the stock value is $S(q, b)$ and

$$S(q, b) = \int_{\beta}^{\omega} (\Pi(q, \xi) - b) dP \tag{18.55}$$

where β is the boundary of the insolvency event and is implicitly defined by the relation $\Pi(q, \beta) - b = 0$. Once the funds have been raised, the firm makes its operating decision to maximize shareholder value. The condition for an optimal operating decision is

$$D_1S = \int_{\beta}^{\omega} D_1\Pi dP = 0 \tag{18.56}$$

It follows by the PIU that the output scale increases with leverage if the probability of insolvency is positive, i.e., $P\{\Pi - b < 0\} > 0$. To see this, note that

$$\begin{aligned} \frac{\partial q}{\partial b} &= \frac{D_{12}S}{D_{22}S} \\ &= \frac{-D_1\Pi(q, \beta)p(\beta)\frac{\partial \beta}{\partial b}}{D_{22}S} \\ &> 0 \end{aligned} \tag{18.57}$$

The inequality follows because the marginal payoff is negative at the boundary of the financial distress event by the PIU, the denominator is negative by the concavity of the payoff function, and the boundary β of the financial distress event is an increasing function of leverage.

We also need to show that the increase in scale reduces the debt and corporate values. The value of the bond issue is $B(q, b)$, where

²⁰See [Rothschild and Stiglitz \(1970\)](#) or a definition of increasing risk and [MacMinn and Holtmann \(1983\)](#) for a demonstration of this equivalence result.

$$\begin{aligned}
 B(q, b) &= \int_{\Xi} \min\{\Pi, b\} dP & (18.58) \\
 &= \int_0^{\beta} \Pi dP + \int_{\beta}^{\omega} b dP
 \end{aligned}$$

The corporate value is

$$\begin{aligned}
 V(q) &= B(q, b) + S(q, b) & (18.59) \\
 &= \int_0^{\omega} \Pi dP
 \end{aligned}$$

The operating scale affects the probability of distress and the bond payoff in the distress event. Note that

$$\begin{aligned}
 D_1 B &= \int_0^{\beta} D_1 \Pi dP \\
 &< 0 & (18.60)
 \end{aligned}$$

by the PIU. Hence, the increase in risk suffices to reduce the bond value. The same increase in risk, of course, increases the stock value. Although it may be less apparent, the increase in risk reduces the corporate value if the probability of financial distress is positive. To see this, observe that Eq. (18.56) implicitly defines operating scale that maximizes the stock value; let q^s denote that scale. Let q^v denote the scale that maximizes corporate value; the next equation implicitly defines that operating scale.

$$\begin{aligned}
 V' &= \int_0^{\omega} D_1 \Pi dP \\
 &= 0 & (18.61)
 \end{aligned}$$

By comparing Eqs. (18.56) and (18.61), it is apparent that the PIU yields $q^s > q^v$ and so $V(q^s) < V(q^v)$. Therefore, in the absence of any mechanism to avoid the agency problem, the levered corporation has an incentive to increase the scale of its operation and so increase the risk of its debt issue. The agency cost of debt is $V(q^v) - V(q^s)$.

Now, consider whether a bond covenant requiring insurance can be written in a way that ameliorates or eliminates this risk shifting. Let i denote the insurance premium. Without the insurance the corporate payoff is $\Pi^u(q, \xi) = R(q, \xi) - L(q, \xi)$, where R and L represent the quasi-rent and property loss, respectively. With insurance, the corporate payoff is $\Pi^i(q, \xi) = R(q, \xi) - L(q, \xi) + \max\{0, L(q, \xi) - d\}$, where d is the deductible on the insurance. The insurance premium is the risk-adjusted presented value of the net loss, i.e.,

$$\begin{aligned}
 i(q, d) &= \int_0^{\omega} \max\{0, L(q, \xi) - d\} dP & (18.62) \\
 &= \int_{\gamma}^{\omega} (L(q, \xi) - d) dP
 \end{aligned}$$

The stock value of the firm with insurance is S^i where

$$\begin{aligned}
 S^i(q, b, d) &= \int_{\Xi} (\Pi^i - b) dP \\
 &= \int_{\beta}^{\omega} (R(q, \xi) - L(q, \xi) + \max\{0, L(q, \xi) - d\} - b) dP(\xi)
 \end{aligned}
 \tag{18.63}$$

Now the boundary of the insolvency event is β and it is implicitly defined by the condition

$$R(q, \beta) - L(q, \beta) + \max\{0, L(q, \beta) - d\} - b = 0
 \tag{18.64}$$

As before the boundary of the insurance event is γ and is implicitly defined by $L(q, \gamma) - d = 0$. The corporation makes the finance and insurance decisions *now*, knowing the impact that those decisions have on the subsequent production decisions. Hence, let $q(b, d)$ denote the optimal production decisions given the financing decisions, i.e., debt and insurance. Recall that the firm makes financing decisions and subsequently a production decision. Hence, the financing decisions may have an impact on the production decisions. Let $q(b, d)$ denote the optimal production decision as a function of the financing decisions. The following lemma shows what impact the financing decisions have on the production decision.

Lemma 1. *The function $q(b, d)$ is non-decreasing in b and d if $\beta > \gamma$.*

Proof 4. For the case the shareholder value is

$$S^i(q, b, d) = \int_{\beta}^{\gamma} (R(q, \xi) - L(q, \xi) - b) dP + \int_{\gamma}^{\omega} (R - b - d) dP
 \tag{18.65}$$

In this case, the first-order condition for the production decision is

$$\begin{aligned}
 D_1 S^i &= \int_{\beta}^{\gamma} (D_1 R(q, \xi) - D_1 L(q, \xi)) dP + \int_{\gamma}^{\omega} D_1 R dP \\
 &= 0
 \end{aligned}
 \tag{18.66}$$

Suppose the second-order condition for the production decisions is satisfied.²¹ It follows that

$$\begin{aligned}
 \frac{\partial q}{\partial b} &= - \frac{D_{21} S^i}{D_{11} S^i} \\
 &= - \frac{-(D_1 R(q, \beta) - D_1 L(q, \beta)) p(\beta) \frac{\partial \beta}{\partial b}}{D_{11} S^i} \\
 &> 0
 \end{aligned}
 \tag{18.67}$$

The inequality in (18.67) follows because the marginal payoff is negative at the boundary by the PIU and β is increasing in leverage b . Similarly,

²¹While the quasi-rent is concave that concavity does not always suffice to make the secondorder condition hold.

$$\begin{aligned}
\frac{\partial q}{\partial d} &= -\frac{D_{31}S^i}{D_{11}S^i} \\
&= -\frac{(D_1R(q, \gamma) - D_1L(q, \gamma))p(\gamma)\frac{\partial \gamma}{\partial d} - D_1R(q, \gamma)p(\gamma)\frac{\partial \gamma}{\partial d}}{D_{11}S^i} \\
&= -\frac{-D_1L(q, \gamma)p(\gamma)\frac{\partial \gamma}{\partial d}}{D_{11}S^i} \\
&< 0
\end{aligned} \tag{18.68}$$

Since the property loss is increasing in q and is increasing in d .

For the case in which $\beta > \gamma$ the shareholder value is

$$S^i(q, b, d) \int_{\beta}^{\omega} (R(q, \xi) - b - d)dP(\xi) \tag{18.69}$$

In this case, the first-order condition for the production decision is

$$D_1S^i = \int_{\beta}^{\omega} D_1RdP = 0 \tag{18.70}$$

Again, suppose the second-order condition for the production level is satisfied. It follows that

$$\begin{aligned}
\frac{\partial q}{\partial b} &= -\frac{D_{21}S^i}{D_{11}S^i} \\
&= -\frac{-D_1R(q, \beta)p(\beta)\frac{\partial \beta}{\partial b}}{D_{11}S^i} \\
&> 0
\end{aligned} \tag{18.71}$$

since β increases with leverage b and the quasi-rent R is negative at the boundary by the PIU. Similarly,

$$\begin{aligned}
\frac{\partial q}{\partial d} &= -\frac{D_{31}S^i}{D_{11}S^i} \\
&= -\frac{-D_1R(q, \beta)p(\beta)\frac{\partial \beta}{\partial d}}{D_{11}S^i} \\
&> 0
\end{aligned} \tag{18.72}$$

again since increases with deductible d and the quasi-rent R is negative at the boundary by the PIU. *QED*

Theorem 3. *If the probability of insolvency is positive, i.e., $P\{B\} > 0$, then insuring the property risk is optimal.*

Proof 5. Recall that the corporation makes insurance and capital structure decisions and subsequently makes the production decision. The production decision is a function of the leverage and insurance decisions. By Corollary 1, the condition for an optimal insurance decision is one that maximizes the risk-adjusted net present value $V(q(b, d), d) - i(q(b, d), d)$. Note that the manager takes the incentive

effects of the financing decisions into account through the function $q(b, d)$. The derivative of this risk-adjusted net present value with respect to the deductible is

$$\begin{aligned} \left. \frac{\partial}{\partial d} (V(q(b, d), d) - i(q(b, d), d)) \right|_{q=q^s} &= (D_1V - D_1i) \frac{\partial q}{\partial d} + D_2V - D_2i \\ &= \left(\int_0^\omega (D_1R - D_1L) dP \right) \frac{\partial q}{\partial d} \\ &< 0 \end{aligned} \quad (18.73)$$

The derivative $D_2V - D_2i$ is zero by direct calculation. At the production decision that maximizes stock value for a levered firm with a positive probability of insolvency, i.e., q^s , the derivative in parentheses is negative by the PIU; similarly, given a positive probability of insolvency the production decision is increasing in the deductible. Hence, the positive probability of insolvency yields a negative sign for the derivative in (18.73) when evaluated at q^s and so it is optimal to reduce the deductible; equivalently, it is optimal to insure. *QED*

Theorem 3 represents one more example of the link between finance decisions, i.e., including insurance, and operating decisions. It does not contradict a corollary of the 1958 Modigliani–Miller theorem which would say that the value of the insured firm equals that of the uninsured firm. Indeed, we see that $D_2V - D_2i = 0$ in (18.73) shows that such a corollary holds. The link between finance and production is more subtle; it enters through the incentives provided by the financial decisions which have been made prior to the production decisions.

This particular application of the risk-shifting problem is as common as any production decision and the result shows that insurance can be effective in mitigating the effects of risk shifting and so credibly committing the firm to a particular operating decision. The theorem shows that the insurance allows the current shareholder value to be increased despite the fact that, viewed by itself, the insurance is a zero risk-adjusted net present value decision.

18.3.6 Management Compensation

Most of the existing literature on the corporate demand for insurance rests either implicitly or explicitly on the notion that the decisions on corporate account are made to maximize the current shareholder value. In Theorem 1 above the manager was assumed to be compensated in part with corporate stock and the theorem shows that the corporate manager will act in the interests of shareholders when making decisions on corporate account. Indeed the manager will make decisions on corporate account to maximize current shareholder value. If, however, the form of compensation is changed then so is the corporate objective function used by the manager to make decisions on behalf of the corporation.

Stock options became an increasingly important component of executive compensation in the last two decades of the twentieth century, e.g., see [Murphy \(1998\)](#) and [Murphy \(1999\)](#). Stock options were supposed to align the incentives of management and shareholders since options give management the incentive to increase the share price. The deductive foundation for this conventional wisdom was, however, never provided in the literature. There were some early empirical pieces that claimed to show that stock options would promote more risk taking to the detriment of shareholders, e.g., see [DeFusco, Johnson, and Zorn \(1990\)](#) who showed that stock return variance increased after the approval of an executive stock option plan. There were also theoretical pieces that showed that stock option plans provided the incentive to take on more risk via more leverage, e.g., see [MacMinn and Page \(1991\)](#),

MacMinn and Page (1995), and MacMinn and Page (2006) who show that a manager paid in stock options has the incentive to make decisions on corporate account to maximize the value of those options.²²

The literature on the demand for corporate insurance is one thread of the broader literature on risk management and management compensation. In this literature Smith and Stulz (1985) consider a managerial motive that provides a linkage between compensation and corporate decision-making. Smith and Stulz show that the risk averse manager compensated with stock will use forward contracts to hedge risk; they also show that when the compensation is stock options, the options will ultimately eliminate the incentive to hedge.²³ There is some empirical support for the managerial theory in Tufano (1996).^{24,25} The Smith and Stulz model differs from that here because they do not allow the corporate executive to hold a portfolio on personal account or diversify that portfolio. The managerial analysis is reframed here and the corporate objective function is derived for the manager paid in stock options. The analysis in Han and MacMinn (2006) shows that the manager paid in stock options will not manage the corporate risk with forward contracts, or equivalently, will not hedge. This might suggest that the manager will also not use insurance to manage risk, but Han and MacMinn (2006) show that not all risk management tools are created equal. A forward contract reduces risk by eliminating weight from the tails of the corporate earnings distribution and this reduces the value of the stock options. The liability insurance considered here requires a premium *now* for coverage *then*; it transfers cash from out-of-the-money states to in-the-money states. If, as supposed, the liability losses to the corporation are positively correlated with its earnings then the liability insurance increases the value of the stock options and so provides the manager with the incentive to insure. This is summarized in the following theorem.

Theorem 4. *Let R , L , and $R-L$ be increasing in state. Ceteris paribus, the manager paid in stock options and financing the corporate investment with safe debt has an incentive to insure liability losses.*

For a proof see Han and MacMinn (2006). While liability losses were considered in Han and MacMinn (2006), it is the positive correlation between earnings and losses that drives the result. If the losses are negatively correlated with earnings so that losses decrease in state but earnings R and net earnings $R-L$ increase in state then insuring the losses would decrease the value of the stock options and leave the manager with no incentive to insure.

While compensation schemes with stock options have been investigated, the literature on bonuses is much smaller, i.e., see Brander and Poitevin (1992) and MacMinn (1992). In a financial market setting MacMinn (1992) shows that the manager compensated with salary and a risky bonus will

²²Also see MacMinn (2005).

²³Also see (Carpenter 2000) for the effects of a convex compensation scheme on the behavior of a risk averse manager.

²⁴Tufano studies the risk management practices in the gold mining industry and finds that managers who own more stock options manage gold price risk less using forward sales, gold loans, options, and other hedging activities as measures of risk management. While this may be consistent with the Smith and Stulz model, it is also consistent with the financial market theory developed in the work by MacMinn and Page; that work does not appeal to risk aversion.

²⁵Doherty et al. (2011) provide an alternative theory of management compensation based upon game theory which creates hedging incentives that do not depend upon risk aversion, as is the case in Tufano's work. In their model, management compensation contracts combine stock options along with firing provisions resulting in a fully revealing subgame-perfect equilibrium in which the manager retains "signal" risks but hedges "noise" risks. "Signal" risks represent corporate risks which convey important information concerning the firm's future earnings prospects whereas uninformative "noise" risks do not. Thus Tufano (1996) empirical finding that option-compensated managers of gold mining firms tend not to hedge gold price risk is consistent with the Doherty, Garven, and Sinclair model since gold prices are presumably "signal" risks. Although Tufano does not consider other forms of corporate hedging in his analysis the Doherty Garven, and Sinclair model predicts that these very same managers who prefer not to hedge gold prices will nevertheless be quite motivated to hedge "noise" risks e.g., by purchasing property-liability insurance.

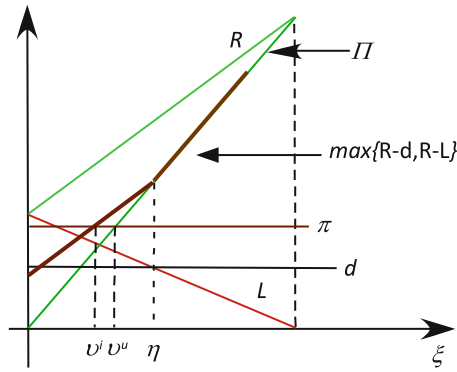


Fig. 18.4

make decisions on corporate account to maximize the value of the bonus scheme. While the empirical literature treats bonuses and stock options similarly, the incentives for some decisions are quite different. A simple generic bonus scheme is considered here without the confounding effects of stock options.

Suppose here that a bonus of m dollars is paid to management if the corporate payoff then exceeds π dollars. The bonus event is shown in the next figure. The bonus payoff is

$$= \begin{cases} 0 & \xi < v \\ m & \xi \geq v \end{cases} \tag{18.74}$$

where v is the boundary of the bonus event. The value of the bonus *now* is

$$M(d) = \int_v^\omega m dP(\xi) \tag{18.75}$$

where d is the deductible in the insurance contract. Note that for sufficiently small d , v is implicitly defined by the condition $R(v) - d = 0$.²⁶ Since R increases in state, it follows that v is a non-decreasing function of the deductible d . Hence, $M'(d) = -mp(v)dv/dd < 0$. The states v^u and v^i are the boundary states in the uninsured and insured cases, respectively. The states v^u and v^i are shown in Fig. 18.4.

The next theorem shows the incentive effects associated with bonus schemes.

Theorem 5. *Suppose the corporate manager receives a salary package (y_0, y_1) and a bonus of m dollars if the corporate payoff then exceeds d dollars. Suppose the manager pursues her own self-interest in making decisions on personal and corporate account. The decisions on personal account may be separated from those on corporate account and the decisions on corporate account are made to maximize bonus value.²⁷*

Letting M^u and M^i denote the bonus value now for the uninsured and insured cases, it may be noted that the manager prefers to insure since $M^i > M^u$. The next theorem verifies this claim.

²⁶There is a deductible such that $v^u = \eta$. For any smaller deductible the boundary of the bonus event decrease with the deductible.

²⁷The proof is like that for Theorem 1 and so is omitted here.

Theorem 6. *Suppose the loss L is decreasing in state and the earnings and net earnings, i.e., R and $R-L$, are increasing in state. The manager compensated with a risky bonus on net earnings has an incentive to purchase insurance.*

Proof 6. Note that $R(v) - d = 0$ implicitly defines the boundary of the bonus event. By the Implicit Function Theorem it follows that

$$\frac{dv}{dd} = \frac{1}{R'} > 0 \quad (18.76)$$

since earnings increase in state. Then by L'Hospital's rule

$$\frac{dM}{d} = -mp(v) \frac{dv}{dd} < 0 \quad (18.77)$$

Hence, the corporate manager can increase the value of the bonus by decreasing the deductible, i.e., by increasing insurance coverage. *QED*

Theorem 6 shows that a manager compensated in part with a bonus has the incentive to manage earnings to increase the probability of obtaining that bonus. *Ceteris paribus*, the insurance does not increase the value of the firm; the insurance does increase that portion of firm value that goes to the manager.²⁸

Some work has gone into determining the corporate objective for other cases in which management has a more complex compensation package, e.g., see [MacMinn and Han \(1990\)](#), [Sundaram and Yermack \(2007\)](#), [Edmans \(2007\)](#), and [MacMinn \(2012\)](#). This work has shown that management paid in stock and fixed deferred compensation²⁹ has an incentive to make decisions on corporate account to maximize a weighted average of current shareholder value and liability value. If the weights are the same then management has the incentive to maximize corporate value or equivalently to maximize the value for all stakeholders of the corporation. If the management has a liability stake larger than its equity stake in the corporation [MacMinn and Han \(1990\)](#) have shown that management has the incentive to purchase liability insurance to protect that stake. Far more work remains to be done to show the incentive effects of more complex compensation packages that exist.

18.4 Empirical Considerations

This chapter addresses the incentives for corporations to purchase insurance. Not surprisingly, many of these same incentives also motivate other forms of risk management, e.g., hedging risk using derivatives. [Smith \(2007\)](#), [Smithson, and Simkins \(2005\)](#) and [Aretz, Batram, and Dufey \(2007\)](#) survey the theory and empirical evidence for hedging. In this section of the chapter, we focus our attention on some empirical considerations pertaining to the study of the demand for corporate insurance.

[Smith \(2007\)](#) enumerates three important limitations pertaining to empirical studies of corporate hedging behavior. Since similar problems exist in empirical studies of corporate insurance purchases, the Smith critique is worth considering and expanding upon here. The first limitation involves the apparent failure of many studies to recognize an important endogeneity problem. Specifically,

²⁸The bonus can be used to solve the risk-shifting problem noted in the last section, e.g., see [MacMinn \(1992\)](#).

²⁹The fixed deferred compensation is a liability claim on the earnings of the corporation and is a claim much like that of bondholders. The analysis in [MacMinn, Ren, and Han \(2012\)](#) assumes that the debt and other liability claims are equal in the pecking order.

the empirical hedging literature typically focuses upon a particular form of hedging, e.g., hedging commodity prices or foreign exchange risks with futures contracts, while ignoring other corporate contractual features which may also have risk management implications, e.g., the issuance of hybrid securities. We believe that it is also potentially problematic to ignore other aspects of risk management decision-making and contracting behavior such as corporate purchases of insurance and managerial compensation contract design. In other words, it is important to consider how a given risk management decision interacts with and is affected by the firm's overall risk management strategy. One must also think carefully about whether managerial compensation contracts provide managers with the incentive to maximize shareholder value or their own welfare in this broader "enterprise" risk management context.

A second limitation noted by Smith is the wide degree of variation that exists pertaining to the disclosure of corporate risk management decisions. Hypothetically, this can cause otherwise identical firms to appear as if they pursue different risk management strategies when in fact these differences may be driven in part by the adoption of different disclosure policies. Although this problem has been mitigated somewhat by various FASB Statements of Financial Accounting Standards, e.g., SFAS 105 and SFAS 133, it has not been eliminated. One popular strategy for addressing this problem has been to study risk management decisions within the context of specific industries, e.g., the [Tufano \(1996\)](#) study of hedging in the North American gold mining industry, the [Jin and Jorion \(2006\)](#) study of hedging in the U.S. oil and gas industry, and the [Mayers and Smith \(1990\)](#) study of reinsurance purchases by U.S. property–liability insurance companies come to mind.³⁰ Unfortunately, the benefit of potentially limiting variation in disclosure comes at the cost of limiting the generality of industry-specific empirical studies.

The third limitation cited by Smith pertains to heterogeneity in terms of important differences in the notional value and duration of different risk management instruments which make it difficult to accurately calibrate the extent to which firms actually hedge. This is also a common data problem for studies of corporate insurance purchases. For example, the NAIC database which is typically used in empirical studies of reinsurance provides information on reinsurance premiums and losses, but it does not include information concerning specific contract features such as deductibles, coinsurance, and upper limits, etc.³¹ A notable exception is the proprietary Swiss Re property insurance database used by [Aunon-Nerin and Ehling \(2008\)](#) which includes highly detailed information including the premium paid, the duration of the contract, and its deductible and coverage limits.

Besides the endogeneity and data problems referenced above, another important problem worth noting concerning empirical research on the demand for corporate insurance relates to model specification. As we showed in [Theorems 2 and 3](#), leverage may give rise to underinvestment and risk-shifting incentives which are mitigated by coordinating financing and risk management decisions. Other literature, however, indicates that excessive leverage may also impose other costs upon the firm, e.g., bankruptcy and tax-related costs, which can be mitigated by risk management. Thus, when we observe that firms with higher leverage buy more insurance than firms with lower leverage, we cannot reliably differentiate between competing hypotheses unless theory is used to inform model specification. For example, [Aunon-Nerin and Ehling \(2008\)](#) claim that their study rationalizes the purchase of property insurance to avoid costs of financial distress by empirically demonstrating that the demand for insurance coverage is higher for firms with higher leverage. What makes their claim convincing is that while deductibles are smaller and coverage limits are larger for leveraged firms,

³⁰In the case of the U.S. property–liability insurance industry, there is virtually no discretion regarding disclosure of reinsurance transactions since the National Association of Insurance Commissioners (NAIC) requires all U.S. domiciled property–liability insurers to systematically report all reinsurance arrangements that they have with other insurers as well as specialist reinsurance companies.

³¹However, it is possible to measure contract duration using this database; see [Garven and Grace \(2011\)](#).

this effect is less pronounced for larger firms than it is for smaller firms, which is logically consistent with the notion due to Warner (1977) that bankruptcy costs are concave in firm size. While this evidence concerning the leverage/size interaction effect does not rule out the importance of other risk management mechanisms *per se*, it certainly favors the financial distress cost hypothesis.

In addition to informing model specification, theory can also help inform proper interpretation of empirical results. As we showed in our Proof of Theorem 4, since executive stock options payoff in the right tail of the distribution, the option compensation encourages insurance to the extent that insurance makes it more likely that right-tail payoffs obtain, i.e., that options end up in the money. Thus insurance is potentially quite valuable to a manager who has a compensation contract which includes options, a result which is largely due to positive correlation between earnings and losses. If, however, earnings and losses are negatively correlated, then insurance only pays off in states where options are likely to be out of the money anyway and in this case insurance lowers the welfare of an option-compensated manager.

Keeping this result in mind, it should at least call into question the generality of the Beatty, Gron, and Jorgensen (2005) result which finds an inverse relationship between the propensity for firms to purchase product liability insurance and the extent to which managers are option-compensated but without noting any necessary correlation between earnings and losses. From a theoretical perspective, it is not clear whether the Beatty, Gron, and Jorgensen's empirical result in their study of product liability insurance contracting would necessarily hold in studies involving other forms of corporate insurance contracting or the same forms of insurance at different times.

18.5 Concluding Remark

The corporation has an active role to play in managing risk if it is possible for the corporation to alter the earnings distribution in a way that investors cannot duplicate on personal account. Investors can protect themselves from the valuation problems caused by hidden knowledge and hidden action on the part of the corporation by valuing the corporate securities based on rational expectations of the decisions made by corporate management. Investors can, for example, hedge the insolvency risk of a corporation on personal account but that hedging on personal account does not affect the magnitude of the risk. Hence, these are areas that provide natural incentives for corporate decision makers to manage risk. The analysis shows that the corporation can increase value by actively pursuing strategies that limit insolvency risk; corporate insurance is emphasized in the analysis but is just part of a more comprehensive strategy that might be designed to control or counter insolvency risk.

In the section on agency problems, the risk management role of insurance is investigated in the context of the underinvestment problem and the risk-shifting problem. The problems are seemingly different; in the underinvestment problem the firm limits the scale of the investment because part of the gain accrues to general creditors rather than shareholders while in the risk-shifting problem the firm selects a riskier project or pushes the scale of production beyond that which maximizes corporate value because additional gains would go to shareholders. An insurance contract can be used in reducing the scope of each problem because each shares a common source. The insolvency risk is that common source and the insurance contract are designed to reduce that risk. Hence, the analysis shows that the corporate operations, i.e., investment and production, can be selected to maximize shareholder value if the contracts used to finance the corporation are structured to credibly commit the corporation to value maximizing actions.

In the section on management compensation, the risk management role of insurance is also investigated. If management is compensated with stock options and the corporate earnings are positively correlated with liability losses then management has an incentive to insure the liability losses. If management is compensated with a bonus scheme and property losses are negatively

correlated with corporate earnings then management has an incentive to insure the property. The theory literature is almost silent on compensation schemes which are more complex; what little literature there is suggests that management will balance decisions made on corporate account to maximize the weighted value of the components of the compensation scheme, but little is known about the demand for corporate insurance given the more complex compensation schemes.³² In the penultimate section, there is some discussion of the need for more empirical tests based on received theory.

Appendix

Consider the function $b(a, d)$ noted in Theorem 1. It is implicitly defined by

$$F(a, b, d) = B(a, d) - i(a, d) = 0 \tag{18.78}$$

Then

$$F(a, b, d) = \int_0^\beta \Pi^i(a, \xi) dP + \int_\beta^\omega b dP - \int_\gamma^\omega (L(a, \xi) - d) dP \tag{18.79}$$

If D_2F is not zero then a function $b(a, d)$ exists. Note that

$$D_1F + D_2F \frac{\partial b}{\partial a} \tag{18.80}$$

and

$$D_2F \frac{\partial b}{\partial d} + D_3F = 0 \tag{18.81}$$

yield

$$\frac{\partial b}{\partial a} = -\frac{D_1F}{D_2F} \tag{18.82}$$

and

$$\frac{\partial b}{\partial d} = -\frac{D_3F}{D_2F} \tag{18.83}$$

Next, note that

$$\begin{aligned} D_1F &= \begin{cases} \int_0^\beta (D_1R - D_1L) dP - \int_\gamma^\omega D_1L dP & \text{if } \beta \leq \gamma \\ \int_0^\gamma (D_1R - D_1L) dP + \int_\gamma^\beta D_1R dP - \int_\gamma^\omega D_1L dP & \text{if } \beta > \gamma \end{cases} \\ &= \begin{cases} \int_0^\beta (D_1R - D_1L) dP - \int_\gamma^\omega D_1L dP & \text{if } \beta > \gamma \\ \int_0^\beta (D_1R - D_1L) dP - \int_\beta^\omega D_1L dP & \text{if } \beta > \gamma \end{cases} \end{aligned} \tag{18.84}$$

$$D_2F = \int_\beta^\omega dP \tag{18.85}$$

³²MacMinn and Han (1990) is an exception. There, however, only liability insurance is considered.

Hence,

$$\frac{\partial b}{\partial d} = \begin{cases} -\frac{\int_{\gamma}^{\omega} dP}{\int_{\beta}^{\omega} dP} & \text{if } \beta \leq \gamma \\ -1 & \text{if } \beta > \gamma \end{cases} \quad (18.86)$$

and

$$\begin{aligned} \frac{\partial b}{\partial a} &= -\frac{D_1 F}{D_2 F} \\ &= \begin{cases} -\frac{\int_0^{\beta} (D_1 R - D_1 L) dP - \int_{\gamma}^{\omega} D_1 L dP}{\int_{\beta}^{\omega} dP} & \text{if } \beta \leq \gamma \\ -\frac{\int_0^{\beta} (D_1 R - D_1 L) dP - \int_{\beta}^{\omega} D_1 L dP}{\int_{\beta}^{\omega} dP} & \text{if } \beta > \gamma \end{cases} \\ &> 0 \end{aligned} \quad (18.87)$$

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Chapter 19

Managing Catastrophic Risks Through Redesigned Insurance: Challenges and Opportunities

Howard Kunreuther and Erwann Michel-Kerjan

Abstract Catastrophic risks associated with natural disasters have been increasing in many countries including the United States because more individuals and firms have located in harm's way while not taking appropriate protective measures. This chapter addresses ways to reduce future losses by first focusing on behavioral biases that lead homeowners and decision-makers *not* to invest in adequate protection. It then turns to developing proposals for risk management strategies that involve private–public partnerships. These include multiyear insurance contracts with risk-based premiums coupled with mitigation loans and insurance vouchers to address affordability concerns for low-income homeowners, tax incentives, well-enforced building codes and land-use regulations.

“Our nation is facing large-scale risks at an accelerating rhythm, and we are more vulnerable to catastrophic losses due to the increasing concentration of population and activities in high-risk coastal regions of the country. The question is not whether catastrophes will occur, but when and how frequently they will strike, and the extent of damage they will cause. Now is the time to develop and implement economically sound policies and strategies for managing the risk and consequences of future disasters. Absence of leadership in this area will inevitably lead to unnecessary loss of lives and economic destruction in the devastated regions.”

Kunreuther & Michel-Kerjan, *At War with the Weather* (2011), Preface

“Insurance plays a vital role in America’s economy by helping households and businesses manage risks. When insurance prices reflect underlying economic costs they can encourage a more efficient allocation of resources. Efforts to keep premiums for insurance against catastrophe hazards artificially low, whether through regulation or through subsidized government programs, can encourage excessively risky behavior on the part of those who might be affected by future catastrophes.”

White House, Economic Report of the President (2007), pp.122–123.

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19.1 Introduction

In 2007, the *Economic Report of the President* devoted an entire chapter to catastrophe risk insurance in which it recognized that the United States is facing increasingly greater losses from extreme events such that innovative measures are required to deal with this situation. Many other countries have also realized that they urgently need to address the challenges posed by large-scale natural disasters and other extreme events.

19.1.1 Economic Losses from Recent Catastrophes

Economic and insured losses from great natural catastrophes such as hurricanes, earthquakes, and floods have increased significantly in recent years. According to [Munich Re \(2013\)](#), economic losses from natural catastrophes alone increased from \$528 billion (1981–1990), \$1,197 billion (1991–2000) to \$1,213 billion (2001–2010). During the past 10 years, the losses were principally due to hurricanes and resulting storm surge occurring in 2004, 2005, 2008, and 2012. Figure 19.1 depicts the evolution of the direct economic losses and the insured portion from great natural disasters over the period 1980–2012.¹

Hurricane Katrina, which severely struck Louisiana and Mississippi in the United States in August 2005, resulted in massive flooding after the inadequate levee system failed. Over 1,300 people died, millions were displaced, and the response by the US Federal Emergency Management Agency was seen by many as being inadequate. Hurricane Katrina was “only” a Category 3 hurricane when it made landfall, but its strength combined with the failure of the flood protection system led to economic losses in the range of \$150–\$200 billion—an historical record in the United States for a natural disaster. Given the massive economic losses from the March 2011 Japan earthquake and resulting tsunami, the year 2011 was the most costly year on record for disasters globally: \$370 billion. The year 2012 was the third most costly, with losses of about \$186 billion, mostly due to Hurricane Sandy ([Swiss Re 2013](#)).

Insured losses have dramatically increased as well. Between 1970 and the mid-1980s, annual insured losses from natural disasters worldwide (including forest fires) were only in the \$3 billion to \$4 billion range. Hurricane Hugo, which made landfall in Charleston, South Carolina, on September 22, 1989, was the first natural disaster in the United States to inflict more than \$1 billion of insured losses, with insured losses of \$4.2 billion (1989 prices). During the period 2001–2010, insured losses from weather-related disasters alone averaged \$30 billion annually ([Swiss Re 2011](#)).

Table 19.1 ranks the 25 most costly *insured* catastrophes that occurred in the world over the period 1970–2012. The data reveals that eighteen of these disasters occurred since 2001, with almost two-thirds in the United States, due in part to the high concentration of values at risk and the high degree of insurance penetration compared to less developed countries.

19.1.2 Impact on Gross Domestic Product (GDP)

At a more aggregate level, one can estimate the economic impact of disasters by determining the losses in relation to the country’s annual GDP. A major flood in the USA or a large European country

¹Catastrophes are classed as “great” if the ability of the region to help itself is overtaxed, making inter-regional or international assistance necessary. This is normally the case when thousands of people are killed, hundreds of thousands made homeless or when a country suffers substantial economic losses.

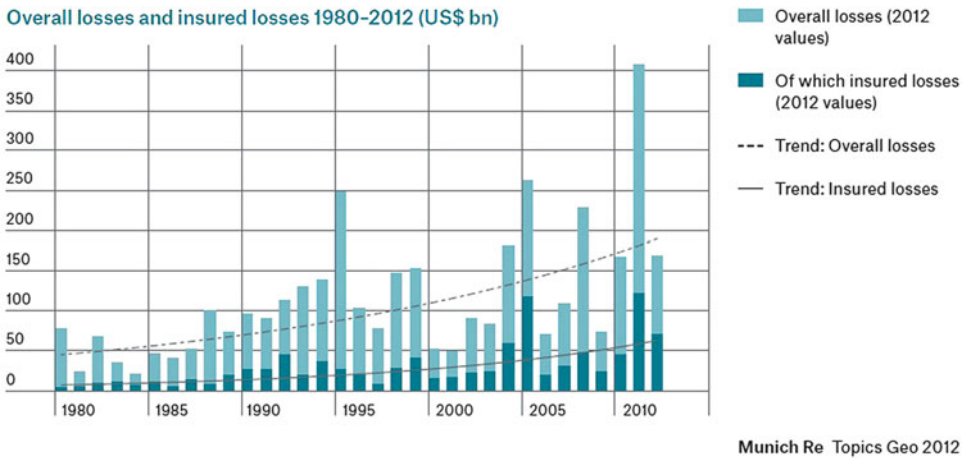


Fig. 19.1 Natural catastrophes worldwide 1980–2012. Overall and insured losses (\$ billion). *Source:* Munich Re (2013)

Table 19.1 The 25 most costly insurance losses (1970–2012) (in \$ billion, indexed to 2012)**

| Insured loss | Event | Victims (Dead and Missing) | Year | Country |
|--------------|--|----------------------------|------|--|
| 76.3* | Hurricane Katrina | 1,836 | 2005 | USA, Bahamas, North Atlantic |
| 35.7 | Earthquake (M _w 9.0) | 19,135 | 2011 | Japan |
| 35.0 | Hurricane Sandy | 237 | 2012 | USA et al. |
| 26.2 | Hurricane Andrew | 43 | 1992 | USA, Bahamas |
| 24.3 | 9/11 attacks | 2,982 | 2001 | USA |
| 21.7 | Northridge earthquake (M 6.6) | 61 | 1994 | USA |
| 21.6 | Hurricane Ike | 136 | 2008 | USA, Caribbean: Gulf of Mexico et al. |
| 15.7 | Hurricane Ivan | 124 | 2004 | USA, Caribbean: Barbados et al. |
| 15.3 | Floods | 815 | 2011 | Thailand |
| 15.3 | Earthquake (M _w 6.3) | 181 | 2011 | New Zealand |
| 14.8 | Hurricane Wilma | 35 | 2005 | USA, Mexico, Jamaica, Haiti et al. |
| 11.9 | Hurricane Rita | 34 | 2005 | USA, Gulf of Mexico, Cuba |
| 11.0 | Drought in the Corn Belt | 123 | 2012 | USA |
| 9.8 | Hurricane Charley | 24 | 2004 | USA, Cuba, Jamaica et al. |
| 9.5 | Typhoon Mireille/No 19 | 51 | 1991 | Japan |
| 8.5 | Hurricane Hugo | 71 | 1989 | USA, Puerto Rico et al. |
| 8.4 | Earthquake (M _w 8.8), tsunami | 562 | 2010 | Chile |
| 8.2 | Winter storm Daria | 95 | 1990 | France, UK, Belgium, Netherlands et al. |
| 8.0 | Winter storm Lothar | 110 | 1999 | Switzerland, UK, France et al. |
| 7.4 | Storm and tornadoes | 354 | 2011 | USA (Alabama et al.) |
| 7.2 | Storms and tornadoes | 155 | 2011 | USA (Missouri et al.) |
| 6.7 | Winter storm Kyrill | 54 | 2007 | Germany, UK, Netherlands, Belgium et al. |
| 6.3 | Storm and floods | 22 | 1987 | France, UK, Netherlands et al. |
| 6.3 | Hurricane Frances | 38 | 2004 | USA, Bahamas |
| 6.0 | Hurricane Irene | 55 | 2011 | USA et al. |

* Includes flood claims covered by NFIP

** Property and business interruption, excluding liability and life insurance losses; US natural catastrophe figures: based on Property Claim Services

Source: Swiss Re (2013)

will have much less impact on GDP than a similar event occurring in a developing country. In the United States where the GDP is nearly US\$15 trillion, even a US\$250 billion loss will have an impact on GDP that is less than 2%. By contrast, in Myanmar, a 2% GDP loss would be associated with damages in the range of US\$1.8 billion.

Smaller countries also often have a more limited geographical spread of their economic assets relative to the spatial impact of disasters and are subject to more direct, indirect, and downstream losses. Island nations can also face increased disaster risks by not only having a smaller economy, but also having a larger proportion of their total land exposed to hazard (UNDP 2004).

Using annual GDP to measure the relative economic consequences of a disaster does not necessarily reveal the impact of the catastrophe on the affected region; property damage, business interruption, and reduction in real estate prices and tax revenues could be severe locally but not enough to have an impact on the GDP. The long-term effects of disasters on a country's GDP can also vary based on the state of development of the country, the size of the event, and the overall economic vulnerability of the country. Potentially negative long-term economic effects after a disaster include the increase of the public deficit and the worsening of the trade balance (demand for imports increase and exports decrease). For example, after Hurricane Mitch in 1998, Honduras experienced total direct and indirect losses that were 80% of its GDP (Mechler 2003).

19.1.3 Fatalities

Natural disasters also have a much higher devastating human impact in low-income countries than in the developed world. The Bhola cyclone in the Ganges Delta in 1970 killed an estimated 500,000 in East Pakistan (now Bangladesh) and is classified as one of the deadliest natural disasters in history. In recent years, the 2004 tsunami in Southeast Asia killed between 225,000 and 275,000; the earthquake in Haiti in 2010 killed approximately 230,000 (CBC News 2010). The historical floods in Pakistan in the summer of 2010 killed 2,000 and affected 20 million people. These fatalities have a long-term impact on the development potential for a country. A population weakened by a natural disaster can often lack the organizational capacity to maintain social assets, making communities more vulnerable. In addition to a disaster's impact on social assets, losses in sanitation, education, health, housing, etc., can further cripple an already affected nation (UNISDR/World Bank 2011).

19.1.4 Increasing Population in High Risk Areas

Driving the aforementioned increasing losses from natural disasters are two socio-economic factors that directly influence the level of economic damage: degree of urbanization and value at risk. In 1950, about 30% of the world's population (2.5 billion people) lived in cities. In 2000, about 50% of the world's population (6 billion) lived in urban areas. Projections by the United Nations show that by 2025, this figure will have increased up to 60% as the population reaches 8.3 billion people. A direct consequence of this trend is the increasing number of so-called mega-cities with populations above 10 million. In 1950, New York City was the only such mega-city. In 1990, there were 12 such cities. By 2015, there are estimated to be 26, including Tokyo (29 million), Shanghai (18 million), New York (17.6 million), and Los Angeles (14.2 million) (Crossett et al. 2004).

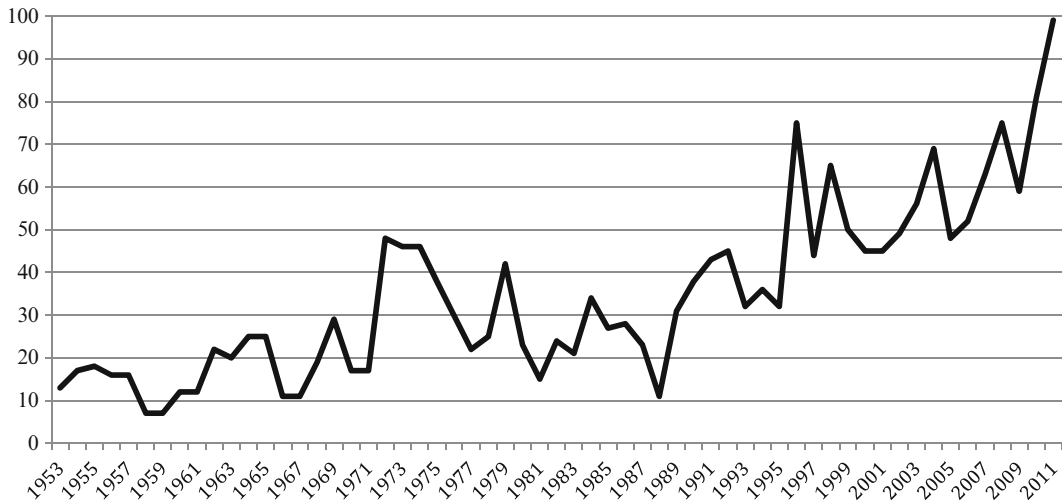


Fig. 19.2 US disaster presidential declarations per year, 1953–2011

With respect to the developing world, Istanbul, a city subject to losses from earthquakes, has significantly increased in population over the past 60 years, from less than 1 million in 1950 to more than 13 million at the end of 2010. This makes the Istanbul metropolitan area the third largest one in Europe after London and Moscow. In India, about 48% of the land is prone to cyclones, 68% to droughts, and more than 40 million hectares (nearly 1/8th of India) are prone to floods ([Government of India 2004](#)). Ten of the deadliest disasters since 1970 occurred in this country. Furthermore, several large cities in India subject to natural disasters are very densely populated. Mumbai (20 million people) has a population density of over 20,000 inhabitants per square kilometer. Between 1998 and 2011, the world's population increased from 6 to 7 billion. In the next 10–15 years, we can expect another billion people on planet Earth. Most of those individuals will reside in urban areas in developing countries subject to natural disasters. The need to build resilient communities is thus greater than ever before.

19.1.5 Increasing Government Disaster Relief

The upward trend in losses has had an impact on post-disaster relief to assist the affected communities in rebuilding destroyed infrastructure² and providing temporary housing to displaced victims. In the United States, federal and state governments have played an increasingly important role in providing such relief. Under the current US system, the Governor of the state(s) can request that the President declare a “major disaster” and offer special assistance if the damage is severe enough. Although the President does not determine the amount of aid (Congress does), the President is responsible for a crucial step in the process. A look at the number of US presidential disaster declarations since 1953 clearly reveals an upward trend (see Fig. 19.2).

Overall, the number of Presidential disaster declarations has dramatically increased over time, from 191 declarations over the decade 1961–1970 to 597 for the period 2001–2010 ([Michel-Kerjan and Kunreuther 2011](#)). As Fig. 19.2 also shows, many of the peak years correspond to presidential election years. This is consistent with recent research that reveals that Presidential election years

²On the question of protection of critical infrastructures, see [Auerswald et al. \(2006\)](#).

Table 19.2 Role of federal government in disaster relief

| Disaster | Federal aid as % of total damage |
|--------------------------|-------------------------------------|
| Hurricane Sandy | >80% |
| Hurricane Ike (2008) | 69% |
| Hurricane Katrina (2005) | 50% |
| Hurricane Hugo (1989) | 23% |
| Hurricane Diane (1955) | 6% |

Source: Michel-Kerjan and Volkman Wise (2011)

spur disaster assistance.³ Four salient examples are the Alaska earthquake (March 1964), Tropical Storm Agnes (June 1972), Hurricane Andrew (September 1992), and the four Florida hurricanes (August–September 2004). In 1996 and 2008 (both presidential election years) there were 75 presidential declarations. This record number was exceeded in 2010 when there were 81 major disaster declarations, and again in 2011 with 99 declarations. The more pronounced role of the federal government in assisting disaster victims can also be seen by examining several major disasters occurring in the past 50 years as shown in Table 19.2.⁴

Media coverage in the immediate aftermath of catastrophes often raises compassion for victims of the tragedy.⁵ The magnitude of the destruction often leads governmental agencies to provide disaster relief to victims, even if the government claimed that it had no intention of doing so before the disaster occurred. This inconsistent behavior has been termed the *natural disaster syndrome* (Kunreuther 1996).

The expectation of governmental funding results in economic disincentives for people and businesses to reduce their own exposure and/or purchase proper insurance coverage (Michel-Kerjan and Volkman Wise 2011).⁶ If individuals assume that they will be bailed out after a disaster, why should they purchase insurance or avoid locating in high-risk areas?⁷ The reality, though, is that governmental disaster relief is usually earmarked to rebuild destroyed infrastructure, not as direct aid to the victims. To the extent that a large portion of such disaster relief goes to the states, post-disaster assistance also distorts the incentives of state and local governments to pre-finance their disaster losses through insurance and other mechanisms.

Insurance can play an important role in dealing with these losses by providing financial protection following a disaster and encouraging property owners living and working in hazard prone areas to invest in cost-effective mitigation measures. As we will demonstrate below, however, many individuals do not purchase insurance voluntarily, nor do they invest in mitigation measures prior to a disaster. Furthermore, many individuals who purchase coverage cancel their policies several years later if they haven't suffered a loss. In the case of flood insurance, many of these uninsured individuals were required to buy a policy as a condition for a mortgage and to keep it for the length of the mortgage.

³Reeves (2004, 2005) shows that a battleground state with 20 electoral votes received more than twice as many Presidential disaster declarations as a state with only three electoral votes.

⁴See Cummins, Suher, and Zanjani (2010) for a more systematic analysis of government exposure to extreme events.

⁵Moss (2002; 2010) and Eisensee and Stromberg (2007) have shown the critical role played by increasing media coverage of disasters in increasing government relief in the United States. See Kunreuther and Miller (1985) for a discussion on the evolution of disaster relief in the 1980s. See also Raschky and Schwindt (2009) and Jaffee and Russell (2012).

⁶It is surprising how little data are publicly available on how much victims of disaster actually receive as direct aid. The Federal Emergency Management Agency (FEMA) has a series of disaster relief programs, but most of them are loan based (e.g. Small Business Administration's program). This can address the liquidity issues that victims and their families face after a disaster, but does not transfer the loss to a third party, as insurance does.

⁷See Browne and Hoyt (2000) for a discussion of the notion of "charity hazard."

19.1.6 Role of State Insurance Regulators

In addition to increasing federal relief, state and federal governments play a much more active role in catastrophe insurance markets than they did 10 or 20 years ago (as regulator and through more risk-sharing). Rate suppression by insurance regulators is not uncommon, especially in coastal areas. State insurance commissioners have constrained premiums in some hurricane-prone coastal regions by either suppressing the rates that private insurers may charge, and/or by providing coverage through state operations such as Florida's Citizens Property Insurance Corporation and the Texas Windstorm Insurance Association. These state pools subsidize rates to homeowners residing in hurricane-prone areas, thus undercutting private insurers' premiums (Klein 2007; Kunreuther and Michel-Kerjan 2011). Since the 2004–2005 hurricane seasons, several states have increased the market share of their state-run wind pools. For instance, Citizens is now the largest provider of homeowners' insurance in Florida, with nearly 1.5 million policyholders as of April 2012.⁸

19.1.7 Outline of the Chapter

This chapter is organized as follows. Section 19.2 proposes two principles for guiding the development of new catastrophe insurance programs. Section 19.3 highlights how investment in cost-effective mitigation can reduce future losses. Section 19.4 discusses why homeowners and businesses do not voluntarily invest in these protective measures and Sect. 19.5 suggests ways to encourage their adoption. Section 19.6 proposes that public and private insurers consider offering multiyear insurance (MYI) contracts tied to the property as a way of ensuring coverage in hazard-prone areas and encouraging adoption of mitigation measures. Section 19.7 shows how MYI could be adapted to cover flood losses through a modification of the National Flood Insurance Program (NFIP) and suggests future research directions for applying this concept to other extreme events. While the US market is an illustrative example in this chapter, we believe that our discussion and proposals apply to many other developed countries (OECD 2008; 2009).

19.2 Guiding Principles for Insurance

For insurance to play a key role in the management and financing of catastrophic risks, we propose the following two guiding principles that are discussed in greater detail in Kunreuther and Michel-Kerjan (2011):

Principle 1—Premiums Should Reflect Risk: Insurance premiums should be based on risk to provide signals to individuals as to the hazards they face and to encourage them to engage in cost-effective mitigation measures to reduce their vulnerability to catastrophes. Risk-based premiums should also reflect the cost of capital insurers needed to integrate into their pricing to assure adequate return to their investors.

Principle 1 provides a clear signal of the expected damage to those currently residing in areas subject to natural disasters and those who are considering moving into these regions. Insurers will also have an economic incentive to reduce premiums to homeowners and businesses who invest in cost-effective loss-reduction mitigation measures. If Principle 1 is applied in hazard-prone areas

⁸There are other insurance programs in which the liability of the federal government is very significant as well, such as flood insurance, crop insurance, and terrorism risk. See Brown (2010) for a review.

where premiums are currently subsidized, some residents will be faced with large price increases. This concern leads to the second guiding principle.

Principle 2—Dealing with Equity and Affordability Issues: Any special treatment given to residents currently residing in hazard-prone areas (e.g., low income homeowners) should come from general public funding and not through insurance premium subsidies.

It is important to note that Principle 2 applies only to those individuals who currently reside in hazard-prone areas. Those who decide to locate in the area in the future will be charged premiums that reflect the risk.

19.2.1 Determining Risk-Based Premiums

Catastrophe models have been developed and improved over the past 20 years to more accurately assess the likelihood and damages resulting from disasters of different magnitudes and intensities. Although there is uncertainty surrounding these figures, insurers and reinsurers have utilized the estimates from these models much more systematically to determine risk-based premiums and how much coverage to offer in hazard-prone areas.

Regulators should permit insurers to price their policies based on these risk assessments. If a competitive market is allowed to operate, then insurers would not engage in price-gouging since they would be undercut by another company who would know that it could profitably market policies at a lower price. Regulators would still have an important role by requiring that insurers have sufficient surplus to protect consumers against the possibility of their becoming insolvent following the next severe disaster.

19.2.2 Affordability of Coverage

Although issues of affordability of insurance have been widely discussed by the media, little economic analysis has been undertaken to examine how serious the problem is today. Using data from the American Housing Survey on eight cities in four states exposed to hurricane risks (Florida, New York, South Carolina and Texas), it was found that between 16% (Dallas) and 31% (Tampa) of owner-occupied homes are owned by households that cannot afford insurance using 200% of the federal poverty line as the threshold level. At 125% of the federal poverty line, the percentage varies from nearly 7% in Dallas to 17% in Tampa. Among low-income households judged unable to afford insurance, a large fraction of homes are nevertheless insured, even when there is no mortgage requiring coverage. Fewer than 28% of low-income homeowners (125% of the federal poverty line) fail to purchase insurance coverage in any of the cities studied. Any plan that directs subsidies to all low-income homeowners will allocate much of the payment to those who are already insured. In summary, these data reveal that many homeowners whose income is below 125% or 200% of the poverty line do purchase homeowners' insurance (Kunreuther and Michel-Kerjan 2011, Chap. 11).⁹

Equity issues also come into play here. If some homeowners see their premiums jump by thousands of dollars in a single year, they may feel treated unjustly relative to others with similar homes whose premiums remain unchanged. To deal with issues of equity and affordability we recommend that residents be given an insurance voucher. This type of in-kind assistance assures that the recipients use the funds for obtaining insurance rather than having the freedom to spend the money on goods and services of their own choosing.

⁹The analysis was undertaken by Mark Pauly.

A low-income family in a hazard-prone area would pay a risk-based insurance premium and then be provided with an insurance voucher to cover some fraction of the increased cost of insurance. The amount of the insurance voucher would be determined by the family's income and the magnitude of the increase in the insurance premium. Several existing programs could serve as models for developing such a voucher system: the Food Stamp Program, the Low Income Home Energy Assistance Program (LIHEAP) and Universal Service Fund (USF); we discuss them briefly in Appendix 1. Although a voucher can be justified on equity grounds and can serve as a basis for risk-based premiums there still may be resistance to this concept by real estate developers and builders and middle- and upper-income households who would prefer the current program of subsidized premiums.

19.2.3 Who Should Provide These Insurance Vouchers?

There are several different ways that funds for these vouchers could be obtained that address the general question as to who should pay for the risks faced by those currently residing in hazard-prone areas that deserve special treatment:

General taxpayer. If one takes the position that everyone in society is responsible for assisting those residing in hazard-prone areas, then one could utilize general taxpayer revenue from the federal government to cover the costs of insurance vouchers. The Food Stamp and the Low Income Home Energy Assistance Programs operate in this manner,

State government. An alternative (or complementary) source of funding would be to tax residents and/or commercial enterprises in the state exposed to natural disaster. States obtain significant financial benefits from economic development in their jurisdictions through the collection of property taxes or other revenue such as gasoline taxes, state income taxes, or sales taxes. If residents in coastal areas receive greater benefits from the economic development in these regions than others in the state, they should be taxed proportionately more than those residing inland.

Insurance policyholders. A tax could be levied on insurance policyholders to provide vouchers to those currently residing in hazard-prone areas who require special treatment. The rationale for this type of tax would be that all homeowners (as opposed to all taxpayers) should be responsible for helping to protect those who cannot afford protection, a rationale that is the basis for the Universal Service Fund that provides affordable telephone service to all residents in the country.

The above risk-sharing programs reflect different views as to who should pay for losses from natural disasters. By examining who bears the costs and who reaps the benefits from each of these proposed risk-sharing arrangements, political leaders could make more informed decisions.

19.3 Reducing Losses Through Mitigation Measures

While insurance can play an important role in hedging some of the financial losses due to natural disasters and other extreme events, it is also critical to find effective ways for it to encourage mitigation so as to reduce the human and social consequences from future natural disasters. We now show how loss-reduction measures can significantly reduce the economic impact of hurricanes as an illustrative example. More specifically we compared the impact of damage from hurricanes making landfall in New York, Texas, South Carolina, and Florida if all property conformed to the most recent building

Table 19.3 Saving from reduced losses from mitigation for different return periods

| State | 100-Year Event | | | 250-Year Event | | | 500-Year Event | | |
|-------|----------------------------|--|--------------------------------------|----------------------------|--|--------------------------------------|----------------------------|--|--------------------------------------|
| | Unmiti- gated Losses | Savings from reduced losses from mitigation | Savings from Mitigation (%) | Unmiti- gated Losses | Savings from reduced losses from mitigation | Savings from Mitigation (%) | Unmiti- gated Losses | Savings from reduced losses from mitigation | Savings from Mitigation (%) |
| FL | \$84 bn | \$51 bn | 61% | \$126 bn | \$69 bn | 55% | \$160 bn | \$83 bn | 52% |
| NY | \$6 bn | \$2 bn | 39% | \$13 bn | \$5 bn | 37% | \$19 bn | \$7 bn | 35% |
| SC | \$4 bn | \$2 bn | 44% | \$7 bn | \$3 bn | 41% | \$9 bn | \$4 bn | 39% |
| TX | \$17 bn | \$6 bn | 34% | \$27 bn | \$9 bn | 32% | \$37 bn | \$12 bn | 31% |

codes (2002 or later ones) with the case where no mitigation measures were in place.¹⁰ Table 19.3 indicates the differences in losses for hurricanes with return periods of 100, 250, and 500 years for each of the above four states with and without loss-reduction measures in place. The analysis reveals that mitigation has the potential to reduce hurricane losses significantly in all four states, ranging from 61% in Florida for a 100-year hurricane to 31% in New York for a 500-year event.

Figure 19.3 depicts these differences in losses graphically for hurricanes with return periods of 100, 250, and 500 years for each of the four states studied.

19.4 Lack of Interest in Undertaking and Promoting Mitigation Measures

Knowledge of the most cost-effective mitigation measures has significantly increased in the past 20 years. Yet recent extreme events have highlighted the challenges in encouraging homeowners to invest in ways to reduce losses from hurricanes and other natural hazards. We first turn to studies revealing the lack of interest by homeowners in investing in these measures voluntarily and then turn to the failure of insurers and politicians to promote these measures.

19.4.1 Empirical Evidence on Homeowner Behavior

A 1974 survey of more than 1,000 California homeowners in earthquake-prone areas revealed that only 12% of the respondents had adopted any protective measures (Kunreuther et al. 1978). Fifteen years later, there was little change despite the increased public awareness of the earthquake hazard. In a 1989 survey of 3,500 homeowners in four California counties at risk from earthquakes, only 5–9% of the respondents in these areas reported adopting any loss-reduction measures (Palm et al. 1990). Burby et al. (1988) and Laska (1991) found a similar reluctance by residents in flood-prone areas to invest in mitigation measures.

Even after the devastating 2004 and 2005 hurricane seasons, a large number of residents had still not invested in relatively inexpensive loss-reduction measures with respect to their property, nor

¹⁰For our Florida analysis, we assumed that the homes met the standards of the “Fortified...for Safer Living” program. Information on this program is available on the website of the Institute for Business and Home Safety at www.disastersafety.org as of June 2012. The benefit analysis was undertaken by the authors in partnership with Risk Management Solutions (RMS). For more detail about the methodology, see Kunreuther and Michel-Kerjan (2011).

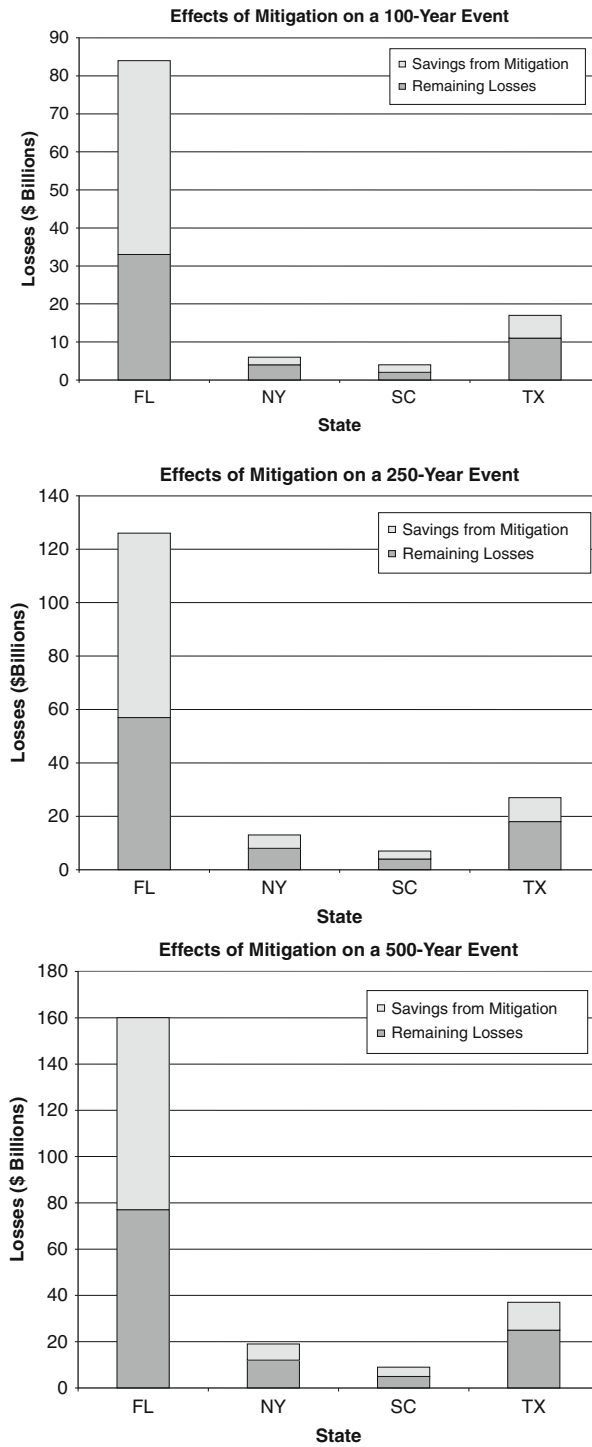


Fig. 19.3 Impact of mitigation on hurricane losses. *Source:* [Kunreuther and Michel-Kerjan \(2011\)](#)

had they undertaken emergency preparedness measures. A survey of 1,100 adults living along the Atlantic and Gulf Coasts undertaken in May 2006 revealed that 83% of the responders had taken no steps to fortify their home, 68% had no hurricane survival kit and 60% had no family disaster plan (Goodnough 2006).

The situation has improved somewhat in the last several years. In a survey of over 500 residents in coastal counties during Hurricane Sandy in 2012, a great majority of respondents indicated doing at least one storm preparation activity (e.g., buying water and food reserves, batteries). But those were mainly short-term preparation actions that required limited effort. Many fewer households undertake protective measures when preparedness requires more effort and substantial resources. For instance, less than half of storm shutter owners in the state of New York who responded to the survey actually installed them to protect their windows before the hurricane came. The others did not because it would have “taken too long” (Baker et al. 2012).

In the case of flood damage, Burby (2006) provides compelling evidence that actions taken by the federal government, such as building levees, may make residents feel totally safe, when in fact, they are still at risk for catastrophes should the levee be breached or overtopped. Gilbert White (1945) pointed out that when these projects are constructed, there is increased development in these “protected” areas. Should a catastrophic disaster occur so that residents of the area are flooded, the damage is likely to be considerably greater than before the flood-control project was initiated. This behavior with its resulting consequences has been termed the *levee effect*. Public officials exacerbate the problem by not enforcing building codes and imposing zoning restrictions.

19.4.1.1 Failure of Insurers to Promote Investment in Mitigation Measures

There are at least three principal reasons why many insurers do not systematically encourage homeowners to adopt risk-reduction measures. A principal factor is that current state regulations often require insurers to charge artificially low premiums that eliminate their incentive to offer discounts to those who invest in mitigation measures. Even if premiums accurately reflected risk, insurers have concluded that the price reduction would be perceived as small relative to the upfront cost of the mitigation measure, and hence would be viewed as unattractive by the policyholder. For example, the Florida Windstorm Underwriting Association discounts for mitigation are quite low: 3–5% for bracing, garage door bracing, roof straps, and about 10% for superior roof sheathing attachment (Grace and Klein 2002). Additionally, insurers would need to inspect the property to make sure the protection measures were in place—a costly process for each individual property on the residential market (Kunreuther, Pauly and McMorro 2013).¹¹

Failure to confirm that appropriate risk reduction measures are in place can be very costly when a hurricane does occur. Insurers learned this lesson following Hurricane Andrew when experts indicated that 25% of the insured losses from this hurricane could have been prevented through better building code compliance and enforcement (Insurance Services Office 1994).

19.4.1.2 Politicians’ Lack of Interest in Mitigating Losses from Disasters

Elected officials do little to encourage their constituents to invest in mitigation investments prior to a disaster (*ex ante*) because they believe that the constituents are not concerned about these events. Yet there is likely to be a groundswell of support for generous assistance to victims from the public

¹¹ Insurers are typically more proactive at working with their commercial clients to reduce their exposure. Those prices are not regulated and the premium for each contract is typically fairly substantial, providing an incentive for the insurers to inspect each commercial building it covers (Auerswald et al. 2006)

sector after a disaster (*ex post*) to aid their recovery. Should elected representatives push for residents and businesses to invest in cost-effective mitigation measures to prevent or limit the occurrence of a disaster? From a long-term perspective, the answer is *yes*. Clearly, taxpayers will pay less in the long run if their money is used for preparation and mitigation before catastrophe strikes. But given short-term re-election considerations, the representative is likely to vote for measures that allocate taxpayers' money where they yield more political capital. The difficulty in promoting these mitigation measures has been characterized as the *politician's dilemma* (Michel-Kerjan 2008).

This lack of interest in mitigation applies to city buildings as well. A survey of facilities and buildings owned and leased by Cities and Counties in the Bay Area in California in 2002 revealed that nearly half had not even evaluated the vulnerability of building contents in their facilities. A more positive finding was that 55% (46 local governments) had abandoned, retrofitted, or replaced at least one of their own facilities due to identified earthquake risk (Association of Bay Area Governments 2002). One still could ask why all of them had not undertaken a probabilistic risk assessment of their buildings given the well-known earthquake risk in California.

19.4.2 *Economic and Behavioral Explanations for Underinvestment in Mitigation*¹²

Why are individuals and communities reluctant to invest in mitigation when the long-term benefits are significant? To explore this issue it is useful to begin by reviewing how a homeowner who maximizes expected utility (EU) should ideally make mitigation decisions. With this EU model as a benchmark, one can examine how heuristics and simplified decision rules foster actions that depart from economic rationality.

Consider the Lowlands, a hypothetical family whose New Orleans home was destroyed by Hurricane Katrina. They have decided to rebuild their property in the same location but are unsure whether they want to invest in a flood-reduction measure (e.g., elevating their home, sealing the foundation of the structure, and waterproofing the walls).¹³ If the flood-proofing measure costs \$20,000, should they make the investment?

Suppose that the family knows that it will be living in their new home for T years, and that there is an annual probability p_t of a Katrina-like flood in year t . Should such an event occur, the annual benefit of a loss-reduction measure will be denoted as B . In this case, the decision to mitigate could be made by observing whether the disutility associated with the upfront cost (C) of mitigation is less than the positive utility associated with the discounted stream of benefits (B); i.e., if

$$U(C) = \sum_{t=1}^T p_t \beta^t u(B) \quad (19.1)$$

where β is the family's discount rate, and $u(x)$ is their utility associated with a value of x where $x = B$ or C to reflect the utility of benefits and costs, respectively.

On the surface, the problem would seem a natural candidate for utilizing expected utility theory. To simplify the problem, the Lowlands could first determine where they should invest in mitigation if they were neutral with respect to risk. If the long-term expected benefits of protection, discounted

¹²This section is based on Kunreuther, Meyer, and Michel-Kerjan (2013).

¹³A discussion of alternative flood reduction measures can be found in Laska (1991) and Federal Emergency Management Agency FEMA (1998).

appropriately to reflect the time value of money, exceeded the upfront costs of the measure, then they should undertake this action. The expected utility model implies that the Lowlands would be even more interested in investing in mitigation if they were averse to the risk of large losses from future disasters.

However, if the family were to attempt such an analysis they would quickly realize that they lack most of the critical information needed to make the relevant comparison of costs and benefits. For example, the future economic benefit of mitigation conditional on a flood is highly uncertain. It depends not only on the quality of implementation (which is unobservable) but also on future social and economic factors over which the Lowlands have little control. For example, the property value of their home is likely to be affected by whether neighbors make similar investments and whether federal disaster relief will be forthcoming following a disaster.

Furthermore, recent empirical research in psychology and behavioral economics has revealed that individuals often utilize informal heuristics that have proven useful for guiding day-to-day decisions in more familiar contexts (Kahneman 2011). However, they are likely to be unsuccessful when applied to the low-probability, high-stakes situations such as whether to invest in protection against losses from catastrophic events. More specifically, homeowners are likely to utilize simplified choice rules for allocating their limited budget by focusing on short-run benefits and costs rather than discounting the future exponentially. They also have distorted beliefs about low probabilities and often treat potential disasters as below their threshold level of concern.

19.4.2.1 Budgeting Heuristics

The simplest explanation as to why individuals fail to mitigate in the face of transparent risks is affordability. If the Lowland family focused on the upfront cost of flood-proofing their house and have limited disposable income after purchasing necessities, there would be little point in their undertaking a benefit–cost analysis on whether to invest in this measure. They would simply say “We cannot afford it.”

Budget constraints can extend to higher income individuals if they set up separate mental accounts for different expenditures (Thaler 1999). Under such a heuristic, a homeowner, uncertain of the cost-effectiveness of mitigation, might simply compare the price of the measure to what is typically paid for comparable home improvements. Hence, the \$20,000 investment may be seen as affordable by those who frame it as a large improvement similar to installing a new roof, but unaffordable to those who frame it as a repair similar to fixing a leaky faucet.

Empirical evidence for this budgeting heuristic comes from a study where many individuals indicated that were willing to pay the same amount for a dead bolt lock when the lease for the apartment was extended from 1 to 5 years. When asked why, one individual responded by saying that:

\$20 is all the dollars I have in the short-run to spend on a lock. If I had more, I would spend more—maybe up to \$50. (Kunreuther, Onculer, and Slovic 1998, p. 284).

Some residents in coastal zones are likely to be discouraged from buying and installing storm shutters to reduce losses from future hurricanes because the cost exceeds that of the window itself—a logical benchmark expenditure.

19.4.2.2 Under-weighting the Future

Extensive experimental evidence reveals that human temporal discounting tends to be *hyperbolic*: temporally distant events are disproportionately discounted relative to immediate ones. As an example,

people are willing to pay more to have the timing of the receipt of a cash prize accelerated from tomorrow to today, than from the day after tomorrow to tomorrow (in both cases a one-day difference) (Loewenstein and Prelec 1992).

The implication of hyperbolic discounting for mitigation decisions is that residents are asked to invest a tangible fixed sum now to achieve a benefit later that they instinctively undervalue—and one that they, paradoxically, hope never to see at all. The effect of placing too much weight on immediate considerations is that the upfront costs of mitigation will loom disproportionately large relative to the delayed expected benefits in losses over time.

A homeowner might recognize the need for mitigation and see it as a worthwhile investment when it is framed as something to be undertaken a few years from now when upfront costs and delayed benefits are equally discounted. However, when the time arrives to actually make the investment, a homeowner subject to hyperbolic discounting might well get cold feet.

19.4.2.3 Procrastination

This tendency to shy away from undertaking investments that abstractly seem worthwhile is exacerbated if individuals have the ability to *postpone* investments—something that would almost always be the case with respect to mitigation. A case in point is the relative lack of preparedness demonstrated by the city of New Orleans and FEMA in advance of Hurricane Katrina in 2005. Just two months prior to the storm, the city engaged in a full-scale simulation that graphically demonstrated what would happen should a hurricane of Katrina's strength hit the city, and the city was moving into the heart of an active hurricane season (Brinkley 2006). Yet, little was done to remedy known flaws in their preparedness plans.

What explains the inaction? While emergency planners and the New Orleans Mayor's office were fully aware of the risks the city faced and understood the need for investments in preparedness, there was inherent ambiguity about just *what* these investments should be and *when* they should be undertaken. Faced with this uncertainty, planners did what decision makers tend to do when faced with a complex discretionary choice: they opted to defer it to the future, in the (usually false) hope that the correct choices would become clearer and/or more resources would then be available (Tversky and Shafir 1992).

To see this effect more formally, imagine the Lowlands view the future benefits of mitigation not in terms of a constant discounting schedule, but rather by the hyperbolic discounting function

$$f(t) = \begin{cases} 1/k & \text{for } t = 0 \\ \beta^t & \text{for } t > 0 \end{cases} \quad (19.2)$$

where $0 < k < 1$ is a constant that reflects the degree to which immediate costs and benefits are given disproportionately more weight than delayed ones (Laibson 1997; Meyer, Zhao, and Han 2008). Suppose that it is January 2015 ($t = 0$) and the Lowlands are considering whether it is worthwhile to invest in a mitigation project that would start January 2016. As long as costs remain temporally distant, the value of the project will be assessed via the rational inter-temporal discounting model in (19.1); i.e., the expected net value of the mitigation project, 1 year from now is:

$$V(I | \text{January}) = \left[\sum_{t=1}^T p_t \beta^t u(B) \right] - \beta u(C) \quad (19.3)$$

Suppose the Lowlands conclude that the project is minimally worthwhile in January 2015, that is, $V(I | \text{January}) = \varepsilon$, where ε is a small positive valuation. Hyperbolic discounting carries a curious implication for how the Lowlands will value the project come June 2015 when the prospect of the

expenditure C is more immediate. In June 2015, the project will look decidedly less attractive, since its value will now be:

$$V(I|June) = \left[\sum_{t=1}^T p_t \beta^t u(B) \right] - u(C)/k \quad (19.4)$$

Hence, if $(1/k-\beta)C > \varepsilon$, it will no longer seem worthwhile to invest. So will the Lowlands abandon their interest in mitigation? We suggest no for the following reason. If the builder offers them the option to restart the project the *following* January, it will once again seem worthwhile, since its valuation would be given by the standard model in (19.3). Hence, the Lowlands would be trapped in an endless cycle of procrastination; when viewed from a temporal distance the investment will always seem worthwhile, but when it comes time to undertaking the work, the prospect of a slight delay always seems more attractive.

The concept of hyperbolic discounting discussed above is distinct from that of *planning myopia*, or the tendency to consider consequences over too short a finite time horizon. For example, if the Lowlands' beliefs about the length of time they would live in their home were biased downward, they would underestimate the benefits of mitigation by using Eq. (19.1).

19.4.2.4 Underestimation of Risk

Another factor that could suppress investments in mitigation is underestimation of the likelihood of a hazard—formally, underestimation of p_t in (19.1). Although underestimation of risk is perhaps the simplest explanation as to why people fail to mitigate, the empirical evidence in the domain of natural hazards is far more complex.

On the one hand, we do know that decisions about mitigation are rarely based on formal beliefs about probabilities. Magat, Viscusi, and Huber (1987) and Camerer and Kunreuther (1989), for example, provide considerable empirical evidence that individuals do not seek out information on probabilities in making their decisions. In a study by Huber, Wider, and Huber (1997), only 22% of subjects sought out probability information when evaluating risk managerial decisions. When consumers are asked to justify their decisions on purchasing warranties for products that may need repair, they rarely use probability as a rationale for purchasing this protection (Hogarth and Kunreuther 1995).

There is also evidence that people tend to ignore risks when they view the likelihood of its occurrence as falling below some threshold level of concern. In a laboratory experiments on financially protecting themselves against a loss by purchasing insurance or a warranty, many individuals bid zero for coverage, apparently viewing the probability of a loss as sufficiently small that they were not interested in protecting themselves against it (McClelland et al. 1993; Schade et al. 2011). Many homeowners residing in communities that are potential sites for nuclear waste facilities have a tendency to dismiss the risk as negligible (Oberholzer-Gee 1998).

Even experts in risk disregard some hazards. After the first terrorist attack against the World Trade Center in 1993, terrorism risk continued to be included as an unnamed peril in most commercial insurance policies in the USA. Insurers were thus liable for losses from a terrorist attack without their ever receiving a penny for this coverage (Kunreuther and Michel-Kerjan 2004). Following 9/11 insurers and their reinsurers had to pay over \$35 billion in claims due to losses from the terrorist attacks, at that time the most cost event in the history of insurance worldwide, now second only to Hurricane Katrina.

19.4.2.5 Affective Forecasting Errors

In our example, the Lowlands are assumed to value benefits from mitigation realized in the distant future in the same way that they would be valued if realized now. How likely is this assumption to be

empirically valid? There are extensive bodies of work showing that individuals tend to be both poor forecasters of future affective states (e.g., [Wilson and Gilbert 2003](#)), and focus on different features of alternatives when they are viewed in the distant future versus today.

Probably the most problematic of these biases for mitigation decisions is the tendency for affective forecasts to be subject to what [Loewenstein, O'Donoghue, and Rabin \(2003\)](#) term the *projection bias*—a tendency to anchor beliefs about how we will feel in the future on what is being felt in the present. Because mitigation decisions are ideally made in tranquil times before a disaster is forecast, the projection bias predicts a tendency for decision makers to both underestimate the likelihood of future hazards and the feelings of trauma that such events can induce—a bias leads to undervaluation of investments in protection.

A common theme heard from survivors of Hurricane Katrina who were trapped in the area was, “Had I known it would be this bad, I would have left.” In reality, the storm was preceded by warnings of the most dire sort, that Katrina was “the big one” that New Orleans’ residents had been warned to fear for years ([Brinkley 2006](#)). It is one thing to imagine being in a large-scale flood, quite another to actually be in one. Judgments of the severity of the experienced were unavoidably biased downward by the relative tranquility of life before the storm.

The tendency to value costs and benefits differently depending on temporal perspective is another mechanism that could result in procrastination. [Trope and Liberman \(2003\)](#) offer a wide array of evidence showing that when making choices for the distant future we tend to focus on the abstract benefits, whereas when making immediate choices we tend to focus on concrete costs. Hence, similar to the predictions made by hyperbolic discounting, it would not be uncommon to hear politicians pledge their deep commitment to building safer societies at election-time (when costs seem small relative to abstract benefits), but then back away from this pledge when the time comes to actually make the investment—when it is the concrete costs that loom larger.

19.4.2.6 Moving in the Next Few Years

If a family is planning to move in the next several years and believes that their investment in a mitigation measure will not be captured through an increase in the valuation of their home, then it may be normatively appropriate not to incur the upfront cost of the disaster-reduction measure. In such cases, the investment expenditure will be greater than the discounted expected reduction in losses during the time that the family expects to be in their house. [Grace and Klein \(2002\)](#) interviewed several realtors in California and Florida who indicated that homeowners could recover 100% of their investments in mitigation when they sold their homes. It would be important to get more empirical evidence on this aspect from housing markets and if confirmed, it would be important for this information to be conveyed to residents in hazard-prone areas.

19.5 Encouraging Mitigation Measures through Public–Private Sector Initiatives

As we have discussed, there may be good reasons why homeowners do not invest in cost-effective mitigation measures on their own unless required to do so. This section briefly discusses six proposals to encourage the adoption of cost-effective mitigation measures using (1) long-term loans; (2) seals of approvals; (3) tax incentives; (4) well-enforced building codes; (5) zoning ordinances; (6) holding political officials legally responsible for avoidable damage; and (7) providing information on the long-term benefits of mitigation.

19.5.1 Proposal 1: Long-Term Loans for Mitigation

Long-term loans for mitigation would encourage individuals to invest in cost-effective risk-reduction measures. Consider a property owner who could invest \$1,500 to reinforce his roof to reduce wind damage by \$30,000 from a future hurricane that has an annual probability of occurrence of 1 in 100. If insurers charged actuarially-based premiums, the annual price of insurance would be reduced by \$300 (i.e., $1/100 \times \$30,000$). If the house was expected to last for 10 or more years, the net present value of the expected benefit of investing in this measure would exceed the upfront cost at an annual discount rate as high as 15%.

Many property owners might be reluctant to incur the \$1,500 expenditure, because they would get only \$300 back next year and are likely to consider only short-term benefits when making their decisions. In addition, budget constraints and heuristics could discourage them from investing in the mitigation measure. A 20-year \$1,500 home improvement loan at an annual interest rate of 10% would result in payments of \$145 per year. Even if the insurance premium was only reduced by \$200, the savings to the homeowner each year would be \$55 plus the resulting mortgage interest tax deductible amount.

Other considerations would also play a role in a family's decision not to invest in these measures. The family may not be sure how long they will reside in the house and whether their property value will reflect the investment in the mitigation measure should they sell it. They may not be clear on whether their insurer will renew their policy and if so, would continue to provide them with premium discounts for having invested in the mitigation measure. These points will be addressed in the next section when we discuss multiyear insurance contracts.

19.5.2 Proposal 2: Providing Mitigation Seals of Approval

Homeowners who adopt cost-effective mitigation measures should receive a seal of approval from a certified inspector that the structure meets or exceeds building code standards. This requirement could either be legislated or imposed by the existing government sponsored enterprises (GSEs) (Fannie Mae, Freddie Mac, and Ginnie Mae) as a condition for obtaining a mortgage. Homeowners may want to seek such a seal of approval if they knew that insurers would provide a premium discount (similar to the discounts that insurers now make available for smoke detectors or burglar alarms), and if home improvement loans were available for this purpose.

A seal of approval could increase the property value of the home by informing potential buyers that damage from future disasters is likely to be reduced because the mitigation measure is in place. There are other direct financial benefits from having a seal of approval. Under the *Fortified...for safer living* program of the Institute for Business & Home Safety, an independent inspector, trained by IBHS, verifies that disaster resistance features have been built into the home that exceed the minimum requirement of building codes and may enable the property owner to receive homeowners' insurance credits in some states (IBHS 2007). The success of such a program requires the support of the building industry and a sufficient number of qualified inspectors to provide accurate information as to whether existing codes and standards are being met or exceeded. Such a certification program can be very useful to insurers who may choose to provide coverage only to those structures that are given a certificate of disaster resistance.

Evidence from a July 1994 telephone survey of 1,241 residents in six hurricane-prone areas on the Atlantic and Gulf Coasts provides supporting evidence for some type of seal of approval. Over 90% of the respondents felt that local home builders should be required to adhere to building codes, and 85% considered it very important that local building departments conduct inspections of new residential construction (Litan et al. 1992).

Certified contractors would perform the inspections required to establish a seal of approval. For *new* properties, the contractor must provide the buyer with this seal of approval. For *existing* properties, the buyer should pay for the inspection and satisfy the guidelines for a seal of approval. If the house does not satisfy the criteria, then banks and other mortgage lenders should roll into their mortgage loans the cost of such improvements.

19.5.3 Proposal 3: Providing Local, State, and Federal Tax Incentives

Communities/cities could provide tax incentives to encourage residents to pursue mitigation measures. If a homeowner reduces the chances of damage from a hurricane by installing a loss-reduction measure, then this property owner could get a rebate or reduction on state taxes and/or property taxes. In practice, communities often create a monetary disincentive to invest in mitigation. Those who improve their home by making it safer are likely to have their property reassessed at a higher value and, hence, be required to pay higher taxes. California has recognized this problem, and in 1990 voters passed Proposition 127, which exempts seismic rehabilitation improvements to buildings from reassessments that would increase property taxes.

The city of Berkeley in California has taken an additional step to encourage home buyers to retrofit newly purchased homes by instituting a transfer tax rebate. The city has a 1.5% tax levied on property transfer transactions; up to one-third of this amount can be applied to seismic upgrades during the sale of property. Qualifying upgrades include foundation repairs or replacement, wall bracing in basements, shear wall installation, water heater anchoring, and securing of chimneys.

South Carolina established Catastrophe Savings Accounts in 2007 that allow residents to set money aside, state income tax-free, to pay for qualified catastrophe expenses. The amount placed in the account reduces the taxpayer's South Carolina taxable income and, as a consequence, reduces the state income tax that the homeowner has to pay. A homeowner may deduct contributions to a Catastrophe Savings Account to cover losses to their legal residence against hurricane, rising floodwaters, or other catastrophic windstorm event damages.¹⁴

South Carolina also offers tax credits for retrofitting, allowing individuals to take state income tax credits for costs to retrofit homes. In order to qualify for the tax credit, costs must not include ordinary repair or replacement of existing items. The homeowner may take a credit in any taxable year for costs associated with specific fortification measures as defined by the Director of Insurance. In addition to obtaining tax credits for retrofitting properties in the mitigation process, consumers will also receive tax credits on the mitigation materials they buy. (For more details on this program see <http://www.doi.sc.gov/faqs/CatSavingsAcct.htm>.)

The principal reason for using tax rebates or credits to encourage mitigation is the immediate and longer-term benefits associated with these measures. By reducing damage to property, residents are much less likely to have to be housed and fed elsewhere. These added benefits cannot be captured through insurance premium reductions, which normally cover only damage to the property. Taxes are associated with broader units of analysis, such as the community, state, or federal level. To the extent that the savings in disaster relief costs accrue to these units of government, tax rebates are financially beneficial. Residents who undertake these measures can clearly see their taxes reduced the same year they start saving to pay for losses from future disasters.

¹⁴Tax incentive programs such as this one should encourage homeowners to take out a larger deductible on their insurance policy and contribute more to the Catastrophe Savings Account. In the process they pay lower insurance premiums and lower taxes at the same time. The insurer benefits by having lower claims following a disaster. If many homeowners take advantage of this program by raising their deductible, the insurer's catastrophic exposure could be significantly reduced.

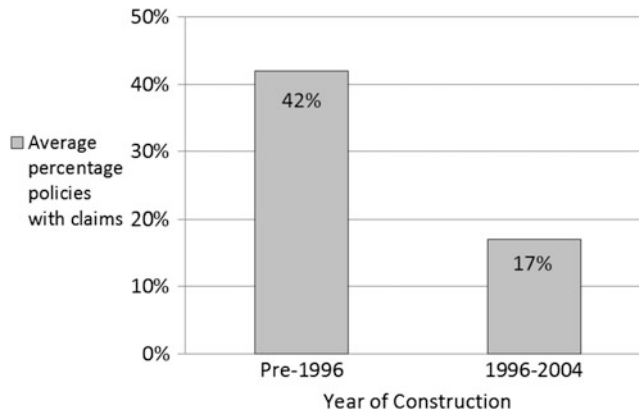


Fig. 19.4 Average claim frequency by building code category from Hurricane Charley. Source: Institute for Business & Home Safety (IBHS)

19.5.4 Proposal 4: Enforcing Building Codes

Risk-based insurance premiums should be coupled with building codes so that those residing in hazard-prone areas adopt cost-effective loss-reduction measures. Following Hurricane Andrew in 1992, Florida reevaluated its building code standards and in 1995, coastal areas of the state began to enforce high-wind design provisions for residential housing. The new Florida Building Code (FBC) 2001 edition, adopted in mid-2002, was accompanied by an extensive education and training program that included a requirement that all licensed engineers, architects, and contractors take a course on the new code.¹⁵

Hurricane Charley in 2004 demonstrated the effectiveness of the new statewide building code. One insurance company provided the Institute for Business and Home Safety (IBHS) data on 5,636 policies in Charlotte County at the time that this hurricane made landfall on August 13, 2004. There were 2,102 reported claims from the hurricane (37% of all the homeowners' insurance policies in Charlotte County for this insurer). Figure 19.4 reveals that homes that met the wind-resistant standards that were enforced in 1996 had a claim frequency that was 60% less than those that were built prior to 1996.

Moreover, this insurer's claims for pre-1996 homes resulted in an average claim of \$24 per square foot, compared to \$14 per square foot for those constructed between 1996 and 2004, as shown in Fig. 19.5. For an average home of 2,000 square feet, the average damage to each of these homes would be \$48,000 and \$28,000, respectively. In other words, the average reduction in claims from Hurricane Charley to *each* damaged home in Charlotte County built according to the newer code was approximately \$20,000 (IBHS 2007).

IBHS released a new report in 2012 that provided an analysis of residential building codes in the 18 hurricane-prone coastal states along the Gulf of Mexico and the Atlantic Coast. To our knowledge, it is the first assessment of individual state performance in developing and promulgating a system, which uses modern residential building codes, coupled with strong enforcement to enhance the protection of homes and families. While Florida scored 98 out of 100, other highly exposed states have a long way to go: Louisiana scored 73, New York 60, Alabama 18, Texas 18, and Mississippi 4 (IBHS 2012).

¹⁵More recent building codes were established in 2004, then in 2007. See www.FloridaBuilding.org.

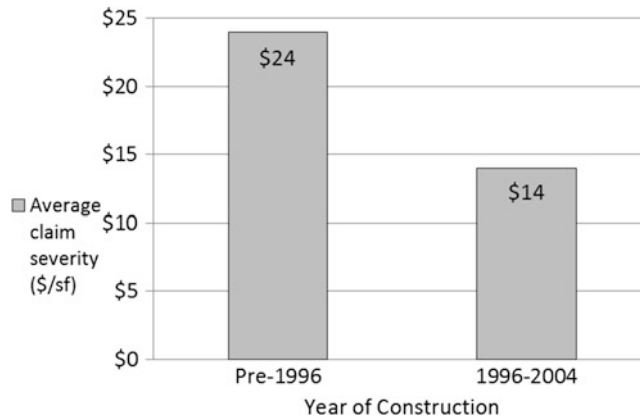


Fig. 19.5 Average claim severity by building code category from Hurricane Charley. Source: Institute for Business & Home Safety (IBHS)

19.5.5 Proposal 5: Encouraging or Mandating Better Zoning

One of more vexing problems facing policy makers after major catastrophes is whether to permit rebuilding in areas that have been severely damaged. In areas that have suffered multiple catastrophes—say, three or more—nature may reveal that these locations are much more likely to be damaged than others. In effect, this is recognized in FEMA’s flood maps, which the agency is in the process of updating. A similar problem exists for other natural disasters such as hurricanes and earthquakes.

Local authorities should adopt zoning policies that do not permit rebuilding in these hazard-prone areas. A countervailing force is the pressure at the local level to permit, if not encourage, rebuilding to increase population and economic activities and tax revenue. This pressure is unlikely to be as intense at the state level, so state officials may be in a position to adopt policies that prevent or discourage localities from allowing rebuilding in areas that have been subject to multiple natural catastrophes.

The federal government could also encourage state governments to undertake these actions by assessing penalties if they do not undertake the above measures. For example, federal highway funds could be withheld if the state did not adopt a zoning policy that restricts new development of property in high hazard areas. Alternatively, the federal government could also deny or reduce the availability of post-disaster financial assistance to communities that fail to adopt such zoning policies and/or enforce them. For reasons we discussed in the introduction this might be difficult, if not impossible, to do in the aftermath of a disaster when media coverage and political pressure is high (Michel-Kerjan and Volkman Wise 2011).

19.5.6 Proposal 6: Holding Political Officials Legally Responsible for Avoidable Damage

The politician’s dilemma described in Sect. 19.4.1.2 could be addressed by holding elected officials legally responsible for negligence if they did not address the natural hazards to which their community is exposed. Although it may be difficult to take such a case to court following a severe disaster, the knowledge by elected officials that they may be legally responsible for some of the damage following a disaster by failing to take action during their term of office, may lead them to pay more attention to the potential for large-scale losses in their political jurisdictions. One silver lining to myopic

politically-driven behavior is that following a natural disaster when residents and the media focus on the magnitude of the losses, politicians will respond by favoring stronger building codes and other loss-reduction measures

19.5.7 Proposal 7: Providing Information on the Long-Term Benefits of Mitigation

To our knowledge there are no programs that inform property owners on the importance and benefits of mitigation and insurance. Given the significant decision-making biases by individuals, consideration should be given to how the government and other institutions could take steps to address these problems more proactively.

One way to address this issue would be to develop educational programs that explain probabilities in a way that people will pay more attention. Research shows that people are willing to pay considerably more to reduce the risk of certain adverse events if the likelihood is depicted as a ratio rather than a very tiny probability. For example, saying that the risk of an event occurring when one is protected is half of what it is when one is not protected elicits a far stronger reaction than saying the risk is reduced from .000006 without protection to .000003 with protection. Similarly, people are more willing to wear seatbelts if they are told they have a .33 chance of an accident over a 50-year lifetime of driving rather than a .00001 chance each trip (Slovic et al. 1978).

Adjusting the time frame also can affect risk perceptions. For example, property owners are far more likely to take the risk seriously if they are told the chance of an earthquake is greater than 1 in 5 during a 25-year period rather than 1 in 100 in any given year (Weinstein et al. 1996). Studies have shown that even just multiplying the single-year risk—presenting it as 10 in 1,000 or 100 in 10,000 instead of 1 in 100—makes it more likely that people will pay attention to the event. Most people feel small numbers can be easily dismissed, while large numbers get their attention (Slovic et al. 2000).

Such information programs could be supported by insurers and realtors (programs targeted to their clients) and local, state, and federal governments.

19.6 Using Market Mechanisms: A Proposal for Multiyear Insurance (MYI) Contracts¹⁶

Given the increase in catastrophic losses over the past two decades, there is some urgency to institute new programs for encouraging long-term thinking while at the same time recognizing that homeowners, insurers, and elected officials tend to be myopic. To address this problem, the Wharton Risk Center has been interacting with key interested parties to design multiyear insurance (MYI) contracts that would be tied to the structure rather than the property owner.

A MYI contract would increase the likelihood that homes at risk are protected over time. Combining MYI with long-term mitigation loans would encourage investments in cost-effective risk-reduction measures by spreading the upfront costs of mitigation measures over time. If insurance rates are actuarially based, then the premium reduction from adopting a risk-reduction measure will be greater than the annual loan cost. Well-enforced building codes could ensure that structures are designed to withstand damages from future disasters. With a multiyear insurance contract, the insurer

¹⁶This section draws on Jaffee, Kunreuther, and Michel-Kerjan (2010), Kunreuther and Michel-Kerjan (2010).

would have a greater incentive to inspect the property over time, something it would not be as likely to do with annual contracts, knowing its policyholders could switch to a competitor in the coming year. Insurance regulators might also be more willing to permit insurers to charge prices that reflect risk, knowing that policies were long term and that there would be competition in the market.

This section discusses the impediments and rationale for MYI policies and suggests ways that MYI could be designed and implemented, using the National Flood Insurance Program as an illustrative example.

19.6.1 Why MYI Does not Exist Today

In his seminal work on uncertainty and welfare economics, Kenneth Arrow defined “the absence of marketability for an action which is identifiable, technologically possible and capable of influencing some individuals’ welfare (...) as a failure of the existing market to provide a means whereby the services can be both offered and demanded upon the payment of a price.” (Arrow 1963)

Several factors have contributed to the non-marketability of MYI for protecting homeowners’ properties against losses from fire, theft and large-scale natural disasters. Today, insurance premiums in many states are restricted to be artificially low in hazard-prone areas. A related second stumbling block for marketing MYI policies is that insurers are unclear as to how much they will be allowed to charge for premiums in the future due to price regulations at the state level. Uncertainty regarding costs of capital and changes in risk over time may also deter insurers from providing MYI.

Although catastrophe models have considerably improved in recent years, there is still significant ambiguity as to the likelihood and consequences of this risk. Controlled experiments with underwriters and actuaries reveal that insurers would want charge more if there is considerable ambiguity with respect to the risk (Kunreuther et al. 1995; Cabantous et al. 2011). For this reason, insurers want financial protection against catastrophic losses over the length of the MYI policy in the form of multiyear reinsurance policies, catastrophe bonds, or other risk transfer instruments.

On the demand side, homeowners may be concerned with the financial solvency of their insurer over a long period, particularly if they feel they would be locked in if they sign a MYI contract. Consumers might also fear being overcharged if insurers set premiums that reflect the uncertainty associated with longer term risks.

19.6.2 Demand for MYI Policy

Jaffee, Kunreuther, and Michel-Kerjan (2010) have developed a two-period model where premiums reflect risk in a competitive market setting to compare the expected benefits of annual contracts versus MYI. They show that a MYI policy reduces the marketing costs for insurers over one-period policies and also reduces the search costs to the consumer if their insurer decides to cancel its policy at the end of period 1. If the policyholder is permitted to cancel a MYI policy at the end of period 1 should s/he learn that the cost of a 1-period policy is sufficiently low to justify paying a cancellation cost (C), then it is always optimal for the insurer to market a MYI policy and for a consumer to purchase one. The insurer will set C at a level which enables it to break even on those policies that are canceled before the maturity date.

To empirically test the demand for multiyear insurance we recently undertook a web-based experiment in the USA, offering individuals a choice between one-year and two-year contracts against losses from hurricane-related damage (Kunreuther and Michel-Kerjan 2011). A large majority of the responders preferred the 2-year contract over the 1-year contract, even when it was priced at a higher

level than the actuarially fair price. Introducing a 2-year insurance policy into the menu of contracts also increased the aggregate demand for disaster insurance.

19.6.3 Developing Multiyear Flood Insurance through the NFIP

Given current rate regulation at the state level, MYI might be difficult for private insurers to develop for homeowners' coverage. However, the National Flood Insurance Program (NFIP), a federal insurance program, is a natural candidate for developing those new contracts.

Since its inception in 1968, the NFIP has expanded dramatically. In 2012 it sold over 5.5 million policies compared to 2.5 million in 1992 and provided almost \$1.3 trillion in coverage compared to \$237 billion in 1992. The catastrophic flood losses from hurricanes in 2004, 2005, 2008, and 2012 created a \$27 billion deficit in the program, an amount that the NFIP had to borrow from the US Treasury to meet its claims obligations and now has to repay. This shortfall in revenue has stimulated considerable discussion and debate as to ways to reform and redesign flood insurance (Michel-Kerjan 2010; Michel-Kerjan and Volkman Wise 2011; King 2013).

An in-depth analysis of the entire portfolio of the NFIP revealed that the median tenure of flood insurance was between 2 and 4 years while the average length of time in a residence was 7 years (Michel-Kerjan, Lemoyne de Forges, and Kunreuther 2012). This behavior occurs even when homeowners are required to purchase flood insurance as a condition for a federally insured mortgage. Some banks and financial institutions have not enforced this regulation for at least two reasons: few of them have been fined and/or the mortgages are transferred to financial institutions in non-flood prone regions of the country that have not focused on either the flood hazard risk or the requirement that homeowners may have to purchase this coverage.

To illustrate this point, consider the flood in August 1998 in northern Vermont. Of the 1,549 victims of this disaster, FEMA found 84% of residents in Special Flood Hazard Areas (SFHAs) did not have insurance, 45% of whom were required to purchase this coverage (Tobin and Calfee 2005). Recent estimates show that only half of those living in flood-prone areas have flood insurance (Kriesel and Landry 2004; Dixon et al. 2006).

To ensure that exposed properties remain covered, the NFIP could introduce multiyear flood insurance into its current menu of contracts with the policy tied to the structure rather than the homeowner. The insurance could be required on all residences in flood-prone areas for the same reason that automobile insurance is required in all states today: providing financial protection in the case of a loss. Should the homeowner move to another location, the flood insurance policy would remain with the property.

Premiums on the flood insurance policy would be fixed for a prespecified time period (for example, 5 years). The two guiding principles for insurance discussed in Sect. 19.2 would be utilized in redesigning the rate structure for the program. Premiums would reflect risk based on updated flood maps. Some homeowners currently residing in flood-prone areas whose premiums increased would be given a mean-tested insurance voucher to reflect the difference.¹⁷ Homeowners who invested in loss-reduction measures would be given a premium discount to reflect the reduction in expected losses from floods whether or not they had an insurance voucher. Long-term loans for mitigation would encourage investments in cost-effective mitigation measures. Well-enforced building codes and seals of approval would provide an additional rationale for undertaking these loss-reduction measures (Michel-Kerjan and Kunreuther 2011).

¹⁷This proposal for risk-based premiums and means-tested vouchers are part of the Biggest-Waters Flood Insurance Reform Act that reauthorized the NFIP for five years in July 2012.

A multiyear flood insurance (MYFI) policy would be a great improvement over the current annual policies from the perspective of the relevant stakeholders: homeowners, FEMA, banks and financial institutions, and the general taxpayer. Such multiyear contracts would prevent millions of individuals from canceling their policies after just a few years—a major issue for the NFIP. Homeowners would be provided with a stable premium and would also have knowledge that they were protected against water damage from floods and hurricanes. This would reduce the legal problems that have plagued victims of recent hurricanes (e.g., the Florida hurricanes of 2004, Hurricane Katrina, Hurricane Ike). Homeowners would not have to argue that the losses were due to wind so they could collect on their homeowners' policy. There would still be a question as to whether the government would pay for some of the loss because it was caused by water or whether private insurers would be responsible if it was wind-related damage.

MYFI would also ensure the spread of risk within the program. Requiring flood insurance for all homeowners residing in hazard-prone areas would provide much needed financial revenue for the program over time increasing the size of the policy base.

MYI and mitigation loans would constitute new financial products. A bank would have a financial incentive to provide this type of loan, since it is now better protected against a catastrophic loss to the property, and the NFIP knows that its potential loss from a major disaster is reduced. Moreover, the general public will now be less likely to have large amounts of their tax dollars going for disaster relief.

19.6.4 Comprehensive Multiyear Disaster Insurance¹⁸

If state regulators were willing to allow insurers to charge premiums that reflect risk, the concept of multiyear insurance could be expanded to cover homeowners' insurance by the private sector. The private sector may further consider offering comprehensive insurance policies that cover earthquakes and floods. A multiyear multi-hazard insurance program reduces the variance associated with insurers' losses relative to their surplus in any given year. Consider an insurer marketing coverage nationwide. It will collect premiums that reflect the earthquake risk in California, hurricane risk on the Gulf Coast, tornado damage in the Great Plains states and flood risk in the Mississippi Valley. According to the law of large numbers, this larger premium base and the diversification of risk across many hazards reduces the likelihood that such an insurer will suffer a loss that exceeds its surplus in any given year. The variance would be reduced further by having multiyear rather than annual policies if premiums reflected risk.

Multi-hazard coverage should also be attractive to insurers and policyholders in hurricane-prone areas because it avoids the costly and time-consuming process of having an adjuster determine whether the damage from hurricanes was caused by wind or water and would avoid lawsuits that are likely to follow. This problem of separating wind damage from water damage was particularly challenging following Hurricane Katrina. Across large portions of the coast, all that remained of buildings were foundations and steps so that it was difficult to determine whether the damage was caused by wind or water. In these cases, insurers decided to pay the coverage limits rather than litigating due to the high costs of taking the case to court. For a house still standing, this process is somewhat easier since one knows, for example, that roof destruction is likely to be caused by the wind, and water marks in the living room are signs of flooding ([Towers Perrin 2005](#)).

Another reason for having a comprehensive disaster insurance policy is that there will be no ambiguity by the homeowner as to whether or not she has coverage. Many residing in the Gulf Coast believed they were covered for water damage from hurricanes when purchasing their homeowners' policies. In fact, lawsuits were filed in Mississippi and Louisiana following Katrina claiming that

¹⁸This subsection is based on [Kunreuther \(2005\)](#).

homeowners' policies should provide protection against water damage even though there are explicit clauses in the contract that excludes these losses (Hood 2005).

Kahneman and Tversky (1979) have demonstrated experimentally the attractiveness of insurance that guarantees that the policyholder will have coverage against all losses. They showed that 80% of their subjects preferred such coverage to what they termed *probabilistic insurance* where there was some chance that a loss was not covered. What matters to an individual is the knowledge that she will be covered if her property is damaged or destroyed, not the cause of the loss. Furthermore, by combining all hazards in a single policy, it is more likely that a property owner will consider purchasing insurance against the financial loss from a disaster because it is above her threshold level of concern. Such a policy has added benefits to the extent that individuals are unaware that they are not covered against rising water or earthquake damage in their current homeowners' policy.

19.7 Open Questions and Conclusion

The United States and other countries have entered a new era of catastrophes. Local interests and myopic behaviors have created the seeds for the perfect storm. Underestimation of the risks of disasters and signals from artificially suppressed catastrophe insurance rates have led to many more people now living in high-risk areas, especially the coast, than 20 years ago. Hurricane Katrina cost insurers \$48 billion—11% of the US property and casualty insurers' surplus at the time—and cost the NFIP \$16 billion. Katrina was the most devastating disaster in US history with a relatively low degree of insurance penetration in Louisiana. Had this hurricane damaged another part of the coast, insured losses could have been considerably higher.

Katrina should have been a wake-up call for the nation to rethink our national strategy for disaster resiliency and recovery, but it was not. Economic development continues in high hazard-prone areas such that population and values exposed to risk are much higher today than they were several years ago. According to data from the modeling firm AIR Worldwide, between December 2004 and December 2007, the total insured residential and commercial values located on the coast of Florida alone went from \$1.9 trillion up to \$2.4 trillion despite the six hurricanes that made landfall in the state in 2004 and 2005. Karen Clark and Company estimates that as of December 2012, the insured value in *coastal* areas from Texas to Maine, was \$15 trillion dollars. The next series of massive hurricanes, storms, or floods in those regions are thus likely to have a significant economic impact, unless proper mitigation measures are implemented on a large scale.

This chapter suggests ways to reduce the potential losses from hurricanes and flooding by encouraging long-term thinking while at the same time providing short-term financial incentives for investing in loss-reduction measures. Our two guiding principles—risk-based insurance premiums and addressing affordability issues—are likely to be the two pillars of any sustainable answer to the challenges posed by natural disasters. The concept of multiyear insurance attached to the property-at-risk, combined with multiyear mitigation loans, has a much broader potential if premiums can reflect risk and means-tested insurance vouchers can deal with equity and affordability issues.

Additional research is needed to design multiyear alternative risk transfer instruments for protecting insurers against catastrophic losses that occur over several years. Additional studies are also needed to integrate insurance with other policy tools such as well-enforced building codes, zoning regulations, tax incentives, and seals of approval. Given the difficulty many have in processing information about risk and uncertainty, risk education is likely to be even more critical in the coming years.

Our focus has been on the USA, but many countries face similar challenges. The question of managing and financing extreme events is likely to become an even more central one around the world in the years to come. For instance, on December 16, 2010, the Council of the Organization for Economic Development and Cooperation (OECD), the highest decision body of the OECD

that comprises 34 member countries, adopted “*Recommendation: Good practices for mitigating and financing catastrophic risks.*”¹⁹ This text provides governments and relevant public and private institutions with an integrated, action-oriented framework for the identification of disaster risks, promotion of risk awareness, enhancement of prevention and loss mitigation strategies, and design of compensation arrangements (OECD 2010). And in 2012 for the first time, the G20, under the Mexican Presidency, has officially recognized disaster risk reduction as a top priority for its working agenda (Michel-Kerjan 2012).

Appendix 1. Government Program to Address Affordability Issues

Food Stamp Program. Under the Food Stamp Program, a family is given vouchers to purchase food based on its annual income and size of the family. This program concept originated in the late 1930s, was initiated as a pilot program in 1961 and extended nationwide in 1974. The current program structure was implemented in 1977 with a goal of alleviating hunger and malnutrition by permitting low-income households to obtain a more nutritious diet through normal purchasing of food from grocery stores. Food stamps are available to most low-income households with limited resources regardless of age, disability status, or family structure. Households, except those with elderly or disabled members, must have gross incomes below 130% of the poverty line. All households must have net incomes below 100% of poverty to be eligible.²⁰ The program is funded entirely by the federal government. Federal and state governments share administrative costs (with the federal government contributing nearly 50%). In 2003, total federal food stamp costs were nearly \$24 billion.

Low Income Home Energy Assistance Program (LIHEAP). The mission of this program is to assist low income households that pay a high proportion of their income for home energy in meeting their immediate energy needs. The funding is provided by the federal government but is administered by the states and federally recognized tribes or insular areas (e.g., Guam, Puerto Rico, Virgin Islands) to help eligible low-income homeowners and renters meet their heating or cooling needs (eligibility based on similar criteria than the food stamp program).²¹ The federal government became involved in awarding energy assistance funds to low-income households program as a result of the increase in oil prices resulting from the Organization of Petroleum Exporting Countries (OPEC) oil embargo in 1973. Over the past few years, the annual appropriation of this program has averaged \$2 billion.²²

*Universal Service Fund (USF).*²³ The USF was created by the Federal Communications Commission in 1997 to ensure that consumers in all regions of the nation have access to and pay rates for telecommunications services that are reasonably comparable to those in urban areas. To achieve this goal, the program first provides discounts to all households living in a particular high cost area (e.g., rural area) so they all pay the same subsidized rate regardless of income. Then there are universal service programs that are strictly aimed at low income people households, regardless of whether they live in high or low cost areas.

¹⁹This document was proposed by the OECD Secretary-General Board on Financial Management of Catastrophes that has been advising the head of the organization and the governments of member countries since its inception in 2006.

²⁰More details on this program can be found at http://www.frac.org/html/federal_food_programs/programs/fsp.html.

²¹For instance, at the end of August 2007, Secretary of Health and Human Services (HHS) Mike Leavitt announced that \$50 million in emergency energy assistance would be given to 12 states that experienced much hotter than normal conditions during the summer.

²²For more details on this program, see U.S. Department of Health and Human Services at <http://www.acf.hhs.gov/programs/liheap/>

²³For more details on this program see <http://www.usac.org/about/universal-service> as of October 2011.

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Chapter 20

Innovations in Insurance Markets: Hybrid and Securitized Risk-Transfer Solutions

J. David Cummins and Pauline Barrieu

Abstract One of the most significant economic developments of the past decade has been the development of innovative risk-financing techniques in the insurance industry. Innovation has been driven by the increase in the frequency and severity of catastrophic losses, capital management needs in the life insurance industry, market inefficiencies created by (re)insurance underwriting cycles and regulation, advances in computing and communications technologies, and other factors. These developments have led to the development of hybrid insurance/financial instruments that blend elements of financial contracts with traditional reinsurance as well as new financial instruments patterned on asset-backed securities, futures, and options that provide direct access to capital markets. This chapter provides a survey and overview of the hybrid and pure financial markets instruments, not only emphasizing CAT bonds but also covering futures, options, industry loss warranties, and sidecars. The chapter also covers life insurance securitizations executed to provide capital release, respond to reserve regulations, and hedge mortality and longevity risk.

20.1 Introduction

Beginning with Hurricane Andrew in 1992, participants in insurance and financial markets have sought innovative solutions to the financing of catastrophic and other types of insurance-linked risks. In nonlife insurance, the importance of developing alternatives to traditional risk-transfer mechanisms such as reinsurance has increased following subsequent events such as the World Trade Center terrorist attacks in 2001 and Hurricanes Katrina, Rita, and Wilma in 2005. After each of these disasters, the capital of reinsurers was seriously depleted. Insurers raised substantial amounts of new equity capital following each of these events through initial public offerings, seasoned equity issues, and capital increases (Cummins 2008). However, it became apparent that new capital alone was not sufficient to solve the catastrophic loss financing problem. In fact, hybrid and securitized risk-transfer devices

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provided much of the additional risk capital that needed to rebuild capacity. In life insurance, the demand for securitized products has been driven primarily by the need for capital release due to capital and reserve regulation and the slow emergence of profits on life insurance products.

The objective of this chapter is to provide an overview and analysis of financial innovations in the market for insurance risk transfer and capital release. Two major types of innovations are considered—(1) *hybrid products* that combine features of financial instruments and traditional (re)insurance but do not necessarily access capital markets and (2) *financial instruments*, which go beyond (re)insurance industry capacity to access capital markets directly. The latter instruments are part of a class of securities known as *event-linked securities* or in this context as *insurance-linked securities (ILS)*, the terminology adopted in this chapter. Particular attention is devoted to insurance-linked bonds, the most successful of the new products, although options and swaps are also considered. The use of insurance-linked products to provide financing and risk-transfer solutions in the markets for life insurance and annuities also is analyzed.

Several economic forces have combined in recent years to accelerate the development of insurance-linked capital market innovations. In nonlife insurance, the first and perhaps most important driver of innovation is the growth in property values in geographical areas prone to catastrophic risk. Trillions of dollars of property exposure exist in disaster prone areas in the USA, Europe, and Asia, resulting in sharp increases in insured losses from property catastrophes. For example, Hurricanes Katrina, Rita, and Wilma (KRW) and other events combined to cause insured losses of \$119 billion in 2005 (Swiss Re 2011b). Such losses are very large relative to the total equity capital of global reinsurers but represent less than 1/2 of 1% of the value of US stock and bond markets. The recognition that it is more efficient to finance this type of risk in securities markets has led to the development of innovative financial instruments. A parallel driver in the life sector is the need to hedge against mortality spikes and longevity risk.

The second major driver of nonlife innovation is the reinsurance underwriting cycle. It is well known that reinsurance markets undergo alternating periods of *soft markets*, when prices are relatively low and coverage is readily available, and *hard markets*, when prices are high and coverage supply is restricted. The existence of hard markets increases the difficulties faced by insurers in predicting costs and managing risks. Because underwriting cycles tend to have low correlations with securities market returns, convergence has the potential to moderate the effects of the reinsurance underwriting cycle and thereby create value for insurers and insurance buyers. A somewhat similar driver on the life side is the need for capital release to finance the growth of new business and to respond to financial crises and regulatory changes.

A third major driver of innovation in both life and nonlife insurance consists of advances in computing and communications technologies. These technologies have facilitated the collection and analysis of underwriting exposure and loss data as well as the development of catastrophe modeling firms. These firms have developed sophisticated models of insurer exposures and loss events, facilitating risk management and enhancing market transparency. Similarly, on the life side, technology has facilitated the modeling of mortality and longevity risk and the creation of complex structured securities to provide capital relief.

A fourth major driver of innovation, which primarily reflects market imperfections, is various regulatory, accounting, tax, and rating agency factors (RATs). RATs not only serve in some cases as market facilitators, enabling (re)insurers to develop products to control regulatory and tax costs but also can impede market development (Cummins 2005; World Economic Forum 2008). RATs have played an important role in many life insurance securitizations. A fifth driver of convergence is modern financial theory, which has enabled market participants to acquire a much deeper understanding of risk management and facilitated financial innovation.

The remainder of the chapter is organized as follows: Section 20.2 reviews the literature on hybrid and securitized insurance-linked products, focusing on the most important scholarly contributions. Section 20.3 discusses criteria for evaluating risk-transfer instruments, analyzes theoretical

considerations, such as the trade-off between moral hazard and basis risk, and briefly reviews pricing models. Section 20.4 discusses hybrid financial products that have characteristics of traditional reinsurance and financial market products. Section 20.5 analyzes financial market instruments with an emphasis on nonlife securitizations. Section 20.6 considers life insurance and annuity securitizations, and Sect. 20.7 concludes.

20.2 Selective Literature Review

This section reviews the literature on hybrid and securitized risk-transfer products. The discussion focuses on the literature that the authors consider to have the most significant scholarly content, i.e., chapters that develop theories or provide rigorous empirical tests.¹ We also discuss the evolution and development of risk-transfer markets and instruments. Industry-oriented publications are not specifically reviewed here but are cited throughout the chapter.²

20.2.1 Developmental Period

Although researchers have analyzed reinsurance markets for decades, scholarly analysis on hybrid reinsurance-financial products and insurance securities is a relatively recent phenomenon. This literature was triggered by Hurricane Andrew in 1992 and the introduction of insurance futures and options by the Chicago Board of Trade (CBOT) in the same year.

Because insurance derivatives were a new phenomenon in the early 1990s, the literature that developed at that time focused on explaining and analyzing insurance derivatives, comparing derivatives to reinsurance, and discussing hedging strategies for insurers. [D’Arcy and France \(1992\)](#) discuss the advantages and disadvantages of the CBOT futures as hedging instruments for insurers. Based on an empirical analysis of catastrophe losses and insurer loss ratios, they find that the use of futures can enable insurers, particularly large firms, to reduce the volatility of their profits. However, they also cite a number of concerns among insurers about the contracts including lack of insurer expertise, counterparty credit risk, and uncertainties about the regulatory treatment of the contracts. The discussion does not use theoretical models. They conclude presciently that, “concerns of insurers about insurance futures... may cause the demise of this contract.” In fact, the CBOT offerings eventually were withdrawn in 2000.

[Cox and Schwebach \(1992\)](#) also analyze the advantages and disadvantages of insurance derivatives for hedging catastrophe risk. They point out that derivatives provide a potentially valuable tool for hedging risk, allow investors to participate in the insurance markets without being a licensed insurer, and may have lower transactions costs than traditional reinsurance. The authors also develop theoretical pricing models for futures and options on futures. However, they also outline some serious barriers to the success of insurance futures. In particular, they argue that basis risk is a problem because futures trade on a marketwide loss portfolio, whereas reinsurance covers the insurer’s own portfolio. Also, none of the risk management services that reinsurers provide their clients are available in the

¹Although there is also a growing literature on mathematical/financial pricing models for insurance derivatives, this literature is outside the scope of this literature review. For example, see [Aase \(2001\)](#), [Bakshi and Madan \(2002\)](#), [Grundl and Schmeiser \(2002\)](#), [Lee and Yu \(2007\)](#), [Egami and Young \(2008\)](#), [Muermann \(2008\)](#), and [Wu and Chung \(2010\)](#). We briefly discuss pricing models in Sect. 20.3.

²A practitioner perspective on insurance-linked securities is provided in [Albertini and Barrieu \(2009\)](#).

futures market. Insurers may not have the expertise needed to trade in the futures market, and the accounting and financial reporting treatment of risk hedging derivatives is uncertain. They provide numerical illustrations of the use of derivatives in hedging insurance risk but do not present insurance or futures market data.

Niehaus and Mann (1992) evaluate the advantages of insurance futures and develop a theoretical model of insurance futures markets. They argue that futures have the potential to reduce counterparty credit risk in comparison with reinsurance because futures sellers are required to post performance bonds (margin) and the clearinghouse guarantees performance on futures transactions. The reduced need to monitor counterparties enables futures markets to operate anonymously, enhancing liquidity in the market for underwriting risk. They develop a theoretical model of futures markets, which predicts that the level of usage of futures by insurers will depend upon the equilibrium risk premium embedded in insurance futures prices.

Interestingly, the early literature on insurance derivatives identified (but did not resolve) most of the issues that continue to be discussed. These include the trade-off between moral hazard, which is highest for indemnity-style contracts, and basis risk, which is associated with indexed products. Other issues include insurer acceptance of the new contracts, counterparty credit risk, and the magnitude of risk premia.

20.2.2 *Evolutionary Period*

The period of time when the market was experimenting with different capital market instruments can be termed the *evolutionary period*, which approximately spans the years 1994 through 2004. Several different types of financial instruments were tried during this period, many of them unsuccessful. As mentioned above, CBOT insurance futures were introduced in December of 1992. When the contracts failed to generate much interest among insurers, they were replaced in 1995 by CBOT options contracts based on catastrophe loss indices compiled by Property Claims Services (PCS). However, due to limited trading, the PCS options were delisted in 2000 (United States GAO 2002). The specific problems with the PCS options and other issues involving insurance-linked options are discussed in more detail in Sect. 20.5.3.

Another early attempt at securitization involved contingent notes issued to investors known as “Act of God” bonds. The funds from the bond issues were held in trust, and the trust agreement permitted the insurer to borrow against the trust in the event of a catastrophic loss. Act of God bonds also failed to catch on, primarily because financing catastrophe losses through the bonds created the obligation for the insurer to repay the trust. A more successful securitization is the catastrophe (Cat) bond, described in more detail below, which releases funds to insurers following catastrophes without creating the obligation to repay. The first successful Cat bond was issued by Hannover Re in 1994 (Swiss Re 2001).

During the evolutionary period, scholarly researchers were generally enthusiastic about the prospects for capital market instruments. chapters were published explaining why it is difficult for conventional insurance and reinsurance markets to finance the risk of large catastrophes.³ For example, Harrington and Niehaus (2003) argue that tax costs of equity capital have a substantial effect on the cost to US insurers of supplying catastrophe reinsurance for high layers of coverage. They suggest that the development of Cat bonds was motivated as a means “by which insurers can reduce tax costs associated with equity financing and simultaneously avoid the financial distress costs of subordinated

³An important chapter by Jaffee and Russell (1997) on this topic is discussed in more detail in the section on demand for insurance-linked securities (Sect. 20.5.1).

debt financing” (p. 367). However, they caution that frictional and regulatory costs may impede the development of the Cat bond market.

Harrington et al. (1995) examine whether insurance futures and options can lower insurers’ costs of bearing correlated risks such as risks posed by natural catastrophes. The analysis evaluates futures/options relative to other techniques such as holding additional equity capital, purchasing reinsurance, and sharing risk with policyholders. They conclude that the success of futures and options will depend upon the relative costs of ensuring performance in futures markets relative to other alternatives. Analyzing insurer loss ratios, they find that line-specific indices provide effective hedges in the short-tail lines, while a national catastrophe index provides significant risk reduction only for homeowners/farmowners insurance.

The evolutionary period literature also analyzed the trade-off between moral hazard and basis risk resulting from the choice of ILS payoff triggers (Doherty 2000). Moral hazard arises if the hedger can potentially manipulate the contract payoff amount or probability, and basis risk arises when contract payoffs are imperfectly correlated with the hedger’s losses. Contracts that pay off on insurer-specific losses (*indemnity triggers*) have low basis risk but expose investors to moral hazard, while contracts that pay off on non-indemnity (e.g., *industry index-linked*) triggers have lower moral hazard but expose the hedger to basis risk.⁴

Doherty (1997, 2000) argues that capital market innovations such as catastrophe bonds and options are driven by the quest to reduce transactions costs such as moral hazard and credit risk. In particular, he argues that the success of capital market instruments will hinge on a trade-off between moral hazard and basis risk. Doherty and Richter (2002) argue that the optimal hedging strategy may involve a combination of index-linked financial instruments and indemnity-based reinsurance contracts to cover the basis risk “gap.” Lee and Yu (2002) develop a mathematical pricing model for Cat bonds that incorporates both moral hazard and basis risk. They show that both types of risk have adverse effects on bond prices, supporting the argument that optimal hedging may involve a combination of indemnity and index-based instruments. Nell and Richter (2004) develop a model that predicts the substitution of index-linked ILS for reinsurance for large losses because of reinsurance market imperfections associated with reinsurer risk aversion, which is highest for large losses.

The two most important empirical studies of the degree of basis risk for insurer hedging using catastrophe index-linked insurance derivatives are Harrington and Niehaus (1999) and Cummins, Lalonde, and Phillips (CLP) (2004). Harrington and Niehaus (1999) study basis risk by correlating insurer loss ratios with loss ratios based on state-specific PCS catastrophe losses and also analyze correlations of individual insurer loss ratios and industry loss ratios in various geographical areas. Their results indicate that state-specific PCS catastrophe derivatives would provide effective hedges for many insurers, especially in homeowners insurance, and that basis risk with state-specific derivatives is not likely to be a significant problem.

CLP form hedges for nearly all insurers writing windstorm insurance in Florida using detailed exposure data and simulated hurricane losses provided by Applied Insurance Research. They find that hedging using statewide contracts is effective only for the largest insurers. However, smaller insurers in the two largest size quartiles can hedge almost as effectively using four interstate regional indices.⁵ These analyses suggest that the basis risk is not a trivial problem for ILS, especially for smaller insurers. Thus, hedging based on index-linked contracts is likely to be most effective for large insurers and reinsurers with broad-based geographical exposure.

During the evolutionary period, researchers noticed that the prices of Cat bonds, defined as the bond premium divided by the expected loss, were higher than expected. The expectations were based on capital market theory, which predicts that securities with near-zero market betas should have prices

⁴Triggers are discussed in more detail below, especially in Sect. 20.5.5.3.

⁵This finding is consistent with Major (1999), who, using simulation analysis, finds that contracts based on zip-code level loss indices provide better hedges than those based on statewide data.

close to the risk-free rate of interest (Canter et al. 1996; Litzenberger et al. 1996). However, Cummins et al. (2004) found that Cat bond premia averaged nearly 7 times expected losses for bonds issued in 1997–2000. The rationale for the high evolutionary-period Cat bond spreads has been investigated by several researchers. Bantwal and Kunreuther (2000) suggest that ambiguity aversion, loss aversion, and uncertainty avoidance may account for the reluctance of investment managers to invest in these products.

A financial theoretic approach to explaining Cat bond spreads is provided by Froot (2001). He provides evidence that the ratio of reinsurance prices to expected losses is comparable to spreads on Cat bonds during significant periods of time (e.g., 1993–1997).⁶ He examines eight potential explanations for the high spreads on reinsurance and Cat bonds, including insufficient capital for reinsurance due to capital market and insurance market imperfections, adverse selection, and moral hazard. The capital market imperfections considered by Froot (2001) include information asymmetries, agency costs, and frictional costs that render external capital more costly than internal capital. For example, direct and indirect costs of financial distress, informational asymmetries between managers and investors, and agency costs of motivating and monitoring managers may raise the costs of external capital and lead to capital shortages that can drive up reinsurance prices.⁷ Insurance market imperfections discussed by Froot (2001) include market power of reinsurers arising from the increasing concentration in the global reinsurance market. He concludes that the most compelling explanations for the high spreads are supply restrictions associated with capital market imperfections and market power exerted by traditional reinsurers. The pricing of reinsurance and Cat bonds is considered in more detail below in Sects. 20.4.1 and 20.5.5.4.

20.2.3 Market Maturity and Beyond

Although the market for insurance-linked futures and options has not yet generated much trading volume, the market for Cat bonds has continued to expand. Industry analysts observe that, “the ILS market is now an established part of the reinsurance and retrocessional scene to be used by insurers and reinsurers alike” (Lane and Beckwith 2008) and that, “the market [has gone] mainstream” (GC Securities 2008). New issues of Cat bonds dropped off significantly due to the subprime financial crisis in 2008–2009, but the market recovered quickly and 2010 was the third largest year on record with new issuance of \$4.3 billion (Swiss Re 2011b). Cat bonds weathered the subprime crisis better than other types of asset-backed securities (ABS) due to their relative simplicity and transparency. Moreover, the ILS market has expanded from covering catastrophes to other perils such as automobile insurance, liability insurance, extreme mortality risk, and other life insurance securitizations (Cowley and Cummins 2005; Swiss Re 2006).

Curiously, even as the Cat bond market has grown, so has the literature which tries to explain why Cat bonds have “not succeeded.” Two chapters in this category provide valuable insights into factors that could lead to the development of an even wider market in ILS. Gibson et al. (2007) develop a theoretical model showing that differences in information gathering incentives between financial markets and reinsurance companies may explain why “financial markets have not displaced reinsurance (p. 3).” They find that the supply of information by informed traders in financial markets may be excessive relative to its value for insurers, causing reinsurance to be preferred. The model predicts that the relative success of reinsurance and financial markets depends crucially on the

⁶High spreads on catastrophe reinsurance are also documented in Froot and O’Connell (2008). Froot and Posner (2003) provide a theoretical analysis suggesting that parameter uncertainty does not appear to be a satisfactory explanation for high event-risk returns.

⁷These costs are discussed and modeled in more detail in Froot et al. (1993).

information acquisition cost structure and on the degree of redundancy in the information produced. The degree of redundancy depends upon the degree to which systematic and nonsystematic error components are present in information gathered on insurance risks. If the systematic (nonsystematic) component is dominant, then information redundancy is high (low) and reinsurance (securitization) will be preferred. This model helps to explain why securitization has been more prevalent for low frequency, high severity events than for high frequency, lower severity events.

Another chapter in this vein is [Barrieu and Louberge \(2009\)](#). They argue that the volume of Cat bond issues would increase if intermediaries issued hybrid Cat bonds, i.e., structured financial instruments combining a simple Cat bond and put option protection against a simultaneous drop in stock market prices. Utilizing a game-theoretic model, they argue that “introducing hybrid cat bonds would increase the volume of capital flowing into the cat bond market, in particular when investors are strongly risk averse, compared to issuers of cat bonds.” The authors are correct that hedging against a joint event is cheaper than hedging against the events independently. Their theory may help to explain the attractiveness of dual trigger contracts such as industry loss warranties.

A third chapter arguing that the ILS market has not yet reached the “tipping point” is [Michel-Kerjan and Morlaye \(2008\)](#). They propose three primary ways to develop a larger, more liquid market: (1) increasing investor interest through tranching, (2) addressing basis risk through index-based derivatives, and (3) developing new products such as derivatives based on equity volatility dispersion. The authors argue that insurers are exposed to large-scale risks such as catastrophes that simultaneously affect both underwriting results (huge claims) and equity investments. They argue that derivatives based on the volatility of a portfolio of insurance and reinsurance stocks could be used to hedge both types of risk.

These chapters reveal some difference of opinion in the literature about whether the current design of ILS is adequate or whether alternative instruments will be needed for the market to achieve its full potential. As discussed in more detail below, developments in the ILS markets have responded to most of these potential concerns such that they do not represent problems at the present time.

A theoretical chapter that helps to explain the coexistence of reinsurance and Cat bonds is [Lakdawalla and Zanjani \(2012\)](#). They point out that fully collateralized Cat bonds initially seem a paradoxical departure from the “time-tested concept of diversification that allows insurers to protect insured value far in excess of the actual assets held as collateral.” In a world with free contracting, where frictional costs are similar for reinsurance and Cat bonds, Cat bonds are “at best redundant, and at worst welfare-reducing.” However, in a world with contracting costs and default risk, Cat bonds can be welfare-improving by, “mitigating differences in default exposure attributable to contractual incompleteness and heterogeneity among insureds.”

Another theoretical chapter with implications for the coexistence of reinsurance and Cat bonds is [Finken and Laux \(2009\)](#). They argue that private information about insurers’ risk affects competition in the reinsurance market. Nonincumbent reinsurers are posited to be subject to adverse selection because only high-risk insurers may find it optimal to change reinsurers. This results in high reinsurance premiums and cross-subsidization of high-risk insurers by low-risk insurers. Because information-insensitive Cat bonds with parametric triggers are not subject to adverse selection, the availability of Cat bonds with sufficiently low basis risk reduces cross-subsidization as well as the incumbent reinsurer’s rents. However, absent specific benefits of Cat bonds, insurers will continue to choose reinsurance contracts with indemnity triggers. Both [Lakdawalla and Zanjani \(2012\)](#) and [Finken and Laux \(2009\)](#) reinforce the conclusion that Cat bonds have a role to play but are not expected to totally displace traditional reinsurance.

[Hardle and Cabrera \(2010\)](#) develop a pricing model for a real parametric earthquake Cat bond issued by the Mexican government. Their analysis shows that a combination of reinsurance and Cat bond is optimal in the sense that it provides coverage for a lower cost and lower exposure at default than reinsurance itself. A hybrid Cat bond for earthquakes is priced in order to reduce the basis and moral hazard risk borne by the sponsor.

20.3 Theoretical Considerations

As for any particular asset class, there are some specificities of the ILS market that need to be emphasized. In particular, when considering the securitization of insurance-related risks, various questions arise regarding the structure and the pricing of the possible products. In this section, we provide some theoretical background, including criteria for evaluating risk-transfer products, the pricing methodology for ILS, and some structuring features.

20.3.1 *Securitization: Introduction*

Securitization involves the repackaging and trading of cash flows that traditionally would have been held on-balance-sheet. Securitizations generally involve the agreement between two parties to trade cash flow streams to manage and diversify risk or take advantage of arbitrage opportunities. The cash flow streams to be traded often involve contingent payments as well as more predictable components and may be subject to credit and other types of counterparty risk. Securitization transactions facilitate risk management and add to the liquidity of (re)insurance markets by creating new tradeable financial instruments that access broader pools of capital.

Securitizations in general fall into two primary categories: (1) ABS such as securities backed by mortgages, corporate bonds, etc. and (2) non-asset backed products such as futures and options. ABS are typically collateralized, i.e., backed by underlying assets, whereas non-ABS are guaranteed by the transaction counterparty and/or by an exchange. Both ABS and non-ABS can be issued and traded on organized exchanges or over-the-counter. Most of the insurance securitizations to date have been patterned after ABS and non-ABS design structures familiar from other financial markets (Cummins 2005).

20.3.2 *Criteria for Evaluating Risk-Transfer Products*

There are several important criteria to use in evaluating risk-transfer products. Traditionally, the only risk-transfer product available to insurers was reinsurance. As new products began to be introduced, they were designed with some features that resemble reinsurance and other features that are significantly different. It is important to keep these considerations in mind when discussing the risk-transfer products in this chapter.

When purchasing a risk-transfer product, the buyer (hedger) needs to be concerned about the credit risk of the seller, i.e., when the event insured in the contract takes place, will the seller actually make the payment. In traditional reinsurance, credit risk is a significant concern, which can be mitigated through spreading reinsurance purchases among more than one reinsurer, dealing only with reinsurers with high financial ratings, and developing long-term relationships such that informational asymmetries about credit risk and other factors can be reduced. As explained below, credit risk affects other risk-transfer products to varying degrees.

Two additional considerations that play an important role in evaluating risk-transfer products are basis risk and moral hazard. In designing new products, there is usually a trade-off between basis risk and moral hazard, whereby reducing basis risk increases moral hazard and vice versa. Basis risk is the risk that the payoff on the risk-transfer product is less than perfectly correlated with the hedger's loss, and moral hazard is the risk that the hedger will take actions (or fail to take precautionary actions) that increase the loss frequency or severity to the detriment of the hedge provider. The trade-off between

moral hazard and basis risk depends very much on the type of structure used in the securitization process. This question concerns the whole ILS market but we use the nonlife segment to introduce and illustrate the concepts.

In traditional reinsurance, there is no basis risk, since there is no mismatch between the risk on which the reinsurance contract is written and the risk to which the insurer is exposed. [Standard and Poor's \(2008\)](#) gives a detailed definition of basis risk as “the risk that the quantum, timing, or currency of the receipts from a particular mitigation strategy fail to at least cover the indemnified losses of the sponsor, for the protected perils and territories.” Some parts of basis risk can be quantified and some cannot. For example, basis risk attributable to trigger type, timing of payment, and currency can be quantified, whereas model risk and data risk cannot. The presence of unquantifiable risk increases the difficulties in understanding and managing risk; and, therefore, the question of trade-off between moral hazard and basis risk is not so simple.

When securitizing insurance risk, one of the first questions to consider is what the underlying risk of the transaction should be, depending mainly on the motivation behind the securitization. In the case of risk transfer, the originator may want a perfect hedge for its risk and therefore decide on an indemnity-based transaction, similar to a reinsurance contract in its logic, as the payout of the security will depend on the evolution of the originator's own portfolio. In this case, it would require an analysis of the insurer's specific exposures and underwriting policies by the investors. The originator may also accept to bear some discrepancy in its hedging strategy and decide for an index-based transaction. Some basis risk is then naturally introduced as the payout of the contract depends on an index rather than on the issuer's exposure. By introducing basis risk, due to a common index, securitization eliminates the problem of moral hazard and brings additional transparency, which is desirable for investors. The degree of basis risk depends obviously on the type of index used for the transaction and on how the originator's portfolio is connected to the index. Popular triggers in nonlife insurance securitization include parametric indices based on the actual physical event or an industry index such as the PCS index.

However, as shown below, a significant proportion of transactions are based directly on the exposure of the originator. They are attractive for the issuer as they mitigate the issue of basis risk. The monitoring of these transactions by the investors, and in particular, the understanding and knowledge of the originator's exposure is the key to their success. New tools have been recently developed to help investors in this process and to improve the overall health and growth of the ILS market. For example, in 2011, Risk Management Solutions (RMS) released a major update to its US hurricane risk model that includes ten times more offshore wind data than its previous major release in 2003.⁸ In 2007, Swiss Re launched several new catastrophe bond price indices, based on secondary market data. In 2009 a new organization (PERILS) was launched to provide indices that can be used in the ILS market to design products for hedging perils such as European floods and windstorms, where adequate indices were previously unavailable ([Swiss Re 2009b](#)). Modeling firms also have developed ILS portfolio risk management and pricing platforms to assist investors in structuring their ILS portfolios.⁹

Transparency is also an important consideration in a risk-transfer transaction. Transparency means that both the hedger and the hedge provider have complete knowledge of all elements of the transaction as well as all circumstances and situational considerations that could affect the effective functioning of the hedge. Traditional reinsurance is of necessity somewhat opaque. Even though both the ceding company and reinsurer have full knowledge of the coverage of the reinsurance contract, the ceding company does not have very much if any information about the reinsurer's underwriting portfolio, exposures to various types of risk, and investment portfolio, all of which can potentially

⁸ See <http://www.artemis.bm/blog/2011/03/01/rms-releases-new-u-s-hurricane-risk-model-wind-risk-to-increase/>.

⁹ For example, RMS developed the Miu Platform, a computer program to facilitate ILS portfolio and risk management, and in 2012 introduced the Miu Pricing service, a collection of reports and metrics to help ILS investors make better investment decisions.

affect payoffs under the reinsurance. More recently, securitized structures such as Cat bonds are much more transparent and, in fact, Cat bonds are more transparent than most other types of asset-backed securities such as collateralized debt obligations (CBOs) and mortgage-backed bonds.

The vast majority of reinsurance contracts cover a 1-year term and only one type of risk such as property damage, marine risks, or workers' compensation. By contrast, more recently developed hybrid and securitized products typically cover multiple year terms and often cover multiple risks in a single instrument. Multi-year products are important because they shelter the buyer from reinsurance price and availability cycles and reduce transactions costs by requiring contracts to be placed less frequently. Multi-risk contracts have the potential to reduce hedging costs by explicitly taking into account diversification across covered perils. Hedging products also can be evaluated based on their degree of standardization. High standardization reduces transactions costs and facilitates secondary market trading in the instruments, whereas specifically tailored products can reduce basis risk and often better meet the needs of ceding insurers. Thus, a trade-off exists between the advantages of standardization versus tailoring.

The final major criterion for evaluating risk-transfer products is whether the products access the broader capital markets. Traditional reinsurance products only access the capital and risk-bearing capacity of the insurance and reinsurance industries. Insurers and reinsurers raise equity in capital markets, but such capital is costly being subject to corporate taxation, regulatory costs, agency costs, and costs arising from informational asymmetries. In addition, the function of such capital is opaque, as it is exposed to the risk of the (re)insurer's entire operation. By contrast, securitization often involves raising capital for "pure play" securities that cover only one or a small number of related transactions, potentially lowering the cost of capital.

The operating model of reinsurers, holding reinsured risks in an underwriting portfolio has been characterized as *risk warehousing* (Cummins and Weiss 2009). This model obviously has some compelling advantages in dealing with the small and medium size, mostly uncorrelated exposures that have been the traditional focus of insurance and reinsurance, explaining why warehousing has been the predominant approach to risk transfer for such a long period of time and likely will continue in this role in the future. By internalizing the benefits of the law of large numbers, the risk warehouse approach enables reinsurers to achieve a high degree of risk reduction through diversification. This means that a relatively small amount of equity capital can support reinsurance coverage with policy limits many hundreds of times larger than the amount of equity committed, while still maintaining acceptable levels of insolvency risk. By warehousing risks over a long period of time, the reinsurer also internalizes significant amounts of information about risk underwriting, risk management, and exposure management, i.e., the reinsurer achieves economies of scale in information acquisition and analysis.

Risk warehousing also has disadvantages, which have led to the development of hybrid products and pure capital market solutions (securitization). Reinsurance contracts held on-balance-sheet tend to be opaque to the securities market, making it difficult for equity holders to evaluate the firm and creating informational asymmetries that raise the cost of capital. Capital costs and informational asymmetries provide an explanation for the reinsurance underwriting cycle, which is a major source of reinsurance market inefficiency. Finally, the market begins to crumble when faced with very large, highly skewed risks which can create major shocks to reinsurer capital. For such risks, and also for some more routine risks, the most efficient way to hedge is likely to be through securitization.

20.3.3 Pricing Models

Due to its relative youth and its limited size in terms of both issuance volume and investors, the ILS market is not a highly liquid market. As a consequence, a dynamic replicating strategy cannot be constructed by investors; and therefore, the various risks embedded in any transaction will be difficult

to dynamically hedge. Given the specific nature of the ILS market and of the considered risks, there is not a clear pricing rule for a given transaction. Various techniques, including those used to price securities in an incomplete market, such as the ones discussed below, can be used to determine the price of a given transaction. However, the ILS market is growing in terms of size, types of products, types of structures, and types of risks covered. In addition, there is an active secondary market in insurance-linked bonds. As a consequence, pricing techniques which cannot be applied today, due to the present size and liquidity of the market, are likely to become the norm in the future. Consequently, and also because they provide a benchmark for the incomplete markets pricing models discussed below, we begin the discussion by briefly considering classic, complete markets pricing models.

Among the available products that permit investment in insurance-linked risks, investors will consider the pricing and design of a transaction in order to select the one, which from their point of view seems the least risky relative to the expected return received. The nature of the underlying risk plays an essential role as its marginal contribution to the risk of an existing portfolio is critical for diversification purposes. Some “non-standard” or “off-peak” risks, such as Mexican earthquake, Turkish earthquake, or Australian bushfire, are very attractive to ILS investors and so the pricing of the associated products is often more aggressive (Hardle and Cabrera 2010). It is also important to point out that the design of new securities is extremely important feature of the transaction and may mean the difference between success and failure. The question of the optimal design of transactions based on non-tradable risk (such as natural catastrophic risk) is studied in detail by Barrieu and El Karoui (2009).

20.3.3.1 Classic Static Pricing Methods

A classical pricing methodology in insurance is that of fair premium corrected with a particular risk loading factor. More precisely, neglecting for the sake of simplicity interest rates, the price of a particular risky cash-flow F can be obtained under the historical probability measure P as

$$\pi(F) = E_P(F) + \gamma \sigma_P(F)$$

The risk premium γ is a measure of the Sharpe ratio of the risky cash-flow F and σ_P denotes standard deviation.

This economic pricing methodology is static and corresponds in this respect mainly to an insurance or accounting point of view. However, the standard financial approach to pricing is different, as it relies on the so-called, risk-neutral methodology. The main underlying assumption of this approach is that it is possible to replicate cash flows of a given transaction dynamically using basic traded securities in a highly liquid market.¹⁰ Using a non-arbitrage argument, the price of the contract is uniquely defined by the cost of the replicating strategy. Using a risk-neutral probability measure as a reference, it can also be proven that this cost is in fact the expected value of the discounted future cash flows. This approach is clearly dynamic, since the replicating strategy is dynamically constructed. Note, the replicating portfolio is not only a tool to find the price of the contract but can also be used to

¹⁰The classic complete markets pricing model involves a replicating strategy. For example, for options, the standard option on a stock is replicated using a portfolio with cash (risk-free securities) and the stock itself. Consequently, a replicating strategy could be utilized if there were a liquid market in the underlying risk. For most types of insurance-linked securities (e.g., Cat bonds, mortality-linked bonds), it is difficult to envision a market in the underlying risk. However, a replicating strategy could be used for more complex options if there were highly liquid markets in at least two insurance-linked derivatives, such as Cat bonds and options. Given the world-wide growth in exposure to catastrophic property and mortality risk, it is not difficult to envision the development of liquid markets in both insurance-linked bonds and options.

dynamically hedge the risks associated with the transaction. In any case, adopting such an approach for the pricing of financial contracts based upon insurance-related risks requires the underlying risks to be dynamically modeled. A highly liquid underlying market is essential for the construction of such a replicating strategy.

In a highly liquid and complete market where any contingent claim can be replicated by a self-financing portfolio, the risk-neutral (universal) pricing rule is used:

$$\pi(F) = E_{P^*}(F) = E_P(F) + \text{cov}\left(F, \frac{dP^*}{dP}\right)$$

where P^* is the so-called risk-neutral probability measure. This pricing rule is linear, similar to the actuarial rule. However, neither of these two approaches takes into account the risk induced by large transactions. Since the present state of the ILS market is far from being sufficiently liquid, the applicability of risk neutral methodology has been questioned in many research chapters. In those cases where hedging strategies cannot be constructed, the nominal amount of the transactions becomes an important risk factor. In such cases, this methodology is no longer accurate, especially when the market is highly illiquid. A more appropriate methodology to address this problem is the utility-based indifference pricing methodology presented below.

20.3.3.2 Indifference Pricing

In an incomplete market framework, where perfect replication is no longer possible, a more appropriate strategy involves utility maximization. Following [Hodges and Neuberger \(1989\)](#), the maximum price that an agent is ready to pay is relative to their indifference towards the transaction and according to their individual preference and their own initial exposure. More precisely, given a utility function u_B and an initial wealth of W_0^B , the indifference buyer price of F is $\pi^B(F)$ determined by the nonlinear relationship:

$$E_P(u_B(W_0^B + F - \pi^B(F))) = E_P(u_B(W_0^B))$$

This price, which theoretically depends upon initial wealth and the utility function, is not necessarily the price at which the transaction will take place. This specifies an upper bound to the price the agent is ready to pay. Similarly, the indifference seller price is determined by the preference of the seller and characterized by

$$E_P(u_S(W_0^S - F + \pi^S(F))) = E_P(u_S(W_0^S))$$

It should be noted that this pricing rule is nonlinear and depends on the existing portfolio of the buyer (resp. the seller). Moreover, this approach provides an acceptable price-range for both parties rather than a single price at which the transaction should take place, leaving room for negotiation. The dependency of the price on the original exposure is an interesting feature in the ILS market, as it has been noted that for similar risk profiles in terms of expected loss and overall risk, some transactions were more expensive due to the fact that they were offering some diversification by introducing unusual risks to investors' portfolio.

When approaching the same subject from an economic point of view, the transaction price can be said to form an equilibrium price. This occurs between either the seller and buyer, or different players in the market. It can be described as a transaction where the agents simultaneously maximize their expected utility (Pareto-optimality). Obviously a transaction only takes place where there are two agents for whom $\pi^B(F) \geq \pi^S(F)$.

Note that it could be argued that to extend the fair price approach to an illiquid and dynamic setting is an appropriate action. Since a perfect hedge does not exist, we can extend the indifference price as

$$\sup E_P(u_S(W_0^S - F + \pi^S(F))) = E_P(u_S(W_0^S))$$

where $\pi^S(F)$ is no longer a static price, but a dynamic price strategy associated with a hedge, and the supremum in the equation is taken over the strategies. Thus an optimal hedge can be derived as [Barrieu and El Karoui \(2009\)](#).

20.4 Hybrid Reinsurance-Financial Risk-Transfer Products

As the risk-transfer market has evolved, products have developed that have characteristics of both reinsurance and financial instruments. This section discusses and analyzes the principal products that fall into this category. Although in principle these products could apply to both life and nonlife risks, in practice they almost always pertain to nonlife insurance.¹¹ To provide context for this discussion, we begin with a brief discussion of reinsurance.

20.4.1 Risk Transfer Through Conventional Reinsurance

Traditionally, the primary method of risk transfer for insurers was reinsurance. Because most of the nonlife hybrid and financial risk-transfer products developed recently have been motivated by the need to deal with “mega” risks such as risks posed by natural catastrophes, the discussion emphasizes reinsurance products for covering this type of risk.¹²

The reinsurance contract structure used to transfer most “mega-risks” is non-proportional or *excess of loss (XOL)* reinsurance. Payoffs on XOL reinsurance have the same mathematical structure as a *call option spread*, which is also the payoff structure for most Cat bonds and options, i.e., the reinsurance pays off once losses exceed a threshold (“lower strike”) and continue up to a higher threshold (“upper strike”). Within the coverage layer, there is usually loss sharing proportion less than 1 (e.g., $\alpha = 0.9$) to control moral hazard. The other important parameters of reinsurance that are useful in understanding the role of hybrid and financial market contracts are the time period (“tenor”) of the contract and the perils covered. Conventional reinsurance contracts are typically negotiated and priced annually and are single-peril contracts.

Inefficiencies in reinsurance markets constitute a primary driver for the development of alternative risk-financing mechanisms. As mentioned above, reinsurance markets undergo alternating periods of *soft markets*, when prices are low and coverage is readily available, and *hard markets*, when prices are high and coverage supply is restricted. The reinsurance cycle is clearly evident in [Fig. 20.1](#), which plots the catastrophe reinsurance rate-on-line indices worldwide and for the USA.¹³ Two important conclusions to be drawn from [Fig. 20.1](#) are: (1) Reinsurance prices are highly volatile and tend to

¹¹Risk transfer is less important in life than in nonlife insurance because life insurance is a relatively stable business with a significant savings component. The nonlife reinsurance market is about three times as large as the life reinsurance market in terms of premium volume ([Swiss Re 2012b](#)).

¹²Other types of reinsurance are discussed in [Swiss Re \(1997, 2010a, b, 2012b\)](#) and various academic sources.

¹³The rate-on-line measures the price of XOL reinsurance as the ratio of the reinsurance premium to the maximum possible payout under the contract.

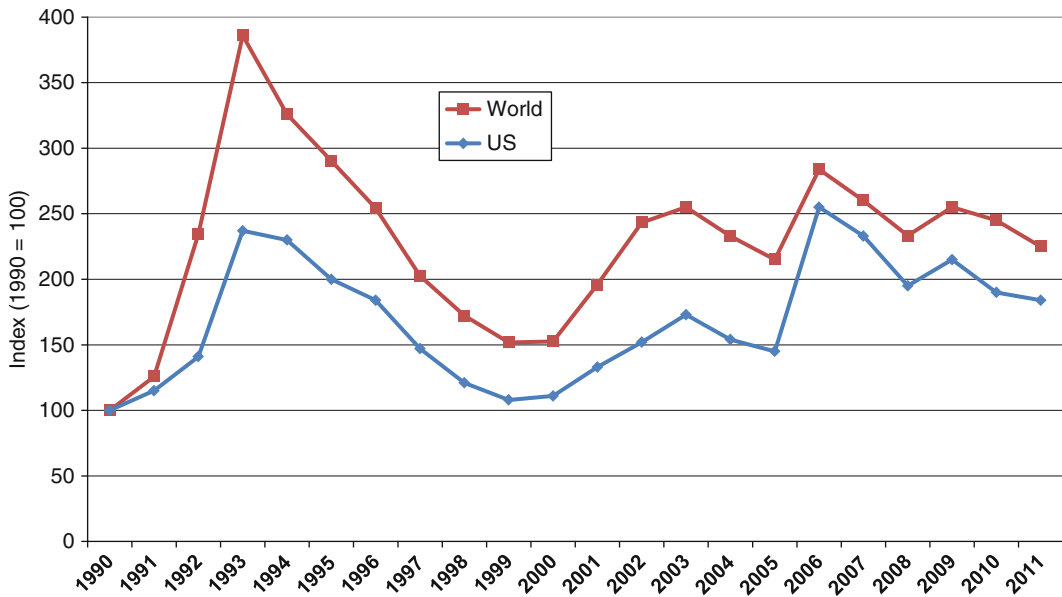


Fig. 20.1 Catastrophe reinsurance: World and US rate on line indices. *Source:* Guy Carpenter (2011, 2012)

spike following large loss events such as Hurricane Andrew and 2005 hurricanes and (2) prices are cyclical. [Cummins and Weiss \(2009\)](#) show that reinsurance price cycles are highly correlated across national markets.

Alternative risk transfer (ART) has developed in part to respond to limitations in reinsurance risk-bearing capacity during hard markets. However, even during soft market periods, the supply of coverage for low frequency, high severity events is often limited ([Froot 2001](#); [Berger et al. 1992](#), [Cummins 2007](#); [Froot and O'Connell 2008](#)). These sources confirm that reinsurance markets have limited capacity, especially for reinsuring catastrophic losses, and that reinsurance prices are highly volatile over the course of the cycle.

The fluctuations of reinsurance prices over time are further illustrated in [Fig. 20.2](#), which plots the ratio of the rate-on-line to the loss-on-line for US property XOL reinsurance annually for 2005–2008.¹⁴ The ratio of the rate-on-line to loss-on-line clearly is highest for low frequency, high severity events, e.g., the ratio ranges from 4 to 13 for a loss on line of 1% but ranges only from 2 to 4 for a loss on line of 7%. The rates-on-line also fluctuate dramatically depending upon the cycle phase, e.g., for a 2% loss on line, the ratio of rate on line to loss on line went from about 7 during the hard market of 2006 to about 3 during the soft market of 2008.

The theoretical literature on the pricing of intermediated risks provides an explanation for the observed price patterns in the reinsurance market. [Froot and Stein \(1998\)](#) hypothesize that holding capital is costly for financial institutions and that such institutions face convex costs of raising new external capital. Holding capital is costly due to frictional costs such as corporate income taxation, agency costs, and regulatory costs, and raising new external capital is costly because of informational asymmetries between firms and the capital market and for other reasons ([Myers and Majluf 1984](#)). In addition, financial institutions invest in illiquid assets such as reinsurance policies which cannot be fully hedged in financial markets.

¹⁴The loss-on-line is the expected loss on the layer expressed as a percentage of the maximum possible payout.

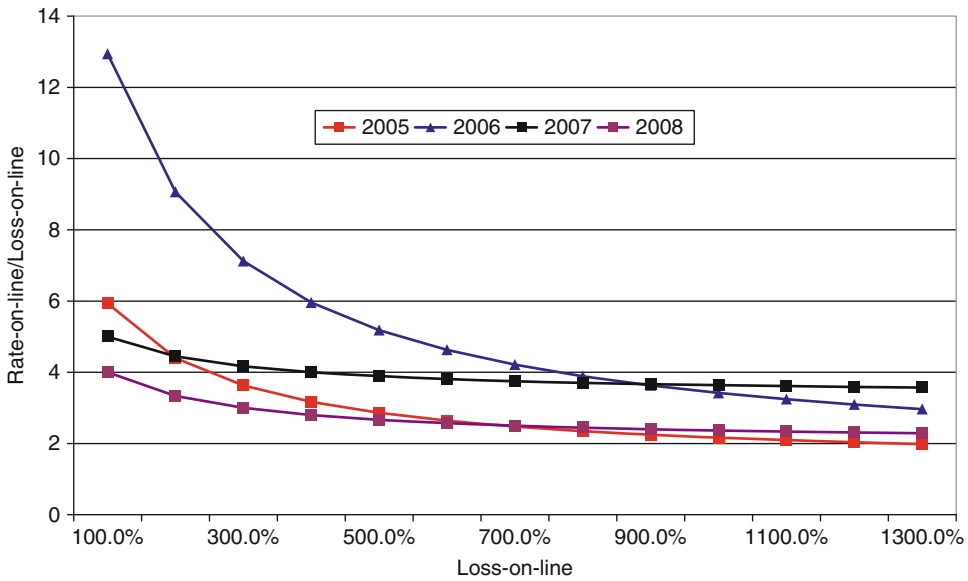


Fig. 20.2 Catastrophe reinsurance pricing multiples: ratio of rate-on-line to loss-on-line, national companies. *Source:* Guy Carpenter

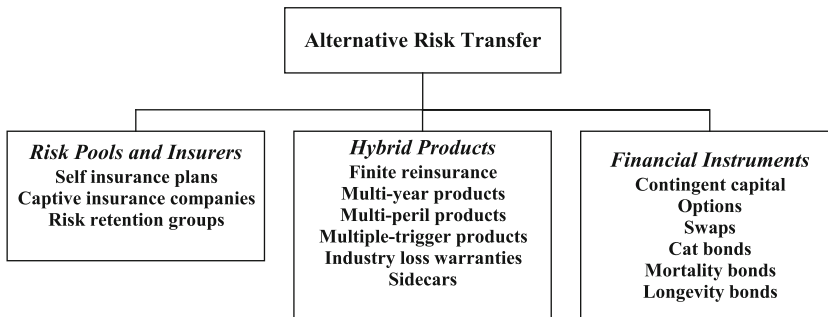


Fig. 20.3 Alternative risk transfer

Under these conditions, [Froot and Stein \(1998\)](#) show that the hurdle rates and hence the prices of illiquid intermediated risk products are given by a two-factor model, consisting of the standard market systematic risk factor and a factor reflecting the covariability of the product’s returns with the institution’s preexisting portfolio of non-tradable risks. The price of the latter covariability term depends upon the institution’s effective risk aversion, which is a function of the capital structure of the institution. The price is inversely related to the amount of capital held by the firm because risk aversion declines as capital increases. Thus, the principal predictions are that the prices of intermediated risks will be positively related to their covariability with the institution’s existing portfolio and inversely related to the institution’s capitalization.

[Froot’s \(2007\)](#) extends the Froot–Stein model based on the observation that insurance companies are likely to be especially sensitive to insuring risks that adversely affect solvency.¹⁵ He argues that

¹⁵Insolvency aversion arises because insurance pays off when the marginal utility of customer wealth is relatively high and because insurance customers face higher costs of diversification of insured risks than investors in traded financial assets ([Merton 1995](#)).

insurers are especially averse to risks that create negatively asymmetric project return distributions, because such asymmetries increase the probability of having to raise costly external capital. The model predicts that (re)insurance prices will rise following large loss shocks and that prices will be especially high for risks that create asymmetrical return distributions.

The observed reinsurance prices in Fig. 20.2 are consistent with Froot's (2007) pricing model, because low frequency, high severity events contribute significantly to negative return asymmetries and reinsurer capital was depleted following the disastrous 2005 hurricane season. The depleted capital led to sharp price increases, which were highest for low probability layers of reinsurance that contribute the most to asymmetrical return distributions. These departures from conventional asset pricing theory represent imperfections in the market for reinsurance and help to explain why securitization is most prevalent for low frequency, high severity events.

20.4.2 *Alternative Risk Transfer: An Overview*

An overview of ART approaches used in the (re)insurance industry is shown in Fig. 20.3, which illustrates how the various institutions and instruments fit into the ART marketplace. Although this chapter focuses on hybrid products and financial instruments, ART risk pools and insurers also are included in the figure for completeness.

The development of the ART market has been motivated by various inefficiencies in the markets for insurance and reinsurance that have led market participants to seek lower cost solutions. For example, noninsurance corporations were motivated to develop self-insurance programs because of the high transactions costs of dealing with the insurance industry, caused by adverse selection, moral hazard, and other imperfections. Beginning in the 1960s, corporations began to seek further cost reductions by formalizing their self-insurance programs in subsidiaries known as *captive insurance companies*, reducing transactions costs and giving the corporate parent investment control of premiums. Unlike self-insurance plans, captives have direct access to reinsurance markets and can receive more favorable terms on the transfer of upper layers of risk. Properly structured captives also have tax advantages over self-insurance.¹⁶ The captive market has grown significantly—by 2012 there were 6,052 captives worldwide (Zolkos 2013).¹⁷

Another ART-type institution available for liability insurance risks in the USA is the *risk-retention group (RRG)*. RRGs are a special type of group captive authorized by Congress in response to the liability insurance crisis of the 1980s to provide additional liability insurance capacity to businesses.¹⁸ RRGs account for only a small proportion of the US liability market, but there are some important

¹⁶The rules governing the deductibility of premiums paid by a parent corporation to a captive are complex. However, premiums now appear to be deductible for captives with a “sufficient” amount of business covering firms other than the parent, captives that cover other subsidiaries owned by the same parent, and group captives jointly owned by several parents. For further discussion, see Wohrmann and Burer (2002) and Swiss Re (2003).

¹⁷The original captives were *single-parent captives*, which insured only the risks of the parent corporation. The market evolved to include *profit-center captives*, which also assume risks from unrelated third-parties. *Group and association captives* insure the risks of several firms from the same industry or association. Insurance intermediaries offer *rent-a-captives* to insure the risks of smaller firms. The most recent form of the rent-a-captive is the *segregated cell captive*, which provides stronger legal protection for firms in a multiple-parent captive.

¹⁸RRGs were authorized in the Liability Risk Retention Act of 1986. The law contains a regulatory pre-emption provision that permits RRGs to write policies for member-owners nationwide after meeting the licensing requirements of the RRG's state of domicile. RRGs can write all types of commercial casualty insurance except workers compensation (*Business Insurance*, September 5, 2011).

lines of insurance such as liability coverage for professionals, the healthcare industry, and educational institutions where RRGs are more prominent.

20.4.3 Hybrid Reinsurance-Financial Products

The types of risk-transfer mechanisms of primary interest in this chapter are hybrid products and pure financial instruments. Hybrid products tend to incorporate characteristics of both financial instruments and reinsurance, while the financial instruments closely resemble products traded in capital markets.

20.4.3.1 Finite Risk Reinsurance

Finite risk reinsurance is used to provide income smoothing for primary insurers, with limited assumption of risk by the reinsurer. Finite reinsurance thus combines a multi-year banking transaction with limited reinsurance coverage and has five distinguishing features: (1) Risk transfer and risk financing are combined in a single contract. (2) Less underwriting risk is transferred to the reinsurer than under conventional reinsurance.¹⁹ (3) Finite risk contracts nearly always cover multi-year periods rather than being annually renewable. (4) Investment income on the premiums paid by the primary insurer is explicitly included when determining the price, placing an emphasis on the time value of money not found in conventional reinsurance. (5) There is usually risk-sharing of the ultimate results (positive or negative balance at the end of the contract) between the reinsurer and the buyer.

Finite risk reinsurance absorbs more credit risk than under an annually renewable contract, because of the possibility that the cedent will default on its agreed-upon premium payments and also exposes the reinsurer to interest rate risk because the investment income feature usually involves some sort of interest guarantee. The premium or claim payments under the policy may also be denominated in a currency other than the reinsurer's home country currency, exposing the reinsurer to foreign exchange risk.

A *spread loss treaty* is a type of finite risk reinsurance designed to reduce the volatility of the ceding insurer's reported underwriting profit.²⁰ To achieve this goal, the cedent enters into an agreement to pay a fixed annual premium to the reinsurer. Under the contract provisions, the primary company borrows money from the reinsurer when its underwriting results are adverse due to unexpectedly high insurance losses and repays the "loan" when losses are relatively low. The premium is deposited into an "experience account" each year, the account is credited with interest, and losses are deducted. Because the experience account is usually carried "off balance sheet (OBS)," the arrangement smoothes the ceding insurer's reported income.²¹

¹⁹The term "finite" reinsurance is somewhat misleading in that conventional reinsurance is also finite, i.e., subject to policy limits, deductibles, etc. Nevertheless, the term does express the idea that the intent of the contract is to provide more limited risk transfer than under conventional policies. In several jurisdictions internationally, finite reinsurance must transfer significant underwriting risk to receive regulatory, tax, and/or accounting treatment as reinsurance. In the USA, the relevant GAAP accounting rule is SFAS 113 ([Financial Accounting Standards Board 1992](#)). For further discussion, see [Swiss Re \(1997, 2003\)](#).

²⁰Other types of finite reinsurance include *finite quota share* reinsurance, which involves the proportionate sharing of the premiums and losses of a block of business. This serves a financing function for the ceding insurer, enabling it to recover the prepaid underwriting expenses on a block of business, thus reducing its leverage ratio.

²¹The OBS feature of these contracts runs afoul of U.S. GAAP accounting rules. Under FASB 113 and EITF 93-6, U.S. insurers must show positive account balances as assets and negative balances as liabilities unless there is no contractual obligation to repay negative balances, mitigating the smoothing aspects of the contract for U.S. firms.

Although finite reinsurance can serve legitimate business purposes, there is also a “dark side” to this product (Culp and Heaton 2005). Because finite reinsurance can be used to manage the capital structure of an insurer by increasing or decreasing its liabilities and because the degree of risk exposure of the reinsurer traditionally was often very limited, there was a temptation for managers to misuse finite reinsurance to manipulate their financial statements and mislead investors. By the early 2000s, the impression had developed that finite reinsurance was primarily used for inappropriate purposes. This perception was significantly reinforced by a scandal involving American International Group (AIG) and General Reinsurance Company. In March, 2005, “Hank” Greenberg, the CEO of AIG, was forced to resign amid allegations that AIG had misused finite reinsurance to fictitiously bolster its loss reserves. Five executives of AIG and General Reinsurance Company, the counterparty to the AIG transactions, were convicted of conspiracy and securities fraud as a result of the incident (Roberts 2008).²²

Partly as a result of the scandal, in 2005 the National Association of Insurance Commissioners (NAIC) adopted finite reinsurance disclosure requirements for property-casualty insurers and began to require that an insurer’s CEO and chief financial officer provide signed statements verifying that finite reinsurance involves a significant transfer of risk and that there are no side agreements that eliminate the risk transfer.²³

As a result of the enhanced regulatory requirements, the reinsurance market has been moving away from traditional finite products and towards the so-called *structured reinsurance products*. Such products resemble finite reinsurance in many ways but involve a significant and documentable transfer of risk, i.e., they combine elements of both conventional and finite risk reinsurance. Whereas many traditional finite products aimed primarily to achieve an accounting result, structured products are more oriented towards capital management and are designed to provide a real transfer of risk that satisfies regulatory requirements (Bradford 2011). Structured products thus combine the nontraditional risk-management features of finite risk reinsurance with the more significant underwriting risk transfer of conventional reinsurance. Thus, structured covers may cover multiple years, insulating the cedent from the reinsurance cycle, and usually involve recognition of the time value of money. Such contracts also may transfer foreign exchange rate risk and timing risk.

20.4.3.2 Retrospective Excess of Loss Covers and Loss Portfolio Transfers

Retrospective excess of loss covers (RXLs) (also called adverse development covers) are a finite risk product that protects the cedent against adverse loss reserve development in lines such as commercial liability insurance. RXLs provide retrospective reinsurance protection because they apply to coverage that has already been provided rather than coverage to be provided in the future, as under prospective

²²The convictions are presently being appealed.

²³The rules regarding risk transfer in U.S. GAAP were originally expressed in FAS 113 and EITF 93-6, both issued in 1993. FASB codified the rules in 2009, and most rules regarding risk transfer are now found under FASB Accounting Standards Codification (ASC) Topics 944 and 340. In practice, FAS 113 was supplemented by the so-called 10–10 rule, which requires at least a 10% probability of a 10% loss for legitimate reinsurance. Because the 10–10 rule holds that many high level catastrophe reinsurance contracts would not constitute risk transfer, it has been expanded in practice by the “product rule,” which looks both at loss probability and loss amount (Munich Re 2010). If reinsurance does not involve legitimate risk transfer, according to U.S. GAAP, it is treated as a deposit, with no effect on underwriting results. Related regulatory rules include the NAIC’s Statement of Statutory Accounting Principles (SSAP) 62 in the U.S. and the European Union (EU) Directive 2005/68/EC in Europe.

reinsurance.²⁴ RXLs provide partial coverage for the primary insurer if reserves exceed a level specified in the contract and thus can be conceptualized as a call option spread purchased by the cedent.²⁵ The reinsurer assumes underwriting risk, timing risk (the risk that the claims will be settled faster than recognized in the discounting process), interest rate risk, and credit risk, extending coverage significantly beyond conventional reinsurance.

Besides transferring risk, RXLs have the less obvious advantage of mitigating a significant source of asymmetrical information between the cedent and the capital market. An insurer's managers inevitably know much more about the firm's reserve adequacy and probable future reserve development than the capital market. This creates a "lemons" problem in which the insurer may have difficulties in raising capital due to uncertainty regarding its reserves. However, one of the core competencies of a reinsurer is the ability to evaluate the adequacy of loss reserves. The reinsurer can leverage this knowledge to create value for its owners by writing RXL reinsurance, signaling the capital markets that a knowledgeable third party has evaluated the cedent's reserves and is willing to risk its own capital by participating in the risk.

With RXL contracts, the insurer retains the subject loss reserves on its own balance sheet. A finite risk cover that restructures the cedent's balance sheet is the *loss portfolio transfer (LPT)*. In an LPT, a block of loss reserves is transferred to the reinsurer in exchange for a premium representing the present value of the reinsurer's expected payments on the policies covered by the reserve transfer. Because loss reserves are usually carried at undiscounted values on the cedent's balance sheet, the value of the reserves transferred exceeds the premium, thus reducing the cedent's leverage. LPTs accomplish a number of objectives including reducing the cedent's cost of capital, making it more attractive as a merger partner, and enabling the cedent to focus on new opportunities. The transferred reserves are usually carried on the reinsurer's balance sheet, but they could be securitized, provided that regulatory issues could be resolved.

20.4.3.3 Multi-year, Multi-line Products

The ultimate evolution of reinsurance away from conventional contracts that primarily transfer underwriting risk towards contracts that protect the cedent against a wider variety of risks is represented by various types of *integrated multi-year/multi-line products (MMPs)* (Swiss Re 2003). MMPs modify conventional reinsurance in four primary ways by: (1) incorporating multiple lines of insurance, (2) providing coverage at a predetermined premium for multiple years, (3) including hedges for financial risks as well as underwriting risks, and (4) sometimes covering risks traditionally considered uninsurable such as political risks (Swiss Re 1999). MMPs not only provide very broad risk protection for the cedent but also lower transactions costs by reducing the number of negotiations needed to place the cedent's reinsurance.

The prices of MMPs also may appear favorable relative to separate reinsurance agreements with multiple reinsurers, because the issuer of the MMP can explicitly allow for the diversification benefits of covering several lines of business. MMPs represent "cross-selling" at the wholesale financial services level. As in the case of retail financial services, however, "cross-selling" does not necessarily

²⁴RXLs are most important under occurrence-based liability policies, where coverage is provided during a specified period (the *accident year*) and claim settlement covers a lengthy period of time following the end of the coverage period. At the end of the accident year, the majority of claim payments has not been made but can only be estimated, leading to the creation of the *loss reserve*. The process through which the reserved claims become payments is called *loss reserve development*, and RXL contracts protect against adverse loss reserve development.

²⁵If developed losses incurred exceed the retention (strike price) specified in the contract, the cedent receives payment from the reinsurer to partly defray the costs of the adverse development. The reinsurer may assume some liability in the event that one or more of the cedent's other reinsurers default.

dominate “cross-buying,” i.e., buying from the best producer of each product purchased. In addition, because such contracts incorporate several elements usually covered separately, a lack of pricing transparency may impede market development. Thus, the ultimate success of MMPs in the risk-transfer market remains uncertain.

20.4.3.4 Multiple Trigger Products

Also going beyond conventional reinsurance are *multiple-trigger products (MTPs)* (Swiss Re 2003). MTPs reflect the principles of “states of the world” theory from financial economics and recognize that reinsurer payments to the cedent are worth more in states of the world where the cedent has suffered from other business reversals in comparison with states when the cedent’s net income is relatively high. Thus, payment under an MTP contract depends upon an insurance event trigger *and* a business event trigger, both of which must be activated to generate a payment. For example, an MTP might cover the cedent for catastrophic hurricane losses that occur simultaneously with an increase in market-wide interest rates. The cedent would thus be protected against having to liquidate bonds at unfavorable prices to pay losses resulting from the catastrophe but would not have to pay for protection covering circumstances where a catastrophe occurs when securities market conditions are more favorable.

In effect, MTPs combine conventional reinsurance protection and financial derivatives in a single, integrated contract, analogous to the contracts modeled by Barrieu and Louberge 2009. In the hurricane example, the MTP product combines reinsurance protection with an embedded interest rate derivative. Because the probability of the simultaneous occurrence of an interest rate spike and a property catastrophe is low, the MTP product is likely to be priced considerably below a catastrophe reinsurance policy, enabling the cedent to direct its hedging expenditures to cover states of the world where the payoff of the hedges has the highest economic value.

20.4.3.5 Industry Loss Warranties

A type of multiple-trigger contract that has become particularly successful is the *industry loss warranty (ILW)*. ILWs are dual trigger contracts that pay off on the occurrence of a joint event in which a specified industry-wide loss index exceeds a particular threshold at the same time that the issuing insurer’s losses from the event equal or exceed a specified amount (McDonnell 2002; Gatzert and Kellner 2011).²⁶ The former trigger is called the *index trigger* or *warranty*, and the latter is the *indemnity trigger*. The insurer purchasing an ILW thus is covered in states of the world when its own losses are high and the reinsurance market is likely to enter a hard-market phase. Because one of the triggers is the insurer’s own losses, ILWs overcome regulatory objections to non-indemnity contracts and hence permit the contracts to qualify for reinsurance accounting treatment.²⁷ The indemnity trigger is usually set very low, such that the insurer is almost certain to recover if industry losses satisfy the index trigger.²⁸ However, because ILW payoffs are primarily driven by the index trigger, they have

²⁶ILWs were the first index-based insurance contracts, introduced during the 1980s (Swiss Re 2009b).

²⁷Insurance regulators sometimes object to non-indemnity products on the grounds that they expose insurers to excessive basis risk and potentially can be used for speculation rather than hedging.

²⁸Several important contractual provisions must be defined in an ILW, such as the geographical regions and perils covered. The contract also specifies the warranty, i.e., the magnitude of the index that triggers payment, the size of the indemnity trigger (e.g., \$10,000), and the maximum limit of coverage (e.g., \$10 million). In addition, the contract must specify the index that triggers the contract, such as one of the Property Claims Services (PCS) indices. Index triggers are usually *binary*, whereby the contract pays 100% of value once losses breach the warranty, but can be *pro rata*, whereby the contract pays proportionately based on how much the index exceeds the warranty.

the disadvantage of exposing the buyer to basis risk (Gatzert and Kellner 2011). ILS contracts are usually highly standardized, but contracts can be negotiated that are more structured and tailored to reduce basis risk and meet other buyer needs (Willis Re 2012).

Also because ILWs are purchased from specific counterparties rather than through an exchange, credit risk is present. Traditionally, ILS sellers were from the (re)insurance industry, but in recent years the majority of market capacity has been provided by capital market participants, including those using a fronting reinsurer to support collateralized coverage (Willis Re 2012). ILWs are viewed by capital market investors as an efficient way to invest in catastrophe-related derivatives.²⁹ Transparency is high for standardized ILWs, because the contracts are relatively simple and well understood, and contract wording is becoming increasingly standardized. ILWs usually cover a 1-year period, but there is growing buyer interest in multi-year contracts as an efficient way to provide a long-term hedge.

In addition to the advantages of a dual trigger, ILWs also are attractive because no underwriting information is usually required due to the fact that the seller is mainly underwriting the industry loss index rather than the buyer's losses. Hence, ILWs reduce the costs of moral hazard (Gatzert et al. 2007). ILWs also are attractive to buyers due to the low indemnity retention and the ability to plug gaps in conventional reinsurance programs. The market has expanded to encompass multi-year ILWs and ILWs with multiple index triggers. Critics of ILWs cite high frictional costs, low liquidity, and lack of transparency in the secondary market as disadvantages, but these problems may be mitigated in the future by securitization and standardization. ILW market capacity was \$6 billion in 2011 and 2012 estimates range from \$7 to \$7.5 billion (Willis Re 2012).

Although minimal volume data on ILWs are available, pricing statistics have recently become available. The ILW prices for the USA from April 2002 through July 2008 are shown in Fig. 20.4. Rates-on-line are shown for contracts attaching at industry losses of \$20, \$30, and \$50 billion. Rates-on-line are expressed as percentages of the maximum coverage limit, e.g., a buyer of \$100 million of protection triggered by an industry loss of \$20 billion would have paid about 15% or \$15 million for the ILS in January of 2005. Prices are highest for the lowest attachment point (\$20 billion) and decline for higher attachment points, which have lower probabilities of exceedance. The cyclicity in reinsurance prices carries over to the ILW market.

20.4.3.6 Sidecars

An innovative financing vehicle that is similar to conventional reinsurance but accesses capital markets directly through private debt and equity investment is the *sidecar*. Sidecars date back to at least 2002 but became much more prominent following the 2005 hurricane season (A.M. Best Company 2006). Most sidecars to date have been established in Bermuda, for regulatory and tax reasons (Ramella and Madeiros 2007).

The sidecar structure is diagrammed in Fig. 20.5. Sidecars are reinsurance companies structured as *special purpose vehicles* (SPVs) (also called single purpose reinsurers (SPRs)). Sidecars are created and funded by an institutional investor, such as a hedge fund, to provide additional underwriting capacity to a single insurer or reinsurer (commonly called the *sponsor*), usually for property catastrophe and marine risks. The sidecar's risk-bearing activities are typically confined to the specific sponsoring reinsurer.³⁰ The capital raised by the sidecar is held in a collateral trust for the benefit of the sponsor, reducing or eliminating credit risk. The cedent then enters into a reinsurance contract

²⁹The market has expanded to include the so-called *cold spot ILWs*, which are reinsurance derivative contracts that trigger on industry loss estimates for nonpeak risks such as New Zealand earthquakes.

³⁰Sidecars can also be "market-facing," i.e., directly issue reinsurance to third-parties other than the sponsoring reinsurer. Some industry observers question whether such structures are true sidecars (Sclafane 2007).

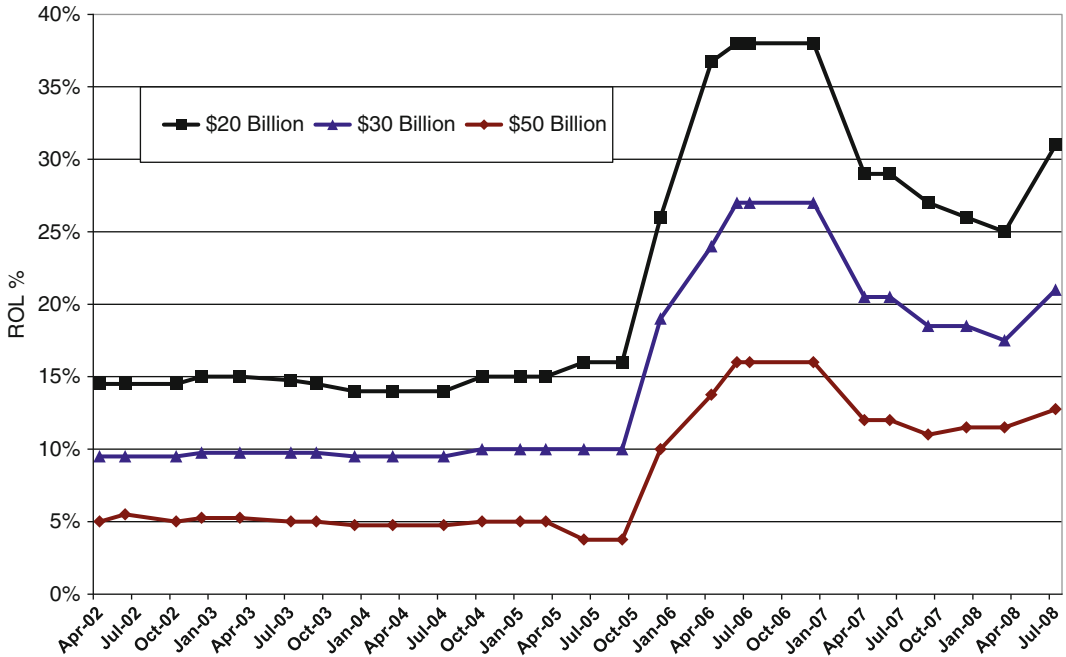


Fig. 20.4 ILW pricing: US all perils. Source: Access Re

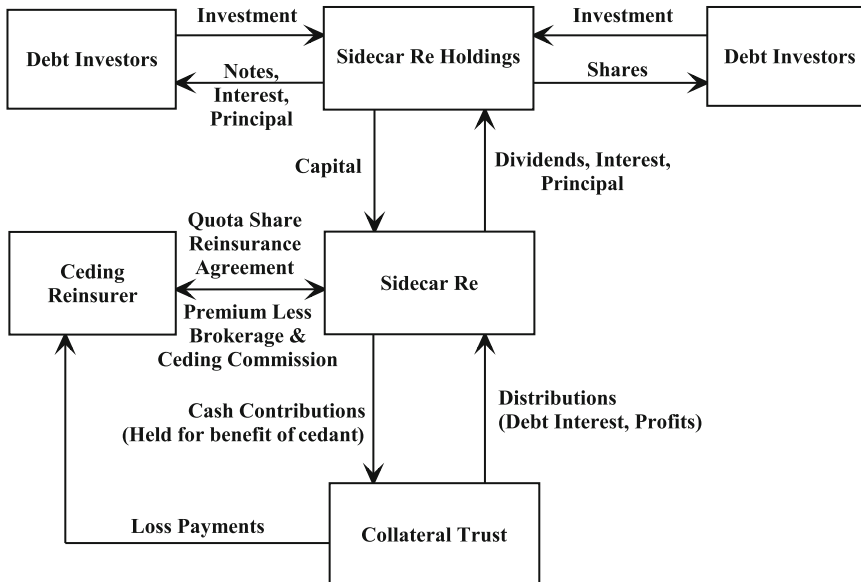


Fig. 20.5 The structure of a typical sidecar

with the sidecar, usually a quota share agreement. The sidecar receives premiums for the reinsurance underwritten and is liable to pay claims under the terms of the reinsurance contracts. Sidecars generally have limited lifetimes such as 2 years to capitalize on high prices in hard markets and quickly withdraw capacity in soft markets (Cummins 2007; Lane 2007).

The ceding reinsurer can earn profits on transactions with the sidecar through ceding commissions and sometimes also profit commissions. Thus, it can replace risk-based underwriting profit income with fee income, transferring the risk to the sidecar. In comparison with issuing debt or equity securities, sidecars are usually formed off-balance-sheet and hence do not affect the issuing reinsurer's capital structure. Thus sidecars may reduce regulatory costs and enhance the issuer's financial rating. Sidecars enable sponsors to leverage access to business and underwriting capabilities on a broader capital base without raising expensive equity capital (Swiss Re 2006). Sidecars can also be formed quickly and with minimal documentation and administrative costs. This is in contrast with Cat bonds, where significant legal, actuarial, investment banking, and risk modeling costs are incurred.

Sidecars are attractive to sponsors in comparison with reinsurance retrocessions because they do not require the sharing of underwriting information with competitors—the counterparty in a retrocession is another general market reinsurer whereas the counterparty in a sidecar transaction is an SPR financed by a bank or hedge fund that does not directly underwrite insurance market risks. Because the parties to the transaction participate in the underwriting results through a quota share arrangement, moral hazard is lower than with retrocession, potentially reducing the costs of the transaction. The quota share approach also mitigates any information asymmetries between the sponsor and the investors with regard to the sponsor's underwriting portfolio.

The sidecar is usually owned by a holding company, which raises capital for the sidecar by issuing equity and/or debt. If debt securities are issued, a tiered structure can be used, similar to an asset-backed security, to appeal to lenders with differing appetites for risk. Private equity funds, hedge funds, and investment banks provide the capital for the typical sidecar (Ramella and Madeiros 2007). In fact, the growth of the sidecar market has been significantly driven by private equity and hedge funds seeking attractive nontraditional sources of investment yield. In effect, the investors obtain access to the uncorrelated risk of retrocession while the sponsoring reinsurer handles all underwriting responsibilities, obviating the hedge fund's need to create its own reinsurance infrastructure (Lane 2007).

It is important to understand some structural differences between sidecars and Cat bonds. While both can accept Cat risk, the structure and risk content are slightly different. In general, sidecars allow investors to participate in the “equity-like” risk of specific insurance exposures. Sidecars sometimes look to add leverage by raising debt to support low-probability risks. It is in these layers that sidecar debt can resemble cat bonds. Similar to cat bonds, these risk layers within sidecars do not expect to suffer losses except due to catastrophic events and carry lower returns than the equity layers as a result. The critical difference between leverage within a sidecar and an indemnity cat bond is that the debt tranches in a sidecar provide leverage to the sidecar's equity investors, while cat bonds provide leverage to the equity investors of the sponsoring insurer (thus complementing the sponsor's traditional reinsurance).

There are several other important differences between sidecars and Cat bonds. While Cat bonds allow insurers to transfer their catastrophic property risk to the capital markets, sidecars are best described as tools that help insurers in financing any risk on their books, including property risks. Cat bonds are structured as bonds and marketed to a wide range of investors, whereas sidecars are usually financed by a single investor such as a hedge fund. Hence, unlike Cat bonds, sidecars do not lend themselves to the development of a secondary market (Lane 2007). Cat bond payoffs are usually designed similarly to XOL reinsurance, whereas sidecars usually are quota share arrangements. Cat bonds also typically cover low frequency, high severity events, whereas sidecars are often designed as “working covers,” reinsuring higher frequency events. Sidecars offer the sponsor and investors more opportunity to tailor the terms and conditions of coverage, in contrast to the more readymade design of Cat bonds. Therefore, sidecars occupy an intermediate position between reinsurance and true securitization of risk.

20.4.3.7 Hybrid Products: Conclusions

Hybrid instruments extend traditional reinsurance and illustrate financial innovation in risk transfer. The contracts have evolved over time from those which primarily extend existing reinsurance products to arrangements such as sidecars that access broader capital markets, providing targeted and time-limited infusions of risk-bearing capacity. Although continued financial innovation can be expected in the future, a few caveats should be kept in mind:

1. Many of the contracts exploit the existence of market imperfections and unexploited arbitrage opportunities. In a complete markets setting with more or less perfect information, many of these contracts would not be viable. For example, if priced in efficient financial markets, a loss portfolio transfer should not change the stock market valuation of either the insurer or the reinsurer unless it enhances diversification or reduces systematic risk. That is, market and information imperfections create the “gains from trade” in many of these transactions. The same is generally not true of reinsurance, such as XOL reinsurance, which provides legitimate opportunities for insurers to diversify risk geographically and cushion shocks to capital.
2. Insurance/financial markets are evolving away from rather than towards highly structured, relatively opaque products such as MMPs and MTPs. Among other potential limitations, these contracts typically access the capital of a single reinsurer. Therefore, MMPs as presently structured do not bring new risk-bearing capital into the market. The fact that MMPs and MTPs are complex, dealing with multiple lines and a variety of financial risks, makes them more difficult to securitize than more transparent products, limiting their growth potential.
3. In principle, many contracts that incorporate both insurance and financial risks could be replicated by separately trading insurance derivatives and financial derivatives. In this case, the value added from constructing the hedge could be uncoupled from the need for a residual claimant such as a reinsurer. Therefore, contracts that payoff based on joint underwriting and financial triggers may not be viable on an ongoing basis, but “pure play” instruments such as sidecars that allow investors to gain exposure to underwriting risk are likely to remain important.

20.5 Nonlife Insurance Securitization

This section focuses on nonlife insurance instruments that access the capital markets directly. Capital market instruments are important because of their ability to absorb the risk of large catastrophes and their potential to add liquidity and transparency to the risk-transfer market.

20.5.1 Demand for Securitized Products: Nonlife

To analyze the demand for securitized products, we first consider the role of traditional reinsurance. Small and medium size insurers often purchase reinsurance to help finance growth in view of the strain placed on equity capital by writing new business. Some insurers also utilize reinsurance to access the expertise of reinsurance companies. Reinsurers can assist clients in pricing and managing risk, designing new products, and expanding their geographical scope of operations ([Swiss Re 2010a](#)). However, the demand for securitized products in the nonlife area is almost exclusively attributable to risk management and diversification needs.

The economic role of insurance is the diversification of risk, and the economic role of reinsurance is to take this diversification to a regional and global scale. The statistical foundation of insurance

is the *law of large numbers*, which implies that insurers can effectively diversify risks by writing insurance on large numbers of relatively small, statistically independent risks. Under these conditions, the average loss becomes arbitrarily close to the population mean, such that pricing is predictable, and the amount of equity capital the insurer must hold to guarantee payment with high probability becomes arbitrarily small on a per policy basis. Such a market has been defined as *locally insurable* (Cummins and Weiss 2000).

The motivation for global reinsurance becomes apparent when we relax the assumptions under which risk is locally insurable. For example, global reinsurance markets are likely to be required for risks with large losses and/or large statistical deviations from expected losses and relatively small numbers of exposures, even if the risks are independent. An example of this type of risk is insurance against pollution claims resulting from oil tanker accidents. The risk of oil spills is relatively uncorrelated across tankers, but there are not very many oil tankers and the losses they can cause are massive.

Further motivation for the development of international reinsurance markets is provided by relaxing the assumption that risks are statistically independent. If risks are dependent, the amount of equity capital needed per risk to achieve a given insolvency target can become uneconomic, eliminating the “gains from trade” arising from insurance transactions (Cummins and Weiss 2009). However, risks that are locally *dependent* may be globally *independent*, e.g., the risk of tornadoes in the American Mid-West versus Australia. This provides an economic motivation for global reinsurance markets where insurers can cede the covariance risk to a reinsurer who pools the risk with independent risks from other regions of the world. Such risks are said to be *globally insurable* (Cummins and Weiss 2000).

There is a third category of risk that is neither locally nor globally insurable. Such risks come from events with low frequency and very high severity, where the covariances among the individual risks making up a portfolio are also relatively high. Examples of such risks are severe hurricanes and earthquakes striking geographical regions with high concentrations of property values. For example, in 2005 Hurricanes Katrina, Rita, and Wilma caused insured losses of more than \$100 billion (indexed to 2011) (Swiss Re 2012b). Such catastrophe losses are large relative to the resources of global reinsurers—the top 40 reinsurers had \$159 billion in premiums and \$321 billion in equity in 2010 (Standard and Poor’s 2011). However, events of this magnitude are small relative to the market capitalization of US securities markets, which is about \$76 trillion.³¹ Thus, by introducing ILS, large catastrophes are diversifiable across the financial markets, i.e., such risks are *globally diversifiable*.

Demand for nonlife securitization arises from risks that are globally diversifiable but not globally insurable. However, hedgers seeking to diversify risks that approach the borderline between the two categories may also be confronted by high prices or limited availability of coverage. Although insurance theory predicts that hedgers should give highest priority to insuring the largest losses, in actual reinsurance markets, the marginal percentage reinsured declines as the size of the insured event increases. For example, according to one study (Froot 2001), for a \$7.5 billion catastrophic event, the percentage of a marginal dollar of industry-wide loss that is reinsured was only about 25%.³² Thus, reinsurance price and availability problems provide a further motivation for nonlife securitizations.

Another way of viewing the catastrophe loss financing problem is that it is a problem of inter-temporal diversification rather than the “point-in-time” diversification that characterizes most insurance transactions (Jaffee and Russell 1997). That is, for most lines of insurance, insurers can price the risk such that the annual ratio of losses to premiums will fall in a relatively narrow range less than 100%. There is some volatility by year but for most lines of insurance the volatility of the loss ratio is not very high. This contrasts with a “once in 100 years” catastrophe, where the loss will

³¹Source, Federal Reserve Flow of Funds Accounts, as of December 2011. Securities include all credit market debt outstanding plus the value of corporate equities.

³²Froot’s estimates are based on data for 1994, with losses expressed in 2011 price levels.

be either zero or a very large multiple of the annual premium. Jaffee and Russell (1997) point out that the problem is “how to match a smooth flow of premium receipts to a highly nonsmooth flow of loss payments. This is a capital market problem and not an insurance market problem.” They also point out that accounting and tax rules prevent insurers from accumulating very large amounts of capital for losses that have not yet occurred. In addition, there are potentially severe agency costs from managers having access to large amounts of underutilized equity capital, and such pools of capital tend to attract corporate raiders.³³ Hence, raising large amounts of capital in anticipation of infrequent catastrophes is not the solution to the inter-temporal diversification problem, once again pointing to a capital market solution.

20.5.2 *Contingent Capital*

Contingent capital is a securitization transaction similar to a put option, which allows an insurer to issue capital (e.g., common stock, hybrid capital, or debt) at a predetermined strike price following the occurrence of a defined catastrophic event.³⁴ For example, if the insurer’s stock price falls below the strike price following a hurricane of specified magnitude, the insurer would have the option of issuing shares at the agreed upon strike to replenish its capital. Contingent capital agreements can be fully funded similar to Cat bonds but are usually in the form of options. The benefits of contingent capital include a low up-front option fee, balance sheet protection when it is most needed—after a major catastrophic event—and access to financing without increasing leverage. A disadvantage of contingent capital is that issuing shares has a dilution effect not present with Cat bonds or options, and issuing contingent debt adversely affects the insurer’s capital structure. Until recently, the presence of both catastrophe risk and credit risk impeded the development of the contingent capital market. The development of the ILS market has enhanced the attractiveness of catastrophe risk exposure to capital market participants, but counterparty credit risk remains a concern for unfunded transactions.³⁵

20.5.3 *Catastrophe Futures and Options*

Hurricane Andrew in 1992 raised questions about the capacity of the insurance and reinsurance industries to respond to large catastrophes. As a result, market participants began to explore alternative measures for hedging catastrophic risk. The first such effort was the introduction of catastrophe futures and options by the CBOT in 1992. The contracts paid off on catastrophe loss indices and were patterned on the derivatives contracts widely traded on financial exchanges for commodities, interest rates, etc. When the options failed to attract much interest among hedgers and speculators,

³³Insurers can and do raise significant amounts of equity capital following large loss shocks such as Hurricane Andrew, Hurricanes Katrina, Rita, and Wilma, and the Financial Crisis of 2008–2010 (Cummins and Mahul 2008; Berry-Stölzle et al. 2011). However, this tends to be capital to support their ongoing insurance operations rather than capital to be held in anticipation of large catastrophic events.

³⁴An early contingent capital transaction, issued over-the-counter by Aon, was called a CAT-E-Put, an abbreviation for “catastrophic equity put option.” Contingent capital is discussed further in Culp (2002) and Aon (2008a).

³⁵An example of a contingent debt transaction is the \$500 million Farmers Insurance Group transaction in 2007, which gave the insurer the option to issue loan notes at a fixed price to a group of banks, triggered by a Texas, Arkansas, Oklahoma or Louisiana windstorm loss of at least \$1.5 billion. The deal represented the first time a commercial bank had cooperated with a reinsurer to provide regulatory capital for an insurer and in doing so assumed the subordinated credit risk of the insurer and catastrophe risk.

they were replaced in 1995 with redesigned options based on catastrophe loss indices compiled by PCS. The CBOT-PCS contracts were generally traded as call and put option spreads. Contracts were offered on a US national index, five regional indices, and three state indices.

The CBOT-PCS options generated moderate trading volume but were delisted in 2000 due to lack of investor interest. Various reasons have been proposed to explain the failure of the CBOT contracts, including excessive basis risk, lack of insurer expertise in options trading,³⁶ low liquidity, counterparty credit risk, and uncertainty about regulatory accounting treatment ([American Academy of Actuaries 1999](#)). Other efforts to launch catastrophe options, e.g., by the Bermuda Commodities Exchange, also failed.

These options market failures are particularly regrettable given that options in theory provide a more efficient mechanism for hedging catastrophe risks than more highly structured and fully collateralized mechanisms such as Cat bonds. Cat bonds are relatively expensive to issue, as they incur significant legal, actuarial, risk modeling, and investment banking costs. For example, the transactions costs of issuing a Cat bond can consume up to 3% of bond issuance volume and account for 20% of the bond coupon rate ([Modu 2007](#)). Full collateralization is also expensive due to fiduciary expenses and the cost of the interest rate swap contracts used to protect the sponsor against interest rate risk. By contrast, in a highly liquid options market, trades can be conducted quickly at low costs, with margin requirements and clearinghouse guarantees protecting buyers against default risk. Maintaining margin is costly to option sellers, but these costs are relatively low compared to the transaction costs of Cat bonds. Futures and options are also potentially more efficient than Cat bonds because of the ability of hedgers and investors to quickly open, restructure, or close out a position. By contrast, Cat bonds take time to set up and generally lock the sponsor into the hedging position for a multi-year period.

Because options make sense from an economic perspective and because insurers have become more comfortable in dealing with financial instruments, there have been several recent efforts to relaunch options with payoffs triggered by catastrophic property losses. In 2007, futures and options contracts were introduced by the New York Mercantile Exchange (NYMEX), the Chicago Mercantile Exchange (CME), and the Insurance Futures Exchange (IFEX), whose contracts trade on the Chicago Climate Exchange (CCX). Deutsche Bank and Swiss Re joined the IFEX effort as market makers. As of mid-2012, the NYMEX contracts had been withdrawn but the CME and IFEX contracts are still listed. To date, there has been minimal trading in the new contracts, but there is potential for future growth. The characteristics of the futures and options contracts launched in 2007 are shown in Table 20.1, which also shows information on the CBOT-PCS options for purposes of comparison. There are some significant differences in design features among the three types of contracts shown in the table.

The IFEX-Event Loss Futures (ELF) contracts are unique among insurance derivative contracts offered to date because they are designed to mimic ILWs and therefore can be used to hedge ILW risk.³⁷ The contracts are designed to pay off on PCS insured catastrophe loss indices, for US tropical windstorm losses in defined geographical regions. A contract is available covering the 50 US states, the District of Columbia, Puerto Rico, and the Virgin Islands, and contracts are also available covering Florida and the Gulf Coast. The contracts currently available are 1st, 2nd, 3rd, and 4th event contracts, with triggers of \$10, \$20, \$30, \$40, and \$50 billion. For example, suppose an insurer buys a 1st event contract with a trigger of \$10 billion. The contracts are *binary*, paralleling the most common type of

³⁶The task of educating insurance industry professionals in the use of options is likely to be somewhat more difficult than for many of the other financial instruments discussed here. Sidecars, ILWs, and Cat bonds all have features that closely resemble reinsurance, whereas options are pure derivative contracts that are less familiar to insurance industry participants. The same is probably true as well for swaps. Nevertheless, the other concerns mentioned are probably more important than lack of insurer expertise in explaining the slow take-off of Cat options.

³⁷Although ELFs generally resemble ILWs, they do not contain an indemnity trigger, and traders do not need to have underwriting exposure in order to utilize the contracts.

Table 20.1 Principal characteristics of catastrophe futures and options

| Exchange | IFEX | CME | CBOT PCS |
|---------------------|---|---|-------------------------------------|
| Type of contract | Futures | Futures and options | Options |
| Loss index | PCS | Carvill hurricane index (parametric) (CHI) | PCS |
| Index definition | PCS loss | Index is function of storm wind speed/radius | PCS loss/100M |
| Event | US tropical wind | US hurricane | US insured property losses |
| Geographical region | 50 US states, DC, Puerto Rico, Virgin Islands; Gulf Coast, Florida | Six US regions | National, 5 regions, 3 states |
| Trigger | Annual aggregate losses from 1 st , 2 nd , 3 rd , or 4 th event | Aggregate loss | Aggregate loss in geographical area |
| Trigger products | \$10, \$20, \$30, \$40, and \$50 billion losses | (1) Numbered event, (2) seasonal, (3) seasonal maximum event | Strikes in multiples of 5 points |
| Trigger type | Binary | Aggregate/American | Aggregate/European |
| Contract payoff | $\$10,000 * \text{If}[I > T, 1, 0]$ | $\$1,000 * \text{CHI}$ | \$200 per index point |
| Maximum payout | \$10,000 per option | No maximum | No maximum |
| Contract period | Annual | (1) landfall + 2 days (2) 6/1 to 11/30 + 2 days (3) 6/1 to 2 days after 11/30 | Calendar quarter |
| Contract expiration | 18 months after end of contract period | (1) 2 days after landfall (2) 11/30 + 2 days (3) 11/30 + 2 days | 6 or 12 month development period |
| Launch date | 9/21/2007 | 3/12/2007 | 9/1995 |

Note: IFEX=Insurance futures exchange, CME=Chicago mercantile exchange, CBOT=Chicago board of trade, PCS=Property claims services. I=Index, T=Trigger

Sources: Websites of IFEX, NYMEX, CME, and [American Academy of Actuaries \(1999\)](#)

ILW contract, meaning that the contract would pay \$10,000 for the 1st event that breached the \$10 billion limit as measured by PCS insured losses. The contract coverage period is the calendar year.³⁸ Because of the binary feature and the geographical areas covered, the IFEX futures are subject to substantial basis risk.

The CME contracts differ from the IFEX contracts in that they are not binary but instead are valued at \$X times the value of the triggering index. The CME offers six US regional contracts, which pay off on a parametric index developed by Carvill Corporation ([Carvill 2007](#)). CME contracts are available covering numbered events (e.g., 1st event, 2nd event), seasonal accumulations, and accumulations from seasonal maximum events. The CME contracts potentially have less basis risk than the IFEX contracts

³⁸Because of the “1st event-binary” feature, the contract would not pay off if two catastrophes occurred, one causing damage of \$5 billion and the next causing damage of \$6 billion. If the 1st event contract is triggered, the insurer could obtain additional protection by purchasing 2nd event contracts.

because more regional contracts are available.³⁹ However, the CME adds a source of basis risk by using a parametric index.

It is instructive to compare the insurance futures and options contracts introduced in 2007 with the earlier CBOT-PCS options. The CBOT options were similar to the IFEX options in using PCS index triggers, and they were similar to the CME contracts in offering regional as well as national contracts. The CBOT contracts differed from the more recent contracts in that they primarily covered losses in calendar quarters rather than annually or during the hurricane season and covered losses from all sources, including earthquake.

Except for the facts that IFEX contracts parallel ILWs and the current contracts exclude terrorism and earthquake, there seem few design features in the current contracts that predict that they will succeed relative to the CBOT-PCS contracts. The hope for success hinges on the market's being more sophisticated now than it was during the 1990s and on the existence of a much larger volume of Cat bonds/ILWs that could be hedged using options. The futures/options market seems to be affected by an unfortunate "Catch 22," i.e., potential hedgers are unwilling to trade until liquidity develops but no liquidity will develop until sufficient numbers of hedgers begin to trade. Uncertainties regarding the accounting, regulatory, and rating agency treatment of the contracts also may impede market development. Although such problems have been overcome in the past with respect to options on other underlyings, such as non-catastrophe weather risk, whether the catastrophe derivatives market will succeed remains unclear.

20.5.4 *Catastrophe Swaps*

Another type of insurance-linked derivative is the *catastrophe swap*. In a catastrophe swap transaction, the insurer (cedent) agrees to pay a series of fixed premium payments to a counterparty in exchange for floating or variable payments triggered by the occurrence of a specified insured event. The swap can be negotiated directly with the counterparty (e.g., a reinsurer) or placed through another financial intermediary. Although it is not necessary for the swap counterparty to have insurance risk exposure, it is possible for two insurers or reinsurers to swap risks. Swaps also can be executed that fund multiple risks simultaneously such as swapping North Atlantic hurricane risk for Japanese typhoon risk in the same contract as an earthquake swap.

Swaps have advantages over Cat bonds in being simpler to execute, having lower fixed costs, and not tying up funds in an SPR. The disadvantage of swaps relative to Cat bonds is that they are not fully collateralized and therefore expose the buyer to counterparty credit risk. The illiquidity of swaps is also a disadvantage relative to tradable securities such as bonds and (potentially) options.

Information on the volume of catastrophe swaps is almost entirely anecdotal. For example, in 2007 the newly formed Caribbean Catastrophe Reinsurance Facility (CCRF), which is jointly sponsored by sixteen Caribbean countries to provide immediate liquidity to their governments in the event of a hurricane or earthquake, arranged a \$30 million swap to transfer part of their risk to capital markets (Cummins and Mahul 2008). Another example is the 2003 agreement between Mitsui Sumitomo Insurance and Swiss Re to swap \$12 billion of Japanese typhoon risk against \$50 million each of North Atlantic hurricane and European windstorm risk. In this type of contract, the objective is to calibrate the contract such that no money changes hands until the occurrence of a triggering event. In 2006, Deutsche Bank introduced event loss swaps (ELS), designed to enable clients to buy or sell protection against the economic impact of US wind or earthquake disasters. A buyer of ELS protection pays

³⁹The NYMEX contracts have an annual coverage period, while the CME contracts cover the hurricane season (June 1 through November 30).

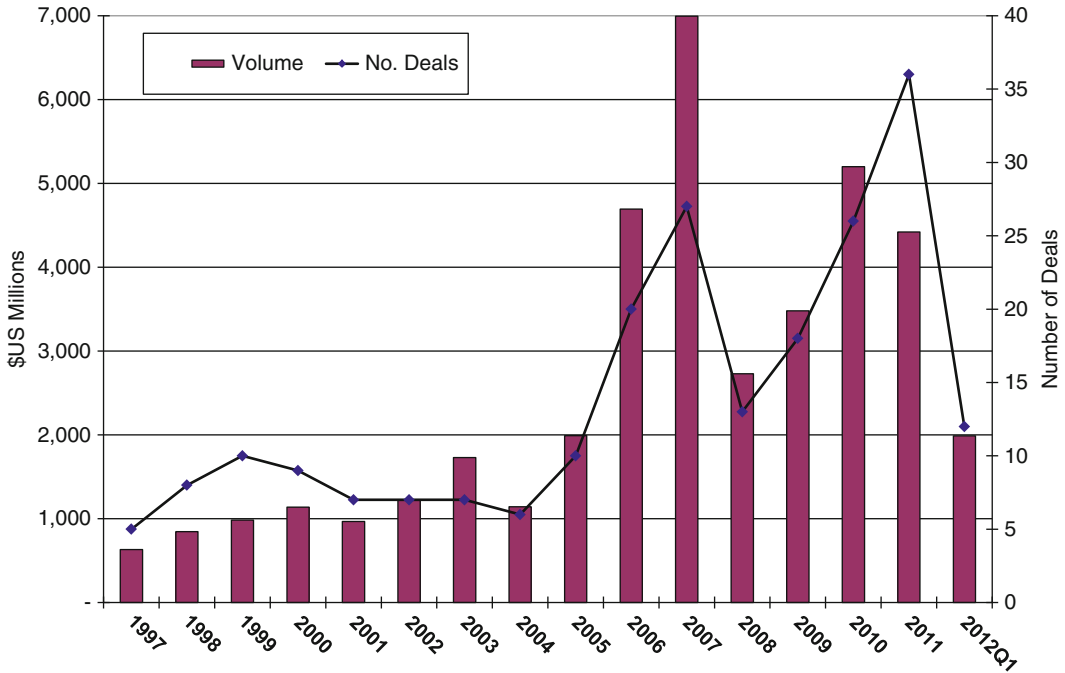


Fig. 20.6 Cat bond new issue volume. *Source:* GC Securities (2008), A.M. Best Company (2010, 2011), Swiss Re (2009a, 2010b, 2011a, 2011b, 2012a), Aon Benfield (2012)

an up-front premium in exchange for a payout of the contract's notional value triggered by industry-wide insured losses exceeding a defined threshold. A seller of ELS protection is paid a premium at the contract's inception and is obliged to pay the buyer the notional amount of the contract when a qualifying loss event occurs. For further discussion of catastrophe swaps, see [Takeda \(2002\)](#) and [Braun \(2011\)](#).

20.5.5 Cat Bonds

Insurance-linked bonds are by far the most successful securitized risk hedging instrument. Although some non-catastrophe nonlife insurance bonds have been issued, the type of contract that predominates in the market is the Cat bond. This section reviews the growth of the Cat bond market and the characteristics of Cat bonds and analyzes Cat bond pricing.

20.5.5.1 The Cat Bond Market Size and Growth

Although the Cat bond market got off to a slow start during the 1990s, the market has matured and has become a steady source of capacity for both insurers and reinsurers. The market set new records for bond issuance volume in 2005, 2006, and 2007 ([Cummins and Weiss 2009](#)). The market has rebounded from the financial crisis, and 2010 was the second largest year on record for Cat bond issuance. Cat bonds make sound economic sense as a mechanism for funding mega-catastrophes, for reasons explained above. Thus, it makes sense to predict that the Cat bond market will continue to

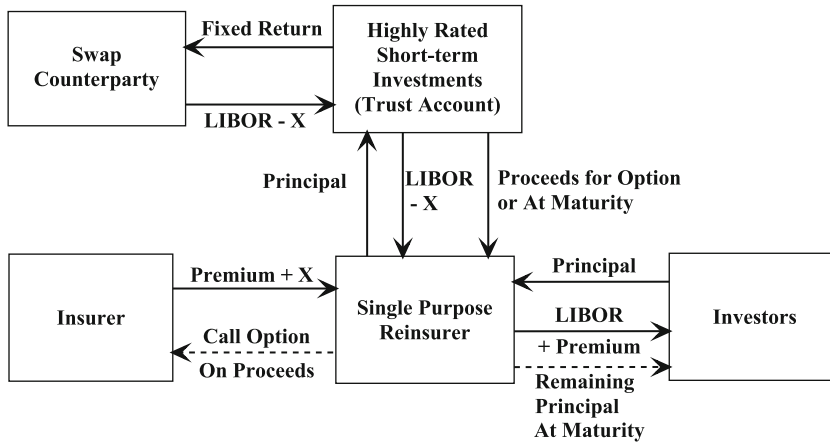


Fig. 20.7 Cat bond with single purpose reinsurer

grow and that Cat bonds will eventually be issued in the public securities markets, rather than being confined primarily to private placements.⁴⁰

The new issue volume in the Cat bond market from 1997 through the first quarter of 2012 is shown in Fig. 20.6.⁴¹ The Cat bond market grew from less than \$1 billion per year in 1997 to \$2 billion in 2005, \$4.7 billion in 2006, and \$7 billion in 2007. Even though the Cat bond market was affected by the subprime financial crisis of 2007–2010, bond issuance in 2008 exceeded 2005, which previously was the third largest year on record. Volume continued to rise in 2009 and 2010 but fell off somewhat in 2011. The structure of the market continues to evolve, and many recent transactions have multiple tranches and include “shelf registrations.”⁴² The amount of risk capital outstanding in the Cat bond market peaked at \$17 billion in 2007 and stood at \$13.6 billion at the end of 2011 (Swiss Re 2012a).

Putting these numbers in perspective, Cat bonds accounted for 8% of global property reinsurance policy limits in 2007 and 12% of US-only property limits, compared to 88% and 82%, respectively, for traditional reinsurance and 4% and 6%, respectively, for ILWs (GC Securities 2008). Because Cat bonds and ILWs tend to be used for higher layers of coverage, they represent much larger proportions of total limits for high-layer property reinsurance. Hence, Cat bonds are becoming an important part of the strategic arsenal of risk-hedging tools regularly used by insurers and reinsurers.

⁴⁰Cat bonds can also be securitized through collateralized debt obligations (CDOs), which in theory do not have the “cliff risk” posed by principal-at-risk Cat bonds (Forrester 2008). However, the recent problems in the CDO market and the general complexity and lack of transparency of CDOs relative to Cat bonds raise questions about the role of CDOs in financing catastrophe risk.

⁴¹Volume is defined as the principal of the bond issuance and hence equals the amount available to pay losses covered by the bonds. The data in the figure apply to nonlife Cat bonds. Event-linked bonds have also been issued to cover third party commercial liability, automobile quota share, and indemnity-based trade credit reinsurance.

⁴²Shelf registrations (offerings) have played an important role in reducing the transactions costs of issuing Cat bonds. First implemented in 2002, shelf offerings allow sponsors to create a single set of offering documents summarizing the general characteristics of an offering, which then provide the basis for issuing additional bonds (*takedowns*), up to a maximum limit over the course of a stated risk period. In addition to enabling sponsors to spread the fixed costs of a transaction over multiple issues, shelf offerings also allow sponsors to access capacity on an as-needed basis, rather than having to make an estimate of their capacity needs several years in advance. Cat bond investors tend to view shelf offerings favorably as they tend to be a reliable source of transaction flow and increase investor confidence by building up a track record of successful transactions (MMC Securities 2007).

20.5.5.2 Cat Bond Structure

A typical Cat bond structure is diagrammed in Fig. 20.7. The transaction begins with the formation of an SPR, which issues bonds to investors (Mocklow et al. 2002). The proceeds are typically invested in safe, short-term securities, which are held in a trust account. Embedded in the Cat bonds is a call option that is triggered by a defined catastrophic event. On the occurrence of an event, proceeds are released from the SPR to the insurer. The release of funds is usually proportional to event size rather than binary. In most Cat bonds, the principal is fully at risk.⁴³ In return for the option, the insurer pays a premium to the investors.

Insurers prefer to use an SPR to capture the tax and accounting benefits associated with traditional reinsurance. Investors prefer SPRs to isolate the risk of their investment from the general business and credit risk of the insurer, creating an investment that is a “pure play” in catastrophic risk. The bonds are fully collateralized, insulating the investors from credit risk. As a result, the issuer of the securitization can realize lower financing costs through segregation. The transaction also is more transparent than a debt issue by the insurer, because the funds are held in trust and are released according to carefully defined criteria.

The fixed returns on the securities held in the trust are usually swapped for floating returns based on LIBOR or another widely accepted index. The arrangement is called a *total return swap (TRS)*. The objective of the swap is to immunize the insurer and the investors from interest rate (mark-to-market) risk and also to reduce default risk. Thus, the investors receive LIBOR plus the risk premium in return for providing capital. If no contingent event occurs, the principal is returned to the investors upon the expiration of the bonds.

The subprime financial crisis revealed some potential problems with Cat bond collateral and TRS arrangements. At the time of its default, Lehman Brothers was the TRS counterparty of four different cat-bonds (Ajax, Carillen, Newton Re 2008, and Willow Re 2007). This triggered a debate focusing on the collateral and the structuring of Cat bond transactions. More precisely, several problems with the collateral were identified, affecting some Cat bonds, including:

- Lack of transparency of the investments in the collateral account (Aon 2008b)
- Broad eligible investment criteria for collateral assets
- Lack of collateral asset diversification
- Maturity mismatch between the assets in the collateral account and the bond
- Lack of regular mark-to-market valuations of collateral assets for most deals
- No top-up provision for the TRS provider if the value of the assets fell below a certain threshold, or top-up provisions linked to the rating on the TRS counterparty and not the value of the assets in the collateral account (Lane and Beckwith 2008)

As a result, the market value of the assets in the collateral accounts of the four bonds affected by the default of Lehman Brothers was so low that no replacement for the TRS counterparty could be found for any of them, exposing investors directly to the investment risk related to the collateral assets. The four cat-bonds were downgraded by rating agencies in late September 2008.

Until Lehman’s default, in many transactions, the collateral was made of the most senior tranches of “structured finance” (AAA with an additional spread, already Libor based). These instruments were selected by investment banks and were poorly diversified. This created a major problem of security and liquidity, since the basic assumptions were “AAA=risk-free assets” and “Libor=risk-free

⁴³Some Cat bond issues have included *principal protected tranches*, where the return of principal is guaranteed. In this tranche, the triggering event would affect the interest and spread payments and the timing of the repayment of principal. Principal protected tranches have become relatively rare, primarily because they do not provide as much risk capital to the sponsor as principal-at-risk bonds.

rate.” These difficulties have underlined a problem in the structure itself but not in the fundamentals. Therefore, innovative structural changes have been introduced in the new transactions. When using a TRS counterparty, the management of the collateral has been improved with more restricted investment guidelines, regular mark-to-market valuations, and top-up provisions. When there is no TRS counterparty, the collateral account is invested in AAA rated government-guaranteed securities, with an option to be sold at par on each quarterly payment date and no mismatch in the maturity date or the collateral account invested in money market funds, which has been the preferred structure so far. The recent downgrade of the US government has made the money market funds even more attractive.

In general, however, Cat bonds performed much better than comparable corporate bonds or ABS during the crisis and seem to be “insulated” from most other segments of the securities market (GC Securities 2008). Although there has been only one publicly announced wipe-out of a Cat bond (KAMP Re, following Hurricane Katrina), there have reportedly been other wipe-outs that were not publicly reported. The impact of the KAMP Re wipeout on the Cat bond market was favorable. The smooth settlement of the bond established an important precedent in the market, showing that Cat bonds function as designed, with minimal confusion and controversy between the sponsor and investors. Thus, the wipeout served to, “reduce the overall uncertainty associated with this marketplace and therefore increase both investor and sponsor demand for these instruments” (Guy Carpenter 2006, p. 4).

20.5.5.3 Cat Bond Characteristics

The characteristics of Cat bonds continue to evolve, but the overall trend is towards more standardization. Cat bonds differ in several respects, including types of triggering events, perils and regions covered, bond tenor (time to maturity), and sponsoring organization.

Cat securities have been structured to pay off on four types of triggers—insurer-specific catastrophe losses (*indemnity triggers*), insurance-industry catastrophe loss indices (*industry-index triggers*), *modeled loss triggers*, and *parametric triggers*, based on the physical characteristics of events. In bonds with indemnity triggers, the bond payoff is determined by the losses of the issuing insurer; whereas in industry-index triggers, the bond payoff is triggered by the value of an industry loss index. In modeled loss triggers,⁴⁴ the payoff is determined by simulated losses generated by inputting specific event parameters into the catastrophe model maintained by one of the catastrophe modeling firms. A *pure parametric trigger* pays off if the covered event exceeds a specified physical severity level, such as a Richter scale reading for an earthquake, while a *parametric index trigger* incorporates more complicated functional forms than pure parametric triggers. Triggers are also used that are *hybrids* of the four basic types.

The choice of a trigger for a Cat bond involves a trade-off between moral hazard and basis risk (Doherty 2000). Pure indemnity triggers are subject to the highest degree of moral hazard. The lowest degree of moral hazard and highest basis risk are provided by pure parametric triggers, where insurer exposures and losses are irrelevant. An intermediate case is provided by modeled triggers, which use as inputs insurer exposure maps and coverage characteristics but not actual reported insurer losses. Because of the higher moral hazard, spreads for bonds with indemnity triggers tend to be higher than for non-indemnity bonds. Bonds with indemnity triggers also tend to have higher transactions costs because more documentation is required regarding the issuer’s exposures and underwriting. Finally, bonds with indemnity triggers may take longer to settle following an event because the issuer’s losses need to be verified.

⁴⁴In modeled industry triggers (“MITs”), industry index weights are set post-event (Swiss Re 2009b).

Fig. 20.8 Triggers of outstanding CAT bonds (As of December 31, 2011).
 Source: Swiss Re (2012a)

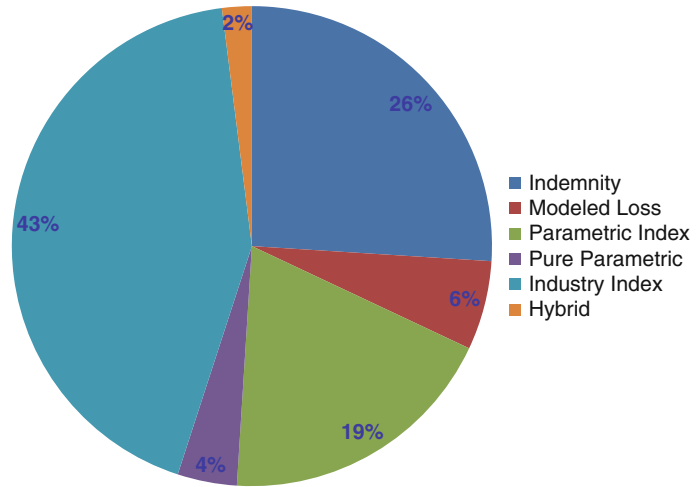
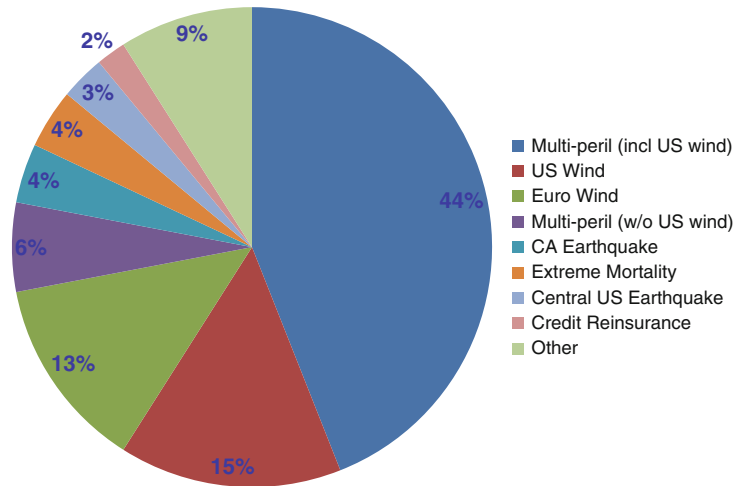


Fig. 20.9 Perils covered by outstanding CAT bonds (As of December 31, 2011).
 Source: Swiss Re (2012a)



Although it might seem that concerns about moral hazard might lead to minimal use of indemnity contracts, the choice of trigger does seem to involve a trade-off between the costs of moral hazard, frictional costs, and settlement delays, on the one hand, and the costs of basis risk, on the other. As a result, no single trigger type predominates. The triggers of CAT bonds outstanding as of December 31, 2011 are shown in Fig. 20.8. Industry index triggers account for 43% of outstanding bonds, indemnity triggers represent 26%, and parametric triggers account for 23%. Modeled loss triggers (6%) and hybrid triggers (2%) account for the remainder.

Figure 20.9 shows the regions and perils covered by Cat bonds outstanding as of December 31, 2011. The US predominates as the primary source of demand for Cat bonds. US multi-peril coverage (including US windstorm) accounts for 44% of outstanding bonds, US windstorm for 15%, multi-period (without US windstorm) for 6%, and US earthquake for 7%. Therefore, in total, the USA accounts for 72% of all outstanding Cat bond coverage. Smaller proportions of outstanding bonds cover “off-peak” perils and regions, including European windstorm (13%), and 4% cover extreme mortality events. Bonds on other regions/perils such as Mexican earthquake and hurricane account for only 9% of outstanding bonds. Spreads are lower for the “off peak” perils and regions than for the USA because off-peak bonds are very valuable to investors for diversification of their catastrophe risk (Cardenas et al. 2007).

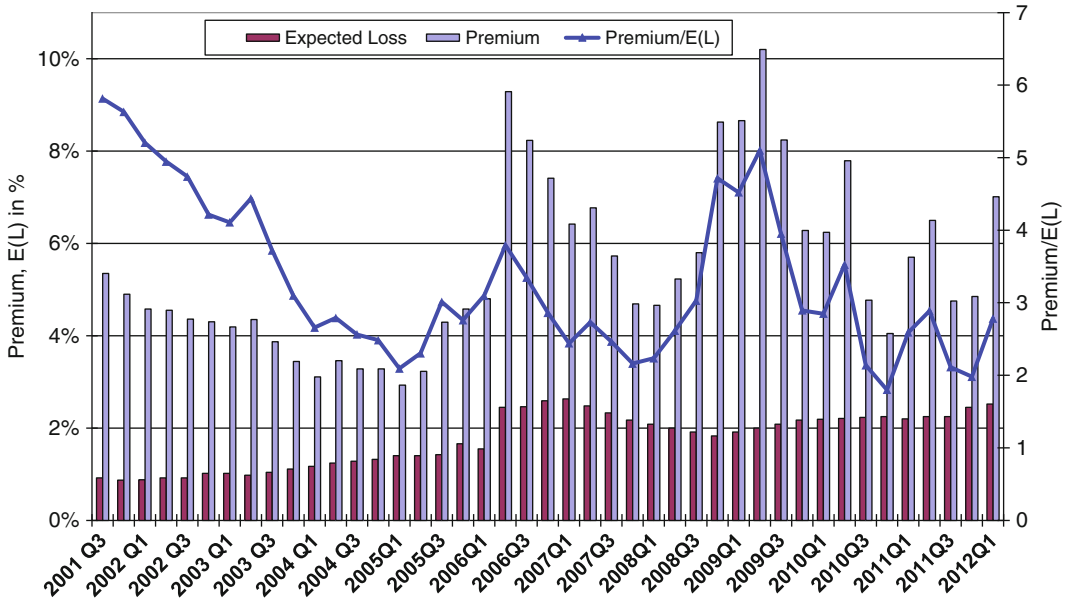


Fig. 20.10 Cat bond spreads. Source: Lane Financial

The market has gravitated towards multiple-year bonds, as issuers seek to avoid the reinsurance underwriting cycle and spread the fixed costs of bond issuance over time. In terms of volume, the majority of new issues from 2006 to 2011 had a maturity of 24–36 months. For the 12-month period from the 2nd quarter of 2011 through the 1st quarter of 2012, about 70% of issue volume was for 24–36 months and only 3% for less than 24 months (Lane and Beckwith 2012).

20.5.5.4 Cat Bond Spreads

Cat bonds are priced at spreads over LIBOR, meaning that investors receive floating interest plus a spread or premium over the floating rate. In the earliest days of the market, Cat bonds were notorious for having high spreads. However, current spreads are not especially high, and Cat bonds are now priced competitively with conventional reinsurance.

Although Cat bonds are not publicly traded, there is an active nonpublic secondary market that provides some guidance on yields. The secondary market yields on Cat bonds are shown quarterly from the third quarter of 2001 through the first quarter of 2012 in Fig. 20.10. Figure 20.10 shows the expected loss, the premium over LIBOR, and the bond spread (ratio of premium to expected loss), based on averages of secondary market transactions.⁴⁵ Figure 20.10 shows that Cat bonds tend to be issued for low probability events, ranging from 1 to 3% expected loss. This reflects the higher capacity of reinsurance for smaller, more frequent events.

The primary conclusion to be drawn from Fig. 20.10 in terms of pricing is that Cat bond spreads have declined significantly as the market has matured. In 2001, the ratio of premium to expected loss was around 6. However, the spreads declined steadily until the time of Hurricane Katrina, standing at slightly over 2.0 in the first quarter of 2005. Hence, the “high” bond prices explored by earlier

⁴⁵The data in Fig. 20.8 are from Lane and Beckwith (2005, 2006, 2007, 2008, 2011, 2012).

researchers did not exist by early 2005. Nevertheless, the Cat bond market is not immune to the underwriting cycle or financial crises—bond premia and spreads increased significantly as the market tightened in 2005 and 2006 following Hurricanes Katrina, Rita, and Wilma, increasing to 3.8 in the second quarter of 2006. However, spreads returned to lower levels, falling to about 2.2 in the fourth quarter of 2007 and first quarter of 2008. Spreads spiked in response to the financial crisis, and rose to 5.1 by the second quarter of 2009. As the market recovered from the crisis, spreads have again fallen and have been in the range of 2.0–3.0 during 2011 and the first quarter of 2012.⁴⁶

Analyses of spreads in reinsurance markets indicate that ratios of premiums to expected loss in the range of 3–5 or higher are to be expected for the higher layers of coverage targeted by most Cat bonds (Froot and O’Connell 2008; Cummins and Mahul 2008), suggesting that reinsurance and Cat bond pricing are similar.

The pricing comparability of catastrophe reinsurance and Cat bonds is reinforced by a comparison of Figs. 20.2 and 20.10, where Fig. 20.2 charts the ratio of rate-on-line to loss-on-line for catastrophe reinsurance at various levels of expected loss.⁴⁷ The expected loss on a Cat bond is comparable to the loss-on-line, and the ratio of rate-on-line to loss-on-line in Fig. 20.2 is analogous to the Cat bond spread (premium/expected loss) in Fig. 20.10. For the expected loss range of most Cat bonds (1–3%), Figures 20.2 and 20.10 show the Cat bonds are now priced competitively with excess of loss reinsurance. For example, in a “typical” reinsurance market of such as 2007, the ratio of rate-on-line to loss-on-line is in the range of 5–6 for the 1–3% loss-on-line. This is comparable to the spreads on Cat bonds except during the worst years of the financial crisis. In fact, during the hard phase of the underwriting cycle in 2006, reinsurance for low probability (1–3% expected loss) events can be more expensive than Cat bonds, with the ratios of rate-on-line to loss-on-line ranging from 5 to 13.

The cyclical behavior of Cat bond prices might seem to be puzzling in view of the fact that securities markets are not exposed to the imperfections of reinsurance markets. Cat bond cycles seem to be driven by two primary factors: (1) Increasing uncertainty about the accuracy of loss models following a large event and (2) time lags in the development of expertise required to participate in the Cat bond market following a surge in demand. Because the Cat bond market is currently small relative to other securities markets, the number of traders with the requisite expertise to create markets in Cat bonds is also relatively limited. Therefore, if demand shifts, it takes time for additional traders to enter the market. Hence, it is not a shortage of capital but a shortage of expertise that contributes to Cat bond cycles. As market volume grows, this problem should become less important; and Cat bond pricing cycles can be expected to diminish.

Another apparent Cat bond “puzzle” is why the spreads on Cat bonds are even in the range of 2–3 rather than being much lower. The early literature on Cat bonds suggested that ILS are “zero-beta” securities and therefore very valuable for portfolio diversification (Canter et al. 1997; Litzenberger et al. 1996). A strict CAPM interpretation would imply that yields on Cat bonds should eventually converge to the risk-free rate of interest. The prediction of low spreads is not changed by the pricing model of Froot’s (2007), because this model applies to financial intermediaries such as reinsurers that hold equity capital and invest in relatively illiquid, unhedgeable projects, not to claims traded in financial markets. Therefore, to go beyond the zero-beta security argument, we need to look elsewhere.

One source of additional information is Cummins and Weiss (2009), which provides a correlation and regression analysis of the prices of Cat securities and other types of assets. The conclusion is that

⁴⁶Lane and Beckwith (2008) find a long-term spread ratio ranging from 2.33 to 2.69, reinforcing this conclusion.

⁴⁷Direct comparisons of Cat bond and reinsurance pricing are somewhat difficult due to the different characteristics of Cat bonds and reinsurance contracts. Most Cat bonds provide multiple year coverage, whereas reinsurance contracts typically cover only 1 year. Therefore, Cat bond prices are expected to include a pricing premium to compensate investors for their inability to reprice annually. On the other hand, reinsurance prices are likely to incorporate a premium for the reinstatement provision contained in most reinsurance contracts, whereas most Cat bonds are not subject to reinstatement. Other contractual features also may lead to price differences.

Cat bonds are significantly correlated with corporate bonds and equities, although the correlations are very low. Therefore, they are not really zero-beta assets, but the correlations are too low to explain the spreads using conventional asset pricing models.

[Dieckmann \(2008\)](#) develops theoretical model that can explain why Cat bonds will continue to trade at nonzero spreads above the risk-free rate even as the market expands, adapting an earlier model developed by [Campbell and Cochrane \(1999\)](#). The Campbell-Cochrane model is a generalization of the familiar representative-agent, consumption-based asset pricing model, which adds a slow-moving habit, or time-varying subsistence level of consumption to a power utility function. [Dieckmann \(2008\)](#) generalizes the model to allow also for catastrophic risk. The intuition is that adverse shocks to consumption drive consumers towards the level of habit, raising risk aversion and leading to prices that are relatively high for assets that do poorly during economic downturns. As Campbell and Cochrane point out, “consumers do not fear stocks because of the resulting risk to wealth or to consumption per se; they fear stocks primarily because stocks are likely to do poorly in recessions, times of low surplus consumption ratios.”

[Dieckmann \(2008\)](#) argues that the catastrophe version of the model can be used to explain spreads on Cat bonds, which lead to adverse shocks to bond-holders during periods when the economy has just suffered a catastrophe and thus consumption is relatively low. Based on a reasonable calibration of his model, Dieckmann finds that relatively small negative economic shocks would generate the pre-Katrina levels of cat bond spreads. That is, the model requires only a small amount of catastrophic risk relative to total economic risk to generate observed spreads on Cat bonds during “normal,” e.g., pre-Katrina periods. The model also predicts increases in spreads following a catastrophe consistent with the increases that occurred post-Katrina. Thus, the consumption-based asset pricing model offers an explanation for observed Cat bond spreads.

20.5.5.5 Demand and Supply for Cat Bonds

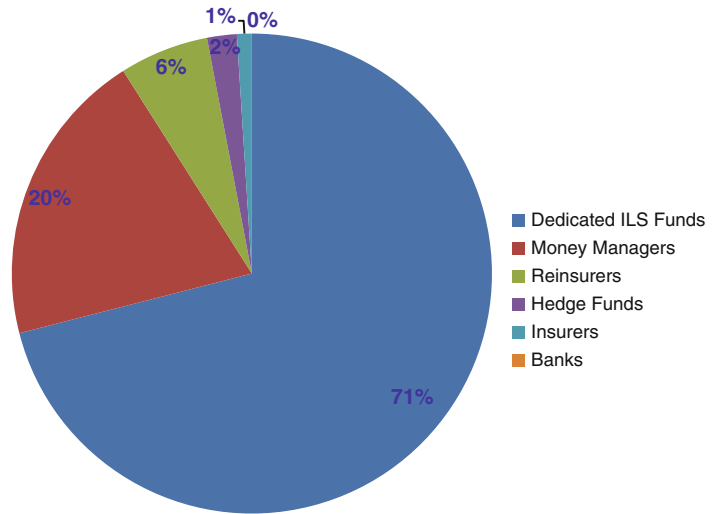
This section focuses on the demand and supply sides of the market for ILS, where the demand side consists of firms or governments with exposure to various types of insurable risks and the supply side consists of providers of protection. Because most trading to date has taken place in Cat bonds, the discussion focuses on these contracts.

A key element in the development of securitized financial markets is the generation of sufficient volume of trading to justify traders’ investment in the information needed to trade the securities. On the demand side, the buyer (hedger) needs extensive information on risk exposures, underwriting standards, probability of loss distributions, and other information. Much of this information is routinely generated by insurers and reinsurers and, in fact, such information represents a core competency for such firms. However, the costs of information investment may help to explain the limited volume of noninsurance corporate issuance of Cat bonds, with most corporate issuers preferring to rely on the (re)insurance industry.

On the supply side, the volume of transactions must be sufficient to justify investment in information for sellers of protection, including investment banks, hedge funds, dedicated mutual funds, etc. Noninsurance sellers need to start from the ground up, investing in information technologies (e.g., catastrophe simulation models) and personnel to run their trading desks. The anticipated trading volume needs to be sufficient to offset the fixed costs of establishing a trading desk and the ongoing variable costs of operating the desk over time. Hence, sellers must be convinced that a “critical mass” of trades will be available to justify the operation. Critical mass has been attained for Cat bonds and ILWs but has not yet materialized for futures and options.

The demand side of the ILS market mainly consists of primary insurers and reinsurers. For example, there were only six corporate issues during the period 1997–2007, compared to 110 issues by insurers and reinsurers ([GC Securities 2008](#)), and there have been few noninsurance issues since

Fig. 20.11 2010–2011 insurance-linked securities investors. *Source:* Swiss Re (2012a)



2008. The corporate issues included bonds sponsored by Oriental Land Company (the operator of Tokyo Disneyland) in 1999 and East Japan Railway in 2007. A 2011 transaction provides 150m of European windstorm coverage for mainland France to benefit a subsidiary of Electricite de France.⁴⁸ In 2006, the first government issued disaster-relief Cat bond placement was executed to provide \$450 million in funds to the government of Mexico to defray costs of disaster recovery. Mexico followed up this issue with Multicat Mexico 2009, valued at \$290 million, protecting against earthquakes and both Pacific and Atlantic hurricane events.

It is likely that future corporate issues will be mainly focused on low frequency, high severity, targeted events rather than general risk management needs. It is usually more efficient for corporations to rely on insurers and reinsurers for risk management rather than making significant investments in the expertise needed to effectively utilize insurance-linked securities. More sovereign issues are to be expected in the future, particularly from developing countries seeking to fund disaster relief and reconstruction, many under the World Bank Multicat program.

The success of the Cat bond market in developing critical mass on the supply side is illustrated by an analysis of investors in Cat bonds in 1999 versus 2010–2011. In 1999, 55% of Cat bond purchases by volume were by primary insurers (30%) and reinsurers (25%), with 30% of the market provided by money managers and smaller shares (about 5% each) provided by Cat mutual funds, hedge funds, and banks.⁴⁹ The breakdown of the market by type of investor in 2010–2011 is shown in Fig. 20.11. The market has broadened significantly, with insurers and reinsurers accounting for only 7% of Cat bond purchases. The primary buyers of Cat bonds in 2010–2011 were dedicated Cat mutual funds (71%) and money managers (20%). Hedge funds accounted for 2%, and banks had no activity as buyers. The growth of dedicated Cat mutual funds shows the importance of the informational investment needed for success in this market. The expertise and specialization on the investor side of the ILS market is often mentioned as one of the key factors that protected the market from panic during the recent financial crisis.

As mentioned above, the market for ILWs has broadened to include capital market participants in addition to insurers and reinsurers (Benfield 2008; Aon Benfield 2012). The swaps market also has attracted capital market participants such as investment banks.

⁴⁸A description of Cat bond deals is provided at the following link: http://www.artemis.bm/deal_directory/.

⁴⁹The 1999 breakdown is based on unpublished data from Swiss Re.

The market for insurance-linked futures and options has not yet reached critical mass, for reasons discussed above, including basis risk and contract design. The relative inactivity in the options market stems from lack of demand rather than limitations of supply. The information investment needed to trade in the options market is significantly less than in the market for Cat bonds, such that the supply of options would likely be sufficient to meet the demand.

20.5.5.6 Regulatory Issues

Some prior commentators have argued that Cat bonds have mostly been issued offshore for regulatory reasons and that the lack of onshore issuance represents a barrier to market development. The argument is that encouraging onshore issuance might reduce transactions costs and facilitate market growth. However, industry experts interviewed by the authors disagree with this point of view. They argue that the offshore jurisdictions, including Bermuda, the Cayman Islands, and Dublin, provide low issuance costs and high levels of expertise in the issuance of ILS. Transaction costs for the onshore Cat bonds that have been issued generally have been higher than for offshore issues. Thus, while issuance of securities onshore (e.g., in the USA) probably would be a favorable development in the long-run, the off-shore jurisdictions perform very effectively and efficiently in handling the issuance and settlement of ILS.

Prior commentators have argued that nonindemnity Cat bonds currently face uncertain prospects with respect to regulatory treatment. The argument was that regulators are concerned about basis risk and the potential use of securitized risk instruments as speculative investments. As a result, it was argued that regulators may deny reinsurance accounting treatment for non-indemnity Cat bonds, impeding the development of the market. However, industry experts interviewed by the authors indicate that regulatory treatment does not presently pose a significant obstacle to market development. Market participants have found a variety of structuring mechanisms to blunt regulatory concerns about risk financing with respect to non-indemnity Cat bonds. For example, contracts can be structured to pay off on narrowly defined geographical indices or combinations of indices which are highly correlated with the insurer's losses. Concerns about speculative investing can be addressed through dual trigger contracts that pay off on an index but where the insurer cannot collect more than its *ultimate net loss*, a familiar reinsurance concept equal to the insurer's total loss from an event less collections under reinsurance contracts.

Even though regulation does not seem to pose a significant barrier to the development of the ILS market, the USA generally takes a heavy-handed and intrusive approach to insurance regulation. Regulation should primarily be designed to ensure transparency of insurance and reinsurance transactions, relying on the market to enforce appropriate behavior by insurers. It would improve the efficiency of insurance markets if regulators were to codify the rules and regulations relating to the statutory accounting treatment of various types of ILS.

20.5.5.7 Cat Bonds: Conclusions

The Cat bond market has become a permanent and mainstream component of the risk-transfer landscape. The market is broader and deeper than ever, and securitizations have expanded to encompass new types of private sector risks as well as sovereign risks. Bond spreads have declined, transactions costs have been reduced, and the market has become more liquid, with a larger investor base. Nevertheless, the market remains small relative to other ABS markets and is susceptible to price volatility from catastrophic events and reinsurance cycles. Continued growth of the market can be expected, which should help to moderate the effects of underwriting cycles, increase liquidity, and further improve the efficiency of risk-transfer markets.

Table 20.2 Risk-transfer and capital release products: summary of features

| Products | Credit risk | Basis risk | Moral hazard | Transparency | Multi-year | Multi-risk | Standardization | Capital market access |
|--|------------------|------------|--------------|--------------|------------------|------------|-----------------|-----------------------|
| Insurance/reinsurance | Yes | No | Yes | Low | Rarely | Rarely | Moderate | No |
| Hybrid reinsurance/financial products: | | | | | | | | |
| Finite/structured reinsurance | Yes | No | Low | High | Yes | Rarely | Low | No |
| Retrospective XOL covers | Yes | No | Yes | High | Often | Rarely | Low | No |
| Loss portfolio transfers | Yes | No | Yes | High | Often | Rarely | Low | No |
| Multi-year, multi-line products | Yes | No | Low | Low | Often | Yes | Low | No |
| Multiple trigger products | Yes | Low | Yes | Low | Often | Often | Low | No |
| Industry loss warranties | Yes | Yes | Low | High | Sometimes | Often | High | Yes ^a |
| Sidecars | No | No | Low | High | Yes | Sometimes | Moderate | Yes ^a |
| Capital market instruments: nonlife | | | | | | | | |
| Contingent capital | Yes | T | T | High | Often | Rarely | Low | Yes |
| Catastrophe futures and options | Low | T | T | High | No | Rarely | High | Yes |
| Catastrophe swaps | Yes | T | T | High | Rarely | Sometimes | Low | Yes |
| Cat bonds | Low | T | T | High | Yes | Sometimes | Moderate | Yes |
| Capital market instruments: life | Credit risk | Basis risk | Moral hazard | Transparency | Long-term | Multi-risk | Standardization | Capital market access |
| Embedded value | High | No | No | Low | Yes | No | No | Yes |
| Regulation XXX and AXX | Low | No | No | Low | Yes | No | Moderate | Yes |
| Catastrophic mortality securitizations | Low | Yes | No | High | Yes ^c | No | Yes | Yes |
| Longevity transactions | Low ^d | Depends | Moderate | Depends | Yes | No | Moderate | Depends |

^aNo, in general, but could be securitized

^bAccesses capital outside of the insurance and reinsurance industries but usually from only one counterparty

^cMortality securitizations are usually multi-year but are not as long-term as other life-annuity sector securitizations

^dLow credit risk for the investors but high for the buyers of protection

Note: T=depends on trigger. Basis risk is low for company loss (indemnity) triggers but moderate to high for index, modeled, and parametric triggers. Moral hazard in moderate to high for indemnity triggers but low for index, modeled, and parametric triggers

20.5.6 *Nonlife Risk-Transfer Products: Summary*

The nonlife risk-transfer products are summarized in the top panel of Table 20.2 in terms of the criteria for evaluating risk-transfer products analyzed in Sect. 20.3.2. Traditional insurance and reinsurance do not perform very well in terms of most of the comparison criteria. Such products are usually single-year, single-risk instruments with low transparency and no direct access to capital markets. The principal advantages of traditional insurance/reinsurance are low basis risk and buyer-specific contract design. However, as explained in Cummins and Weiss (2009), insurance and reinsurance are efficient diversification mechanisms for small and moderate-size risks that are relatively independent statistically.

Finite risk products are similar to traditional (re)insurance, except that these products improve on traditional insurance in that they are relatively transparent and often cover multiple year periods. The standardization of finite risk contracts is low, and they do not access capital markets. Most integrated and multiple-trigger contracts improve on finite risk products by covering multiple risks but are relatively opaque, have low standardization, and do not access capital markets.

Industry loss warranties expose the hedger to credit risk and basis risk. However, because the indemnity trigger is set very low, they do not suffer from moral hazard. The typical ILW is also standardized and transparent, although there are also individually tailored contracts that do not have these features. Most ILWs are 1-year contracts, although there are exceptions. As mentioned, ILWs have begun to attract significant investment from non-reinsurance capital market participants. Sidecars have the advantages of not exposing the sponsoring reinsurer to credit risk or basis risk. They also have low moral hazard because of their quota share design, where the hedger and capital provider share in all losses. They also are multi-year and are moderately standardized. Sidecars are capitalized by non-(re)insurance capital market participants, but there is usually only one counterparty per transaction.

The capital market instruments summarized in Table 20.2 provide direct access to the capital markets, thus significantly broadening the capital base available to finance risks. Cat bonds are usually widely marketed rather than having only one counterparty as in the case of sidecars, and futures and options have the potential for wide market participation once sufficient demand develops. The number of participants involved in contingent capital and swap transactions is usually much smaller. Most of the capital market instruments are highly transparent in comparison with insurance contracts and Cat bonds and options have lower credit risk. The degree of moral hazard, basis risk, and standardization depends upon the contract design parameters. Ultimately, the market is likely to evolve towards contracts that are standardized and transparent, enhancing market liquidity and facilitating more efficient risk management.

20.6 Life Insurance Securitization

While nonlife securitizations tend to focus mainly on risk management, many additional motivations exist for life insurance ILS, including capital strain relief, acceleration of profits, speed of settlement, and duration. Catastrophic mortality bonds provide the closest analogue with nonlife ILS, but these account for only a small fraction of total life ILS issuance. Different motivations require different solutions and structures, as the variety of life ILS instruments illustrates. While the nonlife section of the ILS market is the most visible, famously trading the highly successful Cat bonds, the life section of the ILS market is larger in terms of outstanding volume of securities (estimated at \$22 billion vs. \$13.6 billion for the nonlife segment).⁵⁰

⁵⁰Life ILS data are from Leadenhall Capital Partners. Nonlife data are from Swiss Re (2012a).

There are significant contrasts between the nonlife and the life ILS markets, with success, failure, and future developments depending upon the impact of the subprime financial crisis of 2007–2010. The crisis has had only a limited impact on nonlife ILS, partly due to product structuring, a dedicated investor base, and disciplined market modeling and structuring practices. However, the life-sector has been greatly affected by the crisis. This is mostly due to the structuring of deals and the nature of the underlying risks: with more than half of the transactions pre-crisis being wrapped, or containing embedded investment risks. Therefore, principles governing the constitution and management of the collateral account, as well as the assessment of the counterparty risk are central to current debates aimed at developing a sustainable and robust market. Since 2008, public transactions have been limited, but private deals have taken place in a relative steady way since the financial crisis.

20.6.1 Demand for Life Insurance Securitization

The life insurance securitization sector has grown to prominence over the last 15 years by providing billions of dollars of transactions with a wide variety of different features and motivations. Like the nonlife sector, life insurers and reinsurers have entered into transactions designed to manage risks that are too large or unusual to be effectively dealt with through conventional means such as reinsurance and issuing new capital. One major initiative has been in catastrophic mortality bonds designed to protect against mortality shocks. Longevity risk of annuities and pensions also has received considerable attention, although to date there has been only one successful deal. Risk management securitizations are discussed in more detail below.

However, the bulk of the life insurance transactions and structures has been designed to provide capital release. This is in contrast to the nonlife sector, where securitizations have focused on managing risk rather than balance sheet strengthening or capital management. The main reason for the differences between the two sectors arises from the types of products offered. Nonlife insurance products tend to be relatively short-term and focus primarily on diversifying risk. Such products are not used as investment vehicles, and the accumulation of assets results from the lag between premium and claim payments. While life insurance is used for mortality risk diversification, most assets and profits in the life insurance industry arise from savings-type asset accumulation products such as cash value life insurance and annuities. Such products tend to have high initial acquisition costs, which drain insurer capital and are amortized over a long-period of time. The initial capital strain and long-term emergence of profits has provided a major motivation for life insurance securitizations as insurers attempt to monetize slowly emerging profits and strengthen capital. In addition, stringent reserve requirements in some countries, particularly the USA, further increase leverage and motivate life insurers to seek capital relief through securitization. Accordingly, demand for most life sector securitizations focuses on the three pillars of capital requirements faced by the life insurance industry:

1. *Regulatory capital*, i.e., the capital required by the regulator, whether it is associated with the home state or a portfolio of jurisdictions
2. *Rating agency capital*, i.e., the capital required by the rating agencies to maintain a desired level of rating
3. *Economic capital*, corresponding to the insurer's own view of risk

Each of the three pillars behaves in accordance with its own rules, and in some cases overall capital can be released by addressing a specific pillar. In particular, the first pillar—regulatory capital—has been the driver of a high volume of transactions, including mainly embedded value (or value in force (VIF)) securitizations, and Regulation XXX and AXXX securitizations.

Securitization structures addressing regulatory capital needs are normally designed so that the investor is exposed to the actual performance of a book of business, as regulators have been reluctant

to approve transactions with embedded basis risk. Solvency II and similar approaches permit basis risk in regulatory transactions, so long as basis risk is properly modeled and an appropriate amount of capital is added back from to cover the basis risk (CEIOPS 2009). In this section, we discuss the standard structures used in life insurance securitization and also provide perspective on challenges faced by the life ILS sector after the financial crisis.

20.6.2 *Embedded Value (or Value in Force) Transactions*

Embedded value (EV) and VIF transactions are the securitization of future cash flows from a block of business. More precisely, they have been structured to “monetize” or crystallize a portion of the present value of the expected profit of a book of life insurance business in order to achieve a particular business objective such as the capitalization of prepaid acquisition expenses or the monetization of the embedded value from the block. This type of transaction also includes closed block and open block securitization.

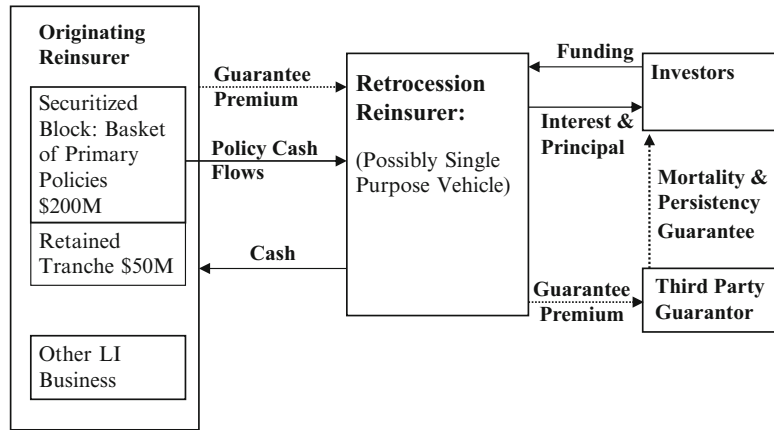
Because the expense of writing new life insurance policies is generally incurred by the insurer in the first policy year and then amortized over the term of the policy, writing new business can create liquidity problems for life insurers. In addition, regulatory accounting requirements usually result in an increase in insurer leverage associated with new business because regulators require that reserves be established for newly issued policies whereas the profits on the policies tend to be “end-loaded,” emerging gradually over the life of the policy. Consequently, one motivation for life insurance securitizations is to reduce leverage and obtain immediate access to the “profits” expected to emerge from a block of life insurance policies, usually referred to as the present value of in-force business or more simply VIF.

The risks transferred to the capital markets are a function of the risks embedded in the specific book of business, although traditionally the following components are present:

- Mortality risk, i.e., the risk of the insured portfolio showing higher than expected mortality over the life of the transaction.
- Lapse or persistency risk, i.e., the risk that a policyholders stops paying the premium and/or changes life insurer.
- Credit risk. Even if the proceeds of the securitization are not paid to the life insurer, a bankruptcy of the life insurer would severely impair its ability to manage the book to extract its profits and lapse and persistency risk increases.
- Other risks. If the underlying portfolio of life business embeds an investment component, the embedded value is also linked to the performance of the investment portfolio (whether it is equity and/or fixed income), although there have been rare attempts to embed significant elements of market risk in transactions to avoid tainting the “alternative investments” feature of the transaction. Friends Provident’s Box Hill securitization in 2004 was the first (and last) EV transaction to include a small component of longevity risk in the overall embedded value transaction by including a component of annuities in the securitized portfolio.

In a typical EV transaction, diagrammed in Fig. 20.12, an originating reinsurer has created a pool of insurance contracts that have been ceded to the reinsurer by a primary insurer or insurers. In originating the policies, the reinsurer has reimbursed the primary insurers for their acquisition costs. The remaining cash flows on the policies are sufficient to amortize the acquisition costs and provide a profit on the business. The insurer seeks to capitalize the acquisition costs and/or profit component of the policies. It enters into a transaction with a retrocessionaire, which may be an actively managed reinsurer or an SPV. The originating reinsurer assigns the rights to a significant proportion of the cash flows on the underlying insurance policies to the retrocessionaire, who repackages the cash flows

Fig. 20.12 Embedded value (Value In Force) securitization



and sells the resulting securities to investors. The principal raised from investors is passed to the originating reinsurer to finance acquisition costs and capitalize all or part of the VIF on the block.

Credit enhancement is an important aspect of most VIF securitizations. The consolidation of policies from several originating insurers provides one form of credit enhancement, by creating a more diversified pool of risk. The reinsurer also may be larger and have a better credit rating than some of the originating insurers, potentially reducing the overall costs of the transaction. In addition, the reinsurer may retain part of the securitized block of business for its own account either through a quota share arrangement or a tranching process where a higher priority in terms of rights to the cash flows is assigned to investors. Either arrangement helps to control moral hazard by giving the originator a strong incentive to perform the monitoring and servicing functions. The tranching seniority arrangement has the added benefit of providing additional security to the investors. The originating reinsurer also may provide a guarantee to the investors against adverse experience on the underlying policies for mortality, persistency, and other risks. The guarantee could be provided by the originator or purchased from a third-party guarantor. Finally, an interest rate swap could be arranged to insulate investors from interest rate risk. Of course, tranching, guarantees, and interest rate swaps add to the cost of the transaction and must be netted against expected benefits in evaluating the transaction’s economic viability.

In principle, it is possible for a VIF securitization to result in a true transfer of risk from the insurer to the bondholders as well as no recourse from the securitized bondholders to the insurer. If the transaction can be arranged so that only specified profit flows are used to fund payments to bondholders, non-securitized cash flows are unencumbered and can be used by the insurer in its other operations. On the other hand, a typical senior debt issue is funded from a variety of profit sources, making a securitized structure a potentially more efficient method of financing. Thus, with an appropriately designed securitization structure, the insurance company can access cheaper financing, thereby reducing the weighted average cost of capital and thus improving the return on equity for the book of business. Most transactions so far have focused on senior rated tranches (triple A to single-A) and in some cases have also utilized monoline insurance companies to wrap the securitized tranches to widen as much as possible the targeted investor universe. Some transactions, on the other hand (such as Swiss Re’s Queensgate and Alps II), have also issued lower rated tranches (issued as longer-dated fixed rate) to test market appetite for higher risk and return, as they did successfully.

The financial crisis has further reduced public issuance of highly rated EV securitizations, but some private/unrated/lower rated transactions have been structured to target specialized investors knowledgeable in the sector but interested in a yield in the high single digit to low teens. The outstanding amount prior to Lehman was estimated to be over \$8 billion. Today, the size of the

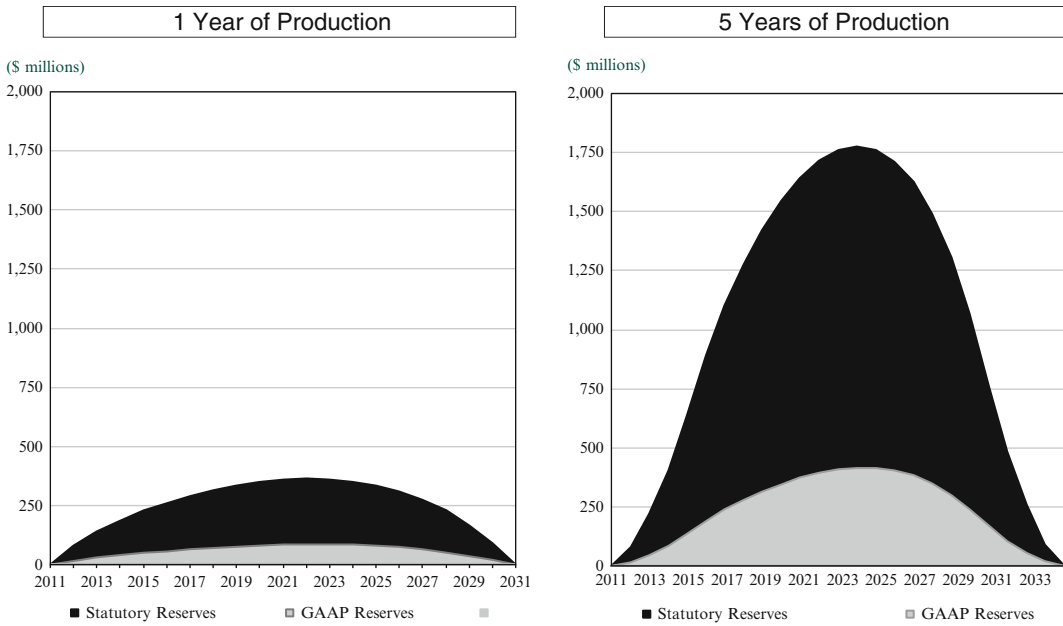


Fig. 20.13 Financing XXX Reserves

market is harder to estimate given the nature of the new transactions. EV deals have been more a feature of the UK, Irish, and US markets, but with the introduction of Solvency II (which should in theory harmonize regulatory and economic capital requirements), the technology is available to provide actual risk transfer to life (re)insurers elsewhere in Europe.

20.6.3 Regulation XXX and AXXX Transactions

Another important class of life insurance transactions consists of reserve funding securitizations. In these transactions, the life insurer seeks relief from regulatory reserving requirements and/or seeks to reduce its leverage in order to finance new business or reduce its cost of capital. Regulation XXX, which was promulgated by the NAIC and became effective in most states in the USA on January 1, 2000, requires insurance companies to establish reserves using very conservative valuation assumptions. The regulation affects the term life business (XXX) and universal life (AXXX) business of US life insurers. The capital required by regulators under Regulation XXX/AXXX significantly exceeds the rating agency and economic capital allocated to the same blocks of business. As a result, redundant excess reserves on certain types of level premium term life insurance policies with long-term premium guarantees are established. The reserves typically build up and disappear over the premium guarantee period, creating a “hump-backed” capital strain for insurers writing this type of coverage. Figure 20.13 shows the regulatory reserve and an illustrative “best estimate” GAAP reserve for 1 and 5 years of new policy production. The regulatory reserve obviously is much more conservative than the GAAP reserve, due to the conservative mortality assumptions required by regulators.

Insurers have sought alternative ways to mitigate the effects of Regulation XXX after finding that their original solution, offshore reinsurance backed by letters of credit, was becoming increasingly expensive and difficult to obtain and that the rating agencies were becoming less comfortable with

solutions that relied upon 1-year letters of credit to back a 20 or 30-year liability. This led to the development of a multi-billion dollar life ILS market, where the majority of transactions were placed with guarantees from the monoline insurance companies as AAA notes. The underlying reserve risk (life insurance mortality) is also considered to be high investment grade by securities markets, as long as the life insurer issuing the underlying insurance policies is subject to acceptable credit risk.

In a typical XXX securitization, the reinsurer issues equity capital to the sponsor in return for a cash payment. The sponsor thus takes the first dollar loss position in the transaction. However, most of the reinsurer's proceeds are raised by issuing notes to a capital markets trust. The trust in turn issues debt securities to investors, raising funds to capitalize an SPV. To qualify for treatment as reinsurance for regulatory purposes, the funds are invested in a *reinsurance reserve credit trust*, which is pledged to the sponsoring life insurer. If adverse mortality experience develops on the underlying insurance policies, funds are released from the SPV to cover any shortfall. The cost to the insurer is the rate paid on the debt securities less the earned rate on the assets in the reinsurance reserve credit trust plus the cost of any financial guarantee policy as well as the cost of establishing the structure, amortized over the expected life of the transaction. Such a transaction may be attractive to the sponsor even if the spread is somewhat higher than the cost of reinsurance or letter of credit because it represents a long-term rather than short-term solution to the XXX problem and insulates the issuer from repricing risk.

Since the financial crisis, the XXX market has been greatly affected by the vanished investor appetite for highly rated, low yielding securitized investments and by the collapse of the business model of monoline insurance companies. The monolines have either defaulted due to other exposures or have very low financial ratings—lower than the underlying XXX quality. New business has been conducted in the private markets and in swap format, thus providing a form of leverage to yield-hungry investors. While the outstanding XXX prior to Lehman's bankruptcy was estimated to exceed \$11 billion, only about \$1 billion has been issued since.

20.6.4 Catastrophic Mortality Securitizations

A different structure has been implemented to cover the risk of a life insurer or reinsurer arising from a catastrophic mortality event. The most likely such event is a pandemic spreading across developed countries and affecting the insured population (i.e., not just the very young and the very old), but the existing transactions also cover events such as mega-terrorist attacks or mortality spikes due to large natural catastrophes.

Catastrophic mortality has been securitized by a number of life reinsurers (Swiss Re, Munich Re, SCOR (in a derivative form), and Scottish Re) and by a life insurer (AXA). The characteristics of several of the major transactions are summarized in Table 20.3. For each of these transactions, the trigger is by reference to an index, based on official data from the statistical offices from covered territories, rather than by actual portfolios. This has been more for ease of execution (less data disclosure on prospectuses) than by investor demand, and we may well see indemnity transactions based on actual portfolios in the future.

The first known mortality risk bond was issued by Swiss Re in December 2003. To carry out the transaction, Swiss Re set up an SPV, Vita Capital Ltd. Vita Capital initially intended to sell \$250 million of mortality index notes in 2003 and \$150 million in a follow-up transaction in 2004, but due to strong investor demand it combined the issues. The bonds carried an A3/A+ ratings from Moody's and S&P, respectively. The notes matured on January 1, 2007 and carried a premium of 135 basis points over 3-month LIBOR. Swiss Re launched three more Vita bonds, issuing the most recent Vita IV tranches in August 2011.

Table 20.3 Features of mortality-linked bonds

| | Vita capital Swiss Re | Vita capital II Swiss Re | Tartan capital Scottish Re | Osiris capital AXA | Vita capital III Swiss Re | Nathan Munich Re |
|---------------------|-----------------------------|--|--|----------------------------|--|---------------------|
| Closing date | Dec-03 | Apr-05 | May-06 | Nov-06 | Jan-07 | Feb-08 |
| Risk period | 4 years | 5 years | 3 years | 4 years | 4 & 5 years | 5 years |
| Notional amount | USD 400 million | USD 362 million | USD 155 million | EUR 345 million | EUR 700 million | USD 100 million |
| Issuance currencies | USD | USD | USD | USD & EUR | USD & EUR | USD |
| Index calculation | 1 year | 2-year average | 2-year average | 2-year average | 2-year average | |
| Tranches issued | 1 | 4 | 2 | 4 | 4 | 1 |
| Ratings | A+/A3 | BBB-/Baa2 to A+/Aa2 | BBB/Baa3 to AAA/Aaa | BB+/Ba1 to AAA/Aaa | A/A1 to AAA/Aaa | A- |
| Modeling firm | Milliman | Milliman | Milliman | Milliman | Milliman | Milliman |
| Redemption date | 1-Jan-07 | 1-Jan-10 | 7-Jan-09 | 15-Jan-10 | 1 January 2011/2012 | 1/15/2013 |
| Extension period | up to 24 months | up to 24 months | up to 30 months | up to 30 months | up to 30 months | up to 30 months |
| Country components | US, UK, FR, IT, CH | US, UK, DE, JP, CAN | US | FR, JP, US | US, UK, DE, JP, CAN | US, UK, CAN, DE |
| Sponsor | Vita capital IV Swiss Re | Vita capital IV Series II Swiss Re | Vita capital IV Series III and IV Swiss Re | Kortis capital Swiss Re | Vita capital IV Series V and VI Swiss Re | |
| Closing date | Nov-09 | May-10 | Oct-10 | Dec-10 | Aug-11 | |
| Risk period | 5 years | 5 years | 5 years | 8 years | 5 years | |
| Notional amount | USD 75 million | USD 50 million | USD 175 million | USD 50 million | USD 180 million | |
| Issuance currencies | USD | USD | USD | USD | USD | |
| Index calculation | 2-year average | 2-year average | 2-year average | 8-year average | 2-year average | |
| Tranches issued | 1 | 1 | 2 | 1 | 2 | |
| Ratings | BB+ | BB+ | BB+ | BB+ | BB+ to BBB | |
| Modeling firm | RMS | RMS | RMS | RMS | RMS | |
| Redemption date | 1/15/2014 | 1/15/2014 | 1/15/2015 | 15-Jan-17 | 1-Jan-16 | |
| Extension period | up to 30 months | up to 30 months | up to 30 months | up to 30 months | up to 30 months | |
| Country components | US, UK | US, UK | US, UK, CAN, DE, JP | US, UK | US, UK, CAN, DE | |

Sources: Standard & Poor's, Swiss Re, and the Artemis deal directory

Vita Capital I was structured similarly to a Cat bond (see Fig. 20.7). In return for paying the premium to Vita Capital, Swiss Re obtained a call option on the proceeds in the SPV. The option would be triggered by a weighted average mortality index based on general population mortality in the USA and four European countries. If cumulative adverse mortality exceeds 130% of the actual number of deaths in the indexed pool in 2002, Swiss Re would withdraw proceeds from the SPV. The full amount of proceeds would flow to Swiss Re if cumulative adverse mortality reached 150% or more of the actual number of deaths in 2002, with proportionate payment from the SPV for adverse mortality falling between 130 and 150%. The contract is thus structured as a call option spread on the index with a lower strike price of 130% of 2002 mortality and an upper strike price of 150%. As in most Cat bonds, Swiss Re executed a swap transaction to swap Swiss Re's fixed premium payment for LIBOR. The subsequent Vita transactions have been structured similarly.

The Swiss Re's Vita transactions are noteworthy because they focus directly on mortality risk and hence are much simpler to model and understand than transactions involving all of the cash flows on whole blocks of life insurance policies. Basing the payoff on population mortality rather than the mortality of a specific insurer has the advantage of reducing investor concerns about moral hazard and also of basing the payoff a large and geographically diversified pool of risks. The downside of index transactions, of course, is that they expose the insurer to basis risk. For this reason, mortality index bonds are likely to appeal primarily to large geographically diversified multi-national insurers or reinsurers.

Catastrophic mortality transactions also have been carried out following the financial crisis, but while pre-2008 some highly rated tranches were placed, post 2008 the focus has been mainly on non-investment grade tranches sold largely to specialized investors who also invest in nonlife ILS. These transactions are understood to have addressed mainly economic capital release and a component of rating capital benefit, but no regulatory capital benefit is believed to have been achieved to date. Prior to the financial crisis, more than \$2 billion of extreme mortality bonds were issued, while post crisis, less than \$1 billion of new issuance has taken place. The volume of life insurance securitizations to date is shown in Fig. 20.14. It is clear that the largest volume of transactions have involved embedded value and regulation XXX/AXXX securitizations with smaller issuance amounts for extreme mortality and other life ILS.

20.6.5 *The Special Challenges of Longevity Risk*

The next step, which seems to be quite natural when considering life insurance securitization, is longevity risk. A steady increase in life expectancy in Europe and North America has been observed since 1960s, representing a significant and evolving risk for both pension funds and life insurers. The risk arises both because of longevity trends and because of uncertainty about future declines in mortality. Various risk mitigation techniques have been advocated to better manage this risk. Using the capital markets to transfer part of the longevity-risk is complementary to traditional reinsurance solutions, and thus seems to be a natural move.

To date, almost all longevity capacity has been provided by the insurance and reinsurance markets. Because exposure to longevity risk for UK pension funds alone is estimated to exceed \$2 trillion, insufficient capacity exists in traditional markets to absorb any substantial portion of the risk; and only capital markets have the potential to satisfy demand.⁵¹ However, taking longevity risk to the capital

⁵¹Putting this \$2 trillion risk in context, U.K. life insurers collected \$138.3 billion in premiums in 2010 and had equity capital of about \$80 billion (Swiss Re estimate). Hence, it would not be feasible for insurers to manage longevity risk solely by raising equity capital. Worldwide, the life insurance industry had premium volume of \$2.5 trillion and equity

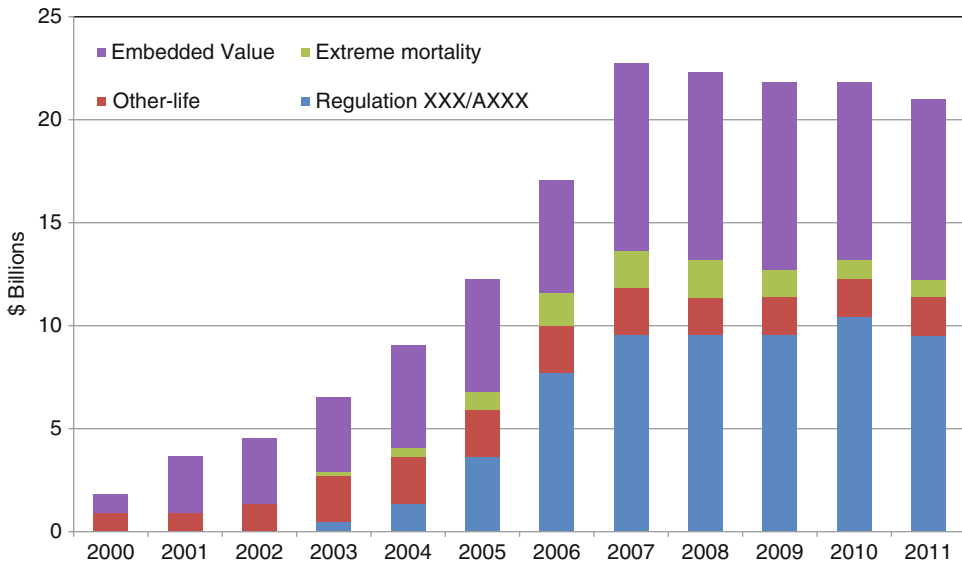


Fig. 20.14 Life securitizations outstanding by type (excluding private deals). *Source:* Leadenhall Capital Partners, London, U.K.

markets is not straightforward due to the nature of the risk itself. In February 2010, with the aim of developing a transparent and liquid market for longevity risk-transfer solutions: a consortium of major European financial institutions established the Life and Longevity Markets Association (LLMA). The LLMA is a nonprofit venture supporting the development of consistent standards, methodologies, and benchmarks. In the last few years, longevity risk has received increasing attention from US and UK pension and life insurance companies, and public and private longevity risk exposure has been estimated as more than \$20 trillion. A number of private equity transactions have been completed, but there have been very few capital market transactions—mainly in the form of swaps.

20.6.5.1 Modeling Challenges

On face value, longevity meets all the basic requirements of a successful market innovation. However, there are some important questions to consider. To create liquidity and attract investors, annuity transfers need to move from an insurance format to a capital markets format. One of the main obstacles for the development of capital market solutions is the one-way exposure experienced by investors, since there are almost no natural buyers of longevity-risk. Inevitably, this could cause problems for demand. Nevertheless, provided it is priced with the right risk-premium, there is potential for securities linked to longevity-risk to become a new asset class, which could interest hedge funds and specialized ILS investors. This would be analogous to the evolution of the nonlife ILS market where the class of investors has greatly expanded over time to include dedicated ILS mutual funds and other specialized buyers.

Another challenge is the absence of both theoretical consensus and established industry practices, making the transfer of longevity risk a difficult process to understand and manage. In particular,

capital of \$1.4 trillion (*Swiss Re 2011c*). Raising large amounts of equity capital not needed for current operations is not cost effective for insurers, as explained above.

because of the long-term nature of the risks, accurate longevity projections are difficult to obtain, and modeling the embedded interest rate risks remains challenging. Prospective life tables containing longevity trend projections are frequently used to better manage longevity risk, proving to be particularly effective in life insurance reserving. However, the irregularity of table updates can cause significant problems.⁵²

Another consideration is that basis-risk could prevent a longevity market from operating successfully. Indeed, the full population mortality indices have basis risk with respect to the liabilities of individual pension funds and insurers. Age and gender are the main sources of basis risk, but regional and socioeconomic basis risk also can be significant. Therefore, the use of standardized instruments based upon a longevity index to hedge a particular exposure could leave the hedging institution with a residual risk that is difficult to understand and manage. An important challenge lies in developing transparency and liquidity by ensuring standardization, but without neglecting the hedging purposes of the instruments.

To better understand longevity risk, its dynamics and causes must be studied carefully, and separated from shorter-term fluctuations around average trends. Among the many standard stochastic models for mortality, a number have been inspired by the classical credit risk and interest rate literature. As a consequence, they produce a limited definition of mortality by age and time. An alternative is the microscopic modeling approach, which can be used for populations where individuals are characterized not only by age, but also by additional indicators that are reflective of lifestyle and living conditions. Such models can provide useful benefits for the risk analysis of a given insurance portfolio. Furthermore, when combined with studies on demographic trends, such as fertility and immigration, microscopic modeling offers guidance for governmental strategies concerning immigration and retirement age policy. The need for microscopic studies is more apparent when the size of the considered portfolio is small and in all likelihood highly heterogeneous. Longevity risk modeling is analyzed further in [Barrieu et al. \(2012\)](#) and [Cox et al. \(2010\)](#).

20.6.5.2 Longevity Indices

Among the initiatives to improve visibility, transparency, and understanding of longevity-risk, various longevity indices have been created. A longevity index needs to be based on national data to have some transparency, but must also be flexible enough to reduce basis-risk for the hedger. National statistical institutes are in a position to construct annual indices based on national data, which could incorporate projected mortality rates or life expectancies (for gender, age, socioeconomic class, and so on). Potentially, this could help insurance companies form weighted average indices applicable to their specific exposures. The existing indices include:

- *Credit Suisse Longevity Index*, launched in December 2005, is based upon national statistics for the US population, incorporating some gender and age specific sub-indices.
- *JP Morgan Index with LifeMetrics*, launched in March 2007. This index covers the USA, England, Wales and the Netherlands, by national population data. The methodology and future longevity modeling are fully disclosed and open (based upon a software platform that includes the various stochastic mortality models).
- *Xpect Data*, launched in March 2008 by Deutsche Börse. This index initially provided monthly data on German life expectancy and has been extended to the Netherlands.

⁵²For example, the French prospective life tables were updated in 2006, replacing the previous set of tables from 1993. The resulting disparities between the 1993 prospective tables and observed longevity caused French insurers to sharply increase their reserves by an average of 8%.

20.6.5.3 q-Forwards and Longevity Swaps

JP Morgan has been particularly active in trying to establish a benchmark for the longevity market. The firm developed the LifeMetrics longevity risk analysis platform and also has developed standardized longevity instruments called “q-forwards.” These contracts are based upon an index that draws upon on either the death probability or survival rate as quoted in LifeMetrics. Survivor swaps are the intuitive hedging instruments for pension funds and insurers. However, the importance assigned to the starting date of the contract (owing to the survival rate being path-dependent) may reduce the fungibility of the different contracts in relation to the same cohort and time in the future. Therefore, mortality swaps are also likely to be applicable, hence the development of the q-forward. The q-forward zero coupon swap that exchanges fixed mortality for realized mortality of a specified population on maturity. The hedger pays an amount proportional to an agreed-upon fixed mortality rate and receives payment from the counterparty if a specified mortality index declines by more than expected.⁵³

Over the last few years, a number of longevity swap transactions have taken place. The transactions have been private, and their pricing remains confidential.⁵⁴ Some swaps were conducted between life insurers and reinsurers, while others have involved counterparties outside the insurance industry. Most of these transactions have long-term maturities and incorporate significant counterparty risk, which is difficult to assess given the long-term commitment. As a consequence, the legal discussions around these agreements make them a particularly drawn out contract to finalize. Longevity swaps can be either index-based or indemnity-based.

20.6.5.4 The First Longevity Securitization: Kortis Capital

The first (and only to date) successful securitization with significant exposure to longevity risk is believed to be Swiss Re’s Kortis Capital, issued in December 2010 (Table 20.3).⁵⁵ The nominal amount of the transaction is \$50 million. Under the transaction, Swiss Re obtained collateralized protection against the risk of divergence in mortality improvements between two reference populations, using a structure similar to an extreme mortality bond. For the transaction, Swiss Re created the Longevity Divergence Index, which measures the difference in the rate of mortality improvement between UK males (ages between 75 and 85) and US males (ages between 55 and 65). The two populations are closely related to Swiss Re exposure but, to make the transaction attractive to the capital markets, Swiss Re elected to take some basis risk by using national statistics rather than an actual portfolio. Swiss Re also shortened the maturity of the notes compared to the maturity of its own risk to address investor concern with potentially illiquid long-dated structures.⁵⁶ The 8-year term of the tranche was considered a sufficient time span to be able to observe a longevity trend while being acceptable to ILS investors. Because Kortis is exposed to catastrophic mortality risk as well as longevity risk, no “pure” longevity securitization has yet taken place in the wider capital markets.

⁵³The term q-forward was adopted because q is standard actuarial notation for the probability of death.

⁵⁴The first publicly announced index-based mortality swap was completed in 2008 between J.P. Morgan and SCOR. The first index-based longevity swap was completed in 2008 between J.P. Morgan and Lucida ([Swiss Re 2009b](#)).

⁵⁵In November 2004, the European Investment Bank (EIB) attempted to launch an offering of longevity bonds to hedge longevity risk for pension funds and annuity providers. The deal failed due to insufficient demand.

⁵⁶Capital markets investors prefer short-dated notes or highly liquid long-dated notes. The financial crisis strengthened these preferences. To develop a market in long dated longevity risk, true market making must be developed, and the question of collateral becomes even more important.

20.6.6 Other Life Insurance Risks

In the life insurance sector, the capital markets have been used to place transactions which benefit a broker or an arranger rather than an insurer or reinsurer. Life settlements have been privately placed both physically (policy sale) and synthetically, thus exposing investors to longevity risk (or to mortality risk when selling synthetic life settlements). There has been no public rated securitization life settlement risk because rating a settlement portfolio would require a very high number of lives and these portfolios tend to consist of fewer policies with high individual value. In some cases, the credit risk in a life settlement or structured settlement has been securitized, but with investors keeping minimal exposure to the underlying life risk.

Another type of transaction which has briefly emerged was repackaging a portfolio of life insurance policies and annuity policies on the same lives. These transactions, called life insurance and life annuity combinations (LILACs), have exploited differences in pricing between life insurance and an annuity on the same life. The structure borrows to purchase an annuity stream and covers the risk of the interruption of the annuity flow via a life insurance policy. While the bulk of the risk is credit-related, the mortality of the book has an impact on the duration of the instrument and on the profit for the bondholder.

20.6.7 Life Sector Capital Release and Risk-Transfer Products: Summary

The life sector capital release and risk-transfer products are summarized in the lower panel of Table 20.2 in terms of the criteria for evaluating risk-transfer products analyzed in Sect. 20.3.2. All life transactions have very long maturities, very often covering a period over 30 years, due to the specificities of the business of the protection buyer (life insurance companies). In comparison, the catastrophic mortality securitizations have a relatively shorter maturity (the longest maturity so far has been 5 years), but it is still long compared to most nonlife securitizations. Most life securitizations can be seen as covering a single risk even if some catastrophic mortality transactions can cover different geographical areas. In this case, the same risk is considered but over various regions, and so these transactions are sometimes seen as multi-risk. The degree of standardization of transactions is very high for catastrophic mortality securitization and quite important for XXX and longevity transactions.

Credit risk is very limited for all types of life securitizations apart from embedded value and longevity transactions to some extent. Indeed, embedded value transactions have a high credit risk for the investor due to their structure—the transaction is the remittance of future cash flows from the seller. In other words, if the seller defaults, two events could happen: (1) the regulator could trap any future cash flow going to the buyer even if it emerges and (2) the lapse rate could spike (so future cash flows are not generated as new premiums are not paid in). For this reason, embedded value transactions are capped at the protection buyer's own rating. On the other hand, embedded value transactions have a low credit risk for the protection buyer.

Similarly, longevity transactions have a low credit risk for the investors, who will only pay under adverse conditions, but have high risk for the protection buyer, due to the structure of the transactions. There is also some limited moral hazard in longevity transaction to the extent that the pool disclosure is not fully transparent and can mislead some investors into less risky trades. However, there is no general portfolio management moral hazard. Finally, many life securitizations are indemnity transactions. The level of transparency then fully depends on the disclosure of the underlying portfolios and risks on the trade prospectuses.

20.7 Conclusions

Although reinsurance was one of the first truly global financial markets, the inherent conservatism and inertia in the insurance and reinsurance industries as well as technological and informational problems long impeded innovations in insurance and financial markets. However, a number of forces have emerged during the past two decades which have accelerated the rate of financial innovation in risk transfer. Perhaps the most important driver of innovation in the nonlife sector has been the growth in property values in geographical areas prone to catastrophic risk, and the most important driver in the life sector has been the need for capital release. Thus, insurers and reinsurers are virtually compelled to seek capital market solutions to their risk-bearing capacity problems. A second major driver of innovation is the reinsurance underwriting cycle, whereby insurers periodically experience high prices and coverage restrictions. Other factors driving innovation include the growth of enterprise risk management, advances in computing technologies, modern financial theory, and regulatory, accounting, and tax factors.

The quest for new sources of risk financing has led to a significant amount of experimentation and financial innovation. The two principal types of innovative risk-transfer products are hybrid instruments that combine features of reinsurance and securities and pure financial market instruments such as insurance-linked swaps, futures, options, and bonds. The pure financial products parallel the design-features of financial instruments and access securities markets directly rather than relying on the capacity of insurance and reinsurance markets.

A variety of hybrid products have been developed. Products that are closer to reinsurance than to financial products include finite reinsurance, multi-year and multi-trigger products, and retrospective excess of loss covers. However, more evolutionary products also have been developed including industry loss warranties (ILWs) and sidecars. It appears that ILWs are the most successful of the hybrid products, and sidecars have an important role to play in expanding capacity during hard markets and hence mitigating somewhat the effects of underwriting cycles. The case to be made for more opaque products such as multi-year, multi-trigger reinsurance is weaker and the continued success of these contracts remains in doubt.

Although there continues to be activity in the contingent capital and insurance swaps market, the most successful nonlife ILS are Cat bonds. The Cat bond market is thriving and seems to have reached “critical mass,” achieving record bond issuance in 2007, and rebounding from the subprime financial crisis in 2010–2012. Bond premia have declined significantly since 2001, and the bonds are now priced competitively with catastrophe reinsurance. Cat bonds now account for a significant share of the property catastrophe reinsurance market, especially for high coverage layers. The life ILS market was more significantly affected by the financial crisis of 2008–2010 than the nonlife market. However, a steady stream of private transactions continues to be issued.

Overall, the future looks bright for the ILS market. Cat bonds, swaps, sidecars, industry loss warranties, and other innovative products will play an increasingly important role in providing risk financing for large catastrophic events. Event-linked bonds are also being used by primary insurers for lower layers of coverage and non-catastrophe coverages such as automobile and liability insurance. The development of a highly liquid market in Cat futures and options has the potential to significantly increase the efficiency of insurance risk management. Futures and options have lower transactions costs than Cat bonds and positions can quickly be opened, modified, and closed, in contrast to the multi-year commitment of a Cat bond. Concerns about basis risk, counterparty credit risk, contract design, and the need to educate insurance industry participants are the primary impediments to success for futures and options contracts. However, considering the evolution of the Cat bond market, which has dealt successfully with similar concerns over time, it seems likely that future and options will succeed eventually. On the life side, catastrophic mortality securitizations are expected to continue, and the market for longevity risk has the potential for significant expansion. More capital-oriented life securitizations will emerge as recovery from the financial crisis continues.

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Chapter 21

Risk Sharing and Pricing in the Reinsurance Market

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Abstract Insurance activities cannot be solely based on pooling arguments as issued policies share common risk drivers which can be hard to diversify. These risks can be transferred from insurers to reinsurers. We describe the reinsurance market and discuss the demand for reinsurance. Moral hazard issues and alternative risk transfer mechanisms (securitization) are studied. We analyze the design of reinsurance contracts from a theoretical perspective, from the earlier study of Arrow (*Essays in the Theory of Risk Bearing*, Markham, Chicago 1971), to more realistic frameworks where background risk, counterparty risk, regulatory constraints, and risk measures are taken into account. Finally we review possible reinsurance premium principles and show the impact of the choice of premium rules on the optimal risk sharing in the reinsurance market.

21.1 Introduction

Between 1980 and 2010, the insurance market has significantly changed. Previously the mere existence of insurance activities was based on pooling arguments using the law of large numbers. By accepting many independent risks, the sample mean for insurance indemnities becomes closer to the theoretical mean and the aggregate reimbursement is more predictable. Insurance companies were thus able to control their risk exposure (e.g., to estimate the variance of their cash flows) and therefore their capital requirements. However sometimes the issued policies share common risk drivers (scenarios) and risks become then difficult to diversify. They cannot be easily hedged by pooling and occasionally give rise to huge aggregate losses for the insurer. Among these drivers, we can list as potential large-scale scenarios: natural catastrophes (e.g., hurricane, earthquakes), terrorism, financial risk (through financial guarantees, interest rate risk, or volatility risk), and nondiversifiable shifts in longevity and systemic shocks. For example, catastrophic events or terrorism imply correlation among property/casualty insurance policies. Longevity risk, epidemics, or terrorism can similarly affect life insurance policies. This contradicts the assumption of independence needed to apply the law of large numbers.

These large-scale risks can be transferred from insurers to those who can diversify these risks, namely to reinsurers (through traditional reinsurance arrangements) or to the financial market (through securitization). A number of large-scale loss events (natural catastrophes and man-made events) in the last 20 years have naturally increased the demand for reinsurance and have shed light on the role that

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reinsurers play as shock absorbers for the global economy. Kunreuther (2008) presents a list of the 20 most costly catastrophe insurance losses between 1970 and 2005. They range from \$3.4 billion to around \$50 billion with the Hurricane Katrina in the USA in 2005. In addition ten of them occurred between 2000 and 2005. Note also that the US insurance industry had never experienced a loss higher than \$1 billion before 1989. The increasing severity and frequency of large losses created demand for an efficient way to transfer large-scale risks.

The rest of this chapter is organized as follows. Section 21.2 describes the reinsurance market and the demand for reinsurance. We further discuss moral hazard issues and alternative risk transfer mechanisms. Section 21.3 is devoted to the design of reinsurance contracts from a theoretical perspective, from the earlier study of Arrow (1971), to more realistic frameworks where background risk, counterparty risk, regulatory constraints, and risk measures are taken into account. Finally Sect. 21.4 discusses pricing in the reinsurance market. In particular, we review possible reinsurance premium principles and show the impact of the choice of premium rules on the optimal risk sharing in the reinsurance market.

21.2 Reinsurance Markets

In essence, a reinsurance contract is an insurance contract bought by an insurance company from a reinsurer or from the financial market. In this section, we first give some empirical elements from the current reinsurance market. We then explain the demand for reinsurance and in particular discuss pros and cons of traditional reinsurance versus alternative risk transfers. The last part is dedicated to understanding failures of the reinsurance market between 1990 and 2010 and proposing potential explanations.

21.2.1 Empirical Study of the Reinsurance Market

This section summarizes a few facts about the reinsurance market at the end of 2010. Although the reinsurance market is a worldwide business, the United States has dominated this market for many years. For example, in 2005, 87% of worldwide insured catastrophe losses were covered by the United States [from a Swiss Re annual report (2006)]. Figures in Table 21.1 demonstrate that the reinsurance market is more developed for nonlife insurance risks than for life insurance risks. Numbers appearing in Table 21.1 can be found in Holzheu and Lechner (2007) and in reports from Swiss Re, Economic Research and Consulting (2011).

Table 21.1 gives the repartition of the \$170 billion US dollars ceded to the reinsurance industry in 2003 and of the \$197 billion US dollars ceded in 2009. We observe that in 2003, 83% of the ceded business was nonlife insurance and 17% was life insurance. The volume of reinsurance increased both in life insurance and nonlife insurance, but the relative percentage of ceded business in life insurance increased. Indeed in 2009, only 77% of the ceded business was nonlife insurance and 23% was life insurance. Life insurers used to seek reinsurance against the risk that more insured die or are disabled than projected which is less volatile and catastrophe prone than nonlife insurance business. Recently life insurers also seek reinsurance against financial risk embedded in guarantees typically offered in equity-linked insurance contracts.

The business ceded to the reinsurance market depends on how developed the primary insurance market is and on how much primary insurers transfer to reinsurers. Table 21.2 summarizes some figures on cession rates or ceded premiums as a percentage of direct premium volume. For example, cession rates are higher in emerging markets than in developed markets because of low capitalization.

Table 21.1 Geographical repartition of ceded business in the reinsurance market in 2003 and in 2009

| Countries | Nonlife | | | | Life | | | |
|------------------|---------|--------------|------|--------------|------|--------------|------|--------------|
| | 2003 | | 2009 | | 2003 | | 2009 | |
| | (%) | \$US billion | (%) | \$US billion | (%) | \$US billion | (%) | \$US billion |
| North America | 50.9 | 71.8 | 39 | 59.3 | 67.9 | 19.9 | 63 | 28.4 |
| Latin America | 3.3 | 4.7 | 4 | 6.1 | 1.4 | 0.4 | 1 | 0.5 |
| Europe | 32.6 | 46 | 33 | 50.2 | 23.9 | 7 | 26 | 11.7 |
| Asia and Oceania | 11.6 | 16.3 | 21 | 31.9 | 5.5 | 1.6 | 8 | 3.6 |
| Africa | 1.6 | 2.3 | 3 | 4.6 | 1.4 | 0.4 | 2 | 0.9 |
| Total | 100 | 141.1 | 100 | 152 | 100 | 29.3 | 100 | 45 |

Table 21.2 Cession rates to the reinsurance industry in life insurance and nonlife insurance in 2003 (expressed in percentage of the total insurance direct premium in the primary market) taken from Tables 18.1 and 18.2 of [Holzheu and Lechner \(2007\)](#)

| Countries | Nonlife insurance cession rate | Life insurance cession rate |
|----------------|--------------------------------|-----------------------------|
| | % of direct premiums | % of direct premiums |
| North America | 13.9 | 3.8 |
| Western Europe | 11.9 | 1.2 |
| Japan | 4.2 | 0.1 |
| Oceania | 14.2 | 3.2 |
| Asia-Pacific | 20.7 | 0.5 |
| Latin America | 22.4 | 3.1 |
| Eastern Europe | 8.7 | 0 |
| Africa | 26.5 | 1.8 |
| Total world | 13.1 | 1.9 |

The USA has a high cession rate explained by a high exposure to natural catastrophes. Low cession rates are typical to insurers with high capitalization but could also reflect government protection as it is the case in Japan. Indeed Japan has a state-organized pool offering earthquake insurance coverage (and a very low cession rate despite its high exposure to catastrophe risk).

[Holzheu and Lechner \(2007\)](#) explain that “the average cession rates, or ceded premiums as a percentage of direct premium volume, were 13.1% in non-life insurance and 1.9% in life insurance.” At the beginning of the twenty-first century, there has been a significant increase in ceded business, mainly due to increased cessions in nonlife insurance which rose from 1990 to 2003 from \$60 billion to almost \$141 billion. This is easily explained by observing that half of the most costly catastrophe insurance losses between 1970 and 2005 occurred between 2000 and 2005 (see the table based on data from Swiss Re, Insurance Information Institute and press releases given by [Kunreuther \(2008\)](#)).

As [Cummins and Weiss \(2009\)](#) note, the convergence of the financial services industry and (re)insurance sectors has been a significant economic development. For example, the market for (nonlife) cat bonds was \$1.136 billion in 2000 ([Doherty and Richter 2002](#)) and around \$7 billion in 2007 ([Carpenter 2008](#)). Though it has grown significantly, some research aims at explaining why the market for cat bonds is not bigger today and why cat bonds should or should not replace traditional reinsurance. Respective costs are discussed. An extensive discussion of the literature on this issue can be found in [Cummins and Weiss \(2009\)](#). This latter contribution also describes in great detail many insurance-linked securities with their strength and respective drawbacks, including hybrid reinsurance-financial products (such as finite risk reinsurance, spread-loss treaties, retrospective excess-of-loss covers, loss portfolio transfers, blended and multiyear multiline products, multiple trigger products and industry-loss warranties, sidecars) and securitization mechanisms through financial products (including cat bonds and other type of securitization such as the use of contingent capital, catastrophes

futures, options, and swaps). See also [Cummins and Mahul \(2009\)](#) for more information on the reinsurance market in emerging countries.

21.2.2 Reinsurance Demand, Moral Hazard, Risk Transfer Alternatives, Basis Risk

The main role of reinsurance is to provide a mechanism for risk sharing and diversification. It enables primary insurers to reduce their risk exposure and capital requirements. By transferring specific insurance risks to the reinsurance market (e.g., catastrophe risk for nonlife insurers, longevity risk or financial risk for life insurers), insurers reduce the volatility of their balance sheet and their tail risk. In the presence of a reinsurance market, insurers make better use of capital since they can afford to accept more business or larger risks with the same amount of capital.

Reinsurance offers diversification across regions for extreme risks and across insurers; it should be seen as a risk-sharing mechanism among market participants. Although a catastrophe can cause simultaneous and therefore dependent losses, catastrophes in different parts of the world may be independent and thus insurable. Reinsurance thus provides a way to protect insurers against extraordinary losses. Since a reinsurer is generally more broadly diversified than an insurer, the reinsurer does not need to hold as much capital to cover the same risk as an insurer. This represents an economic gain produced by the reinsurance market.

Reinsurance can also be used to reduce taxes or to avoid bankruptcy costs. [Mayers and Smith \(1982\)](#) were the first to recognize that insurance purchases are part of firm's financing decision. The findings in [Mayers and Smith \(1982\)](#) have been empirically supported or extended in the literature. For example, [Yamori \(1999\)](#) empirically observes that Japanese corporations can have a low default probability and a high demand for insurance. [Hoyt and Khang \(2000\)](#) argue that corporate insurance purchases are driven by agency conflicts, tax incentives, bankruptcy costs, and regulatory constraints. [Hau \(2006\)](#) shows that liquidity is important for property insurance demand. [Froot et al. \(1993\)](#) and [Froot and Stein \(1998\)](#) explain why a firm may behave risk averse. More details can also be found in [Holzheu and Lechner \(2007\)](#) in the case of reinsurance risk management.

As seen in the previous section and our description of the reinsurance market, motivations for purchasing reinsurance vary according to the primary insurer's level of capitalization, its risk exposure, and regulations. To summarize, insurers buy reinsurance for risks they cannot or do not wish to retain and they can do this in several ways. The most traditional method of providing reinsurance consists of writing a reinsurance policy on the effective losses incurred by the insurer during a given period. The main issue with this form of reinsurance is moral hazard.

21.2.2.1 Moral Hazard

In the reinsurance of large-scale disasters, moral hazard takes two forms, "ex ante" and "ex post" moral hazard (see [Doherty 1997a](#)). "Ex ante" moral hazard often refers to a careless behavior of a policyholder who has purchased insurance, for example, by not adopting precautionary measures that they would have adopted had they been uninsured, and therefore leading to an increase in the actual risk. Primary insurers may indeed be able to manipulate the distribution of loss by choosing a portfolio of risks to insure ([Doherty and Smetters 2005](#)). In the case of insurance of catastrophe events, reinsurers often mention "ex post moral hazard" as an important issue. This refers to primary insurers who do not negotiate claims settlements thoroughly after the occurrence of a catastrophe. For example, a policyholder, who has purchased flood insurance, may move unwanted furniture to

the basement when he expects a flood. In another context, a policyholder may easily claim *ex ante* damages in his house after an earthquake. In these instances it is very difficult for primary insurers to identify the losses caused by the catastrophe and losses that were caused before the catastrophe by other factors. One way to limit that type of moral hazard is to set a very high deductible such that the policyholder has to significantly share the reimbursement of the losses (see Kunreuther 2008). This “*ex post*” moral hazard is exacerbated by the presence of reinsurance and its cost is thus transferred to reinsurers. Indeed the primary insurer, if it purchased reinsurance, has less incentive to control its claims thoroughly (see Doherty 1997a) because of the high verification costs. The number of simultaneous claims and the pressure from regulators and public opinion induce primary insurers to reimburse as much as possible victims of a catastrophe and to reduce verification costs. More discussions on moral hazard can be found in Sects. 21.3.2 and 21.3.4.

21.2.2.2 Alternative Risk Transfers

More recently reinsurance can take an alternative form which reduces moral hazard and passes the risk to the financial market through securitization (with “catastrophic-loss index securities,” catastrophe bonds (cat bonds), and more generally with insurance-linked securities). The first insurance-linked securities were launched in 1992 on the Chicago Board of Trade. There is some rationale to explain why alternative risk transfer mechanisms can be optimal and how they complement the traditional reinsurance market. Laster and Raturi (2001) give an overview of insurance-linked securities and explain how the reinsurance market has a limited capacity and how securitization offers a complement to direct reinsurance. Another explanation is given by Froot (1999). With a traditional reinsurance contract, the insurance company is exposed to some additional risk linked to the performance (creditworthiness) of the reinsurer while the securitization offers a way to get a pure exposure in the natural hazard or catastrophe that the insurer is willing to insure. Moreover the low correlation of insurance-linked securities to the financial market should be attractive as a diversification tool. However, as noted by Doherty (1997a), “if new instruments are to compete successfully with reinsurance and to be attractive to investors, they must be designed to lower costs.” It has been observed that reinsurance through securitization was not necessarily cheaper than traditional reinsurance.

There are many other reasons explaining why securitization could be a good or bad alternative to traditional reinsurance. Both the advantages as well as the potential issues related to securitization are closely related to moral hazard and basis risk. In an alternative risk transfer (securitized contract), the reinsurance indemnity can be triggered by parametric triggers linked to the magnitude of a catastrophe (e.g., Richter scale for earthquakes), location of the event, or by levels reached by an industry-loss index. More details can be found in the review of alternative risk transfers by Cummins and Weiss (2009) and in Doherty and Richter (2002). For example, a cat bond is a bond on which the principal or interest is forgiven if a catastrophe occurs. However, “basis risk” may prevent such alternative risk transfers from being as effective as traditional reinsurance in terms of managing risk. Basis risk appears when the hedging instrument (index) is not directly linked to the insurer’s loss and there is a potential mismatch (see, e.g., Cummins et al. 2004, Doherty and Richter 2002, Doherty 1997a). The choice of a trigger for a catastrophic-loss index security is then a trade-off between moral hazard and basis risk (Cummins and Weiss 2009). Doherty (1997a) also writes that “moral hazard is the flip side of basis risk.”

Due to the presence of moral hazard in the traditional reinsurance market, Doherty and Richter (2002) have shown that investing in insurance-linked securities (partially correlated with actual losses) and not only in pure reinsurance can lead to efficiency gains. In particular, in the absence of transaction costs, it is always optimal to buy some insurance-linked securities as soon as the underlying index is positively correlated with the potential loss for the insurance company. The impact of moral hazard

will be further developed in Sect. 21.3.2 on the optimal design of reinsurance contracts. Finally, note that insurance-linked securities may also mitigate potential credit risk of reinsurers, especially when they are exchanged through a clearinghouse on the market. However as pointed out by [Doherty \(1997a\)](#) this is true when “mark-to-market” values evolve smoothly through time which is not always the case for liabilities driven by the occurrence of catastrophes. Unlike, for example, futures on commodities, credit risk for catastrophe options cannot always be eliminated. In the case of cat bonds, there is usually no credit risk because the principal is forgiven, and there are no additional payments due after the catastrophe happens.

[Cutler and Zeckhauser \(1999\)](#) argue that cataclysms must be reinsured in financial markets or by governments, or both. A cataclysm is here defined as an event with \$5 billion or more of insured losses. However, [Barrieu and Loubergé \(2009\)](#) note that the success of cat bonds has not been as high as one could expect when they first appeared. For example, the capital outstanding in cat bonds was only \$5 billion in 2005, compared to the \$66 billion of insured losses for Hurricane Katrina for the same year. Basis risk or moral hazard might partly explain this, but [Barrieu and Loubergé \(2009\)](#) say that low demand may also be due to the risk aversion to downside risk among investors, combined with parameter uncertainty. They propose to changing the design of cat bonds to “hybrid cat bonds” to increase their popularity where “hybrid cat bonds” are financial instruments combining a simple cat bond and a protection against a simultaneous drop in stock market prices.

21.2.2.3 Typical Reinsurance Arrangements

There are many forms of reinsurance contracts. They either cover entire insurance portfolios or just relate to single risks. They may involve to share insurer’s losses under some specific conditions. In every case they are linked to an actual loss incurred by the primary insurer. Denote by X this loss. The reinsurance indemnity is then a function of X , say $I(X)$. Traditional reinsurance contracts are “quota-share” or “proportional” reinsurance ($I(X) = \alpha X$ with $\alpha > 0$) and “excess-of-loss” reinsurance ($I(X) = (X - d)^+ = \max(X - d, 0)$ where $d > 0$ is the deductible) which is also called “stop-loss” reinsurance or “deductible” reinsurance. Under proportional reinsurance, the primary insurer shares premiums and losses by a ratio specified in the reinsurance treaty (coefficient α above). Additionally the reinsurer compensates the primary insurer by paying a reinsurance commission for the acquisition and administration costs incurred by the primary insurer. Proportional reinsurance is well suited for a homogeneous portfolio of risks, but its drawback is that it does not effectively protect the primary insurer against extreme loss scenarios. For that purpose excess-of-loss reinsurance treaty can be used instead. The reinsurer then only participates in risks exceeding a specific threshold. In addition, the contract may admit an “upper limit,” that is, the indemnity $I(X)$ is bounded by above by a maximum indemnity L so that the reinsurer has limited liability. For example, an excess-of-loss contract with deductible d and upper limit L is a call option spread written on the loss variable, $(X - d)^+ - (X - L)^+$. Note that for extremely large risks, reinsurance contracts are not proportional and are usually excess-of-loss contracts up to a maximum amount from the reinsurer.

[Froot \(2001\)](#) gives empirical evidence that the reinsurance coverage as a fraction of exposure is high at first (for small initial retention) and then declines with the loss level. [Froot \(2001\)](#) explains how insurers tend to retain, rather than share their large-event risks. This may contradict optimal risk sharing as we will show in Sect. 21.3.

21.2.3 Potential Explanations to Failures in the Reinsurance Market Between 1990 and 2010

Between 1990 and 2010, there are noticeable events where property/casualty private insurance firms stopped offering coverage against catastrophe risks. We can cite a few failures such as Florida hurricane insurance after the \$21.5 billion loss of Hurricane Andrew in 1992, earthquake insurance after the \$17.8 billion loss of Northridge quake of 1994, and most recently terrorism insurance after the 9/11 attack (Ibragimov et al. 2009; Kunreuther 2008). Ibragimov et al. (2009) note that although asymmetric information (often implying adverse selection and moral hazard) is usually used as a standard explanation of empirical facts in the insurance market, there is little asymmetry of information for natural disaster and terrorism attacks. A better explanation may actually come from the very high uncertainty on the loss distribution that causes the market to fail because of “uninsurability” (Froot 2001). Failures can be explained by the uncertainty and ambiguity on the loss distribution. For example, Hogarth and Kunreuther (1985, 1989) analyzed the effect of Knightian uncertainty (or ambiguity) on the insurance market (see also Bernard et al. (2012b) for a theoretical treatment of Knightian uncertainty). Kunreuther et al. (1993) investigated the market failure when the insurer has ambiguity on the market. See also Kunreuther (2008). Also the limited capacity of the reinsurance market (Cummins et al. 2002) and limited liability of reinsurers (Cummins and Mahul 2004) contribute to explaining the shortage of coverage possibilities. However, Ibragimov et al. (2009) conclude that size alone cannot explain all failures in the reinsurance market and propose an alternative explanation through “nondiversification traps” that we now explain.

As we have discussed before, reinsurance demand is mainly based on diversification benefits. It is commonly believed that diversifying reduces risk and has positive effects. However, diversifying comes at a cost, and therefore there are difficulties associated with diversification. One argument against geographic diversification is that insurance in the USA is state regulated; therefore establishing insurance in another state has a fixed additional cost (to learn specific regulation and marketing rules). Another reason for low diversification is simply that additional knowledge is required to develop another business line. As a result, Ibragimov et al. (2009) note that few insurers provide coverage in each state and for each business line. In their contribution they explain how it is possible to have two types of equilibrium; one is a “diversification equilibrium” in which insurance is offered and there is full risk sharing in the reinsurance market, and the other one is a “nondiversification equilibrium” in which the reinsurance market is not used. They further examine how reinsurance can be used to obtain the diversification equilibrium. It is shown that heavy-tailed distributions can lead to the nondiversification equilibrium and therefore explain why the reinsurance market may fail for reinsuring catastrophes (e.g., recent hurricanes in Florida).

21.3 Optimal Risk Sharing

In this section, we observe that a reinsurance contract is an insurance contract and present the optimal reinsurance contract as an extension of Arrow (1963, 1971)’s fundamental work on optimal insurance design. The first section presents the base model of Arrow. This base model has then been extended in many directions to account for regulatory constraints, the presence of background risk, specific premium or cost constraints, counterparty risk, and multiperiod and non-expected utility settings.

21.3.1 Base Model: One-Period Reinsurance Model

In a one-period model, Arrow (1963, 1971) shows that excess-of-loss insurance (deductible) is optimal for a risk-averse expected utility individual purchasing insurance from a risk-neutral insurer. See also Gollier (2003) and Eeckhoudt et al. (2005). This model can be adapted to the optimal reinsurance demand as follows.

Consider an insurance company with initial wealth W_0 (that includes its own capital and premiums collected from policyholders). At the end of the coverage period, the insurer has to reimburse policyholders for the incurred losses during the period. Let us denote by X the aggregate reimbursements (net of premiums and other expenses). Note that X can potentially take negative values in cases where the insurer is making profit. For ease of exposition we assume that X is the aggregate loss of the insurer (and that it is 0 if the insurer is making a profit). We assume that X is bounded by a maximum N . Due to exceptional conditions (for instance, catastrophic risk), the insurer might be forced to reimburse significantly more than the collected premiums to many of its policyholders (significantly more than the average). In this case, risks are not diversified anymore and a reinsurance agreement can be purchased covering unexpected high values of X . Let P_0 be the initial premium paid to the reinsurer.

The reinsurer will pay an indemnity $I(X)$ to the insurance company at the end of the period of coverage (which is a function of the aggregate loss X). We denote by W the insurer's final wealth. It is given by¹

$$W = W_0 - P_0 - X + I(X). \quad (21.1)$$

The insurer is assumed to be risk averse with a concave utility function $U(x)$ defined on \mathbb{R}^+ . Consistent with the existing literature on optimal insurance design, we also suppose that² $W \geq 0$, which is automatically satisfied when the maximum loss amount $N \leq W_0 - P_0$. The optimal reinsurance design consists of solving for the optimal reinsurance indemnity $I(X)$ as well as its optimal premium P_0 by maximizing

$$\max_{P_0, I(\cdot)} \mathbb{E}[U(W_0 - P_0 - X + I(X))]. \quad (21.2)$$

This optimization procedure is subject to additional constraints, such as $0 \leq I(X) \leq X$ (to prevent some obvious moral hazard) and the reinsurer's participation constraint. For example, if the reinsurer is risk neutral, his final wealth is given as $W^{\text{re}} := W_0^{\text{re}} + P_0 - I(X) - c(I(X))$ where W_0^{re} denotes the reinsurer's initial wealth and $c(I(X))$ corresponds to the costs associated with the payment of the indemnity $I(X)$. Assuming linear costs ($c(I(X)) = \rho I(X)$) and a risk-neutral reinsurer, the participation constraint for a risk-neutral reinsurer ($\mathbb{E}[W^{\text{re}}] \geq W_0^{\text{re}}$) becomes

$$(1 + \rho)\mathbb{E}[I(X)] \leq P_0, \quad (21.3)$$

where $\rho > 0$ is a constant safety loading. This constraint also appears when the expected value principle is used to calculate the premium. We discuss in Sect. 21.4 other premium choices. Assuming risk neutrality of reinsurers reflects an underlying view that there are risks that insurers cannot diversify whereas reinsurance companies can. In practice reinsurers may also be risk averse because

¹For ease of exposition we ignore interest rates. This is consistent with existing literature on optimal insurance design and does not markedly impact the results.

²The nonnegativity assumption on the wealth is not really restrictive. If it were to be false and that the company can go bankrupt, we would need to consider a utility function defined over \mathbb{R} (such as the exponential utility) instead of a utility function defined on \mathbb{R}_+^* as is the case here.

of frictions. When the insurance seller is risk averse, the base optimal insurance problem (21.2) is solved by Raviv (1979).

The optimal risk sharing presented in (21.2) is a two-step procedure. Usually an optimal indemnity $I(X)$ is determined assuming that P_0 is fixed. Then an optimization over the real line is needed to find the optimal reinsurance demand P_0 . In the case when the indemnity is parametrized by one parameter (e.g., a deductible insurance contract is parametrized by the deductible level), finding the optimal premium P_0 is then equivalent to finding the optimal deductible level (Cai and Tan 2007; Schlesinger 1981).

The solution to the optimal reinsurance design problem (21.2) with the constraints $\mathbb{E}[I(X)] \leq \frac{P_0}{1+\rho}$ and $0 \leq I(X) \leq X$ is a deductible insurance contract $I_d(X) = (X - d)^+$, where the deductible level d is determined by $\mathbb{E}[I_d(X)] = \frac{P_0}{1+\rho}$ (Arrow 1963).

21.3.2 Issues Associated with Policy Design

In a traditional insurance contract, the indemnity is a function of the actual loss incurred to the policyholder. If this loss is not perfectly observable, insurers have to verify the information provided by the policyholder and this implies verification costs. The presence of moral hazard is an important issue in the insurance reimbursement process (see Sect. 21.2.2.1 for a discussion more specific to the reinsurance market; see also Hölmstrom 1979, Doherty 1997a, Doherty and Richter 2002, Doherty and Smetters 2005, and Kunreuther 2008).

There are some elementary ways to limit manipulation of the actual loss by the policyholder by observing the two following adverse incentives for a policyholder. Policyholders might partly hide the actual loss (if the coverage is not an increasing function of the loss for instance), or they might inflate the claims in order to obtain more reimbursements. This induces audit costs for the insurer (a detailed discussion on audit costs can be found in Picard 2000). In order to minimize these audit costs, the design can be constrained such that policyholders have no rational incentive to increase or decrease their actual losses. For instance, assuming the contracts are nondecreasing with respect to the actual loss amount will diminish incentives to hide losses. Assuming the retention ($R(X) = X - I(X)$) of the loss is nondecreasing will induce policyholders not to inflate their losses since their expected utility is lower if they inflate their losses. Contracts that are both nondecreasing in the loss amount and with a nondecreasing retention are continuous (see, e.g., Carlier and Dana 2003).³ In the next section, we will see that optimal risk sharing does not necessarily lead to continuous contracts. Therefore it can be difficult to avoid these two types of moral hazard in the optimal design.

In the case of reinsurance arrangements, the policyholder is an insurance company. The reinsurance contract is often written on the aggregate loss of the company, which corresponds to the aggregate reimbursements made to its policyholders. This figure has to be correctly reported since annual accounting reports are published and highly controlled. Moreover companies have also to reimburse their policyholders as well as they can in order to keep them. Thus they do not have the same incentive as individuals to hide losses. In fact companies may have incentives to reimburse more generously their policyholders if this allows them to take advantage of their reinsurance contracts (ex post moral hazard). For a reinsurance contract it is therefore more important to avoid the incentive of insurers to inflate their losses. A solution is then to consider reinsurance contracts with a nondecreasing retention only. A higher loss X will induce a higher retention $R(X) = X - I(X)$ and thus a lower expected utility because the objective function is $\mathbb{E}[U(W_0 - P_0 - R(X))]$, where U is the nondecreasing utility function of the insurer.

³Precisely nondecreasing indemnities with nondecreasing retentions are 1-Lipschitz and therefore continuous.

Here we only discuss moral hazard issues in a one-period model. Moral hazard is better modeled in a multiperiod setting (see [Doherty and Smetters 2005](#)). Indeed a standard way of controlling moral hazard is to use a retrospective rating and therefore an updated premium. See Sect. 21.3.4 for further discussions.

21.3.3 Reinsurance Demand Under Additional Constraints

We propose to investigate the effects of a few additional constraints on the optimal deductible contract derived in the base model in Sect. 21.3.1. We first investigate the case when the reinsurer imposes a maximum on the reinsurance indemnity; we then examine regulatory constraints which give incentives to insurers to minimize specific risk measures. Finally we study the case when there is counterparty risk.

21.3.3.1 Optimal Reinsurance When the Reinsurer Has Limited Liability

[Cummins and Mahul \(2004\)](#) investigate the optimal reinsurance problem when there is an upper limit $L > 0$ on the reinsurance indemnity. The optimization in the base model seen in Sect. 21.3.1 becomes

$$\begin{aligned} \max_{I, P_0} \mathbb{E} [U (W_0 - P_0 - X + I(X))] & \tag{21.4} \\ \left\{ \begin{array}{l} 0 \leq I(x) \leq L, \\ P_0 = (1 + \rho)\mathbb{E}[I(X)]. \end{array} \right. \end{aligned}$$

They show that the optimal solution to (21.4) is given by

$$I_d^*(X) := \max(X - d, 0) - \max(X - (L + d), 0), \tag{21.5}$$

where d is such that $P_0 = (1 + \rho)\mathbb{E}[I_d^*(X)]$. Note that it satisfies $I(X) \leq X$ and does not introduce moral hazard. The optimal solution with limited coverage is consistent with reinsurance arrangements observed in the industry; it is an excess-of-loss contract with an upper limit (see Sect. 21.2.2.3). This simple reinsurance model can thus justify the existence of layers and the popularity of these types of contracts.

To prove this result, [Cummins and Mahul \(2004\)](#) use convex optimization theory. We give here a similar and short proof based on point-wise optimization. For $\omega \in \Omega$ given, introduce the auxiliary function $f(y) = U(W_0 - P_0 - X(\omega) + y) - \lambda y$ and optimize $f(\cdot)$ over $y \in [0, L]$; the optimal solution is obtained at $y_\lambda^*(\omega) := \min(L, \max(X(\omega) - (W_0 - P_0 - [U']^{-1}(\lambda)), 0))$. Choose λ_0 such that $\mathbb{E}[y_{\lambda_0}^*] = \frac{P_0}{1+\rho}$. Then by optimality of $y_{\lambda_0}^*$ for all $\omega \in \Omega$ and for any indemnity $I(X(\omega))$ satisfying the constraints of (21.4), that is, $0 \leq I(X) \leq L$ and $\mathbb{E}[I(X)] = \frac{P_0}{1+\rho}$,

$$U(W_0 - P_0 - X(\omega) + I(X(\omega))) - \lambda_0 I(X(\omega)) \leq U(W_0 - P_0 - X(\omega) + y_{\lambda_0}^*(\omega)) - \lambda_0 y_{\lambda_0}^*(\omega)$$

After taking the expectation on both sides and simplifying since $\mathbb{E}[I(X)] = \mathbb{E}[y_{\lambda_0}^*]$ one obtains

$$\mathbb{E} [U (W_0 - P_0 - X + I(X))] \leq \mathbb{E} [U (W_0 - P_0 - X + y_{\lambda_0}^*)]$$

which ensures that $y_{\lambda_0}^* = \min(L, \max(X - d, 0))$ is the optimal indemnity to the problem (21.4) where $d = W_0 - P_0 - [U']^{-1}(\lambda_0)$. This can easily be rewritten as (21.5) which ends the proof.

21.3.3.2 Regulatory Constraints

Regulators have the important task of protecting policyholders and the stability of the market. They impose risk management constraints on insurers. The presence of regulation naturally affects the optimal risk sharing. Let us study optimal risk sharing with regulatory constraints in a very simplified framework. The insurer is assumed to be risk neutral but subject to some regulatory constraints. Although it is optimal for a risk-neutral insurer to buy no reinsurance in the presence of costs, it can be proved that the presence of regulatory constraints makes the insurer behave in a risk-averse manner and increases its reinsurance demand (Bernard and Tian 2009).

Accounting standards and regulation systems are changing in many places around the world. Solvency requirements are often based on the Value-at-Risk (quantile) risk measure or more general tail risk measures (as in Basel II for European banks or Solvency II for European insurance companies). Value-at-Risk has become popular since 1988, when US commercial banks started to determine their regulatory capital requirements for financial market risk exposure using Value-at-Risk (VaR) models. Although controversial, Value-at-Risk is used worldwide because of its simplicity. A first part recalls the work of Bernard and Tian (2009) and Gajek and Zagrodny (2004b) on optimal risk sharing when Value-at-Risk or equivalently the survival probability is the objective to minimize. This problem is solved in full details. Other risk measures are mentioned at the end of this section.

To examine the impact of Value-at-Risk constraints on optimal risk sharing, we may solve for the following optimal reinsurance contract $I(X)$ which minimizes insolvency risk for the insurer:

$$\min_{I(X)} \mathbb{P}(W < W_0 - \nu) \quad s.t. \quad \begin{cases} 0 \leq I(X) \leq X \\ \mathbb{E}[I(X) + C(I(X))] \leq \Delta \end{cases} \quad (21.6)$$

Insolvency risk is measured here as the probability that the final wealth W (defined in (21.1)) falls below $W_0 - \nu$ where ν is given and W_0 is the initial wealth level. See also Gajek and Zagrodny (2004b) who study the minimization of the probability of ruin (i.e., $\mathbb{P}(W < 0)$).

As noted by Bernard and Tian (2009), this problem is very similar to the base optimal insurance problem (21.2) as the probability $\mathbb{P}(W < W_0 - \nu)$ can be written as an expected utility $\mathbb{E}[u(W)]$ with a utility function $u(z) = \mathbb{1}_{z < W_0 - \nu}$. This utility function is not concave so that standard Arrow–Raviv first-order conditions (see Arrow 1963, 1971, Borch 1962, and Raviv 1979) are thus not sufficient to characterize the optimum. Using path-wise optimization, Bernard and Tian (2009) solve Problem (21.6) and show that the optimal reinsurance contract is a “truncated deductible.” A “truncated deductible” consists of reinsuring medium losses only but not large losses. This shows that Value-at-Risk could induce adverse incentives to insurers not to buy reinsurance against large losses.

We present here a short proof of this result when $C(y) = \rho y$ for $\rho > 0$. We first observe that the premium constraint in (21.6) is not necessarily binding,⁴ but it is enough to solve the optimal indemnity in (21.6) with the equality instead of the inequality in the premium constraint. We then find an optimal solution $I_{\Delta_0}^*$ such that $\mathbb{E}[(1 + \rho)I_{\Delta_0}^*(X)] = \Delta_0$. It is then enough to minimize $\mathbb{P}(W_0 - P_0 - X + I_{\Delta_0}^* < W_0 - \nu)$ for all $\Delta_0 \in [0, \Delta]$.

⁴See Fig. 1 of Bernard and Tian (2009) for a graphical illustration of the non-monotonicity of the objective function with respect to the premium constraint. The probability $\mathbb{P}(W < W_0 - \nu)$ is not always minimum when the reinsurance premium is maximum. There is a non-monotonic trade-off between the premium and the objective function to minimize which explains the fact that the constraint can be nonbinding.

To solve the non-convex optimization problem (21.6) with the equality constraint $\mathbb{E}[(1+\rho)I(X)] = \Delta_0$, we apply path-wise optimization. It consists of minimizing for each state $\omega \in \Omega$, $f(y) = \mathbb{1}_{W_0 - P_0 - X(\omega) + y < W_0 - v} + \lambda(1 + \rho)y$ over $[0, X(\omega)]$. It is clear that $f(y)$ is

$$\begin{cases} 1 + \lambda(1 + \rho)y & \text{for } y < X(\omega) - (v - P_0) \\ \lambda(1 + \rho)y & \text{for } y \geq X(\omega) - (v - P_0) \end{cases}$$

Denote by y^* the optimum of the function f over $[0, X(\omega)]$. If $X(\omega) < v - P_0$, then $y^* = 0$. Otherwise $X(\omega) \geq v - P_0$ and the optimum is $y^* = 0$ when $\lambda(1 + \rho)(X(\omega) - v + P_0) > 1$ or $y^* = X(\omega) - v + P_0$ when $\lambda(1 + \rho)(X(\omega) - v + P_0) \leq 1$. We find that for $\omega \in \Omega$, the optimum of the function f is then

$$I_\lambda^*(\omega) = (X(\omega) - v + P_0)\mathbb{1}_{v - P_0 \leq X(\omega) < v - P_0 + \frac{1}{\lambda(1+\rho)}}. \quad (21.7)$$

We then choose $\lambda_0 > 0$ such that $(1 + \rho)\mathbb{E}[I_{\lambda_0}^*] = \Delta_0$ and conclude similarly as the derivations of the optimal solution to Problem (21.4) of [Cummins and Mahul \(2004\)](#).

These results provide some rationale for the conventional reinsurance contracts. Indeed [Froot \(2001\)](#) observes that “*most insurers purchase relatively little cat reinsurance against large events.*” He shows that “*excess-of-loss layers*” are suboptimal and that expected utility theory cannot justify the upper limits commonly observed in the reinsurance industry. Several reasons for these departures from the theory are put forward in [Froot \(2001\)](#). The above derivations show that when the insurer minimizes his default probability (or minimizes VaR), the optimal reinsurance indemnity (21.7) is a truncated deductible and it is suboptimal to reinsure large losses. This is somewhat consistent with empirical elements given by [Froot \(2001\)](#). Observe also that this optimal indemnity (21.7) is not nondecreasing and therefore presents moral hazard issues.

Like most theoretical models on optimal risk sharing, the above model is very simple. It neglects transaction costs, background risk, moral hazard, and asymmetric information and considers an oversimplified reinsurance premium (see Sect. 21.4 hereafter for more discussion on reinsurance premiums). Moreover it takes place in a one-period economy, and both the insurer and the reinsurer are risk neutral, and in particular, the distribution of loss is perfectly known by both the insurer and the reinsurer. An extension to the case when the insurer is risk averse can be found in [Bernard and Tian \(2010\)](#) and when there is ambiguity on the loss distribution in [Bernard et al. \(2012b\)](#).

Instead of minimizing Value-at-Risk, many other risk measures have been studied in the literature. See, for example, [Barrieu and El Karoui \(2005\)](#) and [Jouini et al. \(2008\)](#). Optimal reinsurance problems have recently been solved by [Zhou and Wu \(2008\)](#). The latter study considers a regulatory constraint on the expected tail risk instead of the probability of the tail risk, which can be solved by standard convex optimization techniques. Expected shortfall (similarly the average VaR or the conditional tail expectation (CTE)) captures not only the probability to incur a large loss but also the magnitude. It is often argued to be better than VaR because it is coherent; see [Artzner et al. \(1999\)](#). Moreover it has been implemented to regulate some equity-linked insurance products (containing financial guarantees) in Canada ([Hardy 2003](#)). The optimal reinsurance policy varies with the choice of risk measure (subject to regulatory changes). [Bernard and Tian \(2009\)](#) show that the truncated deductible can also be optimal when the insurer wants to minimize the expected shortfall beyond some level using similar techniques of path-wise optimization as to derive the optimal truncated deductible (21.7). However, the optimal reinsurance contract can also be a deductible when the insurer minimizes the expected square of the shortfall.

21.3.3.3 Reinsurance Demand Under Counterparty or Background Risk

Since the recent financial crisis, credit risk (counterparty risk) and systemic dependency between financial firms have become front-page news. Within the reinsurance arena, companies are also paying increased attention to counterparty risk and in particular to the rise in default rates of the reinsurers exactly at the time when reinsurance is most needed. The early work by [Doherty and Schlesinger \(1990\)](#) considered a three-state model of insurance under counterparty risk with total default and was later extended to partial default by [Mahul and Wright \(2007\)](#). See also [Mahul and Wright \(2004\)](#) and [Cardenas and Mahul \(2006\)](#). [Cummins and Mahul \(2003\)](#) considered a loss-dependent counterparty risk but with total default. They prove that deductible insurance is optimal in the presence of a total default risk when the insurance buyer and the insurance seller have the same beliefs about the default probability.

[Bernard and Ludkovski \(2012\)](#) extend this strand of literature by incorporating a loss-dependent probability of default as well as partial recovery in the event of contract nonperformance. In their model, there is a probability that the reinsurer defaults on his contract obligations and only partly reimburses the promised insurance indemnity. Crucially, they assume that this counterparty risk is related to the losses of the reinsurance buyer (insurer). This is intuitive and can be motivated as follows. When the reinsurance buyer has a big loss, the reinsurer is not only responsible for making a large indemnity payment, but it is also likely to be confronted by similar losses from other reinsurance buyers. Indeed large losses are commonly due to a systemic factor and cause undiversifiable stress on the reinsurer's capital. Therefore the likelihood of the reinsurer's default depends on the amount of the loss: there is a "stochastic" probability of default.

To capture these systemic effects, [Bernard and Ludkovski \(2012\)](#) assume negative stochastic dependency in the sense of [Capéraà and Lefoll \(1983\)](#) between the loss incurred by an insurance company X and the fraction $0 \leq \Theta \leq 1$ of indemnity actually paid out by the reinsurer (after default). Θ represents the "recovery rate." The term "default" refers to any event where $\Theta < 1$ and the promised indemnity is not fully paid. This means that conditional on X , Θ is a nonincreasing function. While they assume that a large loss X makes it more likely that $\Theta < 1$, they do not introduce any direct *structural* model of such cause and effect. The problem is formulated as follows. In case of default of the seller, Θ is the recovery rate, in other words, the percentage of the indemnity that the seller can pay. The reinsurance buyer thus receives $\Theta I(X)$. The optimal reinsurance contract solves the following optimization problem,

$$\begin{aligned} \max_{I, P_0} \mathbb{E} [U (W_0 - P_0 - X + \Theta I(X))] & \quad (21.8) \\ \left\{ \begin{array}{l} 0 \leq I(x) \leq x, \\ \mathbb{E}[\Theta I(X)] \leq K. \end{array} \right. \end{aligned}$$

Their results are consistent with the existing literature in special cases. When $\Theta \equiv 1$ and there is no counterparty risk, the above problem reduces to the standard model of reinsurance design, whereby optimal indemnity is a deductible policy. Otherwise, this Problem (21.8) can be seen as an extension of [Cummins and Mahul \(2003\)](#) where the default may happen partially instead of a total default and as an extension of [Doherty and Schlesinger \(1990\)](#) and [Mahul and Wright \(2007\)](#) where the loss X can take more than two values. In this literature, it is generally optimal for a risk-averse insurer (facing default risk of the reinsurer) to lower the reinsurance demand by increasing the optimal deductible level, while at the same time increasing the marginal insurance rate over the deductible. This is sometimes called a "disappearing deductible." If there is partial recovery in case of default, there is an increase in protection from the tail risk, so that the optimal shape of the contract involves marginal overinsurance but the optimal premium is lower. However, in general, when there are some

dependence assumptions, the overall shape of optimal contracts may be very complex and include decreasing indemnification, overinsurance, and counterintuitive comparative statics. Thus, most of the standard properties of optimal indemnities are rendered false.

[Biffis and Millossovich \(2010\)](#) propose an interesting alternative approach: in their model, the reinsurer's default is explicitly caused by the payments of the specific indemnity and the consequent nonperformance of the reinsurer's net assets. As a typical reinsurance company has many policyholders, it is unlikely that default is directly triggered by the payment of one particular indemnity. More realistic models with more than two players (with many insurers) should be investigated, although [Biffis and Millossovich \(2010\)](#)'s optimal reinsurance policy is already not explicit.

Counterparty risk appears naturally as an example of multiplicative background risk. Effects of background risk on risk-sharing agreements have been studied, for instance, by [Schlesinger \(2000\)](#) or by [Dana and Scarsini \(2007\)](#). However, most existing literature assumes that the background risk is additive. The work of [Bernard and Ludkovski \(2012\)](#) thus extends [Dana and Scarsini \(2007\)](#) to the case when the background risk is multiplicative and not additive. It is shown that the presence of multiplicative background risk can be more complex than additive risk which was also noted in another context by [Franke et al. \(2006\)](#).

21.3.4 Discussions and Potential Extensions

We discuss several potential directions. First we explain why relaxing the nonnegativity assumption on indemnities may be reasonable in the context of reinsurance contracts design. Second we give some shortcomings of the static one-period model used in outlining and discussing most results of Sect. 21.3. Finally we underline that the optimal risk sharing studied in this section has been done between two agents: the insurer and the reinsurer, but that optimal risk sharing needs to be studied in a more global way between all players of the insurance and reinsurance market.

21.3.4.1 On the Nonnegativity Constraint on Indemnities

The simple one-period framework exposed above may be useful to design optimal insurance-linked securities by relaxing the nonnegativity constraint on the optimal indemnity. [Gollier \(1987\)](#) and [Breuer \(2006\)](#) were first to investigate the impact of that feature on the optimal insurance contract. Of course the idea of relaxing the nonnegativity constraint is dubious for a standard insurance contract, but it is very interesting in the reinsurance setting. Indeed, it is not realistic to think that an individual will accept to pay a premium to the insurance company at the beginning of the period and to pay again at the end of the period under specific conditions on the occurred claim. Even if she accepts, the presence of moral hazard is obvious. But insurers are interested in sharing risks and in finding alternative risk transfers which reduce costs. For example it is of interest for insurance companies to smooth annual results over years. This can be achieved by sharing their profits on the capital market when the year was profitable (and their aggregate reimbursements are low) or to receive money when they are subject to exceptionally high losses. Observe that this is a kind of swap: losses and gains are both possible. In fact this exists in practice with the example of cat bonds. Their payments are tied to the occurrence of some catastrophic events. Let us describe, for example, the "Alpha hurricane bond." Investors are supposed to buy it at the beginning of the risk period at par (say \$100). At the end of the risk period, investors will receive an uncertain dollar amount. If a major hurricane occurs, then they receive an unfixed recovery amount where a proportional part of their initial investment is given to the insurer. If there is no hurricane, then they get their initial investment back and a high interest rate (typically

a spread of 4% in addition to the LIBOR interest rate). Details can be found for instance in [Bantwal and Kunreuther \(2000\)](#).

Designing a contract written on the aggregate reimbursement of the insurer to the policyholders that can be either positive or negative is thus meaningful. This might be a way to help insurers to reduce the cost of reinsurance and design new insurance-linked securities. Solving this latter problem amounts to analyzing the optimal reinsurance strategy for the insurer: how much risk it should retain, how much risk it should cede to the reinsurance market or the capital market, and how it should share its profits in good years to reduce the cost of reinsurance. For the same reinsurance cost, the insurer will be better covered in case of high losses. Such an idea might be useful to develop new insurance-linked securities. In fact cat bonds can already be understood as an empirical illustration of this design. The payoff of a cat bond is usually tied to the occurrence of natural disasters.

The main difference between the optimal risk sharing without the nonnegativity assumption on indemnities and for instance a cat bond is the fact that the underlying of a cat bond is a perfectly observable variable that cannot be manipulated by the insurer (since it is based on the occurrence of natural events). On the other hand the aggregate reimbursement of the insurer is controlled by the insurer and moral hazard might take place. For instance the insurer can try to hide some losses or to inflate them in order not to share his profit when he makes profit or to get higher reimbursement from the market. Practical application of such reinsurance indemnities requires finding a variable Y that is highly correlated with X but that is perfectly observable (see discussion on basis risk in Sect. 21.2.2 and [Doherty and Richter 2002](#)). Imagine an insurer who insures all houses of the same city: its highest risk is a hurricane. It can thus design a product written on the wind speed. This speed is likely to be highly correlated with the aggregate reimbursement of the insurer. Indeed medium winds will incur medium losses, high winds will mean that exceptional losses incur, and small winds will certainly mean a good year for the insurer.

21.3.4.2 On the One-Period Model

The optimal risk sharing in a static one-period model as it has been investigated throughout this section can be useful to get insights about the impact of the choice of the objective function for the insurer or the reinsurer to maximize or minimize and the effects of constraints stemming from regulators or other risk management decisions. The literature on optimal reinsurance design has become very technical. More and more constraints are considered and more and more general optimal risk-sharing problems can be solved. However all these models are often static, i.e., one-period models. Given that reinsurance contracts can be signed for several years, it is of interest to further analyze dynamic multiperiod models. For instance, at the height of the credit freeze in 2008, there was discussion of reinsurance contracts with premiums tied to the credit rating of the seller. With multiple periods it would also be possible to set up vested reinsurance accounts, so that (a portion of) the premiums paid so far is guaranteed to be available once a claim is filed. Moral hazard is also better modeled in a multiperiod setting as developed by [Doherty and Smetters \(2005\)](#). Similarly [Doherty \(1997a\)](#) writes that “the optimal design of the reinsurance contract is one with retrospective premiums and long-term contracts.”

The deficiency of the classical static one-period model is also examined by [Gollier \(2003\)](#). He notes that in a static one-period model, wealth and consumption are exactly the same variable. In the real world, people can compensate for losses to their wealth by reducing their savings (or by borrowing money) without reducing their consumption. [Gollier \(2003\)](#) then shows that insurance demand can be reduced in a dynamic model when consumers are able to accumulate a wealth buffer when they do not incur a sequence of big losses.

21.3.4.3 Borch Equilibrium and Capacity of the Reinsurance Market

The base model is about the equilibrium between two agents: an insurer and a reinsurer. In the reinsurance markets there are more than two players. [Borch \(1962\)](#) studies the optimal risk sharing among insurers and shows that a Pareto-optimal allocation consists of reinsurance contracts solely written on the aggregate loss in the market. Each insurer's surplus is scaled to its share of aggregate loss. [Cummins et al. \(2002\)](#) use this approach to measure the capacity of the reinsurance market. Let $\sum_i X_i$ be the aggregate loss for the market where X_i is the loss sustained by the insurer i . They then assume that insurer i has limited liability and therefore the loss incurred by insurer i cannot exceed its initial surplus and premium income, or the insurer goes bankrupt. They define the capacity of the insurance market as the proportion of liabilities (incurred among all insurers) that can be paid using the financial resources of the liable insurers as well as their risk-sharing mechanisms among them or by reinsurance. Using a very simple model, they are able to quantify the "capacity" of the reinsurance market. In their model, they show that this capacity is maximized when each insurer has a share of loss α_i of the industry underwriting portfolio (perfect correlation with the aggregate industry losses). Their study is illustrated by the US property-liability insurance market. See also [Acciaio \(2007\)](#), [Ludkovski and Rüschemdorf \(2008\)](#) and [Filipovic and Svindland \(2008\)](#) for additional studies on optimal risk sharing among n players in a market.

21.4 Reinsurance Pricing

Pricing reinsurance contracts turns out to be more difficult than pricing traditional insurance contracts. Reinsurance risks are usually heavy tailed, are not easily pooled, contain systematic components (i.e., risk that cannot be hedged by pooling), and can partly be hedged by the financial market. We start with some empirical elements on reinsurance premiums, discuss some principles for establishing good pricing rules, and finally review the actuarial literature to price reinsurance and insurance-linked securities.

21.4.1 Some Empirical Elements

It is well known that market reinsurance prices are cyclical. [Froot \(2007\)](#) shows that reinsurance prices rise after catastrophes occur and reinsurers' capital has been depleted and when loss risk creates a very asymmetric return distribution as is the case with heavy-tailed distributions. Additional studies on reinsurance prices ([Guy Carpenter 2008](#)) agree with [Froot \(2007\)](#)'s study and provide more empirical evidence that prices increase after low-frequency/high-severity events. Although cyclical reinsurance prices are observed in the market, cycles are hard to model and often neglected in theoretical studies on optimal risk sharing in the reinsurance market.

In addition, the reinsurance market contains a lot of imperfections and prices generally exceed fair prices as is explained in [Froot and O'Connell \(2008\)](#). In this context, fair prices refer to insurance prices solely based on the expected discounted cash flows (pure premium). Industry sources often estimate the transaction costs in a reinsurance contract at 20% or more of the total premium. [Froot and O'Connell \(2008\)](#) suggest that the ratio of [price minus expected losses] to expected losses has been on the order of 60–70% in the 1990s and can be even higher on the highest-level coverages. These substantial additional costs may come from the difficulty of assessing the underlying risk but also from moral hazard as noted by [Doherty \(1997a,b\)](#). [Bantwal and Kunreuther \(2000\)](#) note that alternative risk transfers do not solve this problem since cat bonds can be significantly more expensive

than competitive reinsurance prices. They also provide reasons from behavioral economics to suggest why cat bonds have not been more attractive to investors at current prices.

Finally we remark that cat bonds, mortality bonds, and more generally all securitized bonds are often priced at spreads over LIBOR, meaning that investors receive floating interest plus a spread or premium over the floating rate. See [Bantwal and Kunreuther \(2000\)](#). The yields of cat bonds depend on the occurrence of certain catastrophes. This market has been also studied by [Doherty \(1997a\)](#) and [Froot \(2001\)](#).

21.4.2 General Principles for Pricing Reinsurance

A premium principle is a rule to evaluate an insurance risk. The choice of the reinsurance premium principle essentially reflects the reinsurer's preferences and hedging strategy. [Kunreuther \(2008\)](#) outlines two principles on which a disaster program should be based and which are related to how to price reinsurance. The first rule is that "insurance premiums should reflect the underlying risk associated with the events against which coverage is provided." This goes against, for example, any regulation that attempts to regulate premiums by imposing, for instance, a maximum premium. Moreover, [Kunreuther \(2008\)](#) argues that risk-based premiums are a way to raise the awareness of policyholders of the real risk associated with their insurance policy and to give them incentives to invest in risk mitigation measures. The second principle, however, is that insurance has to stay affordable. Rates should not be subsidized, but rather that only some types of subsidy can be paid to low-income policyholders to help them purchase insurance at a risk-based premium so that they stay aware of the real cost and risks.

In a very comprehensive analysis, [Kunreuther \(2008\)](#) expresses the difficulties associated with insuring catastrophe risk and determining an appropriate risk-based premium. Although he discusses the insurance market, his conclusions can also apply to reinsurance. In particular he notes that catastrophe insurance sellers must be able to identify and quantify the risk despite the low frequency of catastrophes and the lack of observations. He also discusses the effects of ambiguity that may drive catastrophe insurance sellers to charge considerably more for a risk for which they only have a partial knowledge of the probability distribution.

Furthermore reinsurance cannot be priced as traditional insurance. Recall that the expected value of the future cash flows under the physical probability is a relevant quantity when the law of large number applies. However we already discussed in the introduction why the law of large number can fail in the reinsurance business. Indeed there is often significant systematic risk left that cannot be hedged by pooling as traditional insurance business. Below we suggest how to address this issue and price this type of risk. We also explain in more detail why reinsurance premiums should take the financial market into account.

21.4.3 Traditional Approaches to (Re)insurance Pricing

This section presents three common approaches to determine an insurance premium. These three approaches are not exclusive and some premium principles appear natural from several approaches. See, for instance, [Young \(2004\)](#) for more details. More specific reinsurance pricing principles are studied in the following section on weighted premiums.

When the risk is diversifiable, it can be hedged by pooling and the law of large numbers applies. In this case, reinsurance premiums can simply be computed as insurance premiums using quantities estimated from the distribution of the underlying insurance risk. Typical premiums are obtained by

computing the expected value (actuarial value) plus a positive safety loading linked, for example, to the expected value, the standard deviation, or the variance. This “safety loading” accounts for all expenses as well as the reinsurer’s economic return. By construction these premiums are typically “law-invariant” in that they only depend on the distribution of loss.

Premiums can also be derived using a “characterization method” which consists of choosing a premium such that a set of axioms is satisfied. See, for example, the coherent risk measures proposed by Artzner et al. (1999). See also Wang et al. (1997). Examples of standard properties are law-invariance (when the premium depends only on the distribution of loss and not on the states of the economy when the loss happens), monotonicity (when the premium satisfies first-order stochastic dominance), risk loading (when the premium exceeds the expected loss), scale invariance (so that the premium does not depend on the choice of currency), subadditivity (when the premium of the sum is smaller than the sum of the respective premiums to account for diversification effects), additivity for comonotonic, or independent risks.

A third approach, also referred as the “economic” method, incorporates the preferences of the decision makers involved (i.e., the insurance buyer and insurance seller) in the determination of insurance prices. Such premiums are then typically derived from economic indifference principles (using, e.g., expected utility theory or Yaari’s theory). See also the zero-utility premium principle proposed by Bühlmann (1980). For example, assuming that the reinsurance buyer has an exponential utility, $U(x) = -\exp(-\lambda x)$ with $\lambda > 0$ and that the reinsurance contract offers full insurance $I(X) = X$, the premium (bid price) obtained by utility indifference pricing, P_0 , can be calculated as $U(W_0 - P_0) = \mathbb{E}[U(W_0 - X)]$: the reinsurance buyer is indifferent between paying P_0 to fully reinsure the loss X or not purchase reinsurance and suffer the entire loss X . This implicit equation can be solved easily and one obtains $P_0 = \ln(\mathbb{E}[\exp(\lambda X)])/\lambda$. When the utility U is concave (risk-averse policyholder), the above “economic” premium is higher than the expected value and therefore automatically contains a positive safety loading (Bernard and Vanduffel 2012).

21.4.4 Weighted Reinsurance Premiums

As explained earlier, reinsurance risk is heavy tailed and contains systematic risk. Premiums based on the actuarial value or more generally on the moments under the physical probability measure do not sufficiently reflect this tail risk. Instead it is often preferred to evaluate reinsurance premiums based on distorted tail probabilities. The underlying idea is simple: it consists of increasing the importance of the tail by “lifting” the survival function $1 - F(x)$ with a distortion function g , such that $g(0) = 0$, $g(1) = 1$, and $g(t) \geq t$ for all $t \in [0, 1]$. The distorted cumulative distribution function is then computed as $F_g(x) = 1 - g(1 - F(x))$. A random variable X_g with distorted cdf F_g dominates the random variable X with cdf F in terms of first-order stochastic dominance. A premium can be based on the average of the “distorted” random variable X_g

$$\mathbb{E}[X_g] = \int_0^{+\infty} g(1 - F(x))dx. \quad (21.9)$$

It can be shown that this expectation is a “weighted premium,” that is, the average of the “weighted” random variable X for some weight function.

A review of weighted premium principles can be found in Furman and Zitikis (2009). Typically a weight function is a nonnegative function $w(\cdot)$ such that $0 < \mathbb{E}[w(X)] < +\infty$ and such that the weighted premium

$$\mathbb{E} \left[X \frac{w(X)}{\mathbb{E}[w(X)]} \right] \quad (21.10)$$

is well defined. In that case, the corresponding distorted cdf is $F_w(x) = \frac{\mathbb{E}[w(X)\mathbb{1}_{X \leq x}]}{\mathbb{E}[w(X)]}$. This corresponds to a distortion $g_w(u) = 1 - F_w(F^{-1}(1 - u))$ in (21.9) when F is a continuous cdf. It is easy to verify that $g_w(0) = 0$, $g_w(1) = 1$ and that $g_w(u) \geq u$ as soon as F_w dominates in first-order stochastic dominance F .

A lot of well-known premiums are weighted premiums. For example, when $w(x) = \mathbb{1}_{x > x_q}$, then the weighted premium (21.10) corresponds to $\mathbb{E}[X|X > x_q]$ (which is the expected shortfall or CTE). Another famous example of weighted premium is the “exponential tilting premium principle” with respect to a risk Y for which the weight function is $w(X) = \mathbb{E}[e^{\lambda Y}|X]$. Then, the exponential tilting of X with pdf (probability distribution function), $f_X(\cdot)$, with respect to Y has the pdf $f_X^*(\cdot)$, defined as

$$f_X^*(x) = f_X(x) \frac{\mathbb{E}[e^{\lambda Y}|X = x]}{\mathbb{E}[e^{\lambda Y}]}$$

In the case when (X, Y) has a bivariate normal distribution, the Wang transform (Wang 2000) is a special case where the new cdf F_X^* obtained after a distortion of the cdf F_X is computed as

$$F_X^*(x) = \Phi(\Phi^{-1}(F_X(x)) - \beta)$$

where the parameter β is called the “market price of risk” and reflects the level of systematic risk. See Lin and Cox (2005) for an application to the pricing of mortality bonds and Wang (2000) for the valuation of cat bonds. Wang (2007) extends the pricing the exponential tilting and the Wang transform to multivariate risks. When the weight function $w(x) = e^{\lambda x}$ for $\lambda > 0$, then the weighted premium (21.10) is called the Esscher premium. The Esscher premium can also be defined with respect to another risk Z as follows

$$\frac{\mathbb{E}[I(X)e^Z]}{\mathbb{E}[e^Z]} \tag{21.11}$$

for some given random variable Z (often taken to be equal to X or λX with $\lambda > 0$). This pricing rule is particularly useful when risk is securitized or more generally when it is linked to the financial market. For example, insurance-linked securities can be priced with the Esscher premium (21.11). See also Cox et al. (2006) for securitization of longevity risk and the use of the Wang transform and exponential tilting.

We end this section by clarifying the close link between the Esscher premium, a weighted premium, and risk-neutral pricing. When the underlying loss X is traded in a frictionless, liquid, arbitrage-free, and complete market, then there exists an investment strategy in the financial market such that the outcome of the strategy replicates perfectly any indemnity $I(X)$. In this case, the price of $I(X)$ must be unique and must be equal to the initial value of the (replicating) strategy. It can be proved that it writes as a discounted expectation under a unique probability Q (called risk-neutral probability). The price of $I(X)$ paid at the end of the coverage period T is then calculated as $e^{-rT} \mathbb{E}_Q[I(X)]$ (also called risk-neutral price) where $\mathbb{E}_Q[\cdot]$ refers to the expectation under the risk-neutral probability measure Q . For example, in the Black–Scholes market, X is lognormally distributed and this discounted expectation under Q can be expressed as the following distorted expectation under the real-world probability measure (or weighted premium)

$$e^{-rT} \mathbb{E}_Q[I(X)] = \mathbb{E} \left[\alpha \left(\frac{X}{X_0} \right)^{-\beta} I(X) \right] \tag{21.12}$$

where $\alpha = \exp\left(\frac{\theta}{\sigma}\left(\mu - \frac{\sigma^2}{2}\right)T - \left(r + \frac{\theta^2}{2}\right)T\right)$, $\beta = \frac{\theta}{\sigma}$, $\theta = \frac{\mu-r}{\sigma}$, X_0 denotes the value of the underlying at time 0, r is the continuously compounded risk-free rate, μ is the instantaneous expected return in the real world of X , σ is its constant instantaneous volatility, and finally $\mathbb{E}[\cdot]$ is the expectation under the original measure (physical probability). Clearly the risk-neutral premium (21.12) is equal to the product of e^{-rT} by the weighted premium principle for $w(X) = \alpha e^{rT} \left(\frac{X}{X_0}\right)^{-\beta}$. In the Black–Scholes market, $\frac{X}{X_0}$ is lognormal with mean $\left(\mu - \frac{\sigma^2}{2}\right)T$ and variance $\sigma^2 T$ so that $\mathbb{E}[w(X)] = 1$.

21.4.5 Influence of the Financial Market

As Brockett et al. (2009) note, a “striking feature of the actuarial valuation principles is that they are formulated within a framework that generally ignores the financial market.” This is indeed an important issue with traditional reinsurance premiums. With the increasing developments of insurance-linked securities, reinsurance prices cannot ignore anymore the presence of a financial market: it is an opportunity to (at least partially) hedge, a place to invest, and a sharing tool and it is no longer independent of the insured losses. Ignoring the link between the financial market and reinsurance is thus not realistic anymore. Following Hodges and Neuberger (1989) for pricing in incomplete markets and Brockett et al. (2009) for pricing weather derivatives, we can generalize the static utility indifference pricing (“economic” premium) to include the presence of financial markets as a dynamic way to invest and a tool to hedge. Bid and ask prices for a reinsurance indemnity $I(X)$ are defined as follows. Denote by $A(w)$ the set of random wealths Y_T that can be generated at maturity $T > 0$ by trading in the financial market with an initial wealth w . Assume now that during the considered horizon the investor is exposed to a risk with random payoff X . From the viewpoint of the insured the (bid) price p_b is such that

$$\sup_{Y_T \in A(W_0 - p_b)} U[Y_T - X + I(X)] = \sup_{Y_T \in A(W_0)} U[Y_T - X], \tag{21.13}$$

whereas from the viewpoint of the insurer, the ask price p_a follows from

$$\sup_{Y_T \in A(W_0^e + p_a)} V[Y_T - I(X)] = \sup_{Y_T \in A(W_0^e)} V[Y_T]. \tag{21.14}$$

In the context of an arbitrage-free financial market, these bid and ask premiums (defined, respectively, by (21.13) and (21.14)) are market-consistent premiums in the sense that if the indemnity $I(X)$ can be replicated in the financial market, it has a unique price and $p_a = p_b$ is equal to this replication price (market price). In particular in the Black–Scholes model, the bid and ask prices of $I(X)$ are both equal to the weighted premium (21.12). Furthermore Bernard and Vanduffel (2012) show that bid and ask prices p_\bullet (p_a or p_b) verify

$$p_\bullet \geq e^{-rT} \mathbb{E}[I(X)] + \text{Cov}[I(X), w(X)]. \tag{21.15}$$

The discounted expected value is then no longer valid as a classical lower bound for insurance prices, and that it has to be corrected by a covariance term which reflects the interaction between the insurance claim and the financial market. Similarly, Brockett et al. (2009) use indifference pricing in the presence of a financial market for weather derivatives. They show how the hedging part is important and how indifference prices could significantly differ to actuarial prices obtained using the discounted expectation.

21.4.6 *Impact of the Premium on Optimal Reinsurance Demand*

The choice of the premium is of utmost importance; it influences the equilibrium and optimal risk sharing in the reinsurance market in two ways: the reinsurance demand (premium level) and the optimal indemnity type (design of the contract). Most models investigated in Sect. 21.3 concentrate on the expected value principle which is rarely used in reinsurance pricing. It is important to note that the results obtained using the expected value principle as a premium are not necessarily robust to other types of premiums. For example, the deductible insurance contract (or stop-loss) is optimal when the reinsurer uses a premium based on the actuarial value $(1 + \rho)\mathbb{E}[I(X)]$ (Arrow 1971); however, this optimality is generally not robust. For example, Kaluska (2001) showed that the deductible insurance contract is not optimal when the premium is based on the variance or the standard deviation of the indemnity (whereby coinsurance may be optimal). This also holds true for more general premium principles (Gajek and Zagrodny 2004a).

Note that there is a strong link between the reinsurer's preferences and the premium principle. As can be seen in the exposition of the base model in Sect. 21.3.1, the expected value principle is consistent with the case when the reinsurer is risk neutral (and maximizes its expected final wealth) as it appears in (21.3). In practice insurers and reinsurers are subject to additional regulation constraints. The optimal reinsurance policy is strongly impacted by the choice of the risk measure (see Sect. 21.3.3.2). The original article of Raviv (1979) shows that when the reinsurer is risk averse, the participation constraint (21.3) can be written in terms of a minimum expected utility. In this case, the indemnity is not a stop-loss indemnity, but the indemnity becomes more complex (it still has a deductible but is concave over the deductible level). Bernard et al. (2012a) consider optimal risk sharing in the rank-dependent utility setting and also find the suboptimality of deductible insurance.

Finally note that the choice of the premium principle also impacts the reinsurance demand measured by the optimal premium P_0 spent for reinsurance (P_0 is defined as in (21.1)). For example, a higher safety loading ρ decreases the reinsurance demand and how much insurers are willing to spend on reinsurance (Borch 1975). Therefore the choice of the safety loading has a direct effect on the optimal reinsurance demand and the quantity of reinsurance that the insurer is willing to buy.

21.5 Conclusions

This chapter outlines the main role of reinsurance markets in providing a mechanism for risk sharing and diversification. We first explained how the occurrence of severe natural disasters, the presence of moral hazard, credit risk, and basis risk have all contributed in developing alternative risk transfer mechanisms and securitization. Section 21.3 presented the design of reinsurance contracts from a theoretical perspective, from the earlier study of Arrow (1971) to more realistic frameworks that incorporate additional constraints imposed, for example, by regulatory agencies. Section 21.4 examined the difficulties associated with pricing reinsurance risks and the impact of the reinsurance pricing rule on optimal risk sharing.

Although the models presented in this chapter are simple static one-period models, they give quite good equilibrium results. They contribute to the understanding of existing reinsurance contracts as well as the effects and implications of imposing constraints on the risk exposure. Modeling the reinsurance market remains a challenge. For example, we need to develop truly dynamic frameworks for reinsurance to better capture the real-world market. Most of the models discussed in this chapter also assume a perfect knowledge of the loss distribution. However, in the reinsurance business, important losses tend to be large and with low frequency and therefore difficult to model so that model uncertainty needs to be incorporated in the decision making.

As observed in the first section, the reinsurance market has expanded considerably between 1990 and 2010. With the increasing integration between the reinsurance market, the financial market, and the global economy, future models have to relate pricing demand and supply in reinsurance markets with other markets for risk in a consistent fashion. To cope with the reluctance to use alternative risk transfers, further analysis of the potential benefits of securitization is needed. More (cautious) innovation in reinsurance and new designs in securitization may help to resolve basis risk, credit risk, moral hazard, and liquidity that are inherent in reinsurance contracts.

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Chapter 22

Financial Pricing of Insurance

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Abstract The *financial pricing of insurance* refers to the application of asset pricing theory, empirical asset pricing, actuarial science, and mathematical finance to insurance pricing. In this chapter we unify different approaches that assign a value to insurance assets or liabilities in the setting of a securities market. By doing so we present the various approaches in a common framework that allows us to discuss differences and commonalities. The presentation is done as simply as possible while still communicating the important ideas with references pointing the reader to more details.

22.1 Introduction

The very title of this paper [“Recent developments in economic theory and their application to insurance.”] may cause some surprise, since economic theory so far has found virtually no application in insurance. Insurance is obviously an economic activity, and it is indeed strange.

[Karl Borch \(1963\)](#)

Clearly, much has changed since Karl Borch wrote these words in 1963 as insurance markets nowadays are closely linked to general securities markets. On one hand, there are many contracts that depend on both the occurrence of an “insurance” event and the evolution of financial markets—and thus of the economy in general. This dependence may be explicit as in the case of modern savings products or credit insurance or it may be implicit because the insurer’s activities on the asset side of the balance sheet affect its ability to service future liabilities. On the other hand, an army of savvy investors is all too happy to take advantage of insurance prices that are not finely tuned to financial markets. Thus, just as other financial assets, insurance policy prices should reflect equilibrium relationships between risk and return and particularly avoid the creation of arbitrage opportunities.

In this chapter we review the literature on the *financial pricing of insurance*. We do so by drawing upon ideas from various areas of related research including asset pricing theory, empirical asset pricing, and mathematical finance. Our intention is to demonstrate how each contributes to our understanding of the determination of equilibrium insurance asset or liability values in the setting

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of a securities market. Specifically we discuss the underlying economic theory and how it applies to insurance markets, and we discuss applications of the theory to specific mechanisms in these markets and to empirical studies that test the implications of the theory.

The question of how insurance prices are formed in an economic equilibrium is of great academic interest as is evidenced by a large number of contributions in the economics, finance, and insurance literatures. A proper understanding of the topic provides important insights regarding the organization of insurance markets and their regulation [see e.g. [Doherty and Garven \(1986\)](#), [Cummins \(1988\)](#), or [Cummins and Danzon \(1997\)](#)]. It also provides insights on risk pricing and capital allocation for insurance companies [see e.g. [Phillips et al. \(1998\)](#), [Zanjani \(2002\)](#), or [Froot \(2007\)](#)].

The question of how to determine *market values* of insurance liabilities is also becoming increasingly relevant to practitioners. For instance, the derivation of the capital requirements within the dawning regulations of Solvency II or the Swiss Solvency Test relies on a *market-consistent* valuation of insurance liabilities. Similarly, market consistent valuation of insurance liabilities plays an important role in revised accounting standards such as the new International Financial Reporting Standard (IFRS) 4.

Before we discuss the financial pricing of insurance, we first begin by providing an overview of the relevant fundamental ideas for financial *asset pricing*. We then outline the organization of the remainder of this chapter, where we discuss the interjacent details in more depth.

22.1.1 A Primer on Asset Pricing Theory

In this section we provide a brief overview on the basic principles for pricing (financial) assets. We limit our presentation to the basic ideas. Detailed introductions can, e.g., be found in [Cochrane \(2001\)](#), [Duffie \(2001\)](#), or [Skiadis \(2009\)](#).

Consider a *frictionless* securities market that is free of *arbitrage opportunities*. That is—loosely speaking—assume there is no possibility to make a profit without incurring risk. The implications of this—seemingly modest—assumption are far reaching. First, it is possible to show that the absence of arbitrage alone implies the existence of a so-called *state price system* or—equivalently—the existence of an *equivalent martingale measure*. More precisely, given the payoff of any security x_{t+1} at time $t + 1$, by applying various versions of the *separating hyperplane theorem*, we are able to determine the set of prices at time t , p_t , which conforms with the prices and payoffs of existing securities to exclude arbitrage opportunities. We can represent these prices as

$$p_t = E_t[m_{t+1} x_{t+1}] = e^{-r_t} E_t[Z_{t+1} x_{t+1}], \quad (22.1)$$

where $r_t = \log\{1/E_t[m_{t+1}]\}$ is the risk-free rate in the period $[t, t + 1)$, and m_{t+1} and Z_{t+1} denote a *state price system* and a Radon–Nikodym derivative of an equivalent martingale measure Q , respectively.¹

If, in addition to being free of arbitrage opportunities, the market is *complete*, i.e., if every possible payoff can be perfectly replicated with existing assets, this set will be a singleton. Determining the *unique* price of any asset therefore is then simply a matter of determining the *unique* state price system or a replicating strategy in terms of trading the existing *underlying* securities. This is the basic

¹Different authors within different literatures present this result in terms of different objects such as state price systems, equivalent martingale measures, deflators, or pricing kernels, but the underlying idea is always the same. The most general version is provided by [Delbaen and Schachermayer \(1994, 1998\)](#), who use the lingua of equivalent martingale measures for the statement of their results.

idea of *option pricing theory* pioneered by Black, Merton, and Scholes. However, in this context it remains open how the prices of the underlying assets are formed; a question that can only be answered in the context of an economic equilibrium.

Again, the condition of “no arbitrage” plays a fundamental role. Essentially, the absence of arbitrage is equivalent to the existence of optimal portfolios for all agents in the economy, and the security prices correspond to the agents’ marginal utilities of consumption at their respective portfolio optimums. This yields the *basic pricing equation* (cf. [Cochrane 2001](#)):

$$p_t = E_t \left[\beta \frac{u'(c_{t+1})}{u'(c_t)} x_{t+1} \right] = e^{-r_t} E_t [x_{t+1}] + Cov \left[\beta \frac{u'(c_{t+1})}{u'(c_t)}, x_{t+1} \right], \quad (22.2)$$

which states that the price of an asset is the expected value of its payoff x_{t+1} , discounted by the subjective discount factor β and modulated by the agent’s marginal utilities at their optimal consumption levels. Hence, here:

$$m_{t+1} = \beta \frac{u'(C_{t+1})}{u'(C_t)} \text{ and } Z_{t+1} = \frac{u'(C_{t+1})}{E_t [u'(C_{t+1})]}.$$

In the presence of multiple heterogeneous agents and an abundance of available securities it may be very difficult to (theoretically) derive their consumption levels in *equilibrium*, i.e., in the situation where everybody optimizes their portfolio and the security market clears.

In the case of complete markets in an endowment economy, however, the situation simplifies considerably. Here, the equilibrium allocation is Pareto optimal by the *First Welfare Theorem* and we are able to derive prices based on the marginal utilities of a so-called *representative agent* in a non-trade economy, i.e., we may take marginal utilities of the representative agent at the (aggregate) endowment to derive prices.

Hence—in *theory*—Eq. (22.2) provides a complete answer to all issues regarding pricing (cf. [Cochrane 2001](#)). However, the *practical* (empirical) performance of consumption-based pricing models is mixed. Nonetheless, the theorem provides important insights on the interpretation of the state price system and Eq. (22.1) holds generally so that to find the price of any bundle of future cash flows we only need to fix a model for m_{t+1} or, alternatively, Z_{t+1} . An approximating approach is to model them as linear combinations of observable *factors*—giving rise to so-called *factor pricing models*—and to derive the parameter values directly from security prices.² Similarly, it is possible to make alternative functional assumptions on Z_{t+1} , and to estimate the functional relationship from security prices.³ In any case, the task is to approximate the relevant part of the investors’ marginal utility as can be seen from Eq. (22.2).

22.1.2 Applications to Insurance: Organization of the Chapter

As mentioned above, if the underlying security *market* (model) is complete, the state price system is unique and pricing a *derivative financial security* is merely a matter of replication. Similarly, it is possible to interpret an insurance contract as a derivative—though its payoff is contingent on an insurance event in addition to the financial market. But insurance markets are inherently incomplete

²The most famous variants are the Capital Asset Pricing Model [CAPM, [Sharpe \(1964\)](#)], which only requires the “market return” as the single factor. Extensions include Arbitrage Pricing Theory [APT, [Ross \(1976\)](#)] and the Intertemporal Capital Asset Pricing Model [ICAPM, [Merton \(1973\)](#)].

³Note that we do not necessarily require complete markets here. In particular, in an incomplete market, the choice of a parametric form that is identifiable from security data may entail the restriction to a certain subset of all possible state price systems.

since there typically exist no traded securities on individual insurance events. Does this mean that there never exists a unique price for insurance? We address this question in several sections in this chapter.

The interpretation that an insurance contract is a derivative contract is particularly convenient if the insurance risk is completely *diversifiable* in the sense that there exist a large number of independent, identically distributed risks and if these risks—or rather their distributions—are independent of financial markets. In this case complete market arguments carry straight over to insurance pricing resulting in a simple prescription: *Financial risk should be priced according to financial pricing theory that incorporates penalties for aggregate risk, whereas actuarial risk is treated via the expected discounted value under physical or actuarial probabilities.* Deriving adequate prices then reduces to the financial engineering problem of appropriately modeling the cash flows of the insurance exposure—at least for the most part.⁴ We discuss this case in detail in Sect. 22.2.

In Sect. 22.3 we introduce the case of a limited diversification of the insurance risk. Here, it is possible to determine prices by imposing an admissible choice of m_{t+1} or Z_{t+1} in *some* coherent manner. For instance, one may choose the change of measure Z_{t+1} satisfying Eq. (22.1) that is “closest” to the underlying physical probability measure P or the choice might be guided by marginal utility considerations of the trading agents. Here we also discuss the particularly relevant case for the insurance setting, namely a so-called almost complete market when the insurance risk can be considered “small.” In this case, it is possible to separate financial and insurance events in some specific sense and many such “closeness” criteria provide the same result—namely to price financial risks according to financial pricing theory and actuarial risk with physical or actuarial probabilities just as in the completely diversifiable case described above.

Yet for many types of insurance risks, the assumption of separability between financial and insurance markets is not tenable. For instance, major catastrophes often have a considerable influence on securities markets. Nonetheless, the logic from above carries through if the risks’ distributions directly depend on financial markets indices, but one faces the (empirical) problem of determining the dependence structure of insurance risks on capital market risks. The missing link between insurance returns and financial indices is supplied by the so-called *insurance CAPM* and its extensions. We discuss the details in Sect. 22.4.

In contrast, some insurance risks may directly enter marginal utilities of consumption—and thus m_{t+1} or, alternatively, Z_{t+1} . For instance, economic growth is linked to demographic changes, which are in turn material to insurance companies. Hence, in these cases, it may be necessary to consider risk premiums for insurance risk. One popular approach in actuarial science is to simply make a (parametric) assumption on the form of the underlying pricing kernel or, equivalently, on the Radon–Nikodym derivative Z_{t+1} supporting the risk-neutral measure Q . That is, one imposes a certain parametric form for the risk premium of insurance risk. We discuss this approach in detail in Sect. 22.5. The parameters must be estimated from securities that are subject to the relevant risk such as abundant prices of insurance contracts. However, clearly the question arises how the prices of these contracts—or rather the premiums for the relevant risk factors such as demographic or catastrophic risks—are formed in equilibrium. This is one of the areas we identify as important for future research.

A second important area for future research pertains to financial *frictions*. Specifically, there is a growing literature in risk management that highlights the importance of frictions such as capital costs that could originate from tax or agency issues (Froot and Stein 1998) or search costs (Duffie and Strulovici 2012), and their importance for pricing and capital allocation (see also Chap. 29 in this handbook). We provide the important ideas in Sect. 22.6.

Finally, Sect. 22.7 concludes.

⁴Potential exceptions are insurance contracts with exercise-dependent features. Here, optimal exercise rules may be influenced by the policyholders’ preferences since they may not face a quasi-complete market.

22.2 Independent, Perfectly Diversifiable Insurance Risk

In traditional actuarial theory, pricing is simply a matter of calculating expected discounted values. Often referred to as *actuarial present values*, this result—which is typically stated in the form of the so-called *Equivalence Principle* [see e.g. Bowers et al. (1997)]—trivially emerges as the equilibrium price under perfect competition and no informational asymmetries when the inherent actuarial risk can be diversified. Things become more complicated if the insurance payoff includes both (independent) actuarial and financial risks although—under certain conditions—the basic intuition can prevail: financial risk should be priced according to financial pricing theory that incorporates penalties for aggregate risk, whereas the actuarial risk is treated via the expected discounted value under physical or *actuarial* probabilities. Hence, financial pricing entails deriving an expected value under a *product measure*.

To explain the basic idea, we discuss a simplified version of the model by Brennan and Schwartz (1976) for equity linked endowment contracts with a guarantee. More specifically, consider an insurance policy that pays the maximum of the stock price and the initial investment at expiration time 1 in the case of survival and nothing in the case of death during the contract period. We assume a simple one-period Binomial model with risk-free rate of interest is $R = 25\%$, in which the underlying stock priced $S_0 = \$100$ at time zero can take two values at time 1, $S_1(u) = \$200$ and $S_1(d) = \$50$ with probabilities $p_S = 60\%$ and $(1 - p_S) = 40\%$, respectively. Thus, the insurance policy pays the maximum of the stock price and the guaranteed amount $G_0 = S_0 = \$100$ at time 1 in the case the insured event materializes—i.e., here if the policyholder survives—which happens with a probability of $p_x = 75\%$. The situation is illustrated in Fig. 22.1.

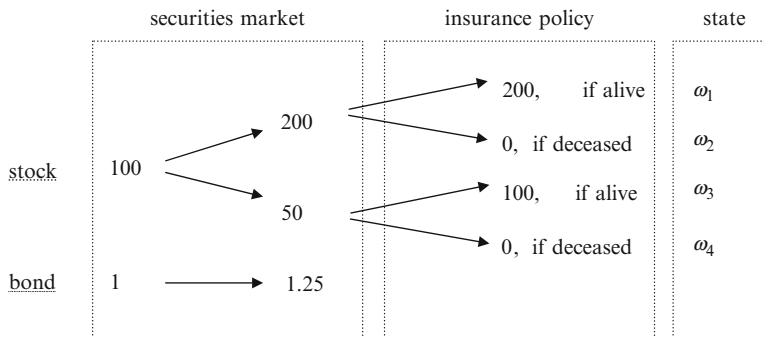


Fig. 22.1 Equity linked endowment insurance with guarantee in a Binomial model

First, note that the basic market model is not complete. Specifically, all state price systems that yield the *correct* price of the traded security at time zero are admissible under the postulate that there is no arbitrage opportunity. Thus,

$$Q(\{\omega_1\} \cup \{\omega_2\}) = \underbrace{q_1 + q_2}_{q_u} = 0.5 = 1 - Q(\{\omega_3\} \cup \{\omega_4\}) = 1 - \underbrace{(q_3 + q_4)}_{q_d} \tag{22.3}$$

and we obtain the following *arbitrage-free interval* (cf. El Karoui and Quenez 1995; Karatzas and Kou 1996):

$$\left(\inf_Q E^Q \left[\frac{1}{1+R} \text{Payoff} \right]; \sup_Q E^Q \left[\frac{1}{1+R} \text{Payoff} \right] \right) = (0; 120)$$

However, clearly a life insurance company will typically not sell a single policy only, but will sell to a large number policyholders N . Thus, from the insurer’s perspective, the total payoff will be $(L_1 \times X)$, where L_1 is the number of survivors and

$$X = 200 \times I_{\{\omega_1, \omega_2\}}(\omega) + 100 \times I_{\{\omega_3, \omega_4\}}(\omega)$$

is the purely security market-contingent payoff per individual in the case of survival. The payoff per policy then is:

$$\frac{(L_1 \times X)}{N} \xrightarrow{N \rightarrow \infty} p_x \times X, \tag{22.4}$$

by the *law of large numbers* or the *central limit theorem*, and the *unique* replication price for the expression on the right-hand side is:

$$E^Q \left[\frac{1}{1 + R} \times p_x \times X \right] = \frac{1}{1 + R} \times (q_u \times p_x \times 200 + q_d \times p_x \times 100) = 90,$$

which again trivially emerges as the equilibrium price under perfect competition and no informational asymmetries. Hence, the price of the insurance contract is formed under a *product measure* of *risk-neutral* and *actuarial* probabilities for independent *financial* and *actuarial* risks, i.e., the pricing exercise is based on prices for cash flow bundles that are weighted by the actuarial probability p_x .

This approach is particularly prevalent in life insurance research since there certainly exist a large number of equivalent risks and payoffs frequently depend on the evolution of certain assets or interest rates. As indicated, among the first to develop pricing models in this context were [Brennan and Schwartz \(1976\)](#), who applied the—then young—option pricing theory by Black, Merton, and Scholes to pricing equity-linked life insurance policies with an asset value guarantee. Since then a large number of contributions have refined and generalized this approach—essentially all by considering financial engineering problems of increasing complexity (see e.g. [Aase and Persson \(1994\)](#) for general unit-linked policies, [Grosen and Jørgensen \(2000\)](#) for participating policies, and [Bauer et al. \(2008\)](#) for Guaranteed Minimum Benefits within Variable Annuities).

Similar ideas have found their way into property and casualty insurance pricing. While there asset-linked indemnities are less prevalent, market risks matter for the insurer’s assets side and, thus, for the realized payoffs when taking into account the possibility of default. To illustrate, consider again the example introduced above, but assume the insurance contract now has an indemnity level $G = \$200$ independent of the security market state in case the risk materializes. However, assume now that the company invests its assets worth $G = A_0 = \$200$ per insured risk in the underlying stock index. Then the insurer can service its liabilities in case the market goes up or in case the risk does not materialize. However, if the price of the risky asset falls and payments become due, assets are not sufficient and the company defaults. Thus, the eventual payoff will be

$$\text{Payoff} = 200 \times I_{\{\omega_1\}}(\omega) + 100 \times I_{\{\omega_3\}}(\omega),$$

and by analogous arguments to above the equilibrium per-contract price for a large number of available risks will be

$$\begin{aligned} 90 &= \frac{1}{1 + R} \times (q_u \times p_x \times 200 + q_d \times p_x \times 100) \\ &= \frac{1}{1 + R} \times p_x \times G - \underbrace{p_x \times E^Q \left[\frac{1}{1 + R} (G - A_1)^+ \right]}_{\text{DPO}}, \end{aligned}$$

where DPO denotes the insurer's *default put option*. Thus, in this context, the insurance liability is akin to risky corporate debt.⁵ Again, deriving an adequate price then solely entails appropriately specifying the cash flows of the insurance exposure in a (stochastic) cash flow model although the inclusion of retention amounts, maximum policy limits, nonlinear deductibles, multiple lines, multiple claims, etc. can make the problem more complex [see e.g. [Doherty and Garven \(1986\)](#), [Shimko \(1992\)](#), [Phillips et al. \(1998\)](#)].

Possible exceptions are cases in which the contract entails *early exercise features* such as surrender options, conversion options, or withdrawal guarantees. In this case financial engineering prescribes the solution of an optimal control problem identifying the strategy yielding the largest (no-arbitrage) value of the contract akin to the valuation of American or Bermudan options. While such an approach could be defended in that it gives the unique supervaluation and superhedging strategy robust to any policyholder behavior (cf. [Bauer et al. 2010a](#)), resulting prices may exceed the levels encountered in practice since these are typically determined based on policyholders' "actual" behavior. Indeed, a deviation from "optimal" strategies associated with value optimization may be rational since—unlike in the option valuation problem—policyholders typically do not have the immediate possibility to sell or repurchase their contracts at the risk-neutral value. Recent contributions attempt to account for this observation by directly considering the policyholder's perspective, e.g., by solving the associated life-cycle portfolio problem or by incorporating individuals' tax considerations [see [Steinorth and Mitchell \(2011\)](#), [Gao and Ulm \(2011\)](#), and [Moening and Bauer \(2011\)](#)].

Nonetheless, the form of the expedient pricing kernel is conceivably simple: it only includes financial risks. Of course, the pricing kernel may reflect additional considerations if we drop the underlying assumptions that insurance risk is perfectly diversifiable and/or independent of financial markets. We address these questions in Sects. 22.3 and 22.4/22.5, respectively.

22.3 The "Almost Complete Case": Small, Independent Insurance Risks

In this section, we drop the assumption that there are an infinite number of insurance risks available in the market. Thus, the arguments from the previous section relying on a perfect diversification do not apply, and the question arises how to choose the risk-neutral probability measure satisfying Eq. (22.3) in this case.

The financial mathematics literature has given various criteria. For instance, the *variance-optimal martingale measure* gives the price associated with a hedging strategy that minimizes the mean-square error of the (necessarily imperfect) hedge of the insurance liability ([Schweizer 2001a](#)). Similarly, other criteria are associated with other choices of the martingale measure. For example, exponential criteria relate to the so-called *minimal entropy martingale measure* that minimizes the relative entropy with respect to the physical measure P ([Frittelli 2000](#))

$$I(Q, P) = E \left[\frac{dQ}{dP} \log \left\{ \frac{dQ}{dP} \right\} \right],$$

and generalized distance measures based on the q -th moment correspond to the so-called *q -optimal martingale measure* ([Hobson 2004](#)).

An alternative approach is to base the choice on *utility-indifference pricing* [see e.g. [Carmona \(2008\)](#)] or *marginal utility indifference pricing* [see [Davis \(1997\)](#), [Hugonnier et al. \(2005\)](#)] from the

⁵Insurance companies are levered corporations that raise debt capital by issuing a specific type of financial instrument—the insurance policy (cf. [Cummins 1988](#); [Phillips et al. 1998](#)).

viewpoint of the trading agents. Given a utility function U , a set of admissible payoffs given wealth w denoted by $A(w)$, and an insurance payoff H , set⁶

$$V(w, y) = \sup_{X \in A(w)} E[U(X + yH)].$$

The utility indifference (bid) price and the marginal utility indifference price are then defined as (cf. [Hobson 2005](#)):

$$p(y) = \sup_q \{q | V(w - q, y) \geq V(w, 0)\} \text{ and } \bar{p} = D_+ p(y)|_{y=0},$$

where D_+ denotes the right-hand derivative.

Clearly, in general all these criteria will give varying answers. However, in the case where (1) the insurance risk does not affect the payoff of financial securities in the market—i.e., if insurance risk is “small” relative to financial markets—and (2) the underlying financial market model is complete, we are in a rather specific situation that is nevertheless very relevant to the insurance setting.⁷ For instance, the example depicted in the previous section with finite N satisfies these assumptions. Here, the resulting *product measure* Q considered above with

$$Q(\{\omega_1\}) = q_u \times p_x, \quad Q(\{\omega_2\}) = q_u \times (1 - p_x), \quad Q(\{\omega_3\}) = q_d \times p_x, \quad Q(\{\omega_4\}) = q_d \times (1 - p_x) \tag{22.5}$$

is in fact the so-called *minimal martingale measure* for the financial market, i.e., it is the martingale measure that leaves orthogonal risks—such as the insurance risk—unchanged (see [Föllmer and Schweizer \(2010\)](#) for a more rigorous description). Moreover, we are in the situation of a so-called *almost complete* market (cf. [Pham et al. 1998](#)), i.e., the market model can be understood as an inflated version of a complete financial market model (by orthogonal risks). In this case, as already pointed out by [Møller \(2001\)](#) in a similar insurance setting, the variance optimal martingale measure actually coincides with the minimal martingale measure, i.e., Eq. (22.5) again is the “right” choice when relying on a quadratic criterion.

To illustrate, consider the quadratic hedging problem in our example for a single insurance risk, where it takes the form of a weighted least-squares problem:

$$\underbrace{\begin{pmatrix} 200 \\ 0 \\ 100 \\ 0 \end{pmatrix}}_y \simeq \begin{pmatrix} \beta_0 + \beta_1 \times 200 \\ \beta_0 + \beta_1 \times 200 \\ \beta_0 + \beta_1 \times 50 \\ \beta_0 + \beta_1 \times 50 \end{pmatrix} = \underbrace{\begin{pmatrix} 1 & 200 \\ 1 & 200 \\ 1 & 50 \\ 1 & 50 \end{pmatrix}}_X \beta,$$

where β_0 denotes the amount in bonds, β_1 denotes the amount in stocks, and the weights W_{ii} are given by the corresponding (physical) probabilities. The solution is then given by $\hat{\beta} = (X'W X)^{-1} X'W y$, and the corresponding price—again—is

⁶We frame the situation from the policyholder’s point of view. Analogously, we could consider the perspective of the insurance company endowed with a utility function.

⁷The assumption of a complete financial market primarily serves to steer clear of the problem of having to “choose” the right pricing kernel in an incomplete financial market that is beyond the scope of this chapter. However, of course generalizations would be possible.

$$\frac{\hat{\beta}_0}{1 + R} + \hat{\beta}_1 \times 100 = 90 = E^Q \left[\frac{1}{1 + R} \text{Payoff} \right]. \tag{22.6}$$

In particular, the resulting pricing rule still is independent of p_S .

This result is not limited to the quadratic criterion. In fact, as shown by [Mania et al. \(2003\)](#), [Mania and Tevzadze \(2008\)](#), [Henderson et al. \(2005\)](#), and [Goll and Rüschenendorf \(2001\)](#), the minimal entropy martingale measure and all q -optimal martingale measures collapse to the minimal martingale measure in the “almost complete” case considered here. Moreover, since “prices under the various q -optimal measures are the marginal (i.e., small quantity) utility-indifference bid prices for agents with HARA utilities” the result can also be “interpreted in terms of utility maximizing agents” (cf. [Henderson et al. \(2005\)](#)). In fact, [Hobson \(2005\)](#) gives an even stronger result that is applicable here: whenever there exists a complete financial market model contained within the larger market model, the utility-indifference (bid) price is bounded from above by the price corresponding to the minimal martingale measure for the (complete) financial market, and the marginal utility price will be exactly given by Eq. (22.5)/(22.6).

Hence, all criteria again point to the same result as in the previous section: Financial risk should be priced according to financial pricing, whereas the actuarial risk is treated via the expected discounted value under actuarial probabilities. This reflects Arrow’s famous limit result that expected utility optimizers are essentially risk-neutral when stakes are infinitesimally small ([Arrow 1971](#)). Hence, the result can again be attributed to “diversification” although the diversification now entails splitting the insurance risk up in arbitrarily small portions and distributing them among all agents in the economy.

22.4 Insurance Pricing Models: Conditionally Independent Risks

The same logic from the previous sections also applies if the incidence probability p_X is a function of the security market state, i.e., if the probability of the insured event can take values $p_{x,u}$ and $p_{x,d}$ depending on the path of the risky asset S . In this case, Eq. (22.4) still pertains and we can buy a *replicating portfolio* that in the limit as N goes to infinity perfectly replicates the per-policy payoff in each state. Similarly, Eq. (22.5) still gives the minimal martingale measure when replacing unconditional incidence probabilities by conditional ones, and all criteria to choose expedient martingale measures still result in the minimal martingale measure.

This is in fact the setup in various applications of financial pricing models in insurance although often it is more suitable and/or convenient to consider continuous diffusion processes rather than a simple Binomial model. To illustrate a common setup, assume that—under the physical measure— the insurer’s assets A and liabilities L evolve according to the stochastic differential equations

$$\begin{aligned} dA_t &= \mu_A A_t dt + \sigma_A A_t dW_t^A, \quad A_0 > 0, \\ dL_t &= \mu_L L_t dt + \sigma_L L_t dW_t^L, \quad L_0 > 0, \end{aligned}$$

where W^A and W^L are two Brownian motions with $Cov(W_t^A, W_t^L) = \rho_t$. Without much loss of generality, let us assume that the insurer’s assets are invested in the “market portfolio” (or that a one-fund theorem holds).

Let us further assume that one of the situations depicted above in Sects. 22.2 or 22.3 holds, i.e., that insurance risk is perfectly diversifiable or that it is relatively “small”. In this case pricing can be done using the minimal martingale measure Q for the financial market consisting of the asset process only. Specifically, Z is chosen as $Z_t = \exp\{-\lambda W_t^A - 0.5\lambda^2 t\}$, where $\lambda = \frac{(\mu_A - r)}{\sigma_A}$ is the (financial market) risk premium, so that under Q the assets and liabilities evolve as

$$\begin{aligned}
 dA_t &= \underbrace{(\mu_A - \lambda\sigma_A)}_r A_t dt + \sigma_A A_t d\tilde{W}_t^A, A_0 > 0, \\
 dL_t &= \underbrace{(\mu_L - \rho\sigma_L\lambda)}_{r_L} L_t dt + \sigma_L L_t d\tilde{W}_t^L, L_0 > 0,
 \end{aligned}
 \tag{22.7}$$

where \tilde{W}^A and \tilde{W}^L are Brownian motions under Q , r is the risk-free rate, and r_L is the so-called *claim inflation rate*. Equation (22.7) is also motivated by the preamble that one assumes pricing is done according to the CAPM, the ICAPM, or the APT, the key assumption in all cases being that state prices depend on the financial market only [see e.g. Phillips et al. (1998) or Kraus and Ross (1982)]. We come back to this characterization in Eq. (22.10) below.

Deriving prices for insurance payoffs is then again “simply” a matter of financial engineering, i.e., calculating expected discounted values of cash flows specified under the dynamics [Eq. (22.7)] or a similar model, though the corresponding calculations may get very sophisticated. For instance, one may consider retention amounts, maximum limits, nonlinear deductibles, multiple lines, multiple claims, etc. [see e.g. Doherty and Garven (1986), Shimko (1992), Phillips et al. (1998)], or one may apply the logic to questions of insurance supply or insurance regulation [see e.g. Cummins and Danzon (1997) or Cummins (1988)].

The key empirical question is then how to derive $p_{x,u}$ and $p_{x,d}$ in the simple model, or ρ in the more general model shown in Eq. (22.7) which summarizes the relationship between insurance claims and financial indices. An important advance in this direction was the linkage of the algebraic model of the insurance firm with conventional asset pricing models, which results in a so-called *insurance asset pricing* model. Key contributions are the algebraic model developed by Ferrari (1969) and the *Insurance CAPM* developed in Cooper (1974), Biger and Kahane (1978), Fairley (1979), and Hill (1979). The key idea is that insurance companies’ stock prices reflect both market and actuarial risks.

To illustrate, consider the following simple model for an insurance company’s net income Y_{t+1} at time $t + 1$:

$$Y_{t+1} = I_{t+1} + \Pi_{t+1}^{(u)} = R_{t+1}^{(a)} A_t + R_{t+1}^{(u)} P_t,$$

where I_{t+1} is the insurer’s investment income at time $t + 1$, $\Pi_{t+1}^{(u)}$ is the underwriting profit at time $t + 1$ —i.e., premium income less stochastic losses and expenses— A_t and P_t denote assets and premiums at time t , respectively, and $R_{t+1}^{(a)}$ and $R_{t+1}^{(u)}$ stand for the corresponding investment and underwriting return rates. Dividing by the company’s equity level G_t and making use of the identity $A_t = G_t + R_t$ with R_t denoting the reserve level, we obtain for the return on equity $R_{t+1}^{(e)}$

$$R_{t+1}^{(e)} = R_{t+1}^{(a)} (R_t/G_t + 1) + R_{t+1}^{(u)} (P_t/G_t) = R_{t+1}^{(a)} (k_t s_t + 1) + R_{t+1}^{(u)} (s_t), \tag{22.8}$$

where $s_t = \frac{P_t}{G_t}$ is the premiums-to-equity (or premiums-to-surplus) ratio and $k_t = \frac{R_t}{P_t}$ is the liabilities-to-premiums ratio (or *funds generating factor*). Equation (22.8) indicates that the insurer’s return on equity is generated by both financial leverage and insurance leverage. Taking expectations, one obtains the insurer’s expected return on equity.

If we in turn assume that the expected return on equity is determined by a factor pricing model based on observable financial indices, as desired we obtain an equilibrium relationship for the underwriting return. For instance, the CAPM implies [see also the relationship in Eq. (22.2)]:

$$E_t \left[R_{t+1}^{(e)} \right] = e^{r_t} + \beta^{(e)} \left(E_t \left[R_{t+1}^{(m)} \right] - e^{r_t} \right),$$

where r_t is the risk-free rate of return, $R_{t+1}^{(m)}$ is the return of the market portfolio, and $\beta^{(e)} = \text{Cov}_t \left[R_{t+1}^{(e)}, R_{t+1}^{(m)} \right] / \text{Var}_t \left[R_{t+1}^{(m)} \right]$ is the insurer's equity beta coefficient. The equilibrium underwriting profit within the *Insurance CAPM* is then obtained by equating the CAPM rate of return with the expected return from Eq. (22.8), implying:⁸

$$E_t \left[R_{t+1}^{(u)} \right] = -k_t e^{r_t} + \beta^{(u)} \left(E_t \left[R_{t+1}^{(m)} \right] - e^{r_t} \right), \tag{22.9}$$

where $\beta^{(u)} = \frac{\text{Cov}_t \left[R_{t+1}^{(u)}, R_{t+1}^{(m)} \right]}{\text{Var}_t \left[R_{t+1}^{(m)} \right]}$ is the company's beta of the underwriting profits (or *underwriting beta*).

Hence, in principle relationship Eq. (22.9) allows one to derive the underwriting beta and thus r_L in Eq. (22.7) as:

$$r_L = \mu_L - \rho \sigma_L \lambda = \mu_L - \beta^{(u)} [\mu_A - r]. \tag{22.10}$$

Similarly, more advanced multifactor pricing models can be used to derive similar *insurance asset pricing models*.

However, there are some structural limitations of such insurance pricing models. One problem is the use of the funds generating factor (k_t) to represent the payout tail. Myers and Cohn (1987) argue that k_t is only an approximation that should be properly expressed within a (multi-period) cash flow model. A second limitation is that the model ignores default risk. As a practical matter, errors in estimating underwriting betas can be significant (Cummins and Harrington 1985), and there is evidence that insurance prices contain markups beyond what should be expected from correlations with conventional market risk factors. The next two sections describe this evidence in more detail and provide potential reasons for its origin: There may be risk premiums immediately linked to certain insurance risks [Sect. 22.5] and/or financial frictions may affect insurance prices [Sect. 22.6].

22.5 Risk Premiums for Insurance Risks

One possible explanation for the observation that insurance prices appear higher than one expects may be due to the choice of empirical asset pricing model used to estimate the systematic risk associated with underwriting insurance liabilities. For example, Cummins and Phillips (2005) estimate cost of equity capital charges for insurers using two models that dominate the empirical asset pricing literature: the single factor Capital Asset Pricing Model and the more recent multi-factor Fama–French Three Factor model. The authors find cost of capital estimates derived using the Fama–French model are significantly higher than those based on the single-factor CAPM. Specifically, insurer stock returns appear particularly sensitive to the Fama–French financial distress (or value) factor, and this relationship contributes to a substantially higher cost of capital for insurers relative to the CAPM.

Moreover, for large and extensive risks such as catastrophic or aggregate demographic risk, the assumption that the risk only enters agents' marginal utilities in Eq. (22.2) via financial indices may no longer be tenable. Indeed, it is conceivable that relevant risk factors affect marginal consumption—and thus insurance prices—directly, even if they show little immediate relation to observable financial

⁸The derivation also uses the CAPM pricing relationship for the insurer's expected asset returns, $E_t \left[R_{t+1}^{(a)} \right] = e^{r_t} + \beta^{(a)} \left(E_t \left[R_{t+1}^{(m)} \right] - e^{r_t} \right)$ as well as the relationship $\beta^{(e)} = \beta^{(a)} (k_t s_t + 1) + \beta^{(u)} s_t$.

indices. For instance, consider an example as in Sect. 22.2 above, but assume that a pension fund has to pay an extra \$200 and \$100 per contract, depending on the security market state, when the insured population lives longer than expected occurring in states ω_1 and ω_3 , respectively (this risk is typically referred to as *longevity risk*). Clearly, in this case selling $N \rightarrow \infty$ contracts does not eliminate the insurance risk through diversification but rather the risk is systematic in that it increases with each written contract.⁹ Nonetheless, if the number and the amount of such risks are “small” relative to financial markets at large, again the arguments from Sect. 22.3 may carry through.

However, if the systematic risk is large, it may also directly affect consumers’ marginal utilities—and thus the pricing kernel according to Eq. (22.2)—even if the risk is independent of the security S as in our example. Examples of such “large” risks include aggregate mortality or longevity risk as above, but also catastrophic (CAT) risk. In fact, there is ample evidence that market prices of annuities exceed their “actuarially fair value,” i.e., the best estimate expected present value (Mitchell et al. 1999).¹⁰ Similarly, Froot (2001) points out that premiums for catastrophic risk are far higher than expected losses.

Indeed, one of the first attempts to apply Arrow and Debreu’s equilibrium theory for asset pricing that underlies our brief introduction in Sect. 22.1.1 is framed in the reinsurance market (Borch 1962). He shows that the price for insuring “a modest amount” of a certain risk is “increasing with the total amount” at risk in the market—indicating a positive risk premium—and he even mentions that such effects can be observed as it can be “expensive to arrange satisfactory reinsurance of particularly large risks.” However, from a modern perspective his framework is not completely satisfactory since he analyzes the reinsurance market in isolation.

In contrast, Buehlmann (1980, 1984) acknowledges that premiums not only depend on the covered risk but also “on the surrounding market conditions.” He presents an equilibrium model for an insurance market that explicitly accounts for cash flows “from outside the market” in view—and thus necessarily has to be interpreted as a partial equilibrium model. He obtains that the price of each individual risk depends on the relation to the total risk (cash flows) from outside the market as well as the (aggregate) risk aversion of the market participants. In particular, in the case of agents with constant absolute risk aversion (CARA), the equilibrium state price density is of the form

$$Z = \frac{\exp\{\lambda \times X\}}{E[\exp\{\lambda \times X\}]}, \quad (22.11)$$

where X is the “aggregate risk” and λ is the inverse of the harmonic sum of the risk aversions of all agents in the market. Now if there are infinitely many agents participating in the market and/or if the individual risk is negligible relative to the aggregate risk, the resulting price equals the expected loss without a loading in analogy with Sects. 22.2 and 22.3 (cf. Wang 2003). However, if the number of agents is small and a particular risk L is independent of the remaining aggregate risk $X - L$, the Radon–Nikodym derivative implies a risk penalty that is given by the so-called *Esscher transform*, a “time-honored tool in actuarial science” (Gerber and Shiu 1994). Moreover, Wang (2003) shows that under certain assumptions (a Normal distribution for X and a Normal distribution for a transformed version of L), this approach yields the premium implied by the so-called Wang transform (Wang 2000) for the original risk distribution F_L ,

$$F_L^*(x) = \Phi[\Phi^{-1}(F_L(x)) - \lambda], \quad (22.12)$$

⁹See e.g. Biffis et al. (2010) for a more detailed definition of *systematic* and *unsystematic* mortality risks.

¹⁰It is important to note that these price differences may be attributable to factors other than risk charges due to systematic risk. For example, Finkelstein and Poterba (2004) suggest adverse selection plays a prominent role explaining why annuity prices exceed their actuarially fair value.

where Φ is the cumulative distribution function of the standard Normal distribution. Here, the parameter λ plays the role of a “market price of risk” that “risk-neutralizes” the statistical distribution F_L . Wang (2002) shows that the transform can be interpreted as an extension of the CAPM and that it recovers the Black–Scholes formula when return distributions are Normal. Thus it presents a “universal pricing framework” that can be applied to financial and insurance risks simultaneously—although there also exist some limitations in the case of more general models/distributions (Pelsser 2008).

Both approaches enjoy great popularity for pricing systematic insurance risks in the actuarial literature, particularly in diffusion-driven models because of their tractability. For instance, the drift of the liability process in Eq. (22.7) will only be changed by a constant “market price of insurance risk” implied by λ when applying Eq. (22.11) or Eq. (22.12).

Aside from the Esscher and the Wang transform, other valuation or *premium principles* that have their origin in actuarial science have been embedded in financial market environments by Schweizer (2001b). According to Møller (2001), the approach works as follows. A given (typically parametric) actuarial premium principle is translated to a “measure of preferences,” which in turn translates to a financial valuation principle via an indifference argument akin to the utility indifference pricing introduced in Sect. 22.3. Applications to insurance pricing for the case of the variance and standard deviation principles are presented in Møller (2001) and for the exponential premium principle in Becherer (2003). Alternatively, in a sequence of papers Bayraktar et al. (2009) develop a pricing theory by assuming that the company issuing protection requires compensation for the assumed risk in the form of a prespecified *instantaneous Sharpe ratio*. Other papers directly rely on the criteria introduced in Sect. 22.3 to pick a suitable pricing measure, where the criteria typically rely on the minimization of the distance between the pricing and the physical measure.

The primary issue with all these approaches is that the resulting measure transforms have to be estimated—or at least calibrated—to suitable data. Ad hoc assumptions based on *expert judgment* or the reliance on values estimated from other asset classes are not satisfactory, especially since these asset classes may exhibit a completely different relationship relative to consumption. Driven by arbitrage considerations, one possibility is to rely on the prices of available securities that depend on the risk in view, such as existing insurance contracts or securitization transactions, although this approach is limited by the thinness of the market for such securities.¹¹ Nonetheless, a number of papers in the actuarial and insurance literature have taken this path.

For instance, Kogure and Kurachi (2010) use the minimal entropy martingale measure for pricing longevity-linked securities. In their setup—as for any exponential Lévy model (cf. Schweizer 2001a)—their approach is equivalent to the application of an Esscher transform. Following Denuit et al. (2007) the transform parameter is calibrated to a standard pricing table, although Denuit et al. rely on the Wang transform to derive their pricing rule. Wang (2000) and Cox et al. (2006) employ data from securitization transactions to determine the risk premium as the parameter of a (generalized) Wang transform for pricing property catastrophe (CAT) bonds and catastrophe mortality bonds, respectively. They show that markups can be considerable. Relying on results from Møller (2003), Venter et al. (2004) employs catastrophe reinsurance contract data to derive loading factors implied by the minimal martingale measure and the minimal entropy martingale measure in a jump process setup. They show that the former choice provides a better overall fit, particularly for small loss levels. Similarly, Bauer et al. (2010b) use a time series of UK life annuities to derive estimates for the longevity risk premium based on different pricing methods. They show that the risk premium has increased over the past decade, and that it shows a considerable relationship to financial market indices.

¹¹As we will detail in the next section, insurance risk sold from within an insurance company may be subject to adjustments resulting from frictional costs, so that the reliance on insurance contract price data may be problematic. However, resulting estimates should still offer an upper bound for the risk premium (cf. Bauer et al. 2010b).

While all these pricing methods (in principle) satisfy the basic postulate of no arbitrage by conjoining resulting prices with existing securities, the question arises how equilibrium prices of these underlying securities are formed in the first place. Furthermore, they do not allow for disentangling “true” risk premiums from frictional costs that may affect different types of securities in a different manner even though the relevant risks are the same (see the next section for details).

One possibility is to directly consider the correlation of relevant risk indices with aggregate consumption relying on Eq. (22.2) in order to derive suitable risk penalties. For instance, [Friedberg and Webb \(2007\)](#) rely on such a *consumption-based asset pricing* approach for aggregate mortality risk, and they find that corresponding risk premiums should be very low. However, as also acknowledged by the authors, these results have to be interpreted with care since consumption-based asset pricing models do not perform particularly well in other instances. Similarly, catastrophic risk is typically considered as “uncorrelated with capital markets, or more exactly, amounts to a small fraction of wealth in the economy” ([Zhu 2011](#)), yet observed spread levels are relatively wide. This observation led [Bantwal and Kunreuther \(2000\)](#) to conclude that there exists a *CAT Bond premium puzzle*, and they allude to behavioral economics for explanations.

In contrast, [Dieckmann \(2011\)](#) finds considerable correlation between CAT bond returns and economic fundamentals, an observation that he attributes to severe natural perils potentially having an impact on consumption. He devises a representative agent equilibrium model with habit formation to analyze CAT bonds, i.e., consumers do not measure their well-being in terms of their absolute consumption but in terms of their consumption relative to their habit process. The key assumption is that rare catastrophes may bring investors close to their subsistence level, thereby amplifying risk premiums for CAT risk relative to normal economic risk due to habit persistence effects. From his calibrated model he finds that consumption shocks due to CAT risk with an impact of -1 % to -3 % are sufficient to explain observed spread levels.

[Maurer \(2011\)](#) presents an overlapping generation equilibrium model that incorporates aggregate demographic uncertainty. His model features aggregate risk in birth and mortality rates that—while not adding instantaneous risk to the economy—has long-term consequences for volatilities and equilibrium interest rates through different channels. Moreover, if agents exhibit recursive utilities, demographic uncertainty is priced in financial markets. He finds that market prices of birth rate and mortality risk may be substantial, and that demographic changes may explain several empirical observations.

While his results allow for various qualitative conclusions, in order to determine applicable equilibrium premiums for demographic risk, it is necessary to devise generalized, estimable models. Furthermore, aside from non-separable preference specifications, there may be other potential culprits for risk premiums of insurance risk such as ambiguity aversion ([Zhu 2011](#)) or information asymmetries ([Wang 1993](#)), and it is important to identify the key determinants. We believe these are exciting avenues for future research.

22.6 Frictions

Another strand of literature considers the influence of frictions on prices in insurance markets. [Brennan \(1993\)](#) already highlighted the importance of search costs for uninformed retail investors, which may give rise to an *intermediary spread*, i.e., a difference between the rates available on primary securities in the capital market and the rates paid on the liabilities of financial intermediaries. This spread recoups, e.g., the costs of educating consumers in the form of management or sales fees.

More recently, researchers started to consider frictions that directly affect the marginal cost of offering insurance. The theoretical mechanism can take a variety of forms but contains three essential elements. First, stakeholders (which could be stockholders or policyholders) must care about solvency or financial distress at the firm level—which in turn motivates insurers to hold (excess) capital. Second,

holding or raising capital is costly—so that the problem of solvency cannot be solved trivially with infinite capital. Third, securities markets must be incomplete with respect to insurance liabilities since, if they were not, then insurance liabilities could be trivially hedged in the capital markets.

Corporate finance theory generally ascribes importance to solvency on the basis of avoiding financial distress costs including direct costs as well as indirect costs from relationships with employees, customers, or suppliers. This general concept applies with special force in the case of insurance. Merton and Perold (1993) and Merton (1995) point out that risk-averse customers of financial firms value risk reduction more than investors since the costs of diversification are higher. And it has long been recognized that risk-averse policyholders will motivate risk management at the level of the insurer [see, e.g., Doherty and Tinic (1981)].

In regards to capital costs, according to Froot (2007), “most articles do not dispute the existence of at least some of these imperfections, though their exact specifications are a matter of debate.” One typically distinguishes two frictional costs: (1) the carry costs due to the double-taxation of dividends or the various agency costs associated with operating an insurance company that contains unencumbered capital (cf. Jensen 1986); and (2) costs associated with raising fresh capital that may be motivated by asymmetric information (cf. Myers and Majluf 1984) or the recently developed equilibrium theories on “slow moving capital” by Duffie (2010) and Duffie and Strulovici (2012). Both provide explanations why raising costs are particularly pronounced in the aftermath of catastrophic events where capital levels are low [see also Gron (1994) or Born and Viscusi (2006)].

Whatever their provenance, capital costs and solvency concerns interact to determine insurance pricing and capitalization in the context of an incomplete market. Froot and Stein (1998) develop a model of financial intermediation with heterogeneous risks where they find the hurdle rate for a new unhedgeable risk reflects the usual component compensating for any systematic market risk but also a novel firm-specific component deriving from the effective risk aversion of the financial institution.

It is important to highlight the assumption of security market incompleteness. If all risks could be traded (i.e., all risks were “hedgeable”), then the firm-specific component in the hurdle rate would disappear. Moreover, the finding concerns risk pricing at an institutional level and is made in a *partial equilibrium* setting; Froot and Stein’s hurdle rate is specific to the firm, and they make no attempt to derive general equilibrium results. This partial equilibrium focus is carried over in much of the subsequent literature, where the setting is generally confined to the boundaries of a particular institution.

These elements come together in the insurance context in Zanjani (2002) and Froot (2007). The outcomes in these papers echo the Froot and Stein (1998) result in that (1) risk pricing is dependent on the liability portfolios of particular institutions and (2) the price of risk can be decomposed into a market-based component (perceived similarly by all market participants) and a component based on the particular risk aversion/appetite of the institution. It is worth noting, however, that the effective risk aversion of the financial institution is sourced differently in these models: Froot (2007) features risk aversion being driven by a convex cost of external financing while Zanjani (2002) relies on counterparty risk aversion.

Similarly, much of the capital allocation literature (see Chap. 29 of this volume) is concerned—at least implicitly—with environments featuring the same three essential elements and with pricing risk at the level of the institution by allocating capital. When a frictional cost of capital exists, then the allocation of capital implies an allocation of cost which then feeds into the price of insurance.¹²

¹²An exception to this characterization is Ibragimov et al. (2010), who remove the assumption of market incompleteness in deriving multi-line capital allocations and insurance prices. The assumption of market completeness is also found in the papers of Phillips et al. (1998) and Sherris (2006), but the important point of departure lies in the assumption of frictional capital costs—which are present in Ibragimov et al. (2010) but absent in the latter articles. Such a maneuver offers an attractive benefit in terms of a uniquely and precisely indicated risk measure for pricing purposes (based on the value of the insurance company’s default option), though it comes with at least two embedded contradictions that must be finessed. Specifically, with a complete market for risk, there is no reason for policyholders to use costly

The empirical evidence suggests these frictional costs of capital are important determinants of insurance prices. One transparent way to investigate the relative magnitude of frictional costs is to look at the market prices of insurance-linked securities. Introduced in the early 1990s, insurance-linked securities are a form of securitization where the securities are most often structured as defaultable bonds with payouts contingent upon an insurable event. The most well known insurance-linked security is the catastrophe bond, and this form of risk transfer now represents a significant proportion of the catastrophe risk transfer market. Thus, catastrophe bonds are a credible substitute for traditional reinsurance and, because they are standardized contracts that trade in public markets, it is possible to get a direct view of prices.

As reported in [Cummins and Weiss \(2009\)](#) and in [Lane and Beckwith \(2012\)](#), for the past 8–10 years catastrophe bonds trade at spreads that imply premiums ranging between two and three times the expected loss underwritten by the contract. In addition, based on conversations with insurance brokers, [Cummins and Weiss \(2009\)](#) report that traditional catastrophe reinsurance contracts most often trade at premium-to-expected loss ratios ranging from 3 to 5. As discussed earlier in this chapter, [Dieckmann \(2011\)](#) suggests a portion of those spreads may be explained by catastrophes being large enough to be correlated with aggregate assumption and thus generate a systematic risk charge. However, most observers suggest the various violations of perfect capital market assumptions generate the majority of these spreads where the size of the spreads is not trivial.

Additional evidence about the significant role that frictional costs of capital play in the determination of insurance prices is suggested by the work of [Phillips et al. \(1998\)](#). As [Froot \(2007\)](#) comments, “[Phillips, Cummins, and Allen \(1998\)](#), for example, estimate directly price discounting for probability of insurer default. They find discounting to be 10 times the economic value of the default probability for long-tailed lines and 20 times for short-tailed lines. These numbers are too large to be consistent with capital markets pricing.”

Future research that seeks to estimate the relative size of the contribution between systematic risk versus frictional cost of capital charges to the overall observed spreads in insurance markets will be important to better understand how prices are determined in equilibrium. In addition, this information will also be useful to consider how changes in the design of insurance organizations or the markets in which they participate may better mitigate the frictional costs and lead to more efficient risk transfer.

22.7 Conclusion

This chapter surveys the financial pricing of insurance models that have been proposed to determine the market value of insurance company liabilities. We begin by providing a review of asset pricing theory generally and then show how this literature has been applied and extended to incorporate important institutional features of insurance markets. One area of significant difference is market incompleteness that arises either because insurance contracts trade bilaterally with very little secondary market trading or because the risks underwritten by insurers often produce large catastrophic losses that cannot be perfectly hedged using traded market instruments. Thus, a fair bit of this chapter considers the pricing implications of market incompleteness and of less-than-complete diversification in insurance markets.

A second area of focus is to review the recent literature that proposes how to value insurance liabilities when an insurer’s capital is either costly to acquire or costly to maintain on the insurer’s balance sheet. Over the past decade a rich array of papers from corporate finance and from insurance economics have sought to better understand the source of these frictions, their relative impact on

intermediaries (absent a theoretician’s fiat preventing them from accessing the market directly), nor is it efficient for the intermediaries themselves to incur frictional costs by holding assets.

determining equilibrium prices for insurance, and their implications for optimal contract design and solvency regulation.

There are many open questions that provide avenues for future research. One area becoming increasingly important is how to model behavior when policyholders are given options they can exercise at different points over the duration of the contract. For example, many Variable Annuity contracts allow policyholders the option to transfer their funds back-and-forth between fixed-income accounts and equity accounts. Determining the fair value of that option requires us to not only model interest rates and equity returns but to also develop models that explain policyholder incentives to exercise their option. Early research that assumed policyholders follow an optimal decision path with regards to maximizing the risk-neutral value proved inadequate. Developing pricing models at the intersection of behavioral economics/finance and asset pricing theory within the context of insurance is an exciting area for future research.

In addition to the models that now exist, a second promising area of research will be to better understand the determinants of insurance values across the various risk charges. Despite a large literature that provides evidence these charges are significant, it is just not well known how much of the premium associated with an insurance policy is due to financial market systematic risk charges versus the frictional costs associated with holding capital in the insurer. Research that rigorously considers this question will be important for the field generally but is particularly important given proposed changes in the global regulatory framework for insurance.

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Chapter 23

Insurance Price Volatility and Underwriting Cycles

Scott E. Harrington, Greg Niehaus, and Tong Yu

Abstract This chapter reviews the literature on underwriting cycles and volatility in property-casualty insurance prices and profits. It provides a conceptual framework for assessing unexplained and possibly cyclical variation. It summarizes time series evidence of whether underwriting results follow a second-order autoregressive process and illustrates these findings using US property-casualty insurance market data during 1955–2009. The chapter then considers (1) evidence of whether underwriting results are stationary or cointegrated with macroeconomic factors, (2) theoretical and empirical work on the effects of shocks to capital on insurance supply, and (3) research on the extent and causes of price reductions during soft markets.

23.1 Introduction

Markets for many types of property-casualty insurance have exhibited soft market periods, where prices and profitability are stable or falling and coverage is readily available to consumers, and subsequent hard market periods, where prices and profits increase abruptly and less coverage is available. The most recent hard market period in the United States occurred during the early part of this century. Prior to that, one of the most severe hard markets occurred in the mid-1980s and is generally referred to as the liability insurance crisis because the high prices and availability issues were centered in the commercial liability insurance market. The mid-1980s experience spawned extensive research on hard markets and the general causes of fluctuations of price and availability of coverage in insurance markets. Research has continued at a slower pace since that time, but large

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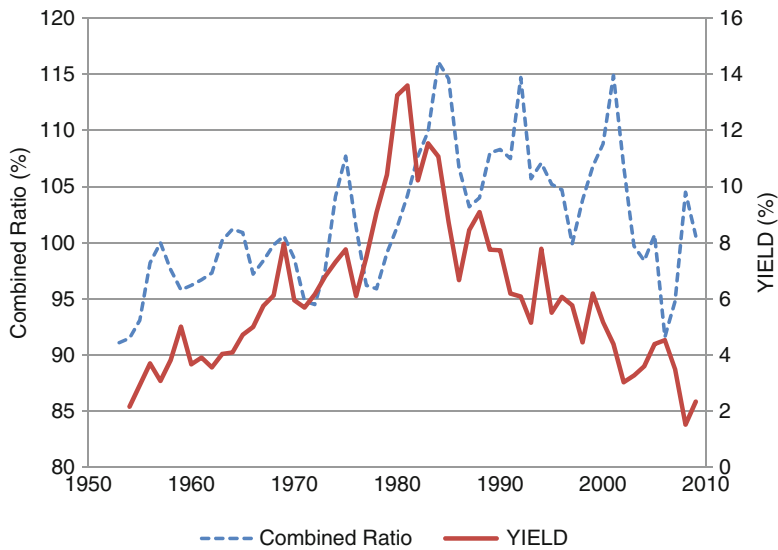


Fig. 23.1 US Property-casualty insurance combined ratios and 5-year treasury yields: 1953–2009

catastrophe losses from natural disasters and from terrorist attacks have continued to fuel interest and research on short-run dynamics of reinsurance and primary market pricing following large losses.

Conventional wisdom among many practitioners and other observers is that soft and hard markets occur in a regular cycle, commonly known as the underwriting cycle. While the phrase “regular cycle” suggests more predictability and less randomness than actually exists, evidence does suggest some cyclicity in the pattern of price variation over time. For example, casual examination of aggregate US underwriting profitability over time, as measured by the combined ratio (see Fig. 23.1), and of aggregate US premiums in relation to gross domestic product (a proxy for aggregate demand for insurance; see Fig. 23.2) indicates material volatility and suggests a cyclical pattern.¹

This chapter reviews the literature on underwriting cycles and volatility in property-casualty insurance prices and profits.² Our purpose is to describe and illustrate the main ideas and findings of research concerning the extent and causes of volatility and cycles. While most empirical research in this area focuses on the behavior of insurance prices, the underwriting cycle lore also relates to the quantity of coverage that is offered by insurers. Due to data availability problems, however, predictions about quantity adjustments generally are not tested. Consistent with the literature, this review focuses on pricing issues, while also describing the basic predictions of certain models with respect to the quantity of coverage.

While prices in any market vary with demand and supply, the pattern of price variation in insurance is puzzling for two reasons. First, the magnitude of price increases in hard markets is sometimes extreme, such as many examples of price increases of over 100 % from 1 year to the next on policies written during the liability crisis in the 1980s (see Priest 1988). Second, an insurance policy is a

¹The combined ratio is the sum of the loss ratio (ratio of claim costs to premiums) and expense ratio (ratio of administrative and sales costs to premiums). One minus the combined ratio gives the underwriting profit (exclusive of investment income) margin in premiums.

²This chapter updates Harrington and Niehaus (2000). Also see Weiss (2007). Ambrose et al. (2012) contribution in this volume provides additional discussion of the liability insurance crisis.

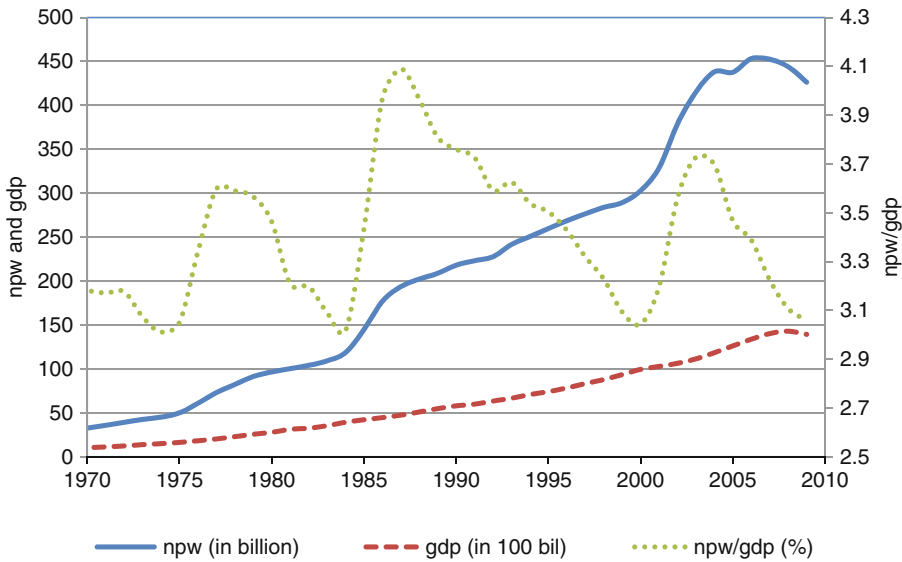


Fig. 23.2 US property-casualty net premiums written (npw) and gross domestic product (gdp): 1970–2009

security that is sold in markets with characteristics consistent with competition (many suppliers and/or relatively low barriers to entry). Economic theory therefore suggests that, as in any security market, prices should vary only with the risk-adjusted expected value of claims.

Section 23.2 provides an overview of the major determinants of insurance prices in a perfectly competitive insurance market in long-run equilibrium. Section 23.3 defines unexplained and possibly cyclical variation in prices and underwriting results compared to this benchmark. We then provide a synopsis of the evidence from time series models of whether underwriting results follow a second-order autoregressive process. We illustrate these findings using data on aggregate underwriting profits for US property-casualty insurance market during the period 1955–2009. We also summarize studies investigating whether underwriting results are stationary or cointegrated with a number of macroeconomic factors. Theoretical and empirical work on the effects of shocks to capital on the supply of insurance is introduced in Section 23.4. Section 23.5 provides an overview of research that focuses on the extent and causes of price reductions during soft markets. Section 23.6 concludes.

23.2 The Perfect Markets Model

Standard financial theory predicts that in long-run equilibrium competitively determined insurance premiums, commonly known as *fair premiums*, will equal the risk-adjusted discounted value of expected cash outflows for claims, sales expenses, income taxes, and any other costs, including the tax and agency costs of capital (e.g., Myers and Cohn 1986; Doherty and Garven 1986). We call this the “perfect markets model” to refer to this model, with the additional assumptions (see Harrington and Danzon 1994) that (1) expectations are optimal forecasts conditional on information available when policies are sold and that (2) insurer capital is sufficient to produce a negligible level of insolvency risk.

Given this framework, volatility in insurance premiums, prices, and profit rates can be viewed as having two components: (1) volatility that can be explained by the perfect markets model, i.e., by

changes in fair premiums, and (2) volatility that cannot be explained by changes in fair premiums. The perfect markets model also implies that the quantity of coverage sold will vary inversely with changes in fair premiums and directly with the demand for coverage and that quantity will not be rationed.

To make these notions concrete, consider a stylized representation of the fair premium for a given policy or group of policies:

$$P_t^f = \delta_t L_t^f + \alpha_t P_t^f + \pi_t P_t^f, \quad (23.1)$$

where, at the beginning of period t , P_t^f is the fair premium, L_t^f is the optimal (rational) forecast of nominal (undiscounted) claim costs (including loss adjustment expenses) for insured events during the coverage period, δ_t is the risk-adjusted discounted value of \$1 of L_t^f (which depends on riskless spot interest rates at time t for periods over which cash flows from the policy occur and any risk premia for systematic risk associated with claim costs), α_t is the known proportionate “loading” in premiums for underwriting and administrative expenses paid at the beginning of the period, and π_t is the fair pretax profit margin that is just sufficient to compensate shareholders for tax and agency costs of capital (and expected taxes on any underwriting profits, again assuming that the amount of capital invested is sufficient to produce a negligible probability of default by the insurer).³

Solving (23.1) for P_t^f gives

$$P_t^f = \delta_t (1 - \alpha_t - \pi_t)^{-1} L_t^f \quad (23.2)$$

The optimal forecasts of the loss ratio (L_t^f/P_t^f) and combined ratio (loss ratio plus underwriting expense ratio) at the beginning of period t are therefore

$$\text{LR}_t^f = \delta^{-1} (1 - \alpha_t - \pi_t), \quad (23.3)$$

$$\text{CR}_t^f = \delta^{-1} (1 - \alpha_t - \pi_t) + \alpha_t \quad (23.4)$$

Borrowing terminology from the literature on financial price volatility, expressions (23.2)–(23.4) indicate that fair premiums, loss ratios, and combined ratios vary over time in relation to the fundamental determinants of prices. These “fundamentals” include predicted claim costs and underwriting expenses, riskless interest rates, any systematic risk of claim costs and associated market risk premia, and the tax and agency costs of holding capital to bond an insurer’s promise to pay claims.⁴ Expense and profit loadings and predicted claims payout patterns tend to vary slowly over time, and systematic claim risk may be negligible for many types of insurance. As a result, short-run variation in fair premiums will be caused largely by changes in predicted claim costs and interest rates. Correspondingly, this model predicts that changes in interest rates will be the primary cause of short-run variation in underwriting profit margins. Over longer periods, changes in capital structure that alter π (capital costs) and changes in technology that alter α (administrative costs) will play a more material role.

Not surprisingly, there is abundant evidence that changes in claim costs, which should be highly correlated with insurer forecasts when policies are priced, explain much of the time series variation

³See Cummins and Phillips (2012) and references cited therein, including discussion of systematic risk of insurance.

⁴Capital shock models (discussed in Sect. 23.4) suggest that capital costs per unit might vary inversely with the total level of capital. Also, models incorporating default risk suggest that, all else equal, premiums will vary directly with the total level of insurer capital. Sommer (1996; also see Phillips et al. 1998) presents evidence that prices vary across insurers in relation to insolvency risk, which depends on the amount of capital held. Choi and Thistle (2000), however, find no long-run relationship between aggregate underwriting profit margins and the ratio of capital to assets. Weiss and Chung (2004) show that non-proportional reinsurance prices during the early 1990s were positively related to capital (policyholder surplus). Epermanis and Harrington (2006) present evidence that premium revenue varies directly with A.M. Best insurer financial strength ratings, especially for insurers specializing in commercial insurance.

in premiums.⁵ Examples include studies of premium growth in automobile insurance (Cummins and Tennyson 1992) and medical malpractice insurance (Danzon 1985; Neale et al. 2009).⁶ Also consistent with the perfect markets model, numerous studies have provided evidence, albeit sometimes weak, of the predicted inverse relationship between interest rates and loss ratios or combined ratios (Doherty and Kang 1988; Fields and Venezian 1989; Smith 1989; Haley 1993; Grace and Hotchkiss 1995; Choi and Thistle 2000; Harrington et al. 2008; Jawad et al. 2009).⁷ As we elaborate next, other evidence is more difficult to reconcile with the model.

23.3 Unexplained/Unpredictable Variation in Underwriting Results

Given the perfect markets framework, unexplained premium volatility can be represented as variation of actual premiums around fair premiums. Letting u_t denote any component in premiums that cannot be explained by fundamentals in period t , the actual premium can be written as

$$P_t = P_t^f + u_t. \quad (23.5)$$

The perfect markets model implies that u_t is negligible and that P_t^f is an optimal forecast of costs, so that the u_t 's are serially uncorrelated and (assuming stationarity):

$$\text{Var}(P_t) \cong \text{Var}(P_t^f) \quad (23.6)$$

There are two principal implications of the perfect markets model. First, u_t should be an optimal forecast error. Thus, it should be serially uncorrelated and uncorrelated with any information available at the beginning of period t , including P_t^f and past profitability. Second, $\text{Var}(u)$ should be comparatively small. Material variation in premiums that cannot be explained by the model and/or material correlation between u_t and information available at the beginning of period t would violate the model's predictions. Depending on the sign of any nonzero covariance between u_t and current and lagged values of P_t^f and any other prior information, unexplained variation in premiums could either increase or decrease premium volatility.

The hypothesis that variation in premiums is fully explained by variation in fair premiums is surely false given real-world frictions. The interesting questions are whether premiums deviate materially from levels predicted by the model, and, if so, the causes of the deviations. Measuring and testing for significant unexplained volatility present formidable challenges. Perhaps most importantly, expectations and the "true" fair premium model and its parameters are unobservable to researchers. Like tests of market efficiency in financial markets, tests of the perfect markets model of insurance

⁵It is also well known that differences in predicted claim costs across regions and risk classes explain much of the cross-sectional variability of premium rates within a given time period.

⁶Evidence indicates that a material proportion of the growth in premiums and availability problems in the 1980s was caused by growth in claim cost forecasts and uncertainty of future liability claim costs rather than by cyclical influences (e.g., Harrington 1988; Harrington and Litan 1988). Basic theory and numerous studies argue that increased uncertainty would be expected to lead to increases in prices needed to cover expected future costs including the cost of capital (Doherty and Garven 1986; Winter 1988).

⁷Evidence also suggests that underwriting results vary in relation to changes in the estimated market price of risk, as is predicted if claim costs load on priced risk factors in the economy (see Cagle 1993). Mei and Saunders (1994) provide evidence of predictable variation in risk premia for insurance stocks.

prices using premium data or data on loss ratios or combined ratios are necessarily tests of a joint hypothesis—that premiums are determined exclusively by fundamentals and that the assumed model of fair premiums is correct.

Because data on average premiums per exposure generally are not available to researchers, most empirical analyses of volatility in insurance markets use data on loss ratios or combined ratios to control for scale effects and abstract in part from the effects of changes in claim cost forecasts over time. These underwriting profit measures reflect realized claim costs that are reported by insurers, specifically, updated forecasts of incurred losses as of the time those losses are reported. Most studies have necessarily relied on “calendar-year” data in order to obtain enough time series observations for meaningful analysis. Calendar-year losses reflect loss forecasts for accidents during the given year and revisions in loss forecasts for prior years’ accidents.

To illustrate the implications of using reported losses (see [Cummins and Outreville \(1987\)](#), and below for further discussion), the reported combined ratio (CR^r) can be written as the combined ratio predicted by the perfect markets model (CR^f) plus two error terms: (1) ε , the difference between reported losses and forecasted losses as a proportion of premiums, and (2) ϕ , the error in the perfect markets model as a predictor of the expected combined ratio in actual insurance markets:

$$CR_t^r = CR_t^f + \varepsilon_t + \phi_t, \quad (23.7)$$

where

$$\varepsilon_t = \frac{L_t^r - L_t^f}{P_t} \quad \text{and} \quad \phi_t = CR_t^a - CR_t^f$$

It is important to note that ε and ϕ cannot be separately observed by the econometrician.

The perfect markets models predict that ϕ_t and thus $\text{Var}(\phi)$ are negligible and that ϕ_t is uncorrelated with prior information. Large variation in the optimal forecast error, ε_t , will produce large variation in reported combined ratios—even if the perfect markets model holds. In addition, serial correlation between *reported* combined ratios (or loss ratios) and any other prior information could reflect accounting effects and reporting bias, such as managerial smoothing of reported losses (see [Cummins and Outreville 1987](#); also see [Weiss 1985](#); [Petroni 1992](#); [Beaver et al. 2003](#); [Grace and Leverty 2012](#)). Serial correlation in reported underwriting profit measures also might reflect adaptive but rational updating of loss forecasts, rather than unexplained variation in premiums.

23.3.1 Time Series Evidence of Second-Order Autoregression in Underwriting Results

As noted in the introduction, casual observation suggests that insurance premiums in some markets change too much to plausibly be explained by the perfect markets model, and many studies document empirical regularities in underwriting profit measures that are not easily reconciled with the model’s predictions. In particular, like many economic time series, many studies provide evidence that property-casualty insurance underwriting results follow a second-order autoregressive process.

This subsection briefly describes time series studies that for the most part do not attempt to explain the causes of second-order autoregression, in contrast to studies that test the predictions of alternative models, such as the capital shock model (see below). The distinction between these avenues of inquiry is not sharp, however, given that shock models predict correlation between current and past underwriting results. Following this brief description, we provide illustrative evidence of second-

order autoregression in underwriting margins and describe analyses that have considered whether underwriting profits are cointegrated with interest rates and macroeconomic factors.⁸

Like many analyses of the business cycle and of long-term predictability of returns on financial assets, time series studies of underwriting results are inherently limited by the comparatively small number of annual observations. In addition, the types of business sold and regulatory environment in the property-casualty insurance industry have changed substantially since data have become available, raising serious questions about the stability of the process generating underwriting profits and the efficacy of extending the time series backwards. While some quarterly data are available since the early 1970s, they may be of limited value in analyzing long-term predictability (see, for example, the general discussion by [Enders \(1995\)](#), but also see [Grace and Hotchkiss \(1995\)](#) who employ quarterly data).

In part reflecting these problems, many studies of volatility in insurance underwriting results employ fairly crude models and statistical methods, especially studies that predate developments in modern time series methods.⁹ When considering the following evidence, it is useful to keep in perspective when particular studies were conducted and that weak data limit the potential returns from increased methodological sophistication.

Consistent with traditional conjecture, several studies using data prior to the mid-1980s provide statistical evidence that loss ratios and reported underwriting profit margins (e.g., one minus the combined ratio) exhibit second-order autoregression that implies a cyclical period of about 6 years (see [Venezian 1985](#); [Cummins and Outreville 1987](#); [Doherty and Kang 1988](#)).¹⁰ Analysis also suggests cyclical underwriting results in a number of other countries ([Cummins and Outreville 1987](#); [Leng and Meier 2006](#); [Meier 2006a, b](#); [Meier and Outreville 2006](#)) and different turning points/cyclical periods for different lines of insurance ([Venezian 1985](#); [Fields and Venezian 1989](#)).¹¹

Studies also suggest that underwriting results remain cyclical after controlling for the expected effects of changes in interest rates (see [Fields and Venezian 1989](#); [Smith 1989](#); also see [Winter 1991a](#)). These results imply that historical cycles in reported underwriting margins cannot simply be explained by the expected effect of changes in interest rates, i.e., operating profits including investment income also are cyclical.¹²

Empirical regularities in reported underwriting results could largely or even exclusively be caused by financial reporting procedures and lags in price changes due to regulation. [Cummins and Outreville \(1987\)](#) show conditions under which accounting and regulatory lags could generate a cycle in underwriting margins without either excessive price-cutting during soft markets or sharp reductions in supply following reductions in capital.¹³ Like other studies, their empirical analysis of underwriting profits cannot distinguish the extent to which correlation in profit measures over time is due to accounting issues and regulatory lags, as opposed to pricing that materially violates the perfect markets model.

⁸[Engle and Granger \(1987\)](#) show that linear regressions on time series data that are nonstationary (e.g., having unit roots) can lead to spurious correlation. If this occurs, cointegration analysis can be used to test for a relationship between the variables.

⁹The focus of time series studies on levels or differences in underwriting profit measures, ignoring possible conditional heteroskedasticity, can be explained at least in part by these problems. The estimation of ARCH and GARCH models with annual data over several decades would be unlikely to provide material insight.

¹⁰A few studies (e.g., [Doherty and Kang 1988](#); [Grace and Hotchkiss 1995](#)) also use spectral analysis.

¹¹[Higgins and Thistle \(2000\)](#) provide evidence of structural shifts in underwriting returns. See [Leng \(2006a, b\)](#) for a more recent analysis of structural shifts.

¹²[Cagle \(1993\)](#) presents some evidence of cyclical variation in underwriting results after controlling for variation in the estimated market price of risk.

¹³The authors note, however, that regulatory lag and financial reporting procedures are unlikely to explain large price fluctuations in the commercial liability insurance market in the mid-1980s.

In addition, evidence suggests that underwriting expense ratios (ratios of underwriting expenses to written premiums) have varied cyclically after controlling for trend and changes in interest rates (Cagle 1993; Harrington and Niehaus 2000).¹⁴ Cyclical variation in premiums would imply cyclical variation in expense ratios, provided that some expenses are fixed in the short run. As a result, the expense ratio evidence suggests that predictability in reported underwriting results is not fully explained by accounting and reporting lags.

Analogous to Cummins and Outreville (1988) argue that cyclical patterns in underwriting results reflect slow but presumably rational adjustment of premiums to changes in expected claim costs and interest rates. Their empirical work does not clearly distinguish this hypothesis from the alternative of material deviations from the perfect markets model due, for example, to possible suboptimal forecasting.¹⁵

23.3.2 Illustrative Evidence

Table 23.1 presents estimates of second-order autoregressive models of aggregate combined ratios for the US property-casualty insurance industry using data for overlapping 25-year subperiods during the period 1955–2009. Results are shown for two equations each period. The first equation includes a time trend (TIME); the second includes a time trend and the year-end yield on 5-year (constant maturity) US Treasury Bonds during the year (YIELD; also see Fig. 23.1).¹⁶

Like many earlier studies, the results generally suggest that combined ratios follow a second-order autoregressive process that is consistent with a cycle, albeit with less statistical reliability for subperiods ending after 1994. The estimated period of the cycle ranges from 4.4 to 6.1 years for the various subperiods. The estimated cycle length is shorter for the later sample periods, in contrast to popular conjectures that the cycle length has increased in the past 2 decades.¹⁷ As predicted by the perfect markets model, the coefficient on YIELD is positive and significant for 1970–1994 and 1975–1999.¹⁸ The coefficient on YIELD is negative for 1985–2009, which includes the unusually low interest rate environments of the early and late 2000s.

Using data for 1970–2009, Table 23.2 presents estimates of second-order autoregressive models of (1) the combined ratio, (2) the gross underwriting margin, defined as 100 % minus the percentage underwriting expense ratio, and (3) the ratio of net premiums written to GDP. The gross margin

¹⁴That is, there is evidence that expense ratios follow a second-order autoregressive process.

¹⁵The causes of lags in adjustment are not explored in this work. Also see Tennyson (1993).

¹⁶The combined ratios are not adjusted for policyholder dividends. Following Harrington and Niehaus (2000), similar results were obtained using dividend-adjusted combined ratios and annual average rather than year-end Treasury yields. Qualitatively similar results were obtained using yields on 1-year Treasuries. Augmented Dickey–Fuller tests (see Enders 1995) including intercept and trend generally reject the null hypothesis of a unit root for both the combined ratio and interest rate series (as well as the gross margin and the ratio of net premiums written to GDP; see below), suggesting that the series were trend stationary during these periods. Box–Pierce and Box–Ljung statistics generally indicate that the residuals in the models reported in Tables 23.1 and 23.2 are white noise (two lags were included). We emphasize that our purpose is illustrative. Apart from these and a few other robustness checks, we have not investigated the sensitivity of the results of alternative specifications, such as alternative lag structures and the use of first differences. Also see our discussion below of studies that fail to reject the null hypothesis of a unit root (sometimes without including a trend variable in the testing equation) and then consider whether underwriting margins are cointegrated with other variables.

¹⁷Meier (2006b), however, adds several other variables to the AR(2) model and finds that cycle lengths are longer using more recent data. As we note below, Boyer et al. (2012) emphasize that there typically is considerable uncertainty about point estimates of cycle length.

¹⁸When TIME trend is omitted, the coefficient on YIELD becomes significant in the earlier subperiods. However, the evidence that the series are trend stationary makes interpretation of the models without a trend problematic.

Table 23.1 Estimates of second-order autoregressive models of industry combined ratio $CR_t = b_0 + b_1CR_{t-1} + b_2CR_{t-2} + b_3TIME_t + b_4YIELD_t + v_t$

| Sample | Constant | CR _{t-1} | CR _{t-2} | TIME _t | YIELD _t | Adj. R ² | Period |
|-----------|--------------|-------------------|-------------------|-------------------|--------------------|---------------------|--------|
| 1955–1979 | 88.17 (6.86) | 0.89 (6.91) | -0.81 | 0.15 (2.76) | | 0.72 | 5.5 |
| | 81.75 (5.88) | 0.94 (7.04) | -0.80 (-6.11) | 0.02 (0.20) | 0.48 (1.15) | 0.73 | 5.5 |
| 1960–1984 | 44.13 (2.64) | 1.24 (6.48) | -0.71 (-3.41) | 0.20 (2.28) | | 0.75 | 6.1 |
| | 37.08 (2.00) | 1.23 (6.40) | -0.63 (-2.79) | 0.03 (0.14) | 0.42 (0.89) | 0.75 | 6.0 |
| 1965–1989 | 52.81 (4.59) | 1.12 (7.27) | -0.70 (-4.56) | 0.31 (3.43) | | 0.81 | 5.8 |
| | 47.35 (3.33) | 1.11 (7.04) | -0.64 (-3.52) | 0.24 (1.76) | 0.23 (0.67) | 0.80 | 5.7 |
| 1970–1994 | 58.12 (3.61) | 0.82 (4.45) | -0.46 (-2.46) | 0.31 (2.14) | | 0.68 | 4.9 |
| | 40.76 (2.50) | 0.84 (5.05) | -0.34 (-1.95) | 0.21 (1.50) | 0.71 (2.36) | 0.74 | 4.8 |
| 1975–1999 | 49.97 (2.99) | 0.80 (4.24) | -0.30 (-1.60) | 0.08 (0.71) | | 0.50 | 4.7 |
| | 26.28 (1.56) | 0.83 (5.06) | -0.23 (-1.38) | 0.24 (2.15) | 0.93 (2.76) | 0.62 | 4.6 |
| 1980–2004 | 68.01 (3.57) | 0.67 (3.47) | -0.27 (-1.46) | -0.11 (-1.03) | | 0.40 | 4.5 |
| | 21.06 (0.56) | 0.81 (3.82) | -0.20 (-1.04) | 0.32 (0.99) | 1.19 (1.42) | 0.42 | 4.5 |
| 1985–2009 | 91.18 (3.31) | 0.51 (2.68) | -0.27 (-1.38) | -0.29 (-1.81) | | 0.47 | 4.4 |
| | 95.99 (2.36) | 0.49 (2.31) | -0.27 (-1.35) | -0.34 (-0.95) | -0.18 (-0.16) | 0.44 | 4.4 |

Note: Dependent variable is CR_t = loss ratio plus expense ratio (in percent). TIME_t = time trend. YIELD_t = year – end percentage yield on 5-year treasury bonds. Period is estimated period of cycle (in years). *t*-ratios are in parentheses below coefficient estimates. 1970–1994, 1975–1999, 1980–2004, and 1985–2009 sample periods include a dummy variable for 1992 (Hurricane Andrew). Sources: *Best’s Aggregates & Averages, Property-Casualty, United States* (A.M. Best Company) and Federal Reserve Bank of St. Louis FRED data system

Table 23.2 Estimates of second-order autoregressive models of industry combined ratio, gross margin, and ratio of net premiums written to gross domestic product: 1970–2009 $Y_t = b_0 + b_1Y_{t-1} + b_2Y_{t-2} + b_3TIME_t + b_4YIELD_t + v_t$

| Y _t | Constant | Y _{t-1} | Y _{t-2} | TIME _t | YIELD _t | Adj.R ² | Period |
|---|--------------|------------------|------------------|-------------------|--------------------|--------------------|--------|
| CR _t = LR _t + ER _t | 44.76 (3.07) | 0.83 (4.97) | -0.31 | 0.11 (1.28) | 0.61 (1.59) | 0.50 | 4.7 |
| | 52.85 (3.76) | 0.82 (4.81) | -0.32(-1.88) | -0.03(-0.35) | | 0.47 | 4.7 |
| GM _t = 100 – ER _t | 31.94 (5.71) | 1.34 (11.90) | -0.72(-6.32) | 0.00 (0.02) | -0.03(-0.78) | 0.84 | 6.7 |
| | 32.69 (5.97) | 1.37 (12.94) | -0.81(-7.60) | 0.01 (1.09) | | 0.84 | 6.9 |
| NPW _t /GDP _t | 1.21 (4.52) | 1.34 (10.76) | -0.61(-4.61) | -0.01(-1.74) | -0.02(-1.92) | 0.82 | 6.2 |
| | 1.12 (4.08) | 1.37 (10.56) | -0.69 | -0.003(-1.32) | | 0.80 | 6.5 |

Note: CR_t = combined ratio (in percent), LR_t = loss ratio (in percent), ER_t = expense ratio (in percent), GM_t = gross margin (in percent), NPW_t/GDP_t = net premiums written divided by gross domestic product (in percent). TIME_t = time trend. YIELD_t = year – end percentage yield on 5-year treasury bonds. Period is estimated period of cycle (in years). *t*-ratios in parentheses below coefficient estimates. Combined ratio model includes a dummy variable for 1992 (Hurricane Andrew). Sources: *Best’s Aggregates & Averages, Property-Casualty, United States* (A.M. Best Company), Federal Reserve Bank of St. Louis FRED data system, and *Statistical Abstract of the United States*

measures the margin available in premiums (exclusive of investment income) to fund predicted claim, tax, and agency costs, and it will reflect any economic profit (or loss). Because neither the gross margin nor the ratio of net premiums written to GDP reflects reported claim costs, any cycle in or interest rate sensitivity of these variables cannot be attributed to bias or lags associated with loss reporting.

Consistent with previous analyses of expense ratios (Cagle 1993; Gron 1994a; Harrington and Niehaus 2000), the estimates of the gross margin equations provide strong evidence of second-order autoregression. Results for the ratio of net premiums written to GDP also indicate second-order autoregression. The coefficient on YIELD is not significantly negative for either series, in contrast

to the prediction of the perfect markets model.¹⁹ The coefficient for YIELD in the combined ratio equation is positive (recall that the combined ratio is an inverse profitability measure) but with t -ratio below 2.

What can be made of these results and those of similar studies? Absent specific details on the causes of any bias, the evidence of second-order autoregression in the series is anomalous from the perspective of the perfect markets model. This result is by and large consistent with the decades old story about periodic hard and soft markets. Because there is no reason to expect that shocks are predictable, the evidence of second-order autoregression in combined ratios or the other variables also is not readily explained by shock models.²⁰ On the other hand, persons predisposed towards the perfect markets model might argue that the evidence of second-order autoregression and the fragile relationship with interest rates could reflect aggregation bias, structural instability due, for example, to changes in regulation, possible omitted variables, and so on. Variation in the estimates for different models and subperiods also indicates some fragility in the results. In addition, Boyer et al. (2012) argue and present evidence that imprecision of parameter estimates and poor out-of-sample forecasts from cyclical models is inconsistent with cyclicality.

23.3.3 *Unit Root and Cointegration Analyses*

The key feature of a nonstationary series (e.g., a series with a unit root) is that shocks are permanent—they persist indefinitely. As noted earlier, standard tests for each of the US property-casualty insurance series analyzed above rejected the existence of a unit root (see footnote 14). This result is consistent with Harrington and Yu (2003), who conducted extensive unit root tests of the series typically analyzed in underwriting cycle research. Haley (2007) takes issue with their use of a time trend factor in unit root tests and their reliance on unit root tests. Leng (2006a, b) presents evidence that combined ratios are nonstationary and subject to structural breaks. The empirical debate and possibility of structural breaks notwithstanding, it is not clear why shocks to ratios of insurance losses and expenses to premiums or GDP would be permanent after controlling for trend.

Under the assumption of non-stationarity, Haley (1993, 1995) presents evidence that underwriting profit margins are cointegrated negatively with interest rates in the long run. Results for error correction models indicate a short-run relation between interest rates and underwriting margins. Grace and Hotchkiss (1995) provide evidence of cointegration between quarterly combined ratios and short-term interest rates, the consumer price index, and real GDP. Choi et al. (2002) provide evidence that underwriting profit margins are cointegrated with annual Treasury bond yields but not with the ratio of capital to assets. Jawad et al. (2009) provide evidence that premiums are cointegrated with interest rates using nonlinear cointegration techniques. Lazar and Denuit (2012) analyze the dynamic relationship between US property-casualty premiums, losses, GDP, and interest rates using both single-equation and vector cointegration analyses. The results suggest long-term equilibrium between premiums, losses, and the general economy and that premiums adjust quickly to long-term equilibrium.

¹⁹When the time trend is omitted, the coefficients are negative but with absolute t -ratios less than 1.4.

²⁰Winter's (1994) model (see below), for example, implies first-order autoregression, although he suggests that overlapping policy periods might explain second-order autoregression within the context of his model.

23.4 Capital Shocks and Capacity Constraints

Common aspects of capital shock models of underwriting cycles are that (1) industry supply depends on the amount of insurer capital and (2) that industry supply is upward sloping in the short run because the stock of capital is costly to increase due to the costs of raising new capital.²¹ These features imply that shocks to capital (e.g., catastrophes or unexpected changes in liability claim costs) affect the price and quantity of insurance supplied in the short run. Holding industry demand fixed, a backward shift in the supply curve due to a capital shock causes price to increase and quantity to decrease, which roughly describes hard markets. Soft markets—low prices and high availability—either are not addressed by these models or are explained by periods of excess capital that is not paid out to shareholders because of capital exit costs.

23.4.1 *The Basic Model*

Theoretical contributions to the literature on the relationship between cycles and insurer capital include Winter (1991a, 1994), Gron (1994a), Cagle and Harrington (1995), Doherty and Garven (1995), and Cummins and Danzon (1997). While the assumptions and specific objectives of these contributions differ on some dimensions, the main message is similar: shocks to capital can cause price increases and quantity reductions consistent with a hard market.

To illustrate the basic story of capital shock models, we focus on the determination of three endogenous variables in a competitive market: price, quantity, and insurer capital. Figure 23.3 illustrates the key ideas for a representative insurer. The horizontal axis measures quantity of coverage as the value of expected claim costs. The vertical axis measures the price of coverage as the difference between the premium and the expected claim cost per unit of coverage. The price of coverage therefore is the premium loading per dollar of expected claim costs, i.e., the excess amount paid for each dollar of expected claim costs. For simplicity, we initially ignore the time value of money and administrative costs (underwriting and claims-processing costs). Given the latter assumption, the only input into production of insurance is financial capital.

All capital shock models incorporate the idea that insolvency risk depends on the amount of insurer capital because of uncertainty in claim costs (due to correlation across policyholders) or uncertainty in investment returns (due for example to uncertainty in interest rates). Although not all models consider the issue, we assume that in the long run insurers choose an optimal amount of capital, which equates the marginal costs and benefits of additional capital.²² By reducing insolvency risk, additional capital benefits insurers by (1) increasing the demand for coverage by consumers who are averse to insolvency risk (Cummins and Danzon 1997) and/or (2) reducing the likelihood that insurers lose franchise value (Cagle and Harrington 1995). The costs of insurer capital include double taxation of investment returns on capital and agency costs (Winter 1994; Cagle and Harrington 1995; Harrington

²¹All of the capital shock models are built on the assumption that external capital is costlier than internal capital. This notion is often justified using the logic of Myers and Majluf (1984) where managers are better informed than investors and that transaction costs make raising new capital costly.

²²While the optimal amount of capital per unit of coverage is likely to decline with the number of units of coverage over some range given the greater diversification of claim costs that can be achieved by writing additional coverage, it is common to assume that demand for coverage (at any price) greatly exceeds the point at which such economies of scale are material.

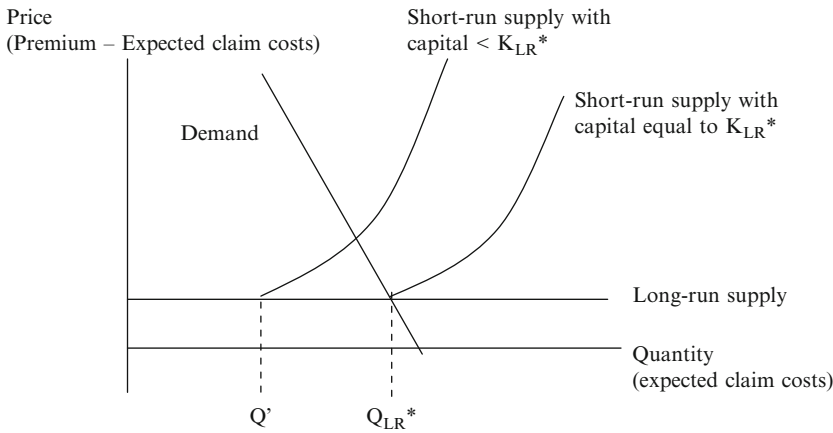


Fig. 23.3 Industry supply relationships

and Niehaus 2003).²³ The cost per dollar of capital equals s . The long-run cost of supplying coverage therefore equals the total capital cost per unit of coverage.²⁴ Instead of modeling insurer choice of capital based on costs and benefits, some models simply assume that insurer capital must satisfy a regulatory constraint on the probability of bankruptcy (Gron 1994a, b; Winter 1994).

Assuming that the optimal level of capital is a fixed proportion of output, the long-run supply curve is perfectly elastic at the cost per unit of coverage of the optimal long-run level of insurer capital (see Fig. 23.3). Exogenously imposing a downward sloping demand curve in Fig. 23.3, the long-run equilibrium corresponds to an output level equal to Q_{LR}^* , a level of insurer capital of K_{LR}^* , and a price (premium loading per unit of coverage) equal to the capital costs per unit of coverage, sK_{LR}^*/Q_{LR}^* .

In capital shock models, short-run equilibrium differs from the long-run equilibrium because capital adjustment costs cause capital to be a fixed (or at least sticky) factor of production in the short run. Consequently, the short-run supply curve is upward sloping. To illustrate, suppose that the representative insurer finds himself or herself with capital equal to the long-run optimum, K_{LR}^* , in Fig. 23.3, which corresponds to a long-run output level of Q_{LR}^* and that capital cannot be adjusted. In order to induce the insurer to supply output beyond the long-run equilibrium, the price of coverage would have to increase above the long-run equilibrium price. If insurers increased output and kept price equal to the long-run equilibrium price, then insolvency risk would increase above the optimum level, which would imply a higher cost of coverage (e.g., there would be an increased likelihood that the insurer would lose part of its franchise value). Thus, there is an additional cost of increasing output beyond Q_{LR}^* , holding capital fixed at K_{LR}^* . Greater increases beyond Q_{LR}^* imply greater increases in costs. Thus, the short-run supply curve is upward sloping.

The location of the short-run supply curve depends on the amount of insurer capital. If insurer capital were depleted below the long-run equilibrium, then the short-run supply curve would be upward sloping starting below Q_{LR}^* . Figure 23.3 illustrates the case where capital is depleted to the point where the insurer’s capital corresponds to a long-run equilibrium output level of Q' .

Within this framework, a capital shock in the form of unexpected claim payments on existing policies or a reduction in the value of assets would deplete insurers’ capital and shift back the short-

²³As discussed below, the cost of new capital in Cummins and Danzon (1997) is that it bails out old claimants without increasing the premiums paid by these claimants.

²⁴The costs of holding capital should be distinguished from the cost of adjusting capital, which are central to short-run analyses of prices and quantities.

run supply curve. Holding demand constant, the short-run equilibrium price would increase and the short-run equilibrium quantity of coverage would decrease, thus producing a hard market.

The higher prices and lower quantities then help to replenish insurer capital and gradually the supply curve shifts back, which lowers price and increases quantity. Insurers also could replenish capital by issuing new debt and equity securities, but raising new capital is costly because of issuance costs and potential underpricing costs. Thus, the short-run supply curve is “bounded” by these costs. That is, if price rose sufficiently above the long-run equilibrium price, insurers would likely raise new capital, which would shift out the supply curve and cause prices to fall and quantities to increase. Insurers therefore would be more likely to raise new capital following large negative shocks to capital.

Although most models focus on negative shocks to capital (an exception is [Doherty and Garven 1995](#)), it is useful to consider whether positive shocks to capital could explain the soft markets with prices below long-run equilibrium prices within the capital shock framework.²⁵ Just as there are costs of raising new capital there also are costs of paying out capital (see [Winter 1991, 1994](#)). Insurers can dispose of excess capital by increasing dividends or stock repurchases. Dividend payments, however, can impose tax costs on owners and stock repurchases involve transaction costs. To the extent that these costs induce insurers to hold excess capital, the price of coverage can fall below long-run equilibrium levels. Selling policies for less than the long-run equilibrium price could be less costly than either paying out the capital or having it less than fully utilized in supporting additional output.

In summary, the main predictions from these models are (1) insurance prices are negatively related to insurer capital, (2) the quantity of coverage falls following negative shocks to capital, but coverage is not rationed, and (3) capital infusions (payouts) take place during periods of high (low) insurance prices.

23.4.2 Discussion of Specific Models

Industry Models. Although the insurance cycle is a dynamic phenomenon, most of the capital shock contributions employ static models like the one outlined above. The dynamic aspects of the market are then explained by periodic exogenous shocks. An exception is [Winter \(1994\)](#), which models the dynamics of the insurance market in a discrete time equilibrium model. The evolution of insurer capital is explicitly modeled and insurers optimally choose to add or dispose of capital each period, as well as the quantity of coverage to offer. Unlike other contributions, Winter explicitly models the capital adjustment costs (the costs of adding and distributing capital). However, he does not model the optimal level of capital based on the costs and benefits of holding capital. Instead, insurers must hold an amount of costly capital that satisfies the constraint that the probability of insolvency is zero. This constraint, along with the capital adjustment costs, gives rise to an upward sloping short-run supply curve. That is, in order for insurers to increase supply beyond the point where existing capital ensures a zero probability of insolvency, price must increase so that the additional revenue from the higher price satisfies the insolvency constraint.

In addition to showing that insurance prices vary inversely with insurer capital and that new additions of capital occur during hard markets, [Winter \(1994\)](#) model also implies that market-to-book ratios are a declining function of insurer capital. Intuitively, as capital becomes scarce, its value within

²⁵Some authors suggest that following negative shocks that cause a hard market capital is gradually restored and prices eventually fall to long-run equilibrium values until another negative capital shock occurs. Accordingly, the soft phase of the underwriting cycle is characterized by prices equal to rather than below long-run equilibrium values implied by the perfect markets model (see e.g., [Gron 1994a, b](#)).

the insurer increases. This suggests that stock market reactions to unexpected losses are less than dollar-for-dollar.²⁶

Cagle and Harrington (1995) examine the extent to which the cost of a capital shock may be passed on to consumers in the form of higher prices. In their model, insurers choose an optimal level of capital based on the cost of holding capital and the benefits of protecting franchise value. They derive comparative statics for the upper bound effect on price of a shock to capital, assuming that demand is perfectly inelastic and that additional capital cannot be raised. In this scenario, they show that the entire cost of the shock is not passed on to policyholders. Intuitively, the supply curve is not sufficiently responsive to a decrease in capital to cause prices to increase enough to offset completely the capital shock. The reason for this is that higher prices help to replenish capital, which dampens the effect of the capital shock on supply.

Firm-Level Models. The basic idea of the industry-level models has also been developed in models of individual insurers. These models do not assume a perfectly competitive market and thus prices can vary across insurers. In addition to the implication that insurance prices rise in response to industry-wide capital shocks, firm-level models provide predictions about firm-specific shocks and cross-sectional predictions about industry-wide shocks.

Doherty and Garven (1995) consider the effects of interest rate changes in the context of capital shock models. A change in interest rates can influence capital by changing the value of insurer assets and liabilities. Depending on whether the duration of assets exceeds the duration of liabilities and the sign of the interest rate change, interest rate changes influence the value of an insurer's capital and thus can cause short-run effects similar to those outlined above. In addition, the level of interest rates influences the long-run equilibrium price of coverage—higher interest rates cause the fair premium to decline, all else equal. Thus, they predict that interest rate changes will cause firm-specific capital shocks, as well as alter the long-run equilibrium price of insurance. They therefore predict that there will be cross-sectional differences in insurers' price response to interest rate changes, depending on the insurer's exposure to interest rate risk (surplus duration) and its costs of raising capital (mutual versus stock).

Cummins and Danzon (1997) also consider firm-specific effects of shocks. They consider an insurer that enters a period with existing liabilities and a stock of capital. The insurer chooses the amount of new capital to raise and the price for new policies. Demand for coverage depends on both price and quality (insolvency risk). The benefit of additional capital is an increase in consumer demand for new policies, but the cost of additional capital is that the old policyholders (existing liabilities) have less insolvency risk, but pay no additional premiums. In essence, capital infusions can bail out old claimants. Thus, unlike other models that either impose explicit capital adjustment costs (**Winter 1994**) or assume capital is fixed in the short run (**Gron 1994a**; **Cagle and Harrington 1995**), Cummins and Danzon impose a specific market imperfection by assuming that contracts with old policyholders cannot be adjusted to reflect changes in default risk.

Another important aspect of Cummins and Danzon's analysis is the explicit modeling of the response of demand to insolvency risk.²⁷ If price is measured as the premium per policy or per dollar of

²⁶As noted, Winter's model predicts a first-order process for prices, not a second-order process. He suggests, however, that a higher order process would result from the model if the assumption of single period contracts was replaced with the more realistic assumption of overlapping contracts. **Winter (1991b)** extends the basic capital shock story by examining the effect of regulation that restricts an insurer's premium to surplus ratio to be below a certain level. This regulatory constraint can further exacerbate the reduction in short-run supply following a capital shock if demand is inelastic. Intuitively, as prices rise in response to the capital shock, inelastic demand implies that premium revenue will increase, which in combination with the reduction in capital causes more insurers to bump up against the regulatory constraint, which in turn causes supply to shift back even more.

²⁷As noted earlier, **Winter (1994)** avoids this issue by imposing a zero probability of insolvency constraint, and **Gron (1994a)** assumes that there is regulatory constraint on the probability of insolvency. **Cagle and Harrington (1995)**

expected *promised* claim costs, as opposed to per dollar of expected claim costs (where the expectation incorporates default risk), then price would be expected to move inversely with insolvency risk, all else equal. The analogy to risky debt is helpful—as default risk increases, a bond’s price would be expected to fall, holding the promised payment constant. Consequently, in response to a capital shock that increased insolvency risk, price could very well fall. In part because of this effect, Cummins and Danzon’s model does not provide an unambiguous prediction concerning the effect of a shock on price. Similarly, their model does not provide an unambiguous prediction concerning the response of capital to a negative shock. In their model, insurers face a trade-off with respect to raising additional capital. Additional capital will transfer wealth to old policyholders, but will also increase demand by new policyholders.²⁸

23.4.3 Empirical Evidence on Capital Shock Models

The most important prediction of capital shock models is that insurance prices are negatively related to insurer capital. As discussed earlier, a problem encountered by empiricists is that the *ex ante* price of insurance is not observable because expected losses are unobservable. Thus, most studies examining the relation between price and capital use some variant of premiums relative to realized losses as a measure of price. Table 23.3 summarizes some of the empirical evidence. The following discussion provides some additional details on selected contributions.

Aggregate Time Series Studies. Winter (1994) calculates an “economic loss ratio” for year t as the present value of an estimate of actual future claims arising from policies sold in year t divided by premiums in year t . The economic loss ratio is regressed on the lagged values of insurer capital relative to its previous 5-year average and interest rates. Consistent with the prediction of the capital shock models that higher prices (lower expected loss ratios) occur when capital is low, the coefficients on the lagged capital variables are positive and statistically significant in most of his specifications.²⁹

Gron (1994a) uses both the difference between premiums and underwriting expenses and the ratio of premiums to underwriting expenses as dependent variables. To control for the present value of claim costs, she includes variables for the expected inflation rate and interest rates. Demand is controlled for using GDP. Consistent with capital shock models, the results indicate that changes in the margin between premiums and underwriting expenses are negatively related to lagged values of capital relative to its long-run equilibrium value, where the latter variable is measured as capital relative to its 5-year average, 3-year average, or GDP.

consider demand responses to capital shocks and show that such responses diminish the ability of insurers to recoup losses from price increases following capital shocks.

²⁸Froot and Stein (1998) present a model of banks and insurers in which capital structure, hedging policy, and investment decisions are jointly determined based on the assumption that financial institutions are concerned about risk because a realization of a random variable that depletes internal funds can cause the firm to pass up profitable investment opportunities due to the costs of raising external capital. The firm can manage the risk by (1) holding capital *ex ante*, which is costly due to tax and agency costs, (2) engaging in costly hedging transactions, and (3) adjusting their exposure to the random variable through their investment policies. Their model implies that financial intermediary pricing depends on intermediaries’ capital. To the extent that insurers operate across different lines of business, the result that insurer pricing depends on their capital implies that capital shocks should affect pricing across lines of business, regardless of the source of the shock.

²⁹During the 1980s, however, the correlation between domestic insurer capital and the economic loss ratio was negative. Winter argues that the 1980s can be explained in part by the omission of reinsurance capacity in the capital variables, a factor which also may have influenced the results of Cummins and Danzon (1997, see below), and which remains an open area for further work.

Table 23.3 Evidence on capital shock models

| Study | Data | Main results |
|--|---------------------------------------|---|
| Industry aggregate time series studies | | |
| Winter (1994) | 1948–1988 | Difference between premiums and prediction of the present value of future losses is negatively related to insurer capital |
| Gron (1994a) | 1949–1990 | Changes in premiums minus underwriting expenses (the “price payment margin” or PPM) are negatively related to lagged capital. Negative capital shocks influence PPM more than positive capital shocks. Capital growth is positively related to contemporaneous PPM. |
| Niehaus and Terry (1993) | 1946–1988 | Premiums are related to lagged capital |
| Choi and Thistle (2000) | 1926–1993 | Surplus is not a determinant of profits in the short run or long run |
| Higgins and Thistle (2000) | 1934–1993 | Underwriting profits follow an AR(1) process when capital is high and AR(2) process when capital is low |
| Insurer panel data | | |
| Doherty and Garven (1995) | 1976–1988 | Sensitivity of insurer underwriting returns to interest rates (speed of adjustment) is negatively related to surplus duration (capital shock from the interest rate change) |
| Cummins and Danzon (1997) | 1980–1988 | Capital flows are positively related to price changes and loss shocks |
| Guo and Winter (1997) | 1990–1995 | Ratio of capital to premiums is positively related to past profitability |
| Weiss and Chung (2004) | 1991–1995 | Non-proportional reinsurance prices are negatively related to worldwide capacity measures |
| Aggregate line-specific data | | |
| Yuengert (1991) | Six lines, 1984–1989 | Prices are positively related to capital and negatively deviations of capital from its average level |
| Gron (1994b) | Four lines, 1952–1986 | Underwriting profits are negatively related to capital for auto physical damage, homeowners, auto liability, but not other liability |
| Froot and O’Connell (1997) | Catastrophe reinsurance | Prices increase following capital shocks even for catastrophes and regions not affected by the shock |
| Other evidence | | |
| Gron and Lucas (1995) | Insurer financing decisions 1970–1993 | Payout ratios fall following shocks; equity issues increase following shocks, but most additional capital is small relative to size of capital shocks |

Aggregate Line-Specific Studies. Gron (1994b) examines aggregate time series data for four lines of business: auto physical damage, auto liability, homeowners’ multiple peril, and other liability. Unlike her time series study of aggregate industry data (1994a), she examines the determinants of the underwriting profit margin, defined as earned premiums minus incurred losses, divided by earned premiums. After controlling for expected inflation, unexpected inflation, changes in expected inflation, and changes in discount rates, she finds that deviations of relative capacity (capital to GDP) from its normal level are negatively related to underwriting profits in all four lines, which is consistent with the notion that prices increase when capacity (insurer capital) is reduced.

Panel Data Studies. Doherty and Garven (1995) use insurer panel data to estimate the sensitivity of insurer underwriting returns to interest rate changes. They then regress these sensitivity measures on

measures of surplus duration and proxies for the cost of raising capital (e.g., whether the insurer is public vs. private and stock vs. mutual). They find that the interest rate sensitivity coefficient from the first-pass regression is negatively related to surplus duration. This finding suggests that if interest rates increase, thus causing the long-run equilibrium underwriting return to decrease, insurers with a high surplus duration and therefore a large decrease in capital from the interest rate increase will adjust less rapidly to the lower equilibrium price. Thus, capital shocks caused by interest rate fluctuations influence price adjustment. They also find that private insurers adjust more slowly to interest rate changes, which is consistent with these insurers having greater capital adjustment costs.

The theory developed by [Cummins and Danzon \(1997\)](#) suggests that price and capital are jointly determined. They therefore estimate a two-equation system using insurer-level data, where price depends on lagged capital (as a measure of financial quality) and additions to capital depend on the change in price. Their results indicate that insurers with more capital charge higher prices, which is consistent with the risky debt notion of insurance policies. In addition, they find that price is inversely related to deviations of capital from normal levels, which lends support to the capital shock models. The capital equation results support the notion that insurers have an optimal capital structure and that capital is more likely to be raised following an increase in price.

[Froot and O'Connell \(1997\)](#) test the extent to which shocks in one insurance market influence pricing in other markets. In particular, they present evidence that catastrophe reinsurance prices changed across the board in response to shocks caused by specific types of catastrophes (e.g., a hurricane) or by catastrophes in specific regions. This evidence suggests that insurance prices vary inversely with insurer capital in the short run (also see the discussion in [Froot \(2001\)](#)). [Weiss and Chung \(2004\)](#) examine the factors that influence non-proportional reinsurance prices from 1991 to 1995, a period that includes the occurrence of hurricane Andrew and the financial difficulties of Lloyds of London. They find that reinsurance prices are negatively related to worldwide relative capacity, consistent with the capital shock model.

23.5 Price-Cutting and Soft Markets

The traditional view of underwriting cycles by insurance industry analysts emphasizes fluctuations in capacity to write coverage as a result of changes in capital and insurer expectations of profitability on new business (see [Stewart 1984](#); also see [Berger 1988](#)). The essence of this explanation is that supply expands when expectations of profits are favorable, that competition then drives prices down to the point where underwriting losses deplete capital, and that supply ultimately contracts in response to unfavorable profit expectations or to avert financial collapse. Price increases then replenish capital until price-cutting ensues again. The traditional explanation of supply contractions is then largely consistent with shock models.

The principal puzzle in the traditional view of underwriting cycles is why competition in soft markets leads to inadequate rates. The traditional view has been appropriately challenged by researchers for failing to explain how and why competition would cause rational insurers to cut prices to the point where premiums and anticipated investment income are insufficient to finance optimal forecasts of claim costs and ensure a low probability of insurer default.³⁰

³⁰Similarly, popular explanations of “cash flow underwriting” usually imply that insurers are irrational in that they reduce rates too much in response to increases in interest rates. Winter’s model implies that hard markets that follow large shocks tend to be preceded by periods of excess capacity and soft prices. However, as suggested earlier, shocks should be unpredictable. Neither Winter’s model nor other shock stories can readily explain second-order autoregression in profits.

It has been suggested that a tendency towards inadequate prices might arise from differences in insurer expectations concerning the magnitude of future loss costs, from differences in insurer incentives for safe and sound operation, or both (McGee 1986; Harrington 1988; Harrington and Danzon 1994).³¹ Harrington and Danzon (1994) develop and test hypotheses based on this intuition and the large literature on optimal bidding and moral hazard within the framework of alleged underpricing of commercial general liability insurance during the early 1980s. In the Harrington and Danzon analysis, some firms may price below cost because of moral hazard that results from limited liability and risk-insensitive guaranty programs. Others may price below cost due to heterogeneous information concerning future claim costs that results in low loss forecasts relative to optimal forecasts accompanied by winners' curse effects. In response to underpricing by some firms, other firms may cut prices to preserve market share and thus avoid loss of quasi-rents from investments in tangible and intangible capital.

Harrington and Danzon (1994) use cross-sectional data from the early 1980s to test whether moral hazard and/or heterogeneous information contributed to differences in general liability insurance prices and premium growth rates among firms. Loss forecast revisions are used as a proxy for inadequate prices.³² Estimation of reduced form equations for loss forecast revisions and premium growth and a structural model to test for a positive relation between premium growth and forecast revisions provides some evidence that is consistent with the moral hazard hypothesis.

In subsequent work, Harrington (2004) presents evidence that higher firm-level premium growth for general liability insurance during the 1992–2001 soft market for such coverage was reliably associated with higher loss forecast revisions, as would be expected if low-priced firms captured market share and ultimately experienced relatively high reported losses. Harrington et al. (2008) provide similar evidence using firm-level data for the US medical malpractice insurance soft market during 1994–1999. An implication of this line of investigation is that increased market or regulatory discipline against low-priced insurers with high default risk would reduce price volatility.³³

23.6 Conclusions

As Harrington and Niehaus (2000) concluded more than a decade ago, there is no reasonable doubt that variation in insurance premiums over time and across buyers is largely attributable to variation in “fundamentals.” There is, however, evidence of material variation in premiums that cannot

³¹McGee (1986) speculated that insurers with optimistic loss forecasts may cause prices to fall below the level implied by industry average forecasts. Winter (1988, 1991a) mentions the possibility of heterogeneous information and winner's curse effects.

³²While insurers' reported loss forecasts may be biased for tax and other reasons, loss forecast revisions should nonetheless reflect moral hazard induced low prices assuming that low price firms deliberately understate initial reported loss forecasts compared with other firms to hide inadequate prices from regulators and other interested parties, but that larger, positive forecast errors materialize compared with other firms as paid claims accumulate. In addition, if prices vary due to differences in true loss forecasts at the time of sale, less-informed firms should experience relatively greater upward forecast revisions over time compared with other firms as information accumulates.

³³Another avenue of inquiry regarding regulatory policy has been whether delays in the rate approval process under prior approval rate regulation could influence or even cause cyclical fluctuations in underwriting results (Cummins and Outreville 1987). Many studies have analyzed whether rate regulation affects cyclical movements in statewide loss ratios (or inverse loss ratios; see, for example, Outreville (1990) and Tennyson (1993)). Such studies generally consider the hypothesis that regulatory lag amplifies cyclical movements in underwriting results by increasing loss ratios in hard markets by delaying rate increases and reduces loss ratios in soft markets by delaying rate reductions. An alternative view is that rate regulation may damp cycles by preventing excessive price-cutting in soft markets. As summarized by Harrington and Niehaus (2000), a number of authors have debated whether cooperative pricing activities in conjunction with the insurance industry's limited exemption from federal antitrust law might aggravate hard markets.

be easily explained by the perfect markets model, especially during certain hard markets. Some evidence suggests that capital shock models and possible underpricing of coverage during soft markets explain some of that variation. The need remains for additional theoretical and empirical work to better understand insurance price dynamics. This includes the development of novel approaches for providing convincing empirical evidence that do not rely on the modest number of usable observations with time series data.

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Chapter 24

On the Choice of Organizational Form: Theory and Evidence from the Insurance Industry

David Mayers and Clifford W. Smith

Abstract Organizational forms within the insurance industry include stock companies, mutuals, reciprocals, and Lloyds. We focus on the association between the choice of organizational form and the firm's contracting costs, arguing that different organizational forms reduce contracting costs in specific dimensions. This suggests that differing costs of controlling particular incentive conflicts among the parties of the insurance firm lead to the efficiency of alternative organizational forms across lines of insurance. We analyze the incentives of individuals performing the three major functions within the insurance firm—the manager function, the owner function, and the customer function. We review evidence from the insurance industry that directly examines this product-specialization hypothesis. We then examine evidence on corporate policy choices by the alternative organizational forms: executive compensation policy, board composition, distribution system choice, reinsurance purchases, and the use of participating policies. Finally, we review evidence of the relative efficiency of the alternative organizational forms.

24.1 Introduction

The range of organizational forms within the insurance industry is perhaps the broadest of any major industry. Included are stock companies that employ the standard corporate form, mutuals, and reciprocals that are more like cooperatives, where customers are the owners of the firm, and Lloyds associations where insurance contracts are offered by syndicates of individual underwriters.

Coase (1960) argues that with no contracting costs, the organizational form of the insurance supplier (the assignment of property rights within the firm) will have no effect on real activity choices. But, where contracting is costly, alternative organizational forms that imply differing incentives among the parties generate differing costs. Relevant contracting costs take a variety of forms—the costs incurred in attempting to control incentive conflicts (for example, negotiation, administration, information, and litigation costs) as well as the opportunity cost that remains after appropriate control steps are taken, since it generally will not be optimal to exercise complete control.

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Our analysis implies an association between the choice of organizational form and the firm's contracting costs. We argue that different organizational forms have differing contracting costs in specific dimensions. These differing costs of controlling particular incentive conflicts among the parties of the insurance firm lead to the efficiency of alternative organizational forms across lines of insurance.

An important aspect of our analysis is its focus on the contracting costs associated with managerial discretion. Required managerial discretion should be lower in lines of insurance for which more loss data are available (Mayers and Smith 1981), variance is lower (Fama and Jensen 1983; Lamm-Tennant and Starks 1993; Doherty and Dionne 1993), screening is less valuable (Hansmann 1985; Smith and Stutzer 1990), and claims are expected to be adjudicated within a more stable legal environment (Mayers and Smith 1988). Generally, the more discretion managers are authorized, the larger the potential they will operate in their own interests. Since required managerial discretion varies across lines of insurance and, we will argue, the costs of controlling managerial discretion vary across organizational forms, the organizational form most appropriate for particular lines of insurance also will vary. Recent empirical analyses provide tests of these hypotheses. In this chapter, we summarize the current theory and accumulating empirical evidence on these organizational choices.

In Sect. 24.2, we analyze the incentives of individuals performing the three major functions within the insurance firm—the management function, the owner function, and the customer function. This section presents our theory of the alternative organizational forms within the insurance industry. In Sect. 24.3, we examine the managerial-discretion hypothesis as a major determinant of the firm's choice of organizational form. In Sect. 24.4 we review evidence from the insurance industry that examines the efficiency of the various organizational forms. In Sect. 24.5, we examine evidence on other aspects of the choice of organizational form by analyzing an array of corporate policy choices including the structure of executive compensation, board composition, distribution system, and insurance contract form. We offer our conclusions in Sect. 24.6.

24.2 Alternative Organizational Forms

We first focus on the costs and benefits of the insurance industry's alternative organizational forms in order to understand better the nature of their respective comparative advantages. Different organizational forms create different incentives for the various contracting parties, and variation in the costs of controlling the resulting incentive problems implies that different forms are efficient in different circumstances. For instance, costs are related to factors such as the degree of managerial discretion required in setting rates in a given line of insurance. Generally, the more discretion managers are authorized, the greater is the potential for the managers to operate in their self-interest at the expense of other parties to the firm. We argue that alternative organizational forms provide inherent control mechanisms that, to varying degrees, limit the ability of particular parties to operate opportunistically.

There are three important functions within each organizational form. The first is the manager function; managers are the decision makers—the administrators who quote rates, market the policies, and settle claims. Second is the owner function; owners provide capital, own claims to the residual income stream of the organization, and are thus the residual riskbearers in the firm. Third is the customer function; policyholders pay premiums in return for a promise that they will receive a stipulated indemnity payment from the insurance firm in the event that they incur specified losses. Figure 24.1 illustrates how the alternative organizational forms differ in the manner in which they combine these three functions.

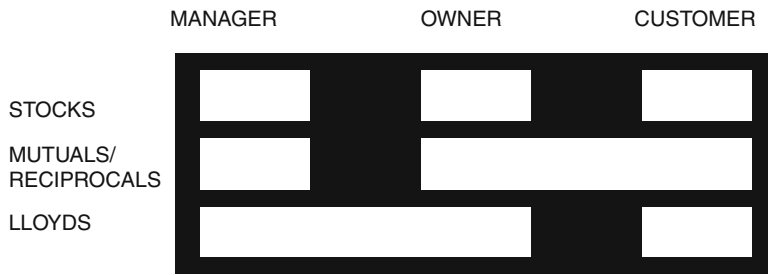


Fig. 24.1 Organizational forms within the insurance industry and the assignment of manager, owner, and customer functions

24.2.1 Common Stock Companies

The distinguishing characteristic of the common stock insurance company is the potentially complete separation of the manager, owner, and customer functions. Separation allows specialization in these functions, which lowers costs. Thus, the unrestricted common stock of the insurance company allows efficiencies in risk-bearing through specialization that are complemented by the benefits of managerial specialization. For example, managerial talent may be chosen in a common stock insurance company without strong consideration to managers’ wealth or willingness to bear risk.

Yet this separation of the manager and owner functions in the common stock insurance company means that managers of a stock company do not bear the full wealth effects of their actions. This leads to an important incentive problem. Managers generally will not have interests that are aligned completely with those of the owners.

This incentive conflict between stockholders and managers is controlled in stock companies in several ways: (1) Insurance industry regulatory bodies and rating agencies monitor managers. (2) The executives are appointed by a stockholder-elected board of directors.¹ (3) Most firms complement an external managerial labor market with a corresponding internal market through which executives compete. (4) Restrictions in the corporate charter limit managerial actions.² (5) Managers are monitored in capital markets by stock analysts, institutional investors, and other large stockholders.³ (6) The manager’s compensation package can include incentive provisions which tie the manager’s compensation to the performance of the firm’s stock.⁴ (7) An alternative management team can gain control from the firm’s current managers through an outside takeover if the firm is run inefficiently.⁵ Yet note that even with these control devices, there is still potential for disagreement between owners and managers.

Because stockholders and policyholders are separate parties, problems arise in stock insurance companies that are similar to the incentive conflict problems between stockholders and bondholders in industrial corporations: stockholders have incentives to change the firm’s dividend, financing, and investment policies after insurance contracts are sold to increase the value of their residual claims at the expense of policyholders’ fixed claims. For example, if customers buy policies expecting the firm

¹ See [Mayers et al. \(1997\)](#).

² See [Mayers and Smith \(2005\)](#).

³ See [Brickley et al. \(1988, 1994\)](#).

⁴ See [Smith and Watts \(1982, 1992\)](#) and [Gaver and Gaver \(1993\)](#).

⁵ See [Manne \(1965\)](#), [Jensen and Ruback \(1983\)](#), and [Jarrell et al. \(1988\)](#).

to maintain its stock dividend payments at its current level, equity value would increase at policyholder expense if the firm increases its stock dividends financed by asset sales.⁶

In competitive markets, potential customers recognize these incentives. Rationally priced insurance reflects an unbiased forecast of these potential costs. Thus by limiting opportunities for expropriation by owners, the demand price for the company's policies increases. Potentially important mechanisms to limit such expropriation include (1) state insurance guaranty funds,⁷ (2) charter restrictions on assets in which the firm can invest,⁸ (3) charter restrictions and regulatory limitations on the dividends that can be paid to stockholders, (4) issuance of participating policies,⁹ and (5) the loss of reputational capital and the consequent expected lower future demand price for the company's policies. Nonetheless, these control mechanisms will usually fail to resolve the conflict between shareholders and policyholders completely.

24.2.2 *Mutual Companies*

In a mutual insurance company, the policyholders are both customers and owners—these functions are merged. Yet, the rights of a policyholder in a mutual are more restricted than the combined stockholder and policyholder rights in a common stock firm. For example, ownership rights are limited through the company charter, policy provisions, and regulation in ways that are not imposed on stockholders of common stock firms. Importantly, ownership rights of the mutual policyholders are not transferable.¹⁰ But by eliminating stockholders with their separate and sometimes conflicting interests, potential conflicts between owners and customers over dividend, financing, and investment policy are internalized. This is the major benefit of the mutual form of organization.

These benefits from control of the customer-owner conflict, however, are offset by less effective control of the owner-manager conflict. Specifically, inalienability of ownership rights in mutuals limits the mechanisms by which the owner-manager conflict can be controlled in at least three ways: (1) Without traded shares, mutual managers are not monitored in capital markets by stock analysts, institutional investors, or block holders. (2) Stock-based compensation plans which can control aspects of the owner-manager conflict are infeasible without alienable shares. (3) A potentially significant factor in controlling management of a stock company is the threat of a hostile takeover. Hostile takeovers (in which a tender offer is made directly to the firm's owners for their shares) are impossible in a mutual. This more restricted corporate-control technology is a cost of the mutual form.

Thus, the potential advantage that mutuals have over stock firms in controlling incentive problems between policyholders and stockholders is offset by the less effective control of incentive problems between owners and managers. If the costs of controlling management in mutual insurers are higher than in stock firms, mutuals should have a comparative advantage in lines of insurance requiring less managerial discretion—for example, in lines of insurance for which there is extensive loss data.

Other aspects of coverage are important as well. For example, consider lines where required discretion is the same, but the effective life of the policy differs. Even small changes in dividend, financing, or investment policies can cumulate to have a material impact on the riskiness of the

⁶See [Smith and Warner \(1979\)](#).

⁷See [Lee et al. \(1997\)](#) and [Downs and Sommer \(1999\)](#).

⁸See [Mayers and Smith \(2005\)](#).

⁹Participating policies in insurance markets act somewhat like convertible bonds in credit markets. See [Smith and Warner \(1979\)](#), [Mayers and Smith \(1981\)](#), [Garven and Pottier \(1995\)](#), and Sect. 24.5, herein.

¹⁰[Hetherington \(1969\)](#), [Anderson \(1973\)](#), and [Kreider \(1972\)](#) debate over the implications of these restrictions for policyholder control of mutuals.

promised payoffs under a longer-lived policy. Hence, mutuals should have a comparative advantage in such lines. For instance, in 1993 mutuals generated \$36.5 billion of premium income in ordinary life compared to \$35.6 billion by stocks. However across all property–liability lines, mutuals only generated \$63.3 billion compared to \$162.7 billion by stocks.

Finally, note that the problems of controlling the managers of a mutual-owned stock are similar to that of a mutual; the owners of a mutual-owned stock company are ultimately the policyholders of the parent mutual. This implies that mutual-owned stock companies should have a comparative advantage in the same lines as mutuals.

24.2.3 *Reciprocal Associations*

Although reciprocal insurance associations appear similar to mutuals (in that the customer and owner functions appear to be merged) there are potentially important differences. A reciprocal is unincorporated with no capital as such, while mutuals are incorporated with stated capital and surplus. In a reciprocal, the policyholders appoint an individual or a corporation as an attorney-in-fact to operate the company, while in a mutual policyholders elect a board of directors to oversee the management of the company.

Further, the reciprocal provides cooperative insurance in which individual subscribers assume their liability as individuals.¹¹ A separate account is generally established for each subscriber, and subscribers can be required to accumulate reserves (typically equal to between two and five annual premiums) before becoming eligible to receive underwriting earnings. Not all reciprocals operate on a separate accounts basis; the subscriber agreement sometimes simply provides for dividends at the discretion of the attorney-in-fact (see Reinmuth 1967, p. 31). Where reserves are fully allocated, the sum of the individual reserve accounts plus the current premiums represent the funds held by the reciprocal. However, generally the reciprocal maintains additional surplus. For example, Norgaard (1964) indicates that unallocated surplus existed in 39 out of 44 reciprocals in his sample. Beyond reserves, reciprocals sometimes retain the option to levy an (limited) assessment.

The manager of a reciprocal, the attorney-in-fact, is usually appointed by the policyholders with an advisory committee, which has control responsibility, representing the members of the association.¹² Some reciprocals, however, are organized and initially financed by corporate attorneys-in-fact who provide a “guaranty surplus,” which is an interest-bearing note (Reinmuth, p. 141). In these cases, the structure of the reciprocal is like that of a closely held stock company, with the manager and owner function effectively residing with the corporate attorney-in-fact.

Even though the management function can be quite similar to that in a common stock insurance company, the insurance policies tend to differ; reciprocals more frequently issue what amount to participating, assessable policies. Thus, depending on the structure of the reciprocal, the owner–manager control problems can be similar to that of either a mutual insurance company or a closely held stock insurance company.

¹¹Reinmuth (1967, p. 32) states, “Those reciprocals operating on a separate account basis usually provide in the subscriber’s agreement for the accumulation of a ‘contingency surplus’ by withholding a stated percentage of each subscriber’s deposit premium or ‘savings’ which will not be available on withdrawal.”

¹²This is really an oversimplification. The management of a reciprocal is appointed by each policyholder through the subscriber’s agreement or power of attorney. Thus, whether a subscriber has voting rights depends on the terms of the subscriber’s agreement. The job of management can in fact be proprietary. If it is, the subscriber usually has the right to vote for an advisory committee, which may or may not have the right to replace the manager. For further discussion, see Reinmuth (p. 15–16).

The owner–manager control problem is potentially more severe in a reciprocal than in either closely held stocks or mutuals because individual subscribers may be required to leave reserves at risk. Of course, the policyholders’ option to withdraw this capital is also a potentially important disciplining mechanism. While policyholders of stock or mutual insurance companies also can withdraw patronage as a disciplining device, this mechanism should be more effective for reciprocal subscribers if their subscriber agreement stipulates the return of surplus. Reinmuth (p. 32) reports, “Those reciprocals operating on a separate account basis usually provide in the subscriber’s agreement for the accumulation of a ‘contingency surplus’ by withholding a stated percentage of each subscriber’s deposit or ‘savings’ which will not be available on withdrawal.”

Another control device that reciprocal policyholders have is the potential to discipline management by forced dissolution of the association through the courts.¹³ This is apparently more easily accomplished for reciprocals than for mutuals due to the courts’ interpretation of the nature of an association as opposed to a mutual corporation. In this regard, Reinmuth suggests that the reciprocal can be considered a “trust for a purpose.”

In sum, it is difficult to classify the managerial-control problems of reciprocals. The managerial-control problems can vary from reciprocal to reciprocal and can be similar to that of a mutual insurance company or that of a closely held stock insurance company. Only the rather weak statement that managerial discretion in a reciprocal should be somewhere in between that of these two alternative organizational forms appears appropriate.

24.2.4 *Lloyds Associations*

In a Lloyds, syndicates of members typically underwrite policies; members are then personally responsible for that portion of the risk underwritten. Thus, since individual underwriters are the insurers, this organizational form merges the manager and owner functions. By merging these functions, incentive problems between managers and owners are naturally controlled. However, this benefit comes with potentially substantial costs. Merging the manager and owner functions reduces gains from specialization as well as raising expected costs of opportunistic actions with respect to policyholders.

Underwriting through syndicates also raises problems of controlling intra-syndicate conflicts. Typically, members have relatively specialized roles within the syndicate; in some cases the organization looks like a partnership with general partners making most decisions and limited partners primarily supplying capital. And while syndicate managers historically were also underwriters, there has been a shift to syndicates run by professional managers. In general, the costs of controlling intra-syndicate conflicts are reduced through (1) mutual monitoring, which controls potential problems among syndicate members as well as problems between owners and policyholders (since syndicate members have few liability limitations included in the contracts, they have incentives to monitor syndicate decisions); (2) restrictions on membership through net worth requirements, mandatory audits, and constraints on the size of commitments in relation to the capital individual members may undertake; (3) the central guarantee fund posted by the members, which acts like a bond; and (4) stable

¹³As reported by Reinmuth, (p. 36): “It would appear that the subscribers of a reciprocal have the power to request a court of equity to dissolve the exchange. In *McAlexander v. Waldschrider* it was held that a court of equity, at the suit of a subscriber, had the power to appoint a receiver for a reciprocal insurance ‘fund,’ upon allegations that the fund was being mismanaged and dissipated by the attorney-in-fact. The receiver was directed to manage, disburse and liquidate the ‘fund’ so as to do justice to all parties in interest under their contract. In *Irwin v. Missouri Valley Bridge and Iron company*, a case involving a similar set of facts, the court reached a similar conclusion.”

syndicates, implying a form of long-run implicit contract. (The differential application of these control mechanisms helps explain reputational difference between London and American Lloyds.)

Thus there are costs and benefits of the Lloyds organizational form. Because the benefits largely stem from controlling the incentive problem between managers and owners, [Mayers and Smith \(1981\)](#) argue that Lloyds associations should have a comparative advantage in writing insurance where managerial discretion in rate setting is important—for example, in insuring against unusual hazards.¹⁴

Within the population of common stock insurance companies, managers are frequently major stockholders. Since merging the manager and owner functions reduces control costs that arise if they are separate, in this respect, a closely held stock insurer is like a member of a Lloyds association. The more complete the merger of owner and manager functions, the greater the internalization of the wealth consequences of the manager's decisions. Thus like Lloyds, closely held stocks should have a comparative advantage in writing insurance where discretion is important.

24.3 Determinants of Organizational Form

24.3.1 *Economic Darwinism and Organizational Efficiency*

[Mayers and Smith \(1981\)](#) suggest that the long-run coexistence of various organizational forms implies that none of the basic structures is inherently inefficient. To arrive at this conclusion, they rely on the concept of economic Darwinism and the survivorship principle.¹⁵ Charles [Darwin \(1859\)](#), in examining natural history, notes how competition weeds out the less fit. In *On the Origin of Species*, he illustrates the principle of “survival of the fittest,” where the major forces at work are random mutations in organisms and shocks from the external environment (for instance, from changes in climate). In markets, what we call “economic” Darwinism operates similarly through competition to weed out ill-designed organizations that fail to adapt—changes, however, are purposeful and voluntary.

Thus, competition in the marketplace provides incentive for efficient decisions—including organizational decisions. Competition dictates that only those firms with low costs survive. If firms adopt inefficient, high-cost policies—including their organizational form—competition will place pressures on these firms to either adapt or close.

Given the firm's business strategy (including its product mix), its choice of organizational form can have an important impact on profitability and value. An appropriate form not only can lower costs by promoting efficient production but also can boost the prices customers are willing to pay by helping to ensure high-quality production, reliable delivery, and responsive service. Given their presumption of efficiency of alternative forms of organization, [Mayers and Smith \(1981\)](#) analyze the observed distribution of organizational forms within the insurance industry.

¹⁴A good example of a case where risks were changing frequently and managerial discretion was important is marine insurance in the early nineteenth century. [Wright and Fayle \(1928\)](#) report the adjustment of rates by an underwriter at Lloyd's of London. “Take, for example, the year of Trafalgar, and the routes specially affected by movements of hostile fleets. For homeward voyages from the West Indies, the average rate on 76 risk accepted by Mr. Janson during the first quarter of the year was 8^{1/2} per cent. The arrival of Villeneuve's fleet in the West Indies, sent it up to 13^{1/2} per cent, and thence to 15 per cent and over. It touched 16 per cent when he was making for the Channel, but fell to 11 per cent after his indecisive actions with Calder and his return to Cadiz.”

¹⁵See [Alchian \(1950\)](#) and [Stigler \(1957\)](#). [Fama and Jensen \(1983\)](#) suggest this survivorship principle: that “the form of organization that survives in an activity is the one that delivers the product demanded by customers at the lowest price while covering costs.”

24.3.2 *Managerial Discretion and the Choice of Organizational Form*

Because managerial-control mechanisms differ across organizational forms, the discretion authorized management also should differ. Moreover, variation in managerial decision-making authority implies that different organizational forms have a comparative advantage in different activities. [Mayers and Smith \(1981\)](#) argue that mutuals should have a comparative advantage in activities which require the lowest managerial discretion, while Lloyds should have a comparative advantage in activities which require the highest.

[Mayers and Smith \(1988\)](#) test this managerial-discretion hypothesis employing cross-sectional data; they document variation in product specialization across organizational forms in the property–liability insurance industry. Their evidence is consistent with the managerial-discretion hypothesis; it suggests that Lloyds operate in the highest discretion lines, followed by stocks and reciprocals, with mutuals in the lowest discretion lines. They also find that stocks operate on a geographically less concentrated basis than Lloyds, mutuals, or reciprocals.

[Pottier and Sommer \(1997\)](#) examine the managerial-discretion hypothesis using data from life insurers. They document systematic differences between stock and mutual life companies consistent with the managerial-discretion hypothesis, but their results are weaker than those in studies using property–liability company data. However, if the variation in required managerial discretion is lower among life companies than property–liability companies, the power of their tests also is correspondingly lower.¹⁶

[Lamm-Tennant and Starks \(1993\)](#) test the managerial-discretion hypothesis by examining insurer activity choices using panel data. They measure underwriting risk by the variance of the loss ratio. Their evidence indicates that, compared to mutual insurers, stocks write more business in lines with higher underwriting risk. [Kleffner and Doherty \(1996\)](#) examine underwriting of catastrophic earthquake insurance. They find that stock insurers underwrite more earthquake insurance than mutuals.¹⁷ If managerial-discretion requirements are greater when underwriting risks are higher, these studies support the managerial-discretion hypothesis.

Yet taxes and regulation vary across organizational forms as well as across states in which the firms do business. For example, [Zanjani \(2007\)](#) notes that the majority of mutual life insurers were established in states that imposed lower capital requirements on mutual than stock life insurers at formation, hence, providing a potential regulatory benefit from structuring the company as a mutual. Tax rules also can vary between stocks and mutuals. Thus, it is unclear how much of the variation documented by [Mayers and Smith](#), [Lamm-Tennant and Starks](#), or [Kleffner and Doherty](#) is attributable to the control-related arguments of the managerial-discretion hypothesis.

To help resolve this identification problem, [Mayers and Smith \(1994\)](#) focus on common stock insurers, which vary widely in ownership structure. At one extreme, the equity is owned by a mutual insurer and, at the other, by a single individual or family. By focusing on variation in ownership across common stock firms, they better control for potential effects of taxes and regulation. And by distinguishing among closely held, widely held, and mutual-owned stock companies, they exploit more texture in organizational form than previous studies, thereby providing a richer understanding of this industry. They argue that the analysis of managerial-control problems of mutuals also applies to stock companies owned by mutuals and that the incentives associated with Lloyd's are similar to those for closely held stock companies. Their evidence indicates that an insurer's activity choices, its

¹⁶[Adams \(1995\)](#) analysis also suffers from this potential problem. Using canonical correlation methods, his examination of 33 New Zealand life insurance companies employing data from a single year finds little support for the managerial discretion hypothesis.

¹⁷[Kleffner and Doherty \(1996\)](#) suggest that ownership structure is important because of stock companies' more ready access to capital.

product lines, are strongly related to ownership structure; in particular, the activities of stocks owned by mutuals are more like those of mutuals and those of closely held stocks are more like those of Lloyds; the activities of widely held stocks fall in between. Hence this evidence is consistent with the hypothesis that different ownership structures have comparative advantage in different lines of insurance.

24.4 Tests of Organizational Efficiency

In several early studies, authors question the efficiency of stock versus mutual or reciprocal organizational forms. For example, Spiller (1972) argues that management exploits its position in a mutual to gain personally at the expense of the firm's other claimholders. Frech (1980) concludes that the "examination of the actual property rights structure of mutual insurers indicates that their owners do not have full property rights. Thus they are expected to perform less efficiently than stock insurers, and that expectation is borne out." Reinmuth (1967) in a study analyzing reciprocals determines that they also are inefficient. Thus, each of these early cross-sectional studies concludes that mutuals and reciprocals are less efficient than stocks.

Cummins et al. (1999) use nonparametric frontier efficiency methods to analyze the efficiency of stock and mutual insurers. They estimate the efficiency of each firm relative to a reference set consisting of all firms with that same organizational form. Their results suggest that stock and mutual firms operate on separate production and cost frontiers; this implies that they employ distinct technologies. Their evidence indicates that the stock technology dominates the mutual technology for producing stock outputs and the mutual technology dominates the stock technology for producing mutual outputs. Their analysis thus provides direct evidence that observed organizational forms are efficient.

A more powerful test of the hypothesis that mutuals are efficient focuses on time-series evidence from firms that switch organizational form from stock to mutual (see Schwert 1981). Mayers and Smith (1986) analyze the impact of switching (mutualizing) on the three major groups of claimholders: managers, owners, and customers. Mayers and Smith examine returns to stockholders, changes in premium income, product mix, policy lapse rates, and management turnover. They conclude that for their sample of firms which change from a stock to a mutual organizational form, on average the change is efficiency-enhancing. Their evidence indicates that growth in premium income does not fall, policy lapse rates do not rise, stockholders receive a substantial premium for their stock, management turnover declines, and there is no material change in product mix. Thus, no group of claimholders systematically loses in this sample of firms that chooses to go through the mutualization process. And if mutuals were inefficient—if the firm were less valuable after the change in organizational form—then at least one of these groups would have to lose. These results also are consistent with rational voting behavior, since stockholders, policyholders, and managers all have effective vetoes of the mutualization plan.

The Mayers and Smith evidence should be contrasted with that of Spiller, Frech, and Reinmuth who conclude that mutuals and reciprocals are inefficient. We believe that this difference in conclusions occurs because the Mayers and Smith time-series examination of changes in organizational form picks up both the additional costs of mutuals associated with less effective control of managers and the additional benefits associated with more effective control of the owner–customer conflict. Cross-sectional tests have more difficulty measuring these additional benefits.

24.4.1 *Environmental Changes and Organizational Efficiency*

There are occasions when the economic environment changes and an organizational choice that had been efficient is no longer. For example, Lee et al. (1997) examine the impact of establishing post-assessment guaranty funds on property–liability insurance company risk-taking. They investigate insurers' portfolio-composition changes that occur around the time state guaranty-fund laws are enacted. Merton (1977) argues that guaranty funds are like put options granted to the insurance firms. To maximize the value of this option, insurers would increase the riskiness of their underlying activities. Yet proponents of guaranty funds have argued that the structure of the funds establishes incentives for competitors to monitor. If such additional monitoring is effective, risk-taking should not increase.

Lee, Mayers, and Smith find that property–liability insurers shift their asset portfolios around the date of guaranty-fund enactments, increasing their holdings of stocks and reducing their holdings of bonds and other assets. Their evidence thus is inconsistent with the hypothesis that the structure of the guaranty funds provides sufficient incentives to control risk-taking in the industry through effective monitoring by either competing insurance firms or regulators. Rather, their evidence is consistent with the hypothesis that because firm's guaranty-fund assessment does not vary with its asset risk, the structure of guaranty funds provides an incentive for increased risk-taking in insurers' investment activities.

The incentives for increased risk-taking differ across organizational forms. When asset adjustments for stock and mutual insurers are investigated separately, the shift to riskier assets following fund establishment occurs only for stock insurers. This supports the hypothesis that stock insurers have stronger incentives to increase investment risk and helps explain the observed higher insolvency rates among stocks than mutuals in the period since 1969. They also find increased risk-taking by stock companies that are owned by mutuals. The bundling of owner and customer claims in a mutual is thus an important factor controlling incentives for increased risk-taking.

This evidence has important implications for survivorship of the mutual form of organization. While the mutual form imposes costs in the form of lost specialization in risk-bearing and limited corporate governance/control mechanisms, this evidence suggests that merging owner and customer functions controls conflicts of interest over investment policy.

The extent to which such an environmental change can impose costs on the firm is limited by the costs of changing organizational form. In fact, a substantial number of insurers have demutualized. Mayers and Smith (2002) examine 98 US property-casualty insurance companies that convert to a stock charter between 1920 and 1990.¹⁸ The evidence indicates that a major motive for conversion is to increase access to capital markets. Furthermore, evidence on the riskiness of firms' operations shows that converting companies began operating more like stock companies prior to conversion.

24.5 Related Organizational Choices

The managerial-discretion hypothesis has implications for other insurer organizational choices, not just organizational form. Studies have examined executive compensation, board composition, distribution system, and risk-management policies.

¹⁸See also McNamara and Rhee (1992), Carson et al. (1998), and Jeng et al. (2007) who examine life insurer demutualizations, and Lai et al. (2008) and Viswanathan and Cummins (2003) who examine both life and property–liability insurer conversions.

24.5.1 *Executive Compensation and Organizational Form*

If mutuals have a comparative advantage in business activities requiring less managerial discretion, then the value of the marginal product of executives of mutual companies should be lower than that of stock-company executives. Therefore, given competitive markets for managers, mutual executives should be paid less and receive less incentive compensation than stock-company executives. But managers of a mutual are not subjected to the same disciplining forces from the market for corporate control as are managers of a widely held stock company. If mutual managers more successfully insulate themselves from competitive market forces than do the managers of widely held stocks, mutual managers' compensation could be higher.

To test these hypotheses [Mayers and Smith \(1992\)](#) examine stock and mutual chief executive officer compensation within the life insurance industry. Their evidence is consistent with the managerial-discretion hypothesis—the compensation of mutual CEOs is significantly lower than that of stock CEOs and the compensation of mutual CEOs is significantly less responsive to firm performance than that of stock CEOs.

Nonetheless, it is possible that mutual CEOs are entrenched and hence extract more total compensation than comparable stock CEOs—not in salary, but through excessive perquisite consumption. Mayers and Smith examine this possibility by exploiting variation in ownership structure across common stock insurance firms. Insurance company subsidiaries can be owned by either a stock or a mutual parent. If subsidiaries have a comparative advantage in business activities similar to those of their parent, then compensation among CEOs of mutual subsidiaries also should be lower than that of CEOs of stock subsidiaries. However, perquisite consumption by subsidiary CEOs should exhibit less variation than that by parent company CEOs so long as control systems between parents and subsidiaries are similar. Mayers and Smith find that, consistent with the managerial-discretion hypothesis, the compensation of mutual-subsidiary CEOs is significantly lower than that of stock-subsidiary CEOs.¹⁹

In their tests, Mayers and Smith assume that the firm's organizational form—although a policy choice and thus ultimately an endogenous variable—can be treated as predetermined with respect to the firm's compensation policy decisions. Under these assumptions, the estimated relations are consistent, conditional on the organizational choice. However this approach faces limitations in identifying the structure of the joint determination of the various policies.

[Milgrom and Roberts \(1995\)](#) examine complementarities among inputs to explain corporate choices of organizational form, technology, and strategy. The standard definition of complementarity in economics states that two inputs to a production process are complements if a decrease in the price of one causes an increase in the use of the other. But Milgrom and Roberts use this term not just in its traditional sense of a relation between pairs of inputs, but also in a broader sense as a relation among groups of activities: several activities are complements if doing more of one activity increases the marginal profitability of each of the other activities. If the activities can be expressed as differentiable functions, this corresponds to positive mixed partial derivatives of the payoff function—the marginal returns to one activity are increasing in the levels of other activities. Their analysis emphasizes that continuity, differentiability, and convexity of the payoff functions are not necessary—only an ability to order the various activities is required.

¹⁹Further evidence on managerial entrenchment among mutual executives is provided by [Bohn \(1995\)](#). He examines CEO turnover for a sample of 93 stock and 168 mutual insurance firms from 1984 to 1992. Inconsistent with the hypothesis that mutual managers are entrenched, he finds that the unconditional probability of CEO turnover is higher in mutuals than stocks (8.3 % per annum compared to 6 %). In addition, he reports that the probability of CEO turnover is related to firm's performance in both stocks and mutuals.

This framework is particularly useful here, where we want to examine various organizational forms, as well as different executive compensation packages, different distribution systems, differences in board of director composition, differences in risk-management activities, and different insurance contract forms. Marx et al. (2001) apply this framework to the joint determination of organizational form and executive compensation. Their critical idea is if choosing a stock organizational form changes the payoffs from adopting a specific executive compensation policy, then organizational form and executive compensation are complements. They derive sufficient conditions under which this complementarity will produce testable restrictions on estimated correlation coefficients, reduced-form coefficients, and structural-equation coefficients. Structural-equation regressions require more information about factors that affect the firm's policy choices. Their analysis thus highlights a basic trade-off between the richness of the underlying theory and the statistical methods to examine the theory.

24.5.2 Board Composition and Organizational Form

Variation in organizational form within the insurance industry affords an opportunity to test hypotheses about the role of board composition in the technology for corporate control. Within the insurance industry, the inalienability of mutual ownership claims restricts corporate-control mechanisms like the external takeover market, capital-market monitoring, and stock-based incentive compensation. These limitations increase the importance of monitoring by outside directors. If these alternate mechanisms are substitutes, mutuals should use more outside directors than stocks. Alternatively, if mutual managers are entrenched, they might use few outside directors to avoid the bother.

Mayers et al. (1997) examine the composition of the board of directors for 345 life insurance companies. Their evidence indicates that mutuals employ a significantly larger fraction of outside directors than do stock companies. This result appears robust; it obtains both in the unadjusted data as well as after controlling for differences in firm size, operating policy, and ownership concentration. Moreover, neither variation in board size nor state laws regulating board composition can explain these results.

They also examine changes in board composition around changes in organizational form. For a sample of 27 life insurance firms that switch from stock to mutual form, they find a significant increase in the use of outside board members. For a sample of 50 property-casualty insurers that switch from mutual to stock charter, they find a significant reduction in the use of outside directors. Board size is unchanged in both samples. This consistency between cross-sectional and time-series evidence helps ensure that the cross-sectional results are not attributable to uncontrolled differences in business operations between stocks and mutuals. Thus, the Mayers, Shivdasani, and Smith evidence supports the hypothesis that outside directors are an important control mechanism.

Monitoring by outside board members and incentive compensation provisions in executive pay packages are alternative mechanisms for controlling incentive problems between owners and managers. This control hypothesis suggests that if incentive conflicts vary materially, those firms with more outside directors also should implement a higher degree of pay-for-performance sensitivity. Mayers and Smith (2010) provide evidence supporting this control hypothesis. They document a relation between board structure and the extent to which executive compensation is tied to performance in mutuals: compensation changes are significantly more sensitive to changes in return on assets when the fraction of outsiders on the board is high.

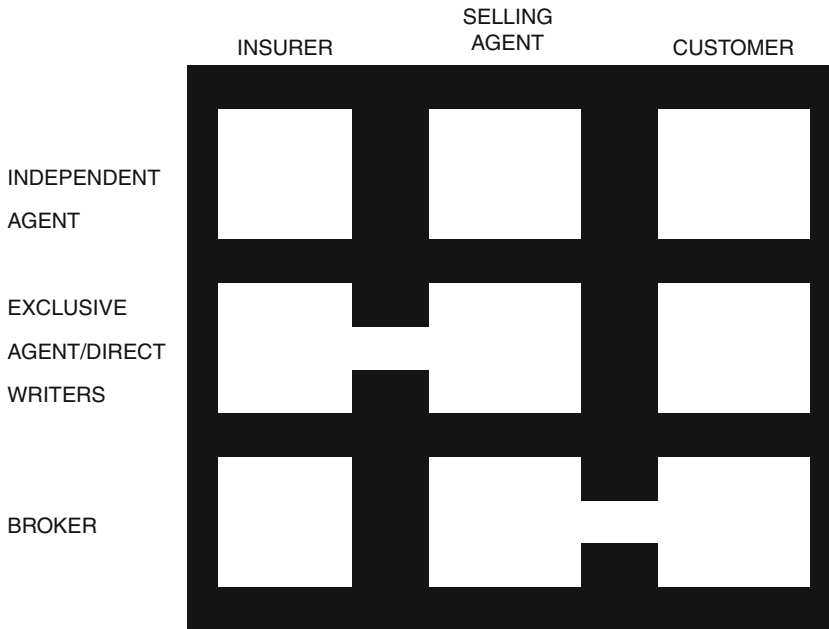


Fig. 24.2 Distribution systems within the insurance industry and the relations among insurer, selling agent, and customer functions

24.5.3 *Distribution System Choice and Organizational Form*

The insurance industry employs a variety of distribution systems: insurance contracts are sold through direct writers, exclusive agents, independent agents, and brokers. In the direct-writer system, the sales agent is an employee of the insurance firm. An exclusive agent also represents a single insurer, yet is not technically the firm’s employee. An independent agent represents more than one insurance company. Finally, a broker represents the customer and negotiates with multiple insurers. Thus, exclusive agents and direct writers are more closely tied contractually to the insurer than are independent agents, while brokers’ interests are more closely aligned with those of their customers than are other agents. These relations are illustrated in Fig. 24.2.

Mayers and Smith (1981) argue that the use of independent agents or brokers better bonds the insurer’s promise to provide services to the policyholder and helps control potential expropriative behavior by the insurer. Thus, the independent-agency system is more valuable for organizational forms where these incentive problems are more severe. In the Kim, Mayers, and Smith analysis, independent agents have a comparative advantage because their knowledge makes them effective in influencing claim settlements and because a threat to switch their business to an alternate insurer is credible.

If the use of independent agents more effectively bonds against policyholder expropriation, the value of an independent-agency system will be higher where the opportunities for expropriation are greater. This should occur in companies with organizational forms and ownership structures that permit more managerial discretion. Therefore, independent agents should be used more frequently by Lloyds and closely held stocks because the value of bonding against opportunistic behavior should be higher for these organizational forms. Conversely, independent agents should be used less frequently by mutuals and mutual-owned stocks because the value of such bonding is lower.

To test this hypothesis [Kim et al. \(1996\)](#) examine a large sample of property-casualty insurance companies. Their evidence is consistent with the managerial-discretion hypothesis. The independent-agency system is more prevalent among Lloyds associations and closely held stock companies, followed in order by widely held stocks, mutuals, mutual-owned stocks, reciprocals, and association-owned stocks. These results obtain either from examining the number of firms employing a particular distribution system or from examining average direct business written by the firms using alternative distribution systems. Thus, for example, more Lloyds associations use the independent-agency system; moreover, the average independent-agency Lloyds writes more business than the average exclusive-agent Lloyds.

[Regan and Tzeng \(1999\)](#) treat organizational form and alternative distribution systems as endogenous policy choices. They find that complex lines of business are more associated with distribution system than organizational form. [Baranoff and Sager \(2003\)](#) also estimate a simultaneous equations system to jointly estimate organizational form, distribution system choice, capital structure, and asset risk. They use life insurance company data from 1993 to 1999. They report a positive relation between stock ownership and brokerage distribution as well as between capital ratios and asset risk. Their evidence suggests that business strategy drives the firms' business decisions. Of course, if the structure that Baranoff and Sager impose to identify their system of simultaneous estimations is correct, they derive more insight into these structural parameters. But if that structure is incorrect, their estimated coefficients are biased. Given our current level of understanding, it is difficult to assess the validity of their assumed structure.

24.5.4 Risk Management and Organizational Form

Incentives for risk management vary with organizational form. [Mayers and Smith \(1990\)](#) examine the determinants of reinsurance purchases. A reinsurance contract is an insurance policy purchased by one insurance company, the ceding company, from another, the reinsurer. Hence, within the insurance industry, reinsurance purchases are like traditional insurance purchases by industrial corporations.

Risk aversion is the primary motive for an individual's insurance purchases; moreover risk aversion can partially explain the demand for insurance by closely held corporations and partnerships. But risk aversion provides a deficient explanation for insurance purchases by widely held corporations. The corporate form is itself a contractual structure with significant risk-management capabilities. Since the corporation's owners, its stockholders, can hold well-diversified portfolios of financial claims, idiosyncratic losses can be managed through diversification. Thus, instead of risk aversion, corporate insurance purchases should be driven by the structure of the tax code, costs of financial distress (including potential investment-incentive effects of a corporation's capital structure), the corporation's organizational form, comparative advantages in real service production, and the composition of corporate managers' compensation packages (see [Mayers and Smith 1982, 1987](#)).

[Mayers and Smith \(1990\)](#) analyze reinsurance purchases for a sample of 1,276 property/liability insurance companies. Their sample includes firms across a broad range of organizational forms—stocks, mutuals, Lloyd's, and reciprocals. They further distinguish among stocks that are widely held, closely held, owned by a single family, owned by a mutual, and owned by an association. Their evidence suggests organizational form matters. Generally, the less diversified the owners' portfolios (the more concentrated is ownership), the greater the reinsurance purchases. Thus, Lloyd's reinsure most, while widely held stocks reinsure least. Moreover, subsidiary and group relations affect the demand for reinsurance. Subsidiaries and group members reinsure more (although their data do not allow distinguishing between intra-group transactions and reinsurance transactions

with external reinsurance companies). They also provide evidence that size, credit standing, and geographic concentration reduce the demand for reinsurance, and weak evidence that line-of-business concentration reduces reinsurance demand as well.²⁰

Shiu (2007) examines risk management by 360 UK insurers by analyzing their use of derivatives contracts. He investigates the relation between derivatives and insurer organizational characteristics using data from 1994 to 2002. He finds limited use of derivatives among the firms in his sample. He does find that use is greater among firms with greater interest rate exposures and among common stock insurers.²¹

24.5.5 Insurance Contracts and Organizational Form

Another way to control the policyholder–stockholder conflict is to issue participating policies (Mayers and Smith 1981; Garven and Pottier 1995). A participating policy gives the policyholder a claim on a fraction of the insurance firm’s accounting earnings. This acts somewhat like a convertibility provision in a corporate bond contract, except that the policyholder has a claim to only current accounting earnings, whereas the convertible bondholder has a claim to the capitalized value of the economic cash flows (Smith and Warner 1979; Mikkelson 1981). To the extent that the firm’s capitalized cash flows and accounting earnings are positively related, the stockholders’ gain from transferring resources to themselves after the sale of the policy is reduced by issuing participating policies.

Thus, participating policies offer stock companies a way to control the policyholder–stockholder problem that is similar to the way mutuals control the problem. This suggests participating policies would be more important in stock companies. In fact, participating policies were first offered, in the United States, by a stock company,²² but they are now more prevalent in mutuals. Garven and Pottier, for a sample of 475 stock life insurers and 109 mutual life insurers in 1991, show that 12.5 % of the stock company business was through participating policies, whereas 94.2 % of the mutuals’ business was through participating policies. In dollar amounts the mutuals had \$4,159 million of participating insurance in force and \$255 million of nonparticipating insurance in force. The numbers are practically reversed for the stock companies.

In a participating policy, higher premiums are charged at the beginning of the period and policy dividends are returned at the end of the period. If the company experiences a shock to surplus during the period, the dividend is reduced. Since mutuals have less effective access to capital markets than stocks, participating policies are more valuable to mutuals in allowing them to better absorb

²⁰Cole and McCullough (2006) examine overall demand for reinsurance by US insurers as well as the utilization of foreign reinsurance. Their analysis supports the prior findings. Their results suggest that the decision to utilize foreign reinsurance is driven primarily by the characteristics of the ceding company.

²¹Shiu’s results are limited by data problems. First, he only has indicator variables [0,1] for the use of derivatives. Second, to the extent that any of the insurers employed hybrid debt or preferred stock to hedge exposures, his data misses those instruments. Third, disclosure has varied over time; some firms report derivatives’ use only if it is material. Finally, even with more detail about the firm’s hedging activities, judging the extent of a hedge is challenging. For example, assume that company A has \$10 million (notional principal) of 3-year interest rate swaps; company B has \$20 million of 3-year swaps. Company A clearly hedges less than either B or C, but company B with C is more difficult. For the next 3 years, B hedges more than C, but for the succeeding 4 years, C hedges more. If we turn to options, the problems become dramatically more difficult—attempting to compare firms with contracts of different size and different exercise prices is quite difficult. In principle, one could estimate the contracts’ deltas, but deltas depend on the prices at which they are evaluated. Such problems limit the power of all empirical work in this area.

²²In 1836, the Girard Life Insurance Annuity and Trust Co. Issued the first participating policy in the United States. A circular issued that year says, “The income of the company will be apportioned between the stockholders and the assured for life, an advantage given in America by this company alone.” (Stalson, 1942, p. 94).

such shocks. In effect, economic leverage is less volatile if the insurer issues participating policies. Thus issuing such policies can help control a form of the underinvestment problem discussed by Myers (1977).

An important cost of the mutual organizational form is less effective control of the owner–manager conflict. One facet of the owner–manager conflict is the managerial-discretion problem labeled the free-cash-flow problem by Jensen (1986). Jensen defines free cash flow as cash in excess of that required to fund all positive net present value projects. If managerial perquisites are positively related to firm size, managers with free cash flow have an incentive to undertake projects that have zero or negative net present value in order to make the firm larger.

Jensen argues that debt reduces the agency costs of free cash flow by reducing the cash available for spending at the discretion of managers. Thus, industrial firms that have large free cash flow should be more highly leveraged to control this problem. Similarly, mutual insurance companies can control this managerial-discretion problem by issuing participating policies (Wells et al. 1995). These policies require the firm to pay dividends that are based on accounting earnings, thus reducing the cash available for unprofitable projects.

The control function of participating policies should be more important in organizations that generate large cash flows but have low growth prospects. Wells et al. (1995) argue that large cash flow and low growth prospects to a large degree characterize the life insurance industry. Since they expect a more severe owner–manager conflict in mutuals, they examine the relation between organizational form and free cash flow. Their results support the joint hypothesis that the managerial-discretion problem is greater in mutuals and that participating policies provide less than complete control—they find that mutual insurers have a greater level of free cash flow than stock insurers.

24.5.6 *Organizational Incentives and Opportunistic Actions*

Most of our attention examines equilibrium variation in efficient contracts. Given that focus, we expect insurer policy choices to cluster into coherent packages. For example, a company specializing in a low managerial-discretion line, like term life, is more likely to be organized as a mutual insurance company, have a relatively low level of executive compensation, use little incentive compensation in the executive compensation package, have a board that is composed primarily of outside board members, distribute policies through direct writers, and engage in limited risk-management activities.

However these policies and contracts also can establish incentives that encourage opportunistic actions. For example, Mayers and Smith (2004) examine the management of accounting information by 63 property–liability insurers that convert from mutual ownership to common stock charter. In the conversion process, policyholders' embedded equity claims must be valued. Since mutuals have no separately traded equity claims, accounting numbers are a critical input in this valuation. The strongest evidence of surplus management is found among firms where the mutuals' executives become the firm's principal shareholders following conversion. The evidence suggests that firms manage accounting information primarily by adjusting liabilities and selectively establishing investment losses—not by altering claims settlement policy.

Browne et al. (2009) note that stock-based compensation creates an incentive for insurance managers to manipulate reserve levels to raise the value of their company's stock. Their evidence suggests that insurance companies whose stock-based executive compensation is more sensitive to the value of their stock report greater under-reserving errors or smaller over-reserving errors than other insurers. Moreover, Eckles and Halek (2010) find that managers who receive no bonuses or bonuses that are likely to be capped tend to over-reserve for current year incurred losses. But managers who receive bonuses that are unlikely to be capped tend to under-reserve for these losses. They also find that firms with managers who exercise stock options tend to under-reserve in the current period.

Wells et al. (2009) examine the market for guaranteed investment contracts (GICs). They report that stock insurance company managers were more likely to engage in a form of asset-substitution which raised firm volatility than were mutual company managers. They find that in the 1980s, life insurers sold GICs to pension plan sponsors and then backed the contracts with portfolios heavily weighted with higher risk assets like common stock and junk bonds.

24.6 Conclusions

Gregor Mendel is generally regarded as the father of modern genetics. Yet this monk's scientific work focused on breeding edible peas in the garden behind his monastery. From peas—dwarfed, tall, smooth, wrinkled, green, yellow—he was to derive the basic laws which make modern genetics the most exact of the biological sciences.

In a sense, the insurance industry offers a laboratory for the study of organizational forms that is like Mendel's garden. Insurance firms exhibit rich variation in their choices of organizational form, executive compensation, board composition, distribution system, risk-management activities, and contract structure. Yet this variation occurs within a single industry. This makes the analysis of this variation more controlled and the likelihood of omitted variables problems lower. And while this industry is important in itself, it is a potentially invaluable springboard for a richer understanding of organizational forms in other industries across the economy.

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Chapter 25

Insurance Distribution

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Abstract This chapter details the use of insurance distribution systems in practice, highlights the theoretical support for the presence of various distribution systems within the insurance marketplace, and discusses public policy and regulatory issues related to insurance distribution. Three important economic issues form the centerpiece of the discussion. The first is the economic rationale for the choice of distribution system and for the variety of distribution systems observed in the industry. The second is the nature of insurer–agent relationships and the role and consequences of alternative compensation methods for intermediaries. The third is the economics of regulatory oversight of insurance distribution. Both the US and international contexts are considered.

25.1 Introduction

Firms in the insurance industry vary along many dimensions, including product distribution systems. A wide variety of distribution methods is used in the industry. Insurance distribution systems span the spectrum from the use of a professional employee sales force, to contracting with independent sales representatives, to direct response methods such as mail, telephone, and increasingly, the Internet. Competitive and technological changes in the financial services industry, including financial services integration, have simultaneously led to greater segmentation of distribution by product and market and to greater use of multiple distribution methods within firms, including the establishment of marketing relationships and alliances with non-insurance concerns such as banks, affinity groups (special interest groups and college alumni associations) and automobile dealers. At the same time, regulatory and judicial pressure has threatened to narrow the range of insurer–producer relationships and compensation systems used in the industry.

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This chapter details the use of insurance distribution systems in practice, highlights the theoretical support for the presence of various distribution systems within the insurance marketplace, and discusses public policy and regulatory issues related to insurance distribution. Because much of the early research literature has focused on the USA, it provides the institutional setting for most of the theoretical and empirical studies discussed; however, many economic issues are common to all countries, and issues in international markets are discussed to the extent existing research and data permit. Additionally, while there have been significant advances in academic research into insurance distribution methods over the past decade, many interesting questions remain unanswered. The approach taken in this chapter is therefore not only to discuss the state of knowledge from existing literature but also to raise questions arising from economic theory regarding areas that need further research.

Our discussion focuses on three major economic issues in insurance distribution. The first is distribution system choice. Much of the research on property-liability insurance distribution has examined aspects of this question. The variety of distribution systems employed in the industry, the differences in contractual relationships across them, and technological advances in advertising and communication suggest that of the choice of distribution system(s) remains an important but evolving issue. In particular, the rise of both the Internet and global call-center outsourcing has made the direct distribution model more appealing for many carriers. Closely linked to this question are issues regarding the nature of insurer–agent relationships. The structure of agent compensation has been an important issue since insurers began offering policies through intermediaries, but recent challenges by regulatory authorities have increased the stakes. Now, not only is the form of compensation important for management but the potential to raise incentives for anticompetitive behavior or consumer deception must also be examined. Thus, we review the research on intermediary compensation, paying particular attention to the value and importance of contingent commission (and similar) arrangements.

Our final focus area is on regulatory oversight of distribution. Stringent state-level regulation of insurance distribution activities has continued in the USA and intensified in Europe with the implementation of the European Commission’s 2002 Insurance Mediation Directive (IMD). Moreover, regulatory oversight has seen wide swings in the past decade, ranging from the Gramm-Leach-Bliley Financial Services Modernization Act of 1999 (GLB), which allowed financial intermediaries of all types to merge and cooperate in production and distribution of financial products, to the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010 (Dodd-Frank). Dodd-Frank is a response to the financial crisis of 2008 and places stringent limitations on many aspects of the financial services industry, including insurance operations for “systemically important” insurers.^{1,2}

The organization of the chapter is as follows. Section 25.2 provides background information and market shares for the various distribution systems employed in the insurance industry. Section 25.3 summarizes the theoretical and empirical literatures on distribution system choice by insurance firms. Section 25.4 discusses economic issues surrounding aspects of commission-based compensation systems in insurance distribution, including contingent commissions and rebating. Section 25.5 describes the regulation of insurance distribution and the potential economic rationales for this regulation. Section 25.6 concludes with a summary of the current state of knowledge and open issues in the economics of insurance distribution.

¹A “systemically important” nonbank financial institution is one whose insolvency is likely to threaten the financial system as a whole. However, no measures have yet been proposed to define the characteristics of such an institution.

²While outside the scope of this chapter, we recognize the importance of the Patient Protection and Affordable Care Act of 2010 (more popularly known as President Obama’s Health Care Reform) for insurance distribution. Significant regulatory change in the health insurance industry will affect health insurance distribution and could have spill-over effects into other lines of insurance.

25.2 Background

Distribution channels may be classified broadly as (1) direct sales through direct mail, call center, and Internet; (2) local agents employed by the insurer; (3) non-employee sales agents who sell for a single company; (4) non-employee agents who sell for more than one company (independent agents); (5) brokers; and (6) bancassurance. The relative importance of each distribution channel varies greatly across lines of insurance, customer classes, and country. Multiple distribution channels coexist within each line of insurance and country; and increasingly, multiple distribution systems are employed within an insurance firm or group.

Direct sales methods use employees to sell and service insurance policies, typically in a call center environment. Employees in the direct sales model field telephone calls and queries by customers responding to a printed advertisement, direct mail, e-mail or Internet advertisement. The direct sales method is most commonly associated with personal auto and residential insurance policies, although several life insurers also employ a direct sales model. While this model continues and provides the majority of business for carriers such as GEICO and Amica in the USA, the Internet has emerged as the primary source of mass marketing policies. By 2008 Internet sales channels accounted for over 15% of automobile insurance purchases in the USA, increasing from 3% in 2007 (ComScore 2008). Direct, including Internet, sales of automobile insurance are also important in the United Kingdom, accounting for 33% of sales in 2001 and growing to 44% by 2006 (CEA 2010).

Employee sales representatives are licensed insurance agents who sell the policies of a single insurer through branch networks. Exclusive agents are not employees of a particular insurer but have a contractual right to offer the products of a single insurer to the public. They are independent from the insurer and are typically small businesses or franchisees with well-specified contractual duties. Exclusive agents (such as agents affiliated with Nationwide, State Farm, and Northwestern Mutual Life) often make significant capital and advertising investments to grow their businesses, but receive some subsidy from the carrier in exchange for their exclusive agreement to sell the carrier's products. In the USA and Europe, exclusive agency is more common than the employee sales model, but employee sales representatives are used in some Asian countries including China and Korea (CEA 2010).

Agents with nonexclusive sales relationships are independent businesses with contractual agreements to sell the products of more than one insurer and can usually make commitments on the insurers' behalf. Independent agents often have authority to bind an insurance policy pending underwriting approval by the carrier (independent agents represent firms including Travelers, Hartford, AIG, and others). In Europe and North America, the independent agency system is populated by fulltime business professionals, but in Asia, agents are often part-time workers affiliated with related non-insurance businesses such as gas stations or car dealerships.³

Similar to independent agents, brokers can sell policies from multiple carriers but have no formal or contractual relationship with carriers; they represent the potential insured as a client. The chief legal distinction between independent agents and brokers in most countries is that brokers have a legal duty to represent the interests of the clients first, while independent agents are the legal representatives of the insurer. However, this legal difference is often blurred and has become more so in the USA since 2004 with the adoption of the Producer Licensing Model Act (PLMA) by a majority of states. Under the PLMA, the regulatory distinction between agents and brokers is eliminated, referring to both as insurance "producers." The same is true in Europe after the adoption of the IMD in 2002, which applies equally to all intermediaries. However, independent agents and brokers often service different markets. In the USA, independent agents typically act as representatives of insurers to personal and

³See, for example, the chapters on Japan and China in Cummins and Venard (2007).

small to mid-size commercial clients. At the same time, brokers represent larger commercial clients with more complex insurance needs, helping them to put together a risk management plan that may include coverage from numerous carriers. In addition, brokers may offer risk management or loss control consulting and other services on a fee-for-service basis. These distinctions are not present in all countries; for example, in Canada and the United Kingdom brokers have a larger share of personal insurance sales than do agents.

Bancassurance, the provision of both banking and insurance products by a single firm, developed in its modern form in France in the 1970s and 1980s (Staikouras 2006). The main examples of successful bancassurance arrangements involve banks entering insurance markets rather than insurers entering banking. One of the key advantages of bancassurance is cross-selling of insurance to bank clients, distributing insurance products via bank branch networks or direct sales techniques. Integration models of bancassurance take many different forms, ranging from true conglomeration in which a bank purchases or starts up an insurer to alliances in which the bank acts only as an exclusive agent for an insurer. Moreover, the integration model used by a bank often evolves over time as it obtains experience and refines its bancassurance strategy. The prevalence of bancassurance varies greatly across countries, in part due to regulatory conditions and barriers to bank-entry into insurance in some countries. Bancassurance is extremely important in several European countries, most notably France, Spain, and Portugal (Wong et al. 2007). In contrast, bancassurance has been slow to develop in the USA. One reason for this may be the regulatory separation between banking and insurance in the USA that was mandated by the Glass-Steagall Act in 1933 (Benoist 2002). Chen et al. (2009) show that the level of financial system deregulation leads to faster growth in bancassurance across countries. Although there was a period of deregulation in the USA beginning in 1999,⁴ renewed financial system regulation post-2008 suggests that bancassurance may not be quick to grow in that market, at least in the near future. Recent regulatory reforms in the USA, Japan, and Korea have enabled greater integration of life insurance and property-liability insurance sales, but strong restrictions still exist in other countries including Canada (Cummins and Venard 2007).

Perhaps because the life and property-liability insurance industries developed separately in most countries, distribution systems in these two branches of the industry often differ significantly.⁵ Although globalization and integration trends have led to insurance firms combining and insurance agencies expanding their product offerings across these traditional industry boundaries, important differences remain between property-liability and life insurance. The contractual relationships between agents and insurers and the functions of agents often differ substantially in the property-liability insurance industry compared to the life insurance industry. These differences have implications for the relative efficiency of different distribution systems and for the relative market shares of distribution systems in the two industry sectors. For these reasons, it is customary and useful to examine property-liability and life insurance distribution systems separately.

25.2.1 *Property-Liability Insurance*

Historically, property-liability insurance has been sold primarily by professional agents. Independent agents (including brokers) and agents tied to a specific insurance firm (whether via employment or exclusive contract) together account for the vast majority of the direct premium revenues of the

⁴The Gramm-Leach Bliley Act of 1999 allowed commercial banks, insurers, and investment banks to operate as conglomerates under a financial holding company structure.

⁵For example, in the USA, regulations prohibited an insurance firm from selling both property-liability and life insurance until the 1940s (Huebner et al. 2000).

Table 25.1 Market shares by distribution system, US property/liability insurance, 2009

| | Independent agency | Broker/MGA | Direct | Captive agent | Total |
|--------------------------------|--------------------|------------|--------|---------------|---------|
| <i>Personal lines</i> | | | | | |
| Auto Physical Damage | 32.17% | 2.52% | 24.63% | 40.17% | 99.49% |
| Auto Liability | 30.49% | 2.47% | 26.03% | 40.64% | 99.63% |
| Homeowners Multiple Peril | 33.00% | 3.51% | 13.76% | 48.55% | 98.82% |
| <i>Commercial lines</i> | | | | | |
| Commercial Multiple Peril | 64.81% | 13.19% | 5.92% | 14.14% | 98.06% |
| Workers Compensation | 64.33% | 18.41% | 13.91% | 2.63% | 99.28% |
| General Liability: Occurrence | 66.08% | 23.90% | 5.87% | 2.29% | 98.14% |
| General Liability: Claims Made | 34.35% | 65.56% | 0.09% | 0.00% | 100.00% |
| Fire | 41.72% | 39.75% | 12.85% | 2.88% | 97.20% |
| Ocean Marine | 53.39% | 43.68% | 0.49% | 0.00% | 97.56% |
| Inland Marine | 55.97% | 16.58% | 22.97% | 3.85% | 99.37% |
| Boiler Machinery | 20.52% | 24.76% | 50.03% | 0.00% | 95.31% |
| Allied Lines | 49.36% | 26.72% | 12.29% | 5.59% | 93.96% |

Source: Best's Insurance Reports, 2010. Direct written premiums by writing company market share. Percentages may not add to 100% due to unreported small distributions systems

industry throughout most of the world (CEA 2010; Skipper 1998). However, the direct sales model, hampered in the past by high initial investment and significant communication costs, has grown dramatically in response to sharp reductions in the cost of communication. This is especially true for personal lines of insurance.

25.2.1.1 Market Shares in the USA

The 2009 US market shares of insurers using independent agency, brokerage, direct marketing, or exclusive agency distribution methods are reported in Table 25.1. The table reports the shares of direct premium revenue by these four major distribution systems for selected personal and commercial lines of property-liability insurance. The data are constructed from direct premiums reported at the individual company level, and each firm is catalogued according to its primary distribution system.⁶ Note that since some companies use more than one distribution method, the table does not provide an exact apportionment of premiums by distribution system. However, this problem is minimized by reporting at the individual firm level rather than by consolidated insurance firms (known as *groups*), because individual firms within groups may use different distribution methods.⁷

The table documents that independent agency companies have the largest market share overall in most commercial lines, while captive agents hold the largest market share in personal lines. There are significant variations in market shares across line of insurance, however. Independent agency firms dominate the commercial insurance lines, except in the claims-made general liability line. Broker distributors also achieve their greatest market penetration in the commercial lines, most notably in claims-made general liability, with significant penetration in the fire and ocean marine lines. Over 60% of the personal lines market is written by direct or exclusive agency firms, with very little sold through broker-based firms.

⁶The classifications are taken from A.M. Best Company's *Best's Insurance Reports*.

⁷Market share figures do not add to 100%, as there are small shares of premium volume written by firms using other primary distribution systems (general agents or mass marketing), which are not reported here.

The charts presented in Fig. 25.1 illustrate the relative changes in distribution since 2004. Figure 25.1a shows the increasing importance of captive agents and direct marketing in personal lines over the past few years, and the slow downward trend for independent agents.

Figure 25.1b demonstrates more pronounced changes since 2004 in the commercial lines, with brokers gaining market share in commercial multiple peril, ocean marine and allied lines. However, despite the shifts, independent agency firms continue to dominate the commercial lines.

25.2.1.2 Market Shares Around the World

Non-life insurance distribution market shares in selected countries around the world are reported in Table 25.2. While these data are not as current (data for Canada and Europe are from 2006 and data for Asia are 2004), they are the latest available worldwide comparisons that include all distribution systems. The main finding of note in the table is the significant variation across countries. Agents dominate in Germany, Italy, Portugal, Poland, and Turkey in Europe, and in Taiwan and Malaysia in Asia. Brokers dominate in Canada, the United Kingdom and Belgium. Direct selling dominates in France, and is the second most prominent distribution method in the United Kingdom, Malaysia, and Poland. A distribution method not present in the US statistics is bancassurance, which is described more fully in the introduction to this section.⁸ Among the 12 countries included in the table, bancassurance accounts for over 10% of non-life insurance sales in five (Germany, UK, Portugal, Turkey and Malaysia).

More recent and detailed data are available on insurance distribution methods in the European Union, specifically. Recent trends are consistent with the data reported in Table 25.2. In 2009, agents and brokers continue to sell most of the non-life insurance, although direct sales are more prominent in some European Union member states including France, Netherlands, Malta, and Croatia (CEA 2011). Bancassurance remains an important presence but market shares remained around 10% or under in all countries (CEA 2011). According to PwC Luxembourg (2011) the broker model is most prominent in western Europe, the agency model is most prominent in southern and eastern Europe, and direct writers are making gains in central Europe in recent years.

25.2.2 Life Insurance

As in property-liability insurance, distribution via professional agents is the dominant form of life insurance sales. In most countries, including the USA, Canada, Germany, and Japan, the majority of life insurance agents are either employees or exclusive agents who sell the products of only one company. However, some countries, including the United Kingdom, continue to rely most heavily on brokers and financial service advisors. Mass-marketing companies are making significant inroads in some countries, and the sale of life insurance products through banks has grown substantially in recent decades. The latter trend began in Western and Southern Europe, and bank sales now represent over two-thirds of life insurance premiums in France, Italy, Spain, and Portugal (CEA 2010). Bancassurance has expanded rapidly in Asia since 2000 and accounts for over 25% of life insurance sales in China, Malaysia, and Singapore.⁹ In the USA, banks involved in life insurance typically act as agents for a single insurer and accounted for \$1.3 billion in new individual life premium volume in 2009, equal to almost 2% of the market (Insurance Information Institute 2012).

⁸Some banks in the USA have begun operating independent agencies, but our data do not allow us to identify this model's penetration.

⁹Statistics for China are from Sun et al. (2007); those for Malaysia and Singapore are from Wong et al. (2007).

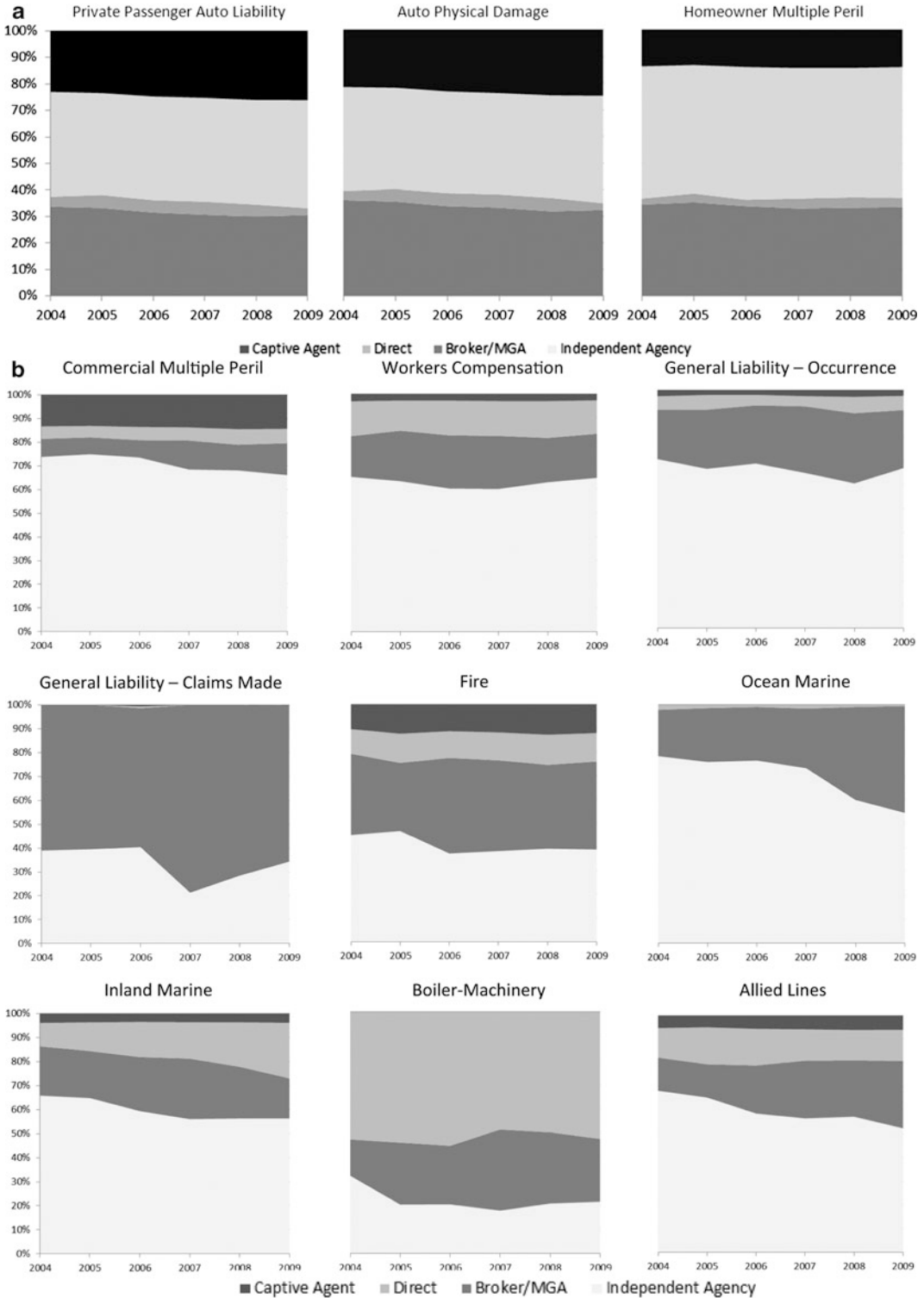


Table 25.2 International non-life insurance distribution market shares

| | Agents | Brokers | Bancassurance | Other (incl direct) |
|----------------|--------|---------|---------------|---------------------|
| North America | | | | |
| Canada | 18.0% | 74.0% | 0.0% | 8.0% |
| Europe | | | | |
| United Kingdom | 4.0% | 54.0% | 10.0% | 32.0% |
| France | 35.0% | 18.0% | 9.0% | 38.0% |
| Germany | 57.0% | 22.0% | 12.0% | 9.0% |
| Italy | 84.2% | 7.6% | 1.7% | 6.5% |
| Spain | 39.5% | 28.3% | 7.1% | 25.2% |
| Belgium | 10.1% | 65.6% | 6.1% | 18.2% |
| Portugal | 60.7% | 16.7% | 10.0% | 12.6% |
| Poland | 58.2% | 15.7% | 0.6% | 25.5% |
| Turkey | 67.5% | 7.8% | 10.0% | 14.7% |
| Asia | | | | |
| Taiwan | 62.0% | 30.0% | 0.0% | 8.0% |
| Malaysia | 40.0% | 23.0% | 10.0% | 27.0% |

Source: SwissRe, 2007; Canadian and European data are for 2006; Asian data are for 2004. Other distribution forms include other distributors, including automobile dealers and multilevel marketing programs

The differences across life insurance distribution systems in the USA are less pronounced than those in property-liability insurance. Importantly, in life insurance there are no differences regarding ownership of policy renewals, with the insurance company typically retaining ownership under all systems (Baranoff and Sager 2003). However, there are differences in the degree of vertical control of the distribution system. Insurers may operate an exclusive agency system in which independent contractors are contractually bound to sell the products of only one insurer. This is commonly called the career agency system, in which the insurer invests heavily in recruiting and training a dedicated sales force. The career agency force may be directly managed by the insurer through a branch office network, or through non-employee managing general agents who operate with the authority of the insurer. Life insurers may also be represented by independent agents or brokers with nonexclusive representation contracts. In this case, the insurer’s control of the distribution channel is much looser and the insurer does not invest in agency building.

25.2.2.1 Market Shares in the USA

US life insurance market shares by distribution system are presented in Table 25.3. The table shows the share of total premiums generated by each distribution system for each major product category in 2009. The data are constructed from reports at the individual writing company level, and each firm is catalogued by its primary distribution system. It should be noted that although most firms do have

Fig. 25.1 (a) Market Shares by Distribution System—US Personal Lines Property/Liability Insurance. *Source:* Best’s Insurance Reports, 2003–2010. Direct written premiums by writing company market share. Premiums are summarized according to writing company primary marketing type. Excludes bank marketing and other marketing forms not otherwise classified. (b) Market Shares by Distribution System—US Commercial Lines Property/Liability Insurance. *Source:* Best’s Insurance Reports, 2003–2010. Direct written premiums by writing company market share. Premiums are summarized according to writing company primary marketing type. Excludes bank marketing and other marketing forms not otherwise classified

Table 25.3 Market shares by distribution system, US life insurance, 2009

| | Independent/broker | Career/exclusive agent | Direct |
|---------------------------|--------------------|------------------------|--------|
| <i>Insurance in force</i> | | | |
| Group life | 50.17% | 28.64% | 6.66% |
| Industrial life | 56.22% | 42.57% | 0.32% |
| Term life | 56.35% | 9.27% | 29.10% |
| Whole life | 65.95% | 19.70% | 8.36% |
| Ordinary life | 59.09% | 12.25% | 23.18% |
| Total life | 56.42% | 17.07% | 18.33% |
| <i>New business</i> | | | |
| Group life | 58.34% | 17.20% | 9.24% |
| Industrial life | 62.25% | 0.00% | 29.71% |
| Term life | 76.77% | 13.12% | 6.05% |
| Whole life | 73.18% | 17.27% | 4.87% |
| Ordinary life | 75.83% | 14.20% | 5.74% |
| Total life | 68.65% | 15.06% | 7.82% |

Source: Best's Insurance Reports, 2010. Direct written premiums by writing company market share. Percentages may not add to 100% due to unreported small distributions systems

a primary distribution system, it is relatively rare for a life insurance firm to use a single distribution method for all products and markets (Carr 1997). Hence, the market share data reported here is only an approximation of true premium shares by distribution system.

The top portion of the table shows market shares of insurance in force (total premiums). Based on this measure, the most prevalent method of distribution is the independent agency/ brokerage system. Career and exclusive agency firms have a 17% market share overall; noncareer (independent) agency distributors hold a 56% market share, and mass marketing insurers take the remaining 18%. Group and industrial life are more strongly represented by career and exclusive agents while credit and term life have the strongest direct presence.

Total premium volume represents premiums collected in a particular year, irrespective of when the original policy was sold. Due to the long-term nature of most policies in this industry, these data overstate the share of current sales for a distribution system experiencing market share declines and understate the share of current sales for a distribution system experiencing market share gains (Fig. 25.2). To provide better evidence on market shares of current sales and to provide some insight into market share gainers and losers, the bottom portion of Table 25.3 presents the market shares of each distribution system using new premium volume rather than total premium volume. New premiums are those arising from the sales of new policies in the reported year (Fig. 25.3).

These data show that, relative to the share of total premiums, independent agency insurers achieve a greater share of new annuity premiums, especially group annuities. In group annuities, the independent agency insurers' share of new premiums is 62.1%, although the share of total premiums is only 22.1%. This increase comes solely at the expense of the career agency system, with the new premiums market share of mass marketers also slightly higher than their share of total premiums. However, both the career agency and independent agency systems achieve higher shares of new premiums than of total premiums in the individual annuity market, with mass marketers experiencing a decrease. The market shares of new premiums and total premiums in life insurance lines are relatively constant for all distribution systems, except in group life and credit life, where mass marketer shares of new premiums are higher. This increase comes primarily at the expense of the independent agency

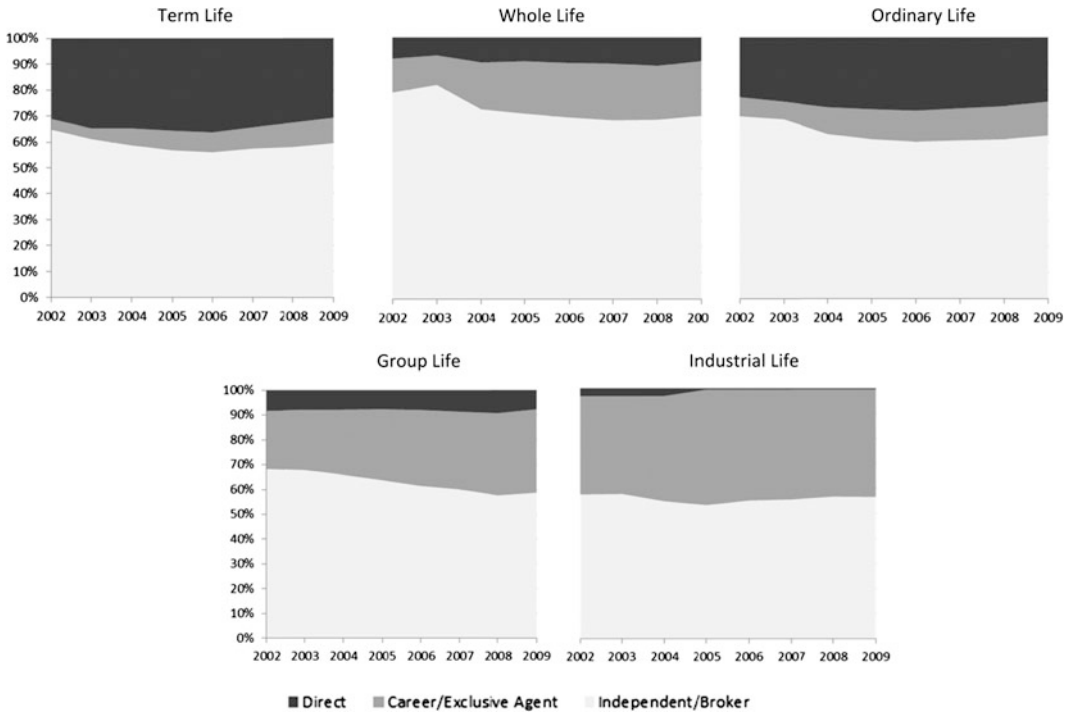


Fig. 25.2 Market Shares by Distribution System—US Life Insurance in Force. *Source:* Best’s Insurance Reports, 2003–2010. Insurance in force written premiums by writing company market share. Premiums are summarized according to writing company primary marketing type. Excludes bank marketing and other marketing forms not otherwise classified

system. Taken together, these findings indicate that market shares for annuities are more fluid than market shares in traditional life insurance products, with the career agency system losing market share to the independent agency and mass marketing distribution systems in annuities markets.

25.2.2.2 Market Shares Around the World

Table 25.4 reports market shares for life insurance distribution systems in selected countries around the world. As previously, these data are a number of years old and represent the entire life insurance sector, but are presented to show variations across countries. The most striking feature of the table is the importance of bancassurance in some countries. Bancassurance has the largest share of the life market in France, Italy, Spain, Belgium, and Portugal and has a significant presence in both Taiwan and Malaysia. In four of these countries (France, Italy, Spain and Portugal), bancassurance accounts for well over 50% of the market. Traditional agent and broker distribution channels continue to dominate life insurance sales in Canada, United Kingdom, Germany, and Malaysia. Other/direct methods of distribution are prevalent in Poland, Turkey, and Taiwan.

More recent data on life insurance distribution for the European Union countries are available and confirm the importance of bancassurance there. Market shares in most countries remain similar to those reported in Table 25.4 (PwC Luxembourg 2011). One exception is Poland, where the market share of bancassurance rose to 44% by 2008. For the EU as a whole, in 2008 bancassurance accounted for 33% of life insurance sales, agents and brokers accounted for 44%, and direct/other selling methods accounted for 23% of sales (PwC Luxembourg 2011). Nonetheless the future of the bancassurance model in Europe is uncertain in the aftermath of the 2008 financial crisis, as regulators

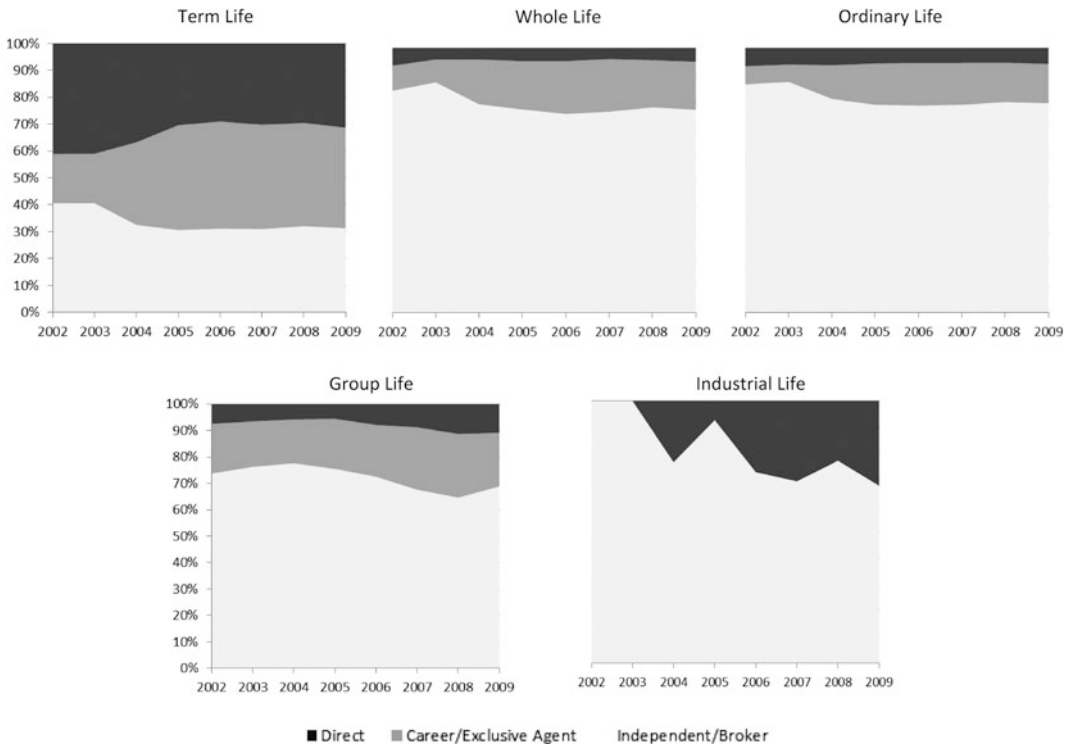


Fig. 25.3 Market Shares by Distribution System—US Life Insurance New Business. *Source:* Best’s Insurance Reports, 2003–2010. New business written premiums by writing company market share. Premiums are summarized according to writing company primary marketing type. Excludes bank marketing and other marketing forms not otherwise classified

have forced some large banks to divest their insurance business. Similarly, in emerging markets in Asia and Latin America the rapid growth in bancassurance since 2000 appears to have leveled off after 2008, with other distribution channels gaining market share (Kalra 2011).

25.3 Distribution System Choice

There is a large academic literature focused on questions regarding the relative efficiency or optimal choice of insurance distribution system. There are two distinct bodies of literature. The first, a largely empirical literature, compares the relative efficiency (costs or profitability) of different distribution systems. The second literature applies economic reasoning to explain insurers’ choice of distribution system(s) in light of the coexistence of different systems. The vast majority of studies have been undertaken in property-liability insurance rather than life insurance,¹⁰ but a more recent literature examines distribution systems in life insurance. We begin with a summary of the findings of the studies of relative efficiency of distribution systems and then discuss the theoretical explanations regarding the relative advantages of the different distribution systems in different market contexts.

¹⁰This is probably due to the greater differences in organizational relationships between firms and agents under the property-liability systems. Moreover, the historical development of property-liability distribution systems in relation to the regulation of rates in this industry has made these differences starkly apparent.

Table 25.4 International life insurance distribution market shares

| | Agents | Brokers | Bancassurance | Other (incl direct) |
|----------------|--------|---------|---------------|---------------------|
| North America | | | | |
| Canada | 60.0 | 34.0 | 1.0 | 5.0 |
| Europe | | | | |
| United Kingdom | 10.0 | 65.0 | 20.3 | 32.0 |
| France | 7.0 | 12.0 | 64.0 | 17.0 |
| Germany | 27.1 | 39.4 | 24.8 | 8.7 |
| Italy | 19.9 | 9.4 | 59.0 | 11.7 |
| Spain | 15.4 | 5.4 | 71.8 | 7.4 |
| Belgium | 3.2 | 26.5 | 48.0 | 22.3 |
| Portugal | 6.9 | 1.3 | 88.3 | 3.5 |
| Poland | 39.7 | 4.3 | 14.4 | 41.6 |
| Turkey | 30.1 | 0.8 | 23.0 | 46.2 |
| Asia | | | | |
| Taiwan | 11.7 | 6.6 | 33.0 | 48.7 |
| Malaysia | 49.4 | 2.4 | 45.3 | 2.9 |

Source: SwissRe, 2007; Canadian and European data are for 2006; Asian data are for 2004. Other distribution forms include other distributors, including automobile dealers and multi-level marketing programs

25.3.1 Relative Efficiency

Perhaps no other distribution issue has been more thoroughly examined than the relation between distribution model choice and insurer cost and profit. Although most research has shown a persistent difference in costs across distribution models, results regarding profitability and revenue efficiency vary.

25.3.1.1 Property-Liability Insurance

In the property-liability insurance industry, comparative studies of insurance distribution systems typically group the various systems into two main categories, based upon the degree of vertical control of the sales force. The two broad categories analyzed are “direct writer” (tied agency) and “independent agency.” The direct writer category encompasses mass marketing, the use of employee sales agents, and exclusive agents. The independent agency category encompasses both the independent agency system of marketing and the use of insurance brokers. The earliest studies use data on insurance firms or groups to estimate regression models of insurer average variable costs, incorporating a dummy variable to distinguish firms with different distribution systems. In these studies, if insurers offer homogeneous products and use identical production technologies, a coefficient estimate on the dummy variable significantly differing from zero implied average cost differences across the two distribution systems.¹¹

Joskow (1973) was the first to study this relationship, finding that expense ratios of insurers using the direct model in 1971 and 1972 were approximately 11% lower than those of insurers using independent agency. More recent studies have examined cost differences for later time periods, and incorporate model specification and data refinements to Joskow’s basic analysis. Cummins and VanDerhei (1979), for example, found that total variable costs (including loss adjustment

¹¹See Braeutigam and Pauly (1986), for a critique of this methodology when insurance products are not homogeneous.

expenses) were borne by independent agents often enough to produce apparent differences in costs if measured by the expense ratio. They also estimate log-linear models of costs premised on a Cobb-Douglas production function. Barrese and Nelson (1992) recognized that many carriers use multiple distribution systems and incorporated this feature as a combination of continuous and discrete variables: the percentage of an insurance group's premiums obtained from independent agents, with an additional dummy variable for groups using direct mail methods or salaried employee distributors. They also test whether incurred losses vary by distribution type.

Even with these refinements, both sets of authors find results consistent with Joskow's. Direct writers have lower average costs both overall and for automobile physical damage insurance separately, and the results hold under both linear and log-linear model specifications. These studies also find no significant decline in the direct writer cost advantage over time. Cummins and VanDerhei use data for the time period 1968–1979, and Barrese and Nelson use data for the period 1978–1990; neither study finds evidence that the cost difference across distribution systems is smaller in the later years of their respective sample periods.

Regan (1999) extends this type of analysis to a much larger sample of firms and analyzes a larger variety of property-liability insurance lines. In regression models of underwriting expense ratios for personal automobile liability, personal automobile physical damage, homeowners' multi-peril, commercial multi-peril, workers compensation and general liability insurance for 260 firms in 1990, Regan finds that direct writer cost advantages differ significantly across lines. Direct writers' expense ratios are significantly lower than those of independent agency firms in homeowners and commercial multi-peril insurance, but not in the other lines of insurance examined. Consistent with previous studies, however, her results show that direct writers have significantly lower expense ratios when all lines of business are combined.

Rather than testing for differences in expense ratios, Berger et al. (1997) use frontier efficiency analysis to examine differences in both cost and profit efficiency across property-liability insurance distribution systems.¹² Their estimation methodology improves over previous studies by allowing for efficiency differences across individual firms rather than simple intercept shifts between direct writer and independent agency firms on average, and by estimating a multi-product cost function derived from economic theory. Consistent with the results from earlier studies, these authors find that independent agency insurers are significantly less cost efficient than direct writers. However, they find no significant differences in profit efficiency across the two distribution systems.¹³ The authors interpret this finding to indicate that product quality or service differences underlay distribution system coexistence, reasoning that such differences will be manifested in costs but not in profits.

However, a study by Brockett et al. (2005) uses data envelopment analysis (DEA) to examine relative efficiency across distribution models and ownership forms (stock versus mutual). Their results suggest that independent agency insurers are generally more efficient than direct insurers, but organizational form is important as well. They find that stock companies are more efficient than mutual companies and that agency insurers are more efficient than direct insurers. Agency insurers are also more efficient for the subset of firms that are classified as stockholder-owned, but direct writers are more efficient for mutual insurers. This finding suggests that there are some combinations of ownership form and distribution system that may be strategic complements. In particular, stock firms seem to be more efficient with agency distribution while mutual firms appear more efficient under direct distribution. Other combinations are reported in Table 25.5.

¹²See Chapter 12 of this volume for an in-depth discussion of this methodology.

¹³An earlier study by Cather et al. (1985) compared the mean accounting profitability levels of 68 insurance groups for each year in the time period 1975 to 1982 and also found little evidence of profitability differences across firms using different distribution systems.

Table 25.5 Strategic complements: organizational form and distribution

| Mann-Whitney Rank Statistic Results Concerning Group Efficiency Differences | | | | | |
|---|------------------|-------------------|--------|--------------|---------------------------------------|
| No. | Subgroup A | Subgroup B | Z | p-Value | Conclusion |
| 1 | Stock | Mutual | -24.48 | <0.000000001 | Stock > mutual |
| 2 | Stock and agency | Mutual and agency | -24.37 | <0.000000001 | Stock and agency > mutual and agency |
| 3 | Stock and direct | Mutual and direct | -4.05 | <0.00001 | Stock and direct > mutual and direct |
| 4 | Agency | Direct | -19.67 | <0.000000001 | Agency > direct |
| 5 | Stock and agent | Stock and direct | -17.28 | <0.000000001 | Stock and agency > stock and direct |
| 6 | Mutual and agent | Mutual and direct | 2.73 | <0.006 | Mutual and direct > mutual and agency |
| 7 | Stock and agency | Mutual and direct | -16.22 | <0.000000001 | Stock and agency > mutual and direct |
| 8 | Stock and direct | Mutual and agency | -6.32 | <0.000000001 | Stock and direct > mutual and agency |

Note: Table taken from [Brockett et al. \(2005\)](#) to illustrate strategic complementarity between organizational form and distribution choice. Results are the DEA differences (net of managerial inefficiencies associated with organizational form) among compared groups. Stock and Agency > Stock and Direct > Mutual and Direct > Mutual and Agency where ">" means "more efficient than"

[Parente et al. \(2010\)](#) also consider strategic complementarities as a determinant of distribution system efficiency. This study finds that when foreign insurers enter the US market, their choice of distribution method depends on the cultural distance between the insurer and the market.¹⁴ The authors find a U-shaped relationship, where the probability of direct writing decreases at first with cultural distance but eventually increases as cultural distance increases. They argue that cultural distance initially increases insurers' desire to rely on local market knowledge through independent agents, but that at high levels of cultural distance it becomes too difficult for insurers to hire and manage local agents effectively. The authors also posit that high levels of cultural difference may be accompanied by different practices that may have some value in the local market.

Several studies have specifically tested the hypothesis that the higher expense ratios of independent agency insurers reflect greater service or quality provision.¹⁵ [Etgar \(1976\)](#) looks for direct evidence of quality or service differences across distribution systems by comparing the services provided by 116 personal lines agents operating in the state of California. Using data from a survey of agent practices, the study reveals that independent agents intervene in claims settlement significantly more often than exclusive agents, but finds no other significant difference in service provision. A larger survey of independent agency operations is undertaken by [Cummins and Weisbart \(1977\)](#), obtaining responses from nearly 700 personal lines agents in three different states. While this study finds that independent agents are significantly more likely to provide claims assistance and to review insurance coverage more frequently than tied agents, in other areas independent agents provide less service than tied agents. A study of German insurance agents by [Eckardt and R  thke-D  ppner \(2010\)](#) finds that independent agents in Germany provide better service quality while exclusive agents provide more additional services. They suggest that when information costs are high to the end purchaser, independent agents provide valuable services; but when products are relatively homogenous independent agents lack the economies of scale that allow specialization of tasks that exclusive agents enjoy.

To surmount the difficulties associated with comparing multiple measures of service, and to capture service provision by the insurance company as well as its agents, [Doerpinghaus \(1991\)](#) measures

¹⁴Cultural distance, according to the authors, is an index reflecting the similarities and differences between the behaviors and business practices in the target market and the home market of the firm entering.

¹⁵[Venezia et al. \(1999\)](#) develop a theoretical model which shows that tied and independent agency insurers may coexist in equilibrium when independent agents provide greater assistance in claims processing. Under the additional assumption that consumers have private information about their risk types, it is shown that higher risk consumers will choose independent agency insurers, which will in turn offer higher prices and lower deductibles in equilibrium.

customer service indirectly by examining consumer complaints to regulators. She posits that better customer service will lead to fewer complaints, and thus tests the hypothesis that independent agency insurers receive fewer complaints than tied agency insurers. Her empirical analysis uses data from three state insurance departments regarding consumer complaints about individual insurance firms. Regressions of each firm's rate of complaints on firm characteristics plus an indicator variable for the firm's distribution system produce no evidence of significant differences in complaint rates across the two systems. A follow-up study by [Barrese et al. \(1995\)](#) uses complaint data from five states, a richer empirical model and tobit estimation methods rather than ordinary least squares. This study finds that independent agency insurers receive fewer complaints when the data from all five states are pooled, and in two of five individual states studied. This provides evidence of greater satisfaction on the part of independent agency customers, which could indicate superior service or quality provision by independent agency insurers.¹⁶

On balance, existing studies present mixed evidence of superior service provision by independent agency insurers or their agents. The focus of many of these studies on personal insurance lines may provide a partial explanation. If independent agency firms enjoy a competitive advantage in service provision, but personal insurance lines are not service-intensive, this could explain both the downward trend of independent agent service advantages found in these studies and the lower independent agency market share in these lines. A difficulty of interpretation arises, however, because these studies do not relate differences in service provision to the costs incurred by insurers or their agents. As a consequence, one cannot determine whether any observed differences in service provision are the source of the cost differences between the two distribution systems. This remains an open question.

25.3.1.2 Life Insurance

There are fewer studies of distribution choice in life insurance, perhaps because of the smaller differences between the traditional systems of distribution in this industry. However, [Trigo-Gamarra and Growitsch \(2010\)](#) use DEA to show that multiple distribution channels in the Germany life insurance market exist due to performance advantages in certain lines of business. In particular, single-channel insurance distributors (both direct and independent) are no more efficient in delivering policies than multichannel providers, even though, according to [Trigo-Gamarra \(2008\)](#), independent agents provide better service to both insurer and insured. They conclude that multiple channel distribution is a superior business model to either direct distribution or independent agency.

Several other studies have examined the efficiency of the bancassurance model compared to more traditional distribution models. As noted above, the bancassurance distribution model has captured significant market share in many countries in the past 20 years. A principal advantage to bank distribution is thought to be lower costs relative to an agency system. This is because the bank does not pay the significant sales commissions seen in the agency system, and it also has a ready-made customer base in its banking clients, which may reduce advertising and solicitation costs ([Davis 2007](#)).

[Fiordelisi and Ricci \(2010\)](#) analyze a sample of 168 observations of insurance firms in the Italian market for the years 2005 and 2006. Using stochastic frontier efficiency methods, they find that bancassurance companies are significantly more cost-efficient than independent companies, but they are not more profit-efficient. The authors attribute the profit-efficiency results to the product mix offered by bancassurance firms. Such firms tend to specialize in lower margin products, such as

¹⁶Of course, if consumer complaints are made only when service fails to live up to expectations, there is the possibility that selection bias in the distribution system clientele will affect these results. For example, if shopping with a particular distribution system is correlated with service expectations or innate tendencies to file complaints, the study results may be compromised.

unit-linked annuities. Similarly, [Hwang and Gao \(2006\)](#) examine the efficiency of life insurance companies operating in the Irish market using a stochastic frontier approach. The authors conclude that life insurers distributing through the bancassurance model are statistically more cost-efficient, after controlling for size, market share, and other factors that might be linked to cost-efficiency. However, they do not find support for the profit-efficiency advantage of bancassurance.

These results differ from [Chang et al. \(2011\)](#), who found that sales efficiency is lower for bancassurance than standard models in Taiwan. They are also inconsistent with the findings of [Chen and Chang \(2010\)](#), who show that direct distribution methods are more efficient than non-direct distribution methods in Taiwan. Whether these differences in results may be due to country-specific factors in life insurance markets or in distribution channel features is unclear. Because the bancassurance distribution model is still relatively new, [Wong et al. \(2007\)](#) note that it takes diverse forms around the world and varies with cultural, economic, and regulatory factors.

25.3.2 *Distribution System Coexistence*¹⁷

The coexistence of distribution systems of persistently differing efficiency could be a short run phenomenon, or it could be a long-run equilibrium.¹⁸ For example, early studies of exclusive versus independent agency in US automobile insurance argued that independent agency existed only due to entry-barriers created by rate regulations ([Joskow 1973](#)). More recent studies of this question find evidence that is somewhat mixed, but generally supports the hypothesis that independent agency insurers have higher market shares in regulated automobile insurance markets.¹⁹ Similarly, regulatory barriers appear to be one factor inhibiting the growth of bancassurance in some countries. While we are not aware of any formal studies, countries with lower bancassurance penetration in Europe and Asia are often those that permitted it later ([Wong et al. 2007](#); [Chang et al. 2011](#)); and the slow growth of bancassurance in countries such as Canada, the United Kingdom, and Germany is often attributed to regulatory barriers ([Davis 2007](#)).²⁰ Absent regulatory barriers, the economic theory of the firm maintains that the organizational choices of firms will be made in an optimizing manner, just as are the operating decisions of ongoing firms.²¹ Under this theory, managers choose the organizational form that minimizes transaction costs (including agency and information costs) associated with incomplete information. This implies that when more than one organizational form is observed in an industry, differences must exist in firms' operating or contracting environments that lead them to efficiently choose different organizational forms. Within this theoretical framework, it is important to determine the key factors that determine the efficiency of one organizational form over others.

¹⁷We refer the reader to the prior edition of this book for a more complete literature review related to the market frictions case for persistence of high-cost distribution methods, especially with respect to regulation.

¹⁸[Seog \(2005\)](#) nonetheless shows that equilibrium coexistence of independent and exclusive agency firms is possible even if independent agency firms are less efficient, if the fixed costs of exclusive agency are sufficiently high relative to the variable cost advantages of this distribution form. [Kelly and Kleffner \(2006\)](#) argue that high fixed costs coupled with small market size may be the reasons that independent agency firms dominate the personal lines insurance market in Canada.

¹⁹See, for example, [Pauly et al. \(1986\)](#), [Grabowski et al. \(1989\)](#), and [Gron \(1995\)](#).

²⁰In the USA, bancassurance was prohibited until 1999; its slow growth since then is often attributed to cultural differences between banks and insurers rather than to regulatory barriers ([Davis 2007](#)).

²¹Important early works taking this perspective include [Alchian and Demsetz \(1972\)](#), [Jensen and Meckling \(1976\)](#), [Williamson \(1979\)](#), and [Fama \(1980\)](#). See [Holmström and Tirole \(1990\)](#) for a complete review of the theoretical literature.

Most studies of the relative prevalence of different distribution systems focused on property-liability insurance. In this context, the factors determining distribution system advantages have been distilled into two general classes: incentive conflicts and consumer search costs.

25.3.2.1 Insurer–Agent Relationships

An important distinction between insurer-agent relationships across the different property-liability insurance distribution systems lies in which party owns the policy “expirations” or customer list. Under independent agency and broker distribution, the ownership rights to the customer list accrue to the agent.²² This means that when a policy is sold by an independent agent, the carrier cannot contact the customer for policy renewal or sale of additional products, without engaging the agent. With tied agents the insurance firm retains ownership of the customer list.

Compensation systems for independent agents also tend to differ from that of tied agents. Independent agents are generally compensated wholly by commissions. The commission rate varies across insurance products, with new policies and renewal policies often receiving the same commission rate. Many insurers also pay contingent commissions to independent agents, based upon premium volume and the loss ratio of the business sold for the insurer (Cummins et al. 2006). Exclusive agents are also generally paid by commission. Commission rates tend to be lower than those for independent agents, and commission rates for renewal policies are lower than those for new business (Rejda 2011). There is also some evidence that exclusive agents are less likely to receive profit-contingent commissions than independent agents (Regan and Kleffner 2011; Regan and Tennyson 1996). However, other forms of compensation, including participation in retirement plans, may be available to exclusive agents. Employee sales agents tend to be compensated at least partially by salary rather than commission, and many are compensated wholly by salary and bonus schemes rather than commissions.

The provision of agent training and support by insurers using exclusive agents or employee sales forces tends to be greater than that provided to independent agents. Exclusive agency insurers often treat new agents as employees during a specified training period. The agent becomes an independent contractor paid on a commission basis only after this period (Rejda 2011). Exclusive agency insurers also advertise more heavily than the independent agency firms, who may rely more on agent marketing efforts (Regan 1997).

Customer service functions such as billing and claims processing are performed by the insurance company under the exclusive agency or employee agency system. Traditionally, the independent agent provided most of these services for his customers. Economies of scale have led insurers using independent agents to provide these services more centrally.²³ Now, many independent agency insurers handle claims, billing, policy issuance and communication functions in insurer-controlled service centers. An alternative to this model is a service center operated jointly by a group of independent agencies, which may be managed by a third party. Under the insurer service center model, commission payments to agents are reduced to reflect the reduction in required agent activities. Under the independent agent service center model each agent pays fees to the center to support the service provision, and insurers generally must agree to the servicing arrangements.

Life insurance agents are organized differently from property-liability agents. When tied to a single insurer, they are usually organized under branch offices or managing general agents of the insurance company. Under the branch office system, the selling agents report to the regional office, and agent

²²Independent agents and brokers are referred to as independent agents throughout the remainder of the chapter unless a clear distinction between them must be made for clarity.

²³See Anderson et al. (1998) for a discussion of the creation of more vertically integrated relationships between independent insurance agents and insurers.

recruitment, training and oversight are often provided at this level of the organization. Under the general agency system the managing general agent is an independent contractor who invests his own capital and is charged with building a full-time career agency sales force for a single insurer. This is similar to the exclusive agency model used in property-liability insurance. The managing general agent typically is not engaged in personal selling but is paid an override on the commissions of the producing agents. As in property-liability insurance, company-provided training and other evidence of committed relationships with agents are relatively higher under tied agency systems than under other agency systems.

Independent agency in life insurance takes two primary forms, known as personal producing general agency and brokerage. Unlike managing general agents, the principal goal of the personal producing general agent is to sell insurance. Although the personal producing general agent may have a primary relationship with a specific insurer, the personal producing agent, and the selling agents appointed by the personal producing general agent, may sell the products of more than one company. Like brokerage in property-liability insurance, life insurance brokers represent the products of more than one insurer. Typically, the insurer fills the role of product manufacturer, providing products for life insurance sales outlets that may be developed by other organizations. For example, many brokerage insurers distribute their products through the independent agency forces of property-liability insurers, or through securities dealers or banks. Brokers are appointed by the insurer as authorized representatives and are compensated solely on a commission basis.

Under all distribution systems in life insurance, agent compensation is largely via commissions. Life insurance commission schemes tend to be weighted heavily toward motivating sales of new policies, rather than rewarding renewals or profitability. A large fraction of the first year premium paid by the consumer is often devoted to the sales commission, with a much smaller percentage of annual renewal premiums (sometimes for up to 10 years) also being paid as commission.

25.3.2.2 Incentive Conflicts

Marvel (1982) suggests that direct writing protects the promotional efforts of the insurance firm. Suppose, for example, that customers are attracted to an agent by a carrier's specific product promotions. If the agent also sells the products of other carriers, he may have a financial incentive to switch customers to the product of a non-advertising firm, to avoid paying the agent's share of the original carrier's promotion costs. A lower price may also entice the customer to switch. Carriers that recognize the potential for free-riding will thus reduce their advertising expenditures. This theory predicts that when insurer-level advertising is the most efficient way to increase sales, direct writing will be used because it preserves the incentive to invest in advertising. Marvel's empirical results bear this out: independent agency insurers spend relatively less on advertising than direct writers. Furthermore, independent agencies are more prevalent in commercial lines where brand advertising is relatively less important. He notes that the higher commission rates compensate for the additional cost of advertising borne by the agent and preserve the appropriate incentives.

Grossman and Hart (1986) extend this argument to allow for moral hazard on the part of both the insurance firm and the agent. In this setting, efficiency requires that productive assets will be owned by the party whose investments most affect the value of those assets, since ownership increases investment incentives. The key productive asset in insurance sales is the customer list, and hence ownership of the customer list will optimally be assigned to that party (insurer or agent) whose investments are most important to the value of the list. Firm ownership of the list will be preferred when the list size is the most important determinant of profitability, and hence the insurer's brand investments are most important. Agent ownership will be preferred when customer persistency is

the most important determinant of profitability, and hence the agent's services are most important. This reasoning implies that independent agency will be used when agent services most affect insurer profitability. Like Marvel's, this theory is also consistent with the prevalence of independent agency in commercial insurance (if agent services are important in building the client list in these lines), and higher commission payments to independent agents (because of agent efforts in building the client list).

Sass and Gisser (1989) theorize that direct writing reduces the costs associated with an agent's sales effort being divided among competing brands. Direct writing lowers the agent's opportunity cost of sales effort devoted to a given firm's product, which allows the firm to pay a lower commission rate per policy. Firm and market size thus are the key limitations affecting a carrier's decision to sell directly. In order for a firm to attract tied agents or employees, the firm must be able to offer the agent a larger sales volume to compensate for the lower commission rate. To provide evidence for their theory, Sass and Gisser (1989) estimate a probit model of the probability that an insurance group is a direct writer. Using data on 116 property-liability insurance groups from 1974, they find that firm size and insurance market density are positively correlated with the use of direct writing. This is consistent with the view that direct writing is limited by the size of the market. They also find that direct writers pay lower commission rates, even after controlling for advertising expenditures and line of business specialization. This is inconsistent with the view that tied agents' commission rates are lower only due to implicit charges for insurers' advertising.

Regan and Tennyson (1996) present an alternative model of agent effort differences across distribution systems. They argue that independent agency provides agents with greater incentives to exert (unverifiable) effort in risk selection and classification. The incentive differences across independent agency and direct writing arise because the independent agent can extract a share of the residual profits from his efforts, through his ability to place desirable risks with other firms. Tied agents with no such leverage must be compensated directly for their risk assessment efforts, even if these efforts do not lead to higher profits. Under this theory, the total cost of independent agent compensation will be greater as a result of profit sharing and commission competition across insurers. However, the marginal cost of compensating an independent agent for information gathering effort will be lower. Independent agency will thus be more efficient only when subjective information provided by the agent is important to profitable underwriting. When applicants can be readily sorted using verifiable information or standardized classification algorithms, direct writing will be preferred due to its lower cost.

Regan and Tennyson estimate regression models of state level market shares of direct writers using panel data for 1980–1987. These regressions support the hypothesis that direct writer shares are lower in markets where risk exposures are relatively heterogeneous and complex, and thus more difficult to classify using standardized tools. In regression models of insurer commission payments, the authors also find that independent agency insurers pay a larger proportion of agent commissions on a profit-contingent basis. This is consistent with their theory, since profit-contingent-commissions reward an agent for distinguishing profitable from unprofitable business.

Kim et al. (1996) focus on potential incentive conflicts between the insurer and consumer as the prime determinant of distribution system choice. They argue that independent agents should be more effective at monitoring and preventing opportunistic behavior by insurers, due to the agent's ownership of the customer list and his relationship with several insurers. Hence, independent agency should be used when agent monitoring of the insurer is important to consumers. Because policyholders are the ultimate owners of the firm under the mutual form of organization, stock insurers may require more monitoring on policyholders' behalf. This theory thus predicts a relationship between ownership form and distribution system, with independent agency used by stock firms and direct writing used by mutual firms. Kim et al. (1996) estimate logistic regression models of distribution systems that

show a positive and significant relationship between direct writing and the mutual ownership form.²⁴ Notice that the predictions and findings of this research presage the results of the efficiency analysis by [Brockett et al. \(2005\)](#) discussed previously.

[Regan \(1997\)](#) proposes a more general transactions costs theory to determine distribution system choice. Transactions costs theory posits that the integration of functions within a firm is more likely when the costs of market transactions are high. Regan argues that integration (direct writing) is more likely when relationship-specific investments are important, and non-integration (independent agency) confers advantages when products are complex or the environment is uncertain. The need for relationship-specific investments favors integration because of the potential for ex-post opportunism under market exchange ([Williamson 1979](#)). Regan hypothesizes that independent agency is preferred when products are complex because of the greater need for agents to intervene in insurer/customer conflicts and the need for agent participation in risk assessment ([Regan and Tennyson 1996](#)). Independent agency is preferred in uncertain environments because the agent's greater ability to diversify risk across insurers lowers the compensation that agents require for risk bearing.

[Regan \(1997\)](#) estimates logit models of the probability that an insurer is a direct writer using data on 149 insurance groups from 1990. Consistent with the findings of [Kim et al. \(1996\)](#), [Regan and Tzeng \(1999\)](#), and [Brockett et al. \(2005\)](#), she finds that direct writing is positively associated with the mutual form of ownership. She also finds that direct writing is positively related to insurer advertising and technology investments, and associated with lower risk and lower product complexity. These findings are consistent with her hypothesis relating distribution system use to transactions costs. Her findings are also consistent with the arguments of [Marvel \(1982\)](#) regarding advertising and those of [Regan and Tennyson \(1996\)](#) regarding product complexity.²⁵

25.3.2.3 Search Costs

There is also a strand of literature focusing on costly consumer search as the reason for the equilibrium coexistence of independent agency and direct writers. What distinguishes this literature is the assumption that the distribution systems differ materially in ways other than costs. For example, information search itself is costly and the direct distribution model differs from the independent agency model in terms of how consumers can obtain that information. Under direct writing, each individual insurer must be contacted for price and product information.²⁶ Under independent agency, the agent may serve as an intermediary between the consumer and multiple insurers, providing multiple quotes simultaneously. This difference in search processes provides a rationale for firms and consumers of differing characteristics to choose different distribution systems.

[Posey and Yavaş \(1995\)](#) present the first formal analysis of this type. These authors model the insurance purchase transaction as requiring two-sided search, due to differences in risk characteristics across consumers and product differentiation across insurers. Independent agents act as middlemen in

²⁴The authors also find evidence consistent with the predictions of [Marvel \(1982\)](#) regarding differences in advertising intensity across distribution systems, and with those of [Sass and Gisser \(1989\)](#) regarding differences in firm size across distribution systems.

²⁵[Regan and Tzeng \(1999\)](#) provide additional evidence on the relationship between insurance distribution system and ownership form. This study explicitly treats the choice of distribution system and ownership structure as jointly determined to control for the fact that common exogenous factors may influence both choices. The findings confirm the view that stock ownership and independent agency distribution are likely to be observed together.

²⁶More recently, some direct carriers have used information from competitor rate filings to provide quotes for up to four competing carriers, even when the competitor has lower premiums. Progressive was an early adopter of this method. However, we are not aware of any studies to determine the accuracy of the quotes provided for other carriers. For example, the competing quotes may not take into account multi-line discounts that may be offered by competitors.

facilitating these matches. Shopping with an independent agent increases the probability of a match in a single search, while shopping in the direct writer sector requires sequential search. The model assumes that price is exogenously set at the zero-profit level, and the only element in the search process is for appropriate coverage. Under fairly general conditions, the authors derive coexistence equilibria in this model. In most of these equilibria, consumers with high costs of search choose the independent agency system.

Posey and Tennyson (1998) analyze distribution system coexistence under pure price search. Similar to Posey and Yavaş, they assume that shopping in the independent agency sector entails simultaneous search, while shopping in the direct writer sector entails sequential search. However, they assume that products are homogeneous and prices are determined endogenously. Under certain conditions regarding the relative distributions of production and search costs, they find that both distribution systems may exist in equilibrium. The constructed equilibrium is one in which low production cost producers and low search cost consumers utilize the direct writer sector, while high cost producers and high search cost consumers utilize independent agency.

Seog (1999) also develops a search model to examine the coexistence of competing distribution systems. Unlike some other search models in this literature, Seog's model assumes that consumers' search process is the same under both distribution systems. The results of the model show that insurers of different cost (and price) levels can coexist in equilibrium in a market with costly consumer search, if consumers have less than perfect information about price distributions. Eckardt (2007) also develops a model that assumes identical search technologies under direct writing and independent agency. In this model, direct and independent agents differ in the quality of information provided, with direct writer information confined to knowledge of a single insurer only. She argues that rational consumers recognize this information limitation and will use direct writers only if they have a preference for low quality information or if prices are low enough to offset the lower quality of information.

The search-based models of distribution system choice have not been extensively tested. Posey and Tennyson (1998) show that price levels and price variances for independent agency and direct writers in automobile insurance are consistent with the predictions of a price search model. However, more direct evidence relating consumer search costs to distribution system choice is needed to test the relevance of these models.

25.3.2.4 Choice of Distribution System in Life Insurance

Finally, more recent research has centered on the choice of distribution by life insurers. Carr et al. (1999) present a transaction cost analysis of distribution system choice in life insurance.²⁷ Consistent with traditional transaction cost reasoning, they find that tied agency is more prevalent among life insurance firms that sell complex products.²⁸ Further, after controlling for product specialization and other firm characteristics, the authors find no significant differences in overall cost efficiency across life insurance distribution systems.²⁹

²⁷Grossman and Hart (1986) present evidence of specialization in term life insurance by independent agency insurers in the USA. However, their arguments regarding why independent agency is optimal for term life insurance rely on differences in client list ownership across the different distribution systems. In life insurance there are no such differences in the USA, with the insurance firm typically retaining ownership of policy renewals (Baranoff and Sager 2003).

²⁸Group insurance programs and individual whole life insurance were classified by the authors as relatively more complex than other products, such as individual term life or credit insurance.

²⁹Efficiency is measured using data envelopment techniques, which decompose cost efficiency into technical and allocative efficiency. The authors find that both independent agency and tied agency insurers are less technically efficient than mass marketing insurers.

[Baranoff and Sager \(2003\)](#) show that insurers which distribute life insurance through nonexclusive channels take on less risk, primarily because they sell life insurance more frequently to group plans for which loss history is more representative of future claims. They also write more group business, as groups tend to purchase life, health and other group policies through a common broker. Despite the results of [Carr et al. \(1999\)](#), [Baranoff and Sager \(2003\)](#) find that distribution method is not correlated with efficiency. [Klumpes and Schuermann \(2011\)](#) find that in the European market, firms with nonexclusive distribution strategies have lower costs and are more profit-efficient, consistent with the findings from prior research about the US property-liability lines. They further find a higher financial crisis survival rate by firms using a direct or exclusive distribution model. These firms also benefit most during regimes of deregulation.

25.3.2.5 Open Issues

The equilibrium coexistence theories of direct writer and independent agency yield predictions consistent with a number of features observed in the property-liability insurance industry. This congruence of theoretical predictions and observed phenomena provides support for the general view that distribution system choices have an efficiency basis. The more detailed empirical evidence discussed in the previous section also makes clear that there are substantial differences in organization, product specialization, and agent compensation across firms using different distribution systems. However, it is difficult to disentangle the results in support of a single theory. The empirical evidence thus far suggests that many factors play a role in determining distribution system choice, and leaves open the question of their relative importance. Other studies that could advance our understanding of this question include examination of the distribution system choices of new entrants to the industry, analysis of the relative success of firms using the same distribution system, and analysis of distribution system use in relation to consumer shopping behaviors.

Many of the conditions apparently at work in the choice of distribution system by property-liability insurers also exist in the life insurance industry. First, life insurance firms may have optimally aligned distribution systems with product characteristics and markets and are thus in equilibrium. It is also possible that the findings in property-liability insurance are driven primarily by the differences in client list ownership across distribution systems, which do not exist in many countries for life insurance. Finally, the existence of multiple distribution systems within a single firm (more common in life insurance lines than property-liability lines), or omitted factors such as bank alliances or other marketing relationships, may explain the persistence of alternative distribution methods in the industry ([Carr 1997](#)). Further research into this question would be useful.

25.4 Agent Compensation and Resale Price Maintenance

Due to both competitive and regulatory concerns, the nature of insurance agent compensation has come under increasing scrutiny within the industry and among policy makers. Insurance agents are most commonly compensated via commissions based on premium revenues. Concerns center on the effects of such commission payments on agent sales and service incentives in general, and on unethical sales practices in particular.

Closely linked to the question of agent compensation is that of resale price maintenance. Resale price maintenance restrictions in the insurance industry prevent sales agents from reducing policy prices below those stated by the insurer, with agent commissions embedded in the retail price. While per se illegal in most industries in the USA since 1975 ([Ippolito and Overstreet 1996](#)), this restrictive

practice is not only legal but required in the insurance industry, due to state laws in effect since the 1940s. Because of the overwhelming use of commission-based compensation in insurance, these state laws are worded as “anti-rebating” laws, which prohibit agents from rebating any portion of their sales commission to the customer.³⁰ A common justification for these laws is to discourage agents from needlessly replacing policies as a way of increasing commission income. Because of this link with agent compensation and incentive issues, we discuss resale price maintenance in conjunction with other issues regarding commission compensation.

25.4.1 *Commission Compensation*

25.4.1.1 **Incentive Issues**

Economic theories of optimal contract design lend insight into the use of commission compensation for sales agents. The perspective of these theories is that sales agents are self-interested and hence must be encouraged to behave in ways that further the interest of the firm. It is further assumed that agents have private information about their efforts, abilities or market conditions related to sales, and that outcomes for the firm (sales or profits) are only stochastically related to agent inputs (effort or ability). The information asymmetry between the employer and the sales agent and the stochastic nature of output precludes the use of direct monitoring and enforcement of agent behaviors by the employer. In this environment, the compensation system can provide financial incentives to motivate the agent to act in the interest of the firm.

The simplest, least costly way to motivate a risk-neutral agent to act in the interest of the firm is to pay direct commissions only, thus directly aligning the agent’s compensation with the employer’s payoffs. For risk-averse agents, commission plans that involve some fixed (salary) component are preferable. Although the straight commission system provides the purest incentives to increase revenues, a risk-averse agent requires additional compensation for bearing income risk, making this form of compensation ultimately more costly. From this perspective, payment of salary plus commission reflects a trade-off between providing work incentives and sharing risk with the agent (Basu et al. 1985). Berry-Stölzle and Eckles (2010) find that when agents can choose their compensation type, their choice depends partly on their inferred level of risk aversion, as measured by education and experience.

The salary component appears in other compensation theories as well. Marketing and organization theorists point out that straight commission schemes are poor instruments for building long-term relationships (John and Barton 1989). Transactions cost theory notes that commission compensation does not provide agents with incentives to invest in firm-specific human capital (Anderson 1985). These arguments imply that commission-only compensation will be preferred only when the sales force is readily replaceable; otherwise the optimal compensation scheme will also involve a salary component. In this view, the optimal weighting of salary and commission compensation reflects a trade-off between effort incentives and relationship-building.

These theoretical predictions about the merits of salary versus commission compensation appear to be borne out in the insurance industry. For example, the compensation of independent agents is often solely commission-based whereas tied agents often receive some additional fixed compensation. Some employee agents are compensated through salary and bonuses only. These differences are consistent both with the greater earnings diversification opportunities of independent agents (risk issues) and their weaker links to a specific insurer (relationship issues).

³⁰Note that California and Florida allow rebating, which will be discussed later.

The heavy reliance on commission compensation in life insurance has recently come into question. Consistent with the theories discussed above, one specific issue cited by life insurers considering compensation system changes is the inability to form long-term relationships with agents. Life insurers currently experience an average 4-year retention rate of new agents of only 10% (Trese 2011). Insurers' concern about the cost of this turnover suggests that the existing compensation structure may be inappropriate in the current environment for life insurance products.

25.4.1.2 Unethical Agent Behavior

It has been argued that commission compensation does not control, and may exacerbate, conflicts of interest between sales agents and consumers (Kurland 1995, 1996). Of particular concern in the insurance industry are the agent's incentives regarding disclosure and information provision, and choice of policy or product to sell (Howe et al. 1994). For example, an agent might recommend a particular insurer's product because it generates a higher commission rather than because it is the best match for the consumer. Inderst and Ottaviani (2009) show that agents compensated by commissions will have sub-optimally low standards for matching products to customers' needs if agents must devote costly effort to finding potential customers. These concerns should be especially salient in circumstances in which part of the value-enhancing input of the agent is to provide consumer information and aid in the choice of product. It is therefore not surprising that concerns about the effects of commissions on agent sales practices are particularly strong in the life insurance industry.

Another aspect of agent private information is the incentive for the agent to withhold customer risk information from carriers to generate low premium offers from carriers offering a more lucrative commission structure. Such actions by agents contribute to the adverse selection problem, as suggested by D'Arcy and Doherty (1990). D'Arcy and Doherty suggest that a commission system at least partly contingent upon profit and volume generates rent-sharing opportunities between carriers and agents and may mitigate the adverse selection problem. Compensation methods that are linked to the insurer's profitability can induce the optimal level of risk assessment by agents so that agents will expend effort on risk assessment when direct risk assessment by the insurer is more costly or less efficient. This will ensure proper risk classification at lower cost, thus resulting in better performance for insurers. Consumers will be better served as well since a proper match between consumers and insurers may result in higher levels of customer satisfaction, and thus lower switching costs for consumers (Regan and Kleffner 2011). Contingent commissions may also provide incentives for agents to provide loss mitigation services to reduce the frequency and/or severity of loss events, thus directly reducing loss ratios (Carson et al. 2007).

Contingent commission arrangements are not fool-proof, however. As shown by Wilder (2004), the structure of a volume-based contingent commission may incentivize sub-optimal behavior by agents (as viewed by carriers and insureds) when the agency is close to achieving the premium volume that triggers an increase in volume-based commissions. These conflicts took center stage in 2004 when New York Attorney General Eliot Spitzer filed a lawsuit against brokers and carriers for anticompetitive behavior and bid-rigging in response to certain contingent commission arrangements. At that time, he suggested wholesale reforms in the industry that would end the use of volume-based contingent commissions systems and constrain profit-based contingent commissions.³¹ While several carriers announced plans to discontinue contingent commissions in response to this lawsuit, and contingent commissions dried up for a short time, most carriers and brokers were using them again by 2006. In 2008, in an appeal of the Spitzer settlement, the first Appellate division of the

³¹For details regarding the Spitzer lawsuit, see Chapter 9 in Masters (2006) and the conversation recorded in Cummins et al. (2006).

New York Supreme Court ruled that contingent commissions were not illegal and their use did not create a conflict of interest between brokers and clients.³² Most recently, the NAIC has created a broker compensation task force with the charge to monitor changes to broker compensation disclosure regulations across states (National Association of Insurance Commissioners 2009).³³

Cummins and Doherty (2006) suggest that contingent commissions were, in general, beneficial for the consumers, as they can enhance the competitive bidding process by aligning the agent's interests with the insurer's. Indeed, Ghosh and Hilliard (2012) showed that stock prices of the insurers most reliant on contingent commissions in New York State faced the biggest declines when the future of contingent commissions was threatened by the Spitzer lawsuit. Both Cheng et al. (2010) and Ghosh and Hilliard (2012) find strong adverse stock market reactions to the announcement that the contingent commission system was being challenged in 2004. Ghosh and Hilliard (2012) indicate that the initial stock market reaction (\$21 billion in stock market value lost) suggested that investors valued the contingent commission system in the US insurance industry. This may indicate that equity investors believe that contingent commissions improve insurer underwriting performance. Regan and Kleffner (2011) conduct an empirical analysis of the relationship between contingent commission use and insurer performance. Using a sample of insurance companies from the period 2001–2005, they measure insurer underwriting performance using the loss ratio, the combined ratio, and the underwriting return on equity. They find a strong and consistently positive relationship between the use of contingent commissions and insurer performance. Further, as the proportion of contingent commission in the compensation scheme increases, performance improves. This provides strong support for the hypothesis that contingent commission payment can align incentives between insurers and intermediaries to generate effort on risk assessment.

While there was substantial academic inquiry into the ethical and legal violations in the Spitzer case (see, for example, Fitzpatrick 2006; O'Brien 2005), other aspects of potential unethical behavior resulting from compensation structure remain relatively unexamined in the literature. A few studies do exist, however. Kurland (1995) surveyed insurance agents regarding their predicted actions in scenarios that involved ethical dilemmas. Contrary to her hypothesis, she finds that the percentage of annual earnings from commissions does not affect insurance agents' ethical intentions toward consumers. A study by Howe et al. (1994) may provide indirect evidence regarding the effect of compensation method on ethical behavior. This study finds that agents with higher customer orientation (as opposed to sales orientation) exhibit higher ethical standards in sales practices. If commission compensation encourages a stronger sales orientation, this finding suggests a link between commission-based compensation and unethical practices.³⁴

The general marketing literature on sales practices provides suggestive evidence of a link between commission compensation and sales practices (Anderson 1985). Agents in more competitive environments are more likely to approve of unethical solutions to problems, and the operating environment is found to affect agents' perceptions of acceptable sales practices. However, this literature concludes that there is no direct effect of compensation practices on agent ethics. Rather, a complex set of factors which include the compensation system, management practices, perceived corporate codes of ethics, competitive pressures and the agent's personal ethics affect the ethical behavior of sales agents.

³²See *People ex rel. Cuomo v. Liberty Mut. Ins. Co.* 52 A.D. 3d 378, 861 N.Y.S.2d 294 (June 19, 2008).

³³Both New York and Colorado have adopted laws to require commission disclosure in all cases, while six other states (RI, UT, CT, WA, IL, OR) now require disclosure when the producer receives compensation from the insurer and the insured.

³⁴Eastman et al. (1996) find that the professional ethics of insurance agents are lower than their personal ethics but do not study the relationship between compensation methods and ethical beliefs.

25.4.1.3 Alternative Compensation Systems

An often-suggested alternative to commission compensation for life insurance agents is for consumers to pay fees to the agent (either with or without salary compensation from the insurer). To highlight the issues in determining whether consumers would be better served under alternative systems, Gravelle (1993,1994) undertakes a theoretical welfare analysis of commission-based versus fee-based compensation systems in a life insurance market. Consistent with current public policy concerns, Gravelle assumes that agents play an important informational role in the market. The insurance market is assumed to be competitive, but agents hold a monopoly in providing consumers information about the benefits of life insurance.

In this model, all agents have a financial incentive to exaggerate the benefits of life insurance to consumers if compensated by sales commissions from the insurer. However, even dishonest agents have some social value because they may contact consumers whose *true* benefit from life insurance exceeds the purchase price. Replacing sales commissions with fees paid by consumers may or may not improve social welfare. The quality of advice will be greater under the fee-based system (that is, agent dishonesty will be less common), as generally argued. However, the fee will be set at the monopoly level, and hence too few consumers will become informed and will potentially make purchasing errors. This latter finding depends of course on the assumption that agents have a monopoly in information provision, which is questionable in the current market environment.³⁵ Nonetheless, Gravelle's analysis demonstrates that the relative merits of compensation systems depend not only on agent actions, but also on the equilibrium prices for products and services, availability of product variety and services, and the number of agents and insurers that enter the market under alternative compensation schemes.

Focht et al. (2012) develop a model of independent agent remuneration in markets where the agent's role is confined to matching the client with an appropriate insurer. They model the trade-off between a fee-based and a commission-based compensation system where fees are paid by the insurance buyer for advice, and commissions are paid by insurers. They show that if the agent does not behave strategically, each system is equally efficient, and the agent properly matches all uninformed consumers. However, if the agent has private information the insurer must compensate the agent for revealing this, or the agent will have incentives to mismatch insureds. Therefore, in this model, the payment of commissions by the insurer can be welfare maximizing.

Hofmann and Nell (2011) develop a similar model but allow consumers to search privately or utilize an agent to become informed. Like Focht et al. (2012) they find that commission and fee-for-service compensation systems for agents yield equal expected profits in equilibrium, but unlike those authors they find that the fee system is superior from a social welfare viewpoint. A commission system results in more consumers becoming informed by an intermediary than is socially optimal, "crowding-out" private search activities. They additionally note that when collusion with agents is possible, commission compensation allows monopoly pricing for consumers who purchase through intermediaries, resulting in the highest possible profits.

Another alternative to the current life insurance compensation system is to offer a more level commission structure, reducing first-year sales commissions and raising renewal-year commissions. Puelz and Snow (1991) demonstrate theoretically that high first-year premiums are optimal if agent efforts in attracting new customers are more productive than agent efforts in attracting renewal customers. However, their analysis does not consider effects that this commission scheme may have on the non-sales behavior of agents. In addition to concerns about service and information provision, it has been argued that large first year commissions engender incentives for "twisting." Policy twisting is said to occur when an agent convinces a consumer to replace an existing policy with one of no greater

³⁵In Gravelle's model, there is also no competition between agents. Consumers are contacted by at most one agent and cannot seek out advice from other agents.

benefit, in order to generate commission income for the agent. While we are aware of no empirical studies of the effects of commission structure on the prevalence of twisting, it is apparent that higher first year commissions will increase agents' incentives to replace rather than renew policies.

Largely because of concerns about unethical agent behavior, regulatory commissions in several countries have mandated fee-based compensation for insurance sellers who provide financial advice. Some US states prohibit financial service agents from receiving both fees and commissions on the same transaction (Lefenfeld 1996). The hypothesized benefit of fee-based systems is that agents compensated by fees would have no incentive to offer biased advice regarding the merits of purchase, or the relative merits of alternative products.

25.4.2 Resale Price Maintenance

In the abstract, an insurance firm can be viewed as an upstream supplier of a product to an insurance agent, who adds some value to the product and sells it in the retail market. The insurer chooses the wholesale price for the product by specifying the premium for the consumer and the sales commission for the insurance agent. In the absence of legal or contractual restrictions, the agent could alter the retail price of the policy by either offering a rebate of part of his commission to the consumer, or charging a separate service fee. Resale price maintenance restrictions prevent the agent from influencing the retail price in this way. In the insurance industry these restrictions operate as a price floor, prohibiting agents from rebating commissions to consumers. Resale price maintenance restrictions have received the most attention in the life insurance industry, where agent first-year commissions are high and hence there exists significant potential for rebating.

25.4.2.1 Economic Issues

While there are no existing studies of the rationale for resale price maintenance in the insurance industry, economic theory identifies two possibilities: resale price restrictions may support price collusion or other anti-competitive practices, or may represent a solution to some principal-agent problem (Ippolito 1988; Katz 1989).

Collusion theories focus on the anti-competitive effects of reducing retail market price differences. One argument is that removing uncertainty about prices at the retail level increases the monitoring ability of a price-setting cartel. Thus, if industry conditions are otherwise conducive, anti-rebating agreements can help maintain price collusion by inhibiting secret chiseling on price agreements. Short of collusion, resale price restraints may reduce price competition by reducing consumer search, since price dispersion will be lower in a market with no retail price competition. Resale price restraints may also facilitate price discrimination, which can increase insurer profits. Uniform prices charged to all customers are a form of price discrimination if the marginal cost of product provision differs across customers, for example, due to different levels of service demand (Caves 1986).

Principal-agent theories focus on how resale price restraints may change the behavior of retail sellers in ways that benefit the producer. One argument is that price floors encourage service provision. Resale price floors prevent consumers from shopping at a full-price outlet to obtain pre-sale services, but purchasing from a discount seller. If the price floor involves a high retailer profit margin, competition among retail sellers will take the form of service competition and advertising, thereby building markets and brand reputations for upstream producers (Katz 1989).

A similar argument refers to quality provision by the retail seller when consumers cannot distinguish product quality from retailer quality. If the level of retailer quality or service can be specified and periodically monitored by the upstream producer, the retail price floor will serve to

increase the retailer's costs of dismissal for inadequate quality provision (Telser 1960). This provides direct financial incentives for quality or service provision by the agent.

These latter theories of resale price are related to insurer arguments for resale price maintenance in the life insurance industry. While there are no existing studies of the rationale for resale price maintenance in the insurance industry, economic theory identifies two possibilities: (a) resale price restrictions on insurance products require agents to provide greater information services and (b) rebating may undermine customer persistency. A customer who will purchase only if offered a rebate has a lower valuation of the product, or of the services provided by the agent, than the customer who purchases at full price. If low-valuation customers are more likely to cash in their policies early, insurers may not recover the fixed costs of selling and underwriting these policies. Under this argument, insurers' expectations of losing money on such customers could explain resale price restrictions.

The history of the anti-rebating laws in the United States life insurance industry offers some corroboration of this perspective. Stalson's classic book on the history of life insurance distribution makes clear that agent rebating was viewed as a problem by life insurers as early as the 1860s and was something that insurers and agents unsuccessfully tried to deal with via informal agreements (Stalson 1969). While the precise reasons for industry opposition to rebating are not made clear in that text, it appears that the practice created problems associated with the twisting of policies. High commission levels and the ability to rebate commissions to policyholders heighten the agent's incentives to engage in this policy turnover. In addition, if first year commissions exceed the first year policy premium it is possible for an agent to collude with consumers (those not interested in maintaining the policy) against the insurance company for financial gain. Stalson notes that in the heavy rebating era of the late 1800s competition for agents led to some first year commissions in excess of 200% of the first year premium, so this scenario is a possibility.

New York was the first state to outlaw rebating in 1889, and 21 other states quickly followed (Conniff 1986). However, rebating continued, and in fact intensified in the ensuing 10 years. With the 1906 New York State Armstrong Commission review of the insurance industry, New York and other state legislatures enacted stricter laws which made not only giving a rebate but also receiving a rebate, illegal. These laws were incorporated into the National Association of Insurance Commissioner's 1945 Unfair Trade Practices Model Act. Supported by the industry, the stated rationale of the legislation is to protect consumers from "unfair discrimination" and to prevent "destructive price competition."

These concerns provide a weak justification for resale price restrictions in the current regulatory environment. Solvency regulation, guaranty funds, and direct restrictions on discriminatory pricing are other tools to meet these objectives. Moreover, the public interest arguments for anti-rebating laws are strongest within the prevailing compensation system that pays life insurance agents a large first year commission. Changes to the commission structure would be a more direct way to reduce agents' incentives to twist policies or to offer discriminatory rebates.

At best, the effect of resale price maintenance agreements on consumer welfare is ambiguous. Even if resale price maintenance fosters agent service, it will enforce a uniform level of quality provision that may be greater than that desired by some consumers. For example, life insurance buyers who do not need as much information as others are forced via resale price maintenance to pay the high-information price. Resale price maintenance will also lessen price differences at the retail level. Given the empirical evidence on costly price search in insurance markets (Dahlby and West 1986; Mathewson and Winter 1983), this will reduce consumer search with negative implications for consumer welfare.

In 1986 the state of Florida repealed its anti-rebating law after it was declared unconstitutional by the state Supreme Court. California repealed its law in 1988 with the passage of Proposition 103, which contained a provision overturning rebating restrictions. Russell (1997) uses state-level data on life insurance surrender activity for the period 1960–1992 to examine the effect of rebating on policy replacements. The study develops a regression model of surrender activity which includes a

dummy variable equal to one in the states and years for which rebating is allowed. In all model specifications employed, the estimated coefficient on the rebating dummy variable is positive and significant, indicating that state surrender activity is higher when rebating is allowed. Interpretation of this positive correlation is difficult because there are no data available to determine whether the policies surrendered were replaced with other policies, and there are a very small number of observations in the data for which rebating activity was allowed. Nonetheless, these results warrant further research into the question.

25.5 The Regulation of Insurance Distribution

The regulation of insurance distribution is extensive in virtually all countries with developed markets for these services.³⁶ Insurance distribution is regulated in two distinct ways: the set of market participants is restricted, and the conduct of insurers and their intermediaries is regulated. Entry restrictions take the form of licensing requirements for insurers, agents and brokers, and regulations that prohibit insurance sales by certain types of firms (e.g., banks) or methods (e.g., direct mail). Market conduct regulations take such forms as requiring dissemination of certain types of information, and prohibiting misrepresentation and false advertising. Regulations are often directed at both insurance companies and their agents or brokers, but insurance companies also are typically held responsible for the actions of their representatives.

25.5.1 Entry Regulation

25.5.1.1 Major Regulations

Entry restrictions for insurance producers and sellers exist in virtually all countries, but the focus and extent of these restrictions varies greatly. Prior to 1999, in the USA, the Glass-Steagall Act prohibited commercial banks from entering other financial services industries, including insurance. Even though some exceptions always existed for certain state-chartered banks, and banks serving very small markets, the repeal of Glass-Steagall in 1999 relaxed these constraints broadly. Bank alliances with insurance companies have become increasingly common, and banks are now a significant distributor of annuities in the USA. In most European countries there are fewer restrictions on bank involvement in insurance, and bancassurance has become the main distribution channel for life insurance in Western Europe.

In most countries both insurance companies and sales agents must be licensed. Licensing requirements for insurers generally include financial and ethical standards for company officers. In the USA, licensing is done at the state level and firms must be licensed in all states in which they do business on an admitted basis. Each company has a primary state of domicile, however, and it is this state that takes primary responsibility for regulatory oversight. In the EU, the single market directives require insurers to be licensed only in their home country rather in each country in which they intend to sell insurance.³⁷ This single market, and the move toward price and product deregulation in

³⁶These policies and regulations tend to be similar in intent to those directed toward marketing practices in other financial services industries.

³⁷The home country retains responsibility for solvency oversight of the insurer.

Europe, has led to increased attention toward the professional qualifications and conduct of insurance intermediaries. The European Union's Insurance Mediation Directive of 2002 harmonized standards for licensing qualifications and professional liability of insurance intermediaries.

The standardization of licensing requirements and licensing reciprocity across jurisdictions is an important issue across the individual states of the USA as well. Not only do licensing requirements vary, but agents must also be licensed in each jurisdiction in which they sell. Barriers to agents operating across borders are eroding, however. Under state-based insurance regulation in the USA, producers, agencies, and insurers must hold licenses for each state and line of business in which they operate. Under the Gramm-Leach-Bliley Act (GLBA), also known as the Financial Services Modernization Act of 1999, a majority of states were required to either adopt uniform nonresident producer licensing laws, or enter into reciprocity agreements with other states by a November, 2002 deadline. If this requirement was not met, a federal self-regulatory organization, the National Association of Registered Agents and Brokers (NARAB) would be created to manage producer licensing. The NAIC reports that 37 states are now in compliance with the uniformity standard under the GLBA.³⁸

25.5.1.2 Economic Issues

Legal restrictions on the entry of banks into insurance are rationalized by concerns about the stability of the financial system and about detrimental effects of market power in financial services delivery. While both of these concerns have some theoretical and historical foundations, it is not clear that prohibiting entry is a necessary response to the potential problems. In countries that allow banks to enter insurance, laws still prohibit direct ownership and funds co-mingling at banks and insurance firms. This reduces the risk that banks will use insurance assets to meet liquidity needs and makes regulatory monitoring easier. Empirical studies also suggest that the overall risk of a combined banking-insurance entity could be lower than that of either one separately (see, for example, Estrella 2001; Fields et al. 2007).

Market power in financial services provision is a serious concern as bank markets are becoming increasingly concentrated. However, an alternative to entry restrictions is to mitigate abuses by market conduct regulation. Most countries ban explicit tying of insurance products to bank loans, for example, and some countries limit the use of cross-selling of insurance to bank customers. Moreover, allowing greater entry into insurance markets should foster competition in those markets and spur efficiency-enhancing innovations. Thus, while many complex regulatory issues remain to be resolved, allowing bank-insurance combinations may be economically sound.

Licensing requirements for agents are often justified as protecting consumers from incompetent or dishonest practitioners, and often are imposed with the support of the regulated industry or profession. The efficiency argument for industry support is that incompetent or dishonest sellers create negative externalities for other sellers by undermining industry reputation. However, there is also a political argument for industry support based on the fact that licensing requirements act as barriers to entry into the market. The requirements are sufficiently lenient that this argument seems weak in most markets. However, differences in license requirements across states or countries do limit entry, thereby protecting resident agents and insurers from competition. In addition, differential

³⁸There is still widespread dissatisfaction with the variation in licensing requirements across states. In support of increasing uniformity, a revised version of the NARAB was introduced in the US House of Representatives in March, 2011, with broad bipartisan support. The bill has not yet made it to the US Senate as of this writing.

licensing requirements for independent versus tied agents may increase the costs of distribution through independent agents or brokers relative to other systems.³⁹

Even if licensing does not serve to raise entry barriers and limit competition, there is the additional question of whether licensing requirements provide any benefits to consumers. Studies of the impact of licensing restrictions in industries other than insurance tend to show no significant quality improvements obtained from licensing. Benefits from licensing sales representatives may be particularly low, since imposing liability on insurance companies for the actions of their agents may give sufficient incentives for companies to choose honest agents and provide adequate training. Although differences in agent licensing requirements across jurisdictions and changes in requirements over time make it possible to examine its effects empirically, to our knowledge this has not been studied.

25.5.1.3 State Licensing and the Optional Federal Charter

The optional federal charter for insurance regulation, formally known as the National Insurance Act (NIA), was introduced to Congress most recently in 2007, and is expected to be reintroduced in a future session. The law proposes to create a national insurance regulator with broad authority to monitor insurer solvency. The law also anticipates a single licensing mechanism for federally licensed insurers and producers.⁴⁰

A continuing complaint about state-based insurance regulation is the lack of uniformity in producer licensing across states. The Producer Licensing Model Act (PLMA) was developed by the NAIC in 2000 to bring uniformity to licensing regulation across states. However, differences continue to exist for pre-licensing education requirements, post-licensing continuing education requirements, treatment of nonresident producers, and licensing and examination fees across states.⁴¹ For example, in Pennsylvania, the producer licensing fee is \$55.00 for residents and \$110.00 for nonresidents. In Maine, the resident license fee is \$45.00 and the nonresident fee is \$85.00. Texas has a licensing fee of \$50.00. The resident producer license fee in New York is \$80.00, and the nonresident license fee is a minimum of \$80.00, with higher fees depending on the producer's resident state. Nonresident license fees for life, accident, and annuities lines range from \$80.00 to a total of \$280 in Georgia and Oklahoma, and \$300.00 for New York nonresident producers domiciled in Hawaii. Similarly, in California, the resident license fee is \$144, and it is a minimum of \$144 for nonresident licenses, and higher if the domicile state charges a higher nonresident fee to California resident producers.⁴²

Perhaps more importantly, there are significant differences in state pre-licensing education requirements and continuing education requirements across states. For example, Pennsylvania requires 24 hours of pre-licensing education and 24 hours of continuing education over a 2-year period. Texas

³⁹It has been argued that licensing of service providers acts as a barrier to entry and protects the market position of incumbents. There are several studies that test this hypothesis for the accounting industry (see, for example, [Jacob and Murray 2006](#), and [Carpenter and Stephenson 2006](#)). These authors find a significant decrease in the number of candidates taking the CPA exam after the adoption of the requirement that undergraduate accounting majors take 150 university credit hours. Similarly, [Adams et al. \(2002\)](#) find a significant decrease in the number of practicing cosmetologists after state imposition of occupational licensing. To our knowledge though, there is no study that examines the impact of producer licensing on competition or market structure in the insurance industry.

⁴⁰The NIA refers to all insurance intermediaries as producers and we will follow that standard for the purposes of the discussion here.

⁴¹Much of what follows here is from [Regan \(2007\)](#), *The Optional Federal Charter: Implications for Life Insurance Producers*, a study sponsored by the American Council of Life Insurers.

⁴²Source: Search of state insurance department websites as of May, 2007.

requires no pre-licensing education, and 30 continuing education hours over a 2-year period. Illinois requires 40 hours of pre-licensing education and 15 hours of continuing education over a 2-year period.

The NAIC reports that 59% of states were in compliance with the pre-licensing education standard of the PLMA, while just 22% were in compliance with the continuing education requirements as of year-end 2005.⁴³ Do these differing requirements result in different levels of producer quality across states? Are there implications for customer service across states with different professional qualification standards? These are important questions that need to be addressed in future research.

Lack of uniformity in producer licensing and the need for multiple licenses for producers operating across states continues to impose substantial costs. The NAIC reports that there were 4,314,337 insurance producer licenses held in 2004 across all lines of insurance. On average, each insurance producer holds 7.9 separate licenses.⁴⁴ Assuming a cost, including fees and continuing education, of \$100 per license per year, the total direct cost of insurance licensing per year is \$431,733,400. Under a uniform licensing system with a single license covering all states and lines of business, insurance producer licensing costs could decline to \$54,390,800. Even if a producer held separate licenses for life, health, and property-liability lines, licensing costs would reach only \$163,172,400, just 38% of current levels.

Despite the inefficiencies inherent in the state-based regulation system, [Cooper \(2010\)](#) suggests that efforts to achieve regulatory uniformity in other financial services industries like banking has harmed consumers, and that a Consumer Financial Protection Agency may be a better solution. This is an extension of his arguments in [Cooper \(2008\)](#), in which he suggests alternative and less-invasive hybrid solutions, such as licenses issued by one state being effective in all states and state regulators enforcing rules enacted at the federal level.

25.5.2 *Conduct Regulation*

25.5.2.1 *Major Regulations*

Market conduct in distribution is a major focus of regulatory oversight in insurance. Virtually all countries have legislation in place to regulate insurance company and agent practices in the marketing of insurance. For example, the 1945 Unfair Trade Practices Model Act of the National Association of Insurance Commissioners (NAIC) defines and prohibits: the misrepresentation of policy benefits, terms and conditions, dividends or premiums, and the financial condition of the insurer; false, misleading or deceptive advertising about the business of insurance or the business of a specific insurer; agent misrepresentations on insurance applications in order to get a fee or commission; and agent misrepresentation of himself as a financial advisor.⁴⁵ This legislation has been adopted in whole or in part by all US states.

Additional legislation has been adopted in many US states to specify in more detail the allowable marketing practices of companies and agents offering life insurance and accident and health insurance.

⁴³Source: The Producer Licensing Uniformity Survey, accessed May 31, 2007 at http://www.naic.org/documents/committees_d_plwg_uniform_licensing_survey.xls.

⁴⁴The Bureau of Labor statistics reports that 627,346 people were employed in insurance agencies and brokerages in 2002, the last year the data is reported. The author assumes a 2% growth rate that matches the US population growth, and that 85% are licensed producers and 15% are non-licensed support staff. This is consistent with [Smith et al. \(2000\)](#). Based on this, we calculate that there are 543,908 insurance producers.

⁴⁵Commission rebating is also prohibited in the Act.

Advertising regulations adopted by some states move beyond general proscriptions against certain types of practices to provide detailed instructions regarding elements of policies that must be disclosed in advertising materials. Virtually all states have also adopted legislation regulating the activities of insurance agents with respect to the replacement of life insurance and annuities. This legislation requires agents to fully inform the buyer of changes in terms and conditions of insurance under the new policy, and to have the buyer sign a statement indicating knowledge that a replacement policy is being issued. The agent must include a statement on the policy application that indicates whether a policy is being replaced, and the buyer must be given a free-look period to compare the replacement policy with the existing policy.⁴⁶

Another aspect of life insurance regulation is rules regarding illustrations and projections of death benefits and cash values. All states have regulations specifying the nature and content of materials that must be disclosed to potential purchasers, including allowable methods to calculate the yields of different types of policies. Sellers are also required to provide Buyers Guides and other comparative information on forms approved by the state commissioner. More stringent rules exist for illustrations for whole life, universal and term life products in most countries, designed to prevent exaggerations and to ensure that consumers understand the hypothetical nature of the projections.

The EU Insurance Mediation Directive (2002) requires insurance intermediaries to disclose their relationship status with insurers and the nature of their remuneration for sales, specifies extensive disclosure of information to consumers, and requires extensive documentation of advice provided as the basis of an insurance sale.⁴⁷ All participating countries have implemented the directives, but revisions are currently underway due to Solvency II requirements and concerns that harmonization must encompass all sellers of insurance products and not just insurance agents. [PwC Luxembourg \(2011\)](#) reported that proposed revisions to the Directive would extend sales practice and disclosure regulations to direct writers. Based on their review of the industry and interviews with stakeholders from across the industry, PwC concluded that these extensions were not likely to create significant costs within the sales process.

To protect consumers from high-pressure sales tactics, 48 of the 73 countries reporting data to the International Association of Insurance Supervisors mandate a “cooling off” period (within which the policyholder may withdraw from the contract) for life insurance policies; 27 mandate a cooling off period for non-life policies (International Association of Insurance Supervisors 2011). Intermediaries are additionally required to adhere to codes of ethical conduct and are subject to training requirements and tests for competence and necessary skills, but standards vary across jurisdictions. Some jurisdictions, including the EU, USA, Canada, Japan and Australia, require agents selling products that have an investment component to provide impartial advice, and to offer products that are suitable to a customer’s needs and risk tolerance. The allowable forms of compensation to intermediaries may also be regulated, and/or intermediaries may be required to reveal to consumers potential conflicts of interest arising from the nature of their compensation.

Arguably, the weakest link in market conduct regulation is discovery and enforcement ([Tennyson 2011](#)). In the USA, each state insurance commissioner has broad powers to investigate insurer and agent practices, to issue cease and desist orders and to invoke fines or revoke licenses if violations of the law are found. In other countries enforcement authority may be shared between state or provincial and federal regulatory agencies, and in some other countries enforcement authority lies

⁴⁶Replacement of a policy with one that does not significantly increase insurance or other benefits is costly to the consumer because of the high levels of commission that go to agents at the time of sale. Other detrimental effects may include higher premium rates because the consumer is older, loss of cash value in the policy, and new incontestability and suicide clauses imposed in the new policy.

⁴⁷The value of the documentation, in particular, has been questioned by many. [Heinrich et al. \(2008\)](#) provide a case study suggesting that better documentation creates value for the insurer, however.

with industry self-regulatory bodies. A significant problem is that investigations are costly and are most effective at the level of the individual agent; this implies that abuses may go on for a long time without being discovered. Another impediment is the lack of information sharing and coordination across jurisdictions, a growing concern among the US states and the individual members of the EU. This latter problem may be mitigated somewhat in the USA as the NAIC implements its producer information database. This database aims to collect and disseminate information about licensed agents in every state, including licensing status and disciplinary actions. Finally, it should be noted that agent and broker behavior also must respond to state and federal judicial action, including litigation and guidance from state Attorneys General, as well as federal legislative action.

25.5.2.2 Economic Issues

Economic efficiency rationales for government intervention into sales and distribution practices are generally couched in terms of information problems, especially information asymmetries between sellers and buyers.⁴⁸ A central information problem that consumers face in insurance markets is judging product quality. The quality characteristics of an insurance policy are difficult to ascertain due to the complexity of the contract, the contingent nature of many of the services provided (e.g., claims handling and payments), and the fact that many services are provided over time (e.g., investments). This implies that quality is difficult to ascertain in advance of purchase, and may continue to be even after significant experience with the product.⁴⁹ Under this circumstance insurance sellers may have a financial incentive to charge a high price but to provide low quality. From this perspective, government regulations that prevent false or misleading advertising and that mandate full disclosure of relevant policy features may improve consumers' ability to estimate product quality at the point of purchase. Disclosure of relationships and commissions can be justified as making consumers aware of potentially biased incentives of the selling agent.

Arguments against disclosure regulation are often couched in terms of market responses to these problems. One argument is that firms have reputational incentives to maintain faith in their products and thus to provide high quality products. However, this mechanism may work imperfectly in markets for personal insurance because of consumers' limited opportunities to observe many aspects of quality. Moreover, the nature of insurance policies and their pricing is such that information may be difficult to compare across consumers. This may reduce the information content of negative consumer experiences, and hence mitigate adverse effects on reputation.

Another argument is that insurers have an incentive to provide information that is valued by consumers, because the consumer can be charged for it by the bundling of insurance products with information. This may be the case, for example, with sales through a professional agent. In this circumstance, high quality producers have an incentive to inform consumers about quality. However, to the extent consumers may obtain information about insurance and then use this to purchase elsewhere, the incentive to provide information is reduced. Thus, if a significant fraction of information provision in the insurance sale is of a general educational nature, information may be under-provided in the unregulated market.

If individual insurance companies have insufficient incentive to provide quality information to consumers, other market entities may arise to provide this information. For example, consumer publications may provide general information and quality comparisons. However, because information of

⁴⁸These issues are discussed extensively in [Ippolito \(1988\)](#).

⁴⁹At least as significant for consumers is the possibility that product quality may change after the purchase is made. Even if quality can be determined at the time of purchase, it may vary over time and hence continuous monitoring is required. This problem may be mitigated by solvency regulation and regulation of other insurer practices.

this sort is not proprietary, there will still be free-riding problems and hence likely under-provision of the information. Similarly, an industry cooperative association may provide educational materials that would benefit the sales of all companies, but would not have the correct incentives to provide company-specific information or comparative information across companies.

Given the nature of information problems in insurance markets, it is not clear that the market alone will provide sufficient information to insurance consumers. Hence, government intervention could improve the working of the market. The optimal form of intervention and the benefits of current regulatory measures are uncertain, however. It is possible that detailed regulations on information provision do not improve consumer decision making. Additional information may not be processed efficiently by the consumer, and large amounts of information may even exacerbate information-processing problems. The appropriate level of detail in the regulatory standards is also uncertain given the costs of compliance to insurance companies.

25.6 Concluding Remarks

The deregulation and increasing integration of financial services markets, technological progress, and changing demographics have resulted in a vast expansion of financial products and providers in direct competition with the insurance industry. For property and liability risks, the development of inexpensive hedging methods that substitute for insurance products has reduced the share of business risks covered by traditional insurance to less than 50% as of 1996. Even medium size businesses increasingly make use of self-insurance, captives and risk retention groups. The alternative risk transfer market has seen growth averaging 6% per year since the mid-1980s, about twice the growth rate in the commercial insurance market ([Andre and Sodowsky 1997](#)).

In the life insurance market, demographic shifts, longer life expectancies in retirement, and reductions in benefits from government retirement plans have reduced the demand for traditional life insurance products and increased demand for annuities and other financial planning products. Sales of ordinary life insurance continue to decline each year, while annuity sales increase at a rapid rate ([Hoesly 1996](#)). This shift in product demand has increased insurers' competition from banks and investment houses, which are licensed to sell investment products and tend to have lower distribution costs.

At the same time, in both property-liability and life insurance markets technological progress and competition have resulted in increasing standardization of the simpler insurance products. For these products there is an increasing emphasis on low-cost distribution, and nontraditional methods of reaching customers are an important area of growth in this sector. Direct response selling has attracted interest from even the more traditional insurers, as communication technology advances, including the Internet, make direct response more cost-effective. Insurers are also focusing on affinity markets and employer-based marketing programs for simple products. These programs differ from the traditional group insurance programs in that customers pay their own premiums and insurers use individual underwriting, but at lower cost due to administrative and marketing cost savings. These new distribution methods have been most effective for products such as automobile, homeowners, credit, and term life insurance—standardized products for which price is seen as an important factor in the buying decision. These forces have put considerable stress on traditional insurance distribution systems and produced pressure for innovation.

Two important trends are becoming visible in insurance marketing relationships: the use of multiple distribution systems within a single firm and increased specialization of the roles of different distribution systems. The industry is moving away from a set of fixed relationships between insurer and agent based upon company traditions, toward a more flexible system in which the distribution method is determined by the product and the customer base. Professional agents are

increasingly focused on the sale of complex, service-oriented products such as commercial insurance or other hedging instruments in property-liability markets, or estate and accumulation products in life insurance markets. Low-cost direct response alternatives are becoming more common for standardized insurance products. Some industry analysts have predicted that the tied agency system will be the ultimate loser in this shift, as it has neither the advantages of independent advice and service provided by brokers, nor the low costs of the direct selling alternatives (Nuttney 1995).

The increasing polarization of distribution systems by product and market is in keeping with economic theories of the firm that predict organizational structures that maximize profits. While existing academic studies of distribution system choice have focused primarily on the choice between an independent and a tied agency force, current market trends distinguish more clearly between fully integrated distribution without the use of professional agents versus the agency system of distribution itself. This appears to be due to both technological and competitive changes in insurance markets.

As the professional agent's role becomes more specialized, and as increasing numbers of insurance products are being sold without the benefit of agent advice, market conduct and disclosure regulation will become increasingly important in the industry. Professional certification and regulatory monitoring of agents must receive more attention in the service-oriented sectors of the industry. Consistent with approaches in other financial services industries, disclosure issues will likely become the key enforcement tool for standardized insurance products sold via direct marketing. Issues surrounding resale price maintenance and the potential for agent discounting should become less important, as price-sensitive products are increasingly sold through alternative means.

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Chapter 26

Corporate Governance in the Insurance Industry: A Synthesis

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Abstract In this chapter, we synthesize the literature and empirical research on the nature and consequences of corporate governance in the insurance industry. We focus on several mechanisms of corporate governance such as the Board of Directors, CEO compensation, ownership structure, among other things and discuss their impact on firm performance and risk taking. The chapter finally identifies several avenues for future research on the subject.

26.1 Introduction

The last two decades have witnessed a continuing trend of deregulation and integration of capital markets, accompanied by major events in the financial world. The 1997 East-Asian crisis, followed by recent corporate scandals in the USA and around the world, culminated with a worldwide financial crisis like no other in its global reach. All these events have one underlying common feature, failing corporate governance. While the 1997 Asian crisis was largely blamed by commentators on the expropriation of resources by family concentrated ownership and the prevalence of pyramids and conglomerates (e.g., *The Economist*, April 20th, 2006; [Rajan and Zingales 2005](#)), the recent financial scandals resulting from accounting frauds and earnings' management in such large players as Enron, WorldCom, and Adelphia were primarily blamed on the behavior of top executives and their excessive risk taking that does not serve the best interest of shareholders (and other stakeholders in the firm). Around the world, the recent financial turmoil brought to the forefront the magnitude of resources' expropriation by highly paid executives and their risk taking behavior (e.g., [Bebchuck 2009](#); [Fahlenbrach and Stultz 2010](#); [Hill 2011](#)). Unsurprisingly then, all these events attracted the attention of investors, practitioners, and regulators alike to the practices of corporate governance and their effectiveness in curbing such behavior.

The insurance industry was not immune to the most recent crisis, and the recent bailout of the "giant" American Insurance Group (AIG) by the US government was equally attributed to excessive

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risk taking.¹ The fact that by the end of 2007 the life insurance industry held \$482 billion of Mortgage Backed Securities (which accounted for close to 22% of their collective bond portfolio and 16% of total invested assets) has similarly raised questions about risk taking behavior and triggered the interest in corporate governance practices in the insurance industry, by investors as well as policy-makers (Baranoff and Sager 2009). More precisely, following the crisis, questions pertaining to executive compensation packages, board of directors duties, the importance of risk management within the firm, and the impact of regulation (among others) have surfaced, leading to a large debate on the type of effective monitoring mechanisms that could curtail managers, excessive risk taking behavior (e.g., Erkens et al. 2012; Hill 2011; Bebhuck and Spamann 2009; Kirkpatrick 2009). The magnitude of the crisis added importance to the emergency of identifying and implementing such mechanisms, and central banks and international organizations in developed and developing countries alike, from Ireland to Nigeria, have issued tighter corporate governance codes for credit institutions and insurance firms. In recent days, executive compensation in the insurance industry has come under the spotlight following a shareholder “revolt” at Aviva (one of the most important insurers in the UK) when “54% of shareholders voted against the remuneration committee’s salary structure which would have seen then Chief Executive Andrew Moss’s salary increase from 960,000 to 1.05M British pounds” (The Post, May 24th, 2012). Similarly, The Boston Globe (April 11th, 2012) reports that Liberty Mutual’s long-time Chief earned an average of nearly \$50 million a year from 2008 to 2010, making him one of the highest-paid corporate executives in the country, and prompting the State Division of Insurance to launch a thorough examination of executive compensation in the industry.

In this chapter we review the literature and empirical research on the nature and consequences of corporate governance, particularly focusing on the corporate outcomes of corporate governance. We also describe a wide array of governance mechanisms, as documented in the literature, and assess their effectiveness in aligning the incentives of managers in the insurance industry.

The rest of the discussion is organized as follows: after we define corporate governance, we synthesize the evidence on corporate governance and its importance to corporate performance and risk taking in the particular setting of the insurance industry. We finally describe the proposed and ongoing reforms in corporate governance and discuss some avenues for future research.

26.2 What Is Corporate Governance?

In general, corporate governance is defined as the set of mechanisms that are put in place to oversee the way firms are managed and long-term shareholder value is enhanced.² In the corporate governance literature, the firm is viewed as a nexus of contracts (both implicit and explicit). When contracts are incomplete because of, among other things, uncertainty, informational asymmetries and “contracting costs” (Grossman and Hart 1986; Hart and Moore 1990; Hart 1995), conflicts of interest

¹Please refer to Harrington (2009) for a study on the role of AIG and insurance sectors in the financial crisis and overall implications for insurance regulation. Also refer to Dionne (2009) for a discussion of the main causes of the crisis as well as the implications in terms of risk management.

²More exhaustive definitions abound in the literature. For instance Shleifer and Vishny (1997, p. 737) state that corporate governance “deals with the ways in which suppliers of finance to corporations assure themselves of getting a return on their investment.” A similar definition is proposed by John and Senbet (1998, p. 372) who consider all stakeholders in the firm and argue that “corporate governance deals with mechanisms by which stakeholders of a corporation exercise control over corporate insiders and management such that their interests are protected.” A contemporaneous definition is proposed by Zingales (1998, p. 4) who states that corporate governance is “the complex set of constraints that shape the ex-post bargaining over the quasi-rents generated by a firm.”

between insiders and outsiders resulting from the separation between ownership and control arise, and corporate governance becomes necessary (as first suggested by Jensen and Meckling 1976).

In Jensen and Meckling's (1976) model, the principal (the external owner of the firm) engages in a contract of an agency relationship with an agent (the manager). The authors show that the utility maximizing agent has an incentive to expropriate resources from the firm, especially if it is widely held. This expropriation of resources takes the form of perquisites and less effort (shirking), which both lead to a destruction of value to shareholders. To limit this self-serving behavior of the agent, the principal needs to put in place costly monitoring mechanisms such as nominating independent directors on the board or calling upon rating agencies and auditing agencies. In addition, as Jensen and Meckling (1976) propose, the principal may be led to incur some bonding costs in order to commit the agent to a value-maximizing behavior. Such costs may include designing a new compensation package or granting a larger equity participation in the firm to the agent (i.e., allowing for insider ownership). In equilibrium, however, the marginal benefits in terms of value creation should compensate for these costs.

In addition to the perquisites and the shirking problems discussed in Jensen and Meckling (1976), the literature identifies several other problems resulting from the principal–agent relationship: While firms have an infinite life leading shareholders to anticipate perpetual cash flows, managers' expected cash flows are limited to their salaries while they manage the firm. They thus have a shorter horizon than shareholders which is likely to enhance their preference for short-term projects or projects with a higher short-term return (negative net present value). Agents also exhibit different risk preferences which worsen the principal–agent conflict. While managers have undiversified portfolios (a large portion of their wealth being tied to the company), shareholders are able to diversify their portfolios and thus eliminate all unsystematic risk specific to the company. Finally, widely-dispersed ownership contributes to the conflicts between the agent and the principal because of “the free-riding problem of minority shareholders” that short of incentives to monitor managerial actions, will provide the agent with discretion over the decisions of the firm.

These theoretical arguments have fostered a large empirical literature on the magnitude and outcome of the principal–agent conflicts (also called the equity agency costs). In what follows, we review the monitoring devices or corporate governance mechanisms and describe their documented link to risk taking and performance in the particular context of insurance firms. These corporate governance mechanisms basically fall into two main categories: internal and external to the firm.

26.2.1 Internal Mechanisms of Corporate Governance

The literature identifies several internal governance mechanisms that permit the firm to control agency problems. One of the most widely studied such mechanisms is the *Board of Directors* (BOD hereafter). Previous studies characterize the effectiveness of the BOD through different dimensions: for example, smaller boards have been shown to be more effective than larger ones as these latter are harder to coordinate. Indeed, the literature shows that large BODs do not seem to be associated with a higher firm value (Cheng 2008). Sah and Stiglitz (1986, 1991) argue that a large board is more likely to reject risky projects because convincing a large number of directors that a project is worthwhile is more difficult. In other words, coordination and agreement are harder to reach in larger boards.

Another measure of the quality of corporate governance at the board level that has drawn much attention lately is the independence of the board and the weight of *outside directors* herein. Firm value is found to increase with the number of outside directors suggesting that they play a positive role in the

monitoring and control function of the board. Coles et al. (2006) report that the percentage of insiders on the board is positively related to firm risk and argue this is the case because insiders have incentives to increase volatility and to adopt financing and investment policies that heighten firm risk. Brick and Chidambaran (2008) find that board independence (i.e., higher percentage of outsiders) is negatively related to firm risk when measured by the volatility of stock returns. In general, however, the results in the empirical literature remain mixed as to whether outside directors are systematically correlated with firm performance and value (Dahya et al. 2002). In the insurance industry, more specifically the US property/casualty insurance industry, Lai and Lin (2008) show that asset risk is lower, and total equity risk and systematic risk are higher when board size increases. MacCrimmon and Wehrung (1990), however, document that a higher percentage of executives on the board will lead to *less* risk taking. These contrasting results seem to support the argument put forward by Amihud and Lev (1981) that managers may become risk averse and choose to focus on maximizing their job security. In this case, they become more likely to reject high-risk projects. The same argument also appears in Laeven and Levine (2007) and Bebchuk and Weisbach (2009). A related study by Huang et al. (2011) examines the link between the efficiency of the US property/casualty insurance firms and corporate governance dimensions related to board size, independent directors, financial experts on the audit committee, as well as CEO tenure, auditor independence, and the existence of blockholding. The authors observe that corporate governance and efficiency are indeed significantly related.

The duality of the Chief Executive Officer (CEO) as the chair of BOD has also been extensively studied. The argument is that having the CEO also holding the BOD leadership is likely to create conflicts of interest and to increase the incentives of the manager to expropriate firms' resources at the expense of shareholders. The board thus becomes ineffective at protecting shareholders' interests as suggested by Jensen (1993, p. 866) who notes that "Without the direction of an independent leader, it is much more difficult for the board to perform its critical function." The literature provides mixed evidence on this issue, although it is more generally found that independence of the BOD³ contributes to a closer monitoring of managerial behavior (e.g., Brickley et al. 1997; Baliga et al. 1996; Dalton and Dalton 2011).

Focusing on the insurance industry, Adams et al. (2005) find that firms with dual CEOs (i.e., also chairing the BOD) exhibit a high risk taking behavior (i.e., stock return volatility). They interpret this as evidence that "the likelihood of either very good or very bad decisions is higher in a firm whose CEO has more power to influence decisions than in a firm whose CEO has less power in the decision-making process." A more recent study by Boubakri et al. (2008) shows that CEO duality is positively related to mergers and acquisitions in the insurance industry considered to be risky investments. These studies overall confirm that CEO duality is costly to shareholders and worsens agency conflicts within the firm. This evidence in the insurance industry is at odds with the argument in Bebchuk and Weisbach (2009) that CEOs in seeking to protect their job are likely to become more risk averse. Another aspect that has been recently addressed in the insurance literature is CEO turnover (He et al. 2011). Based on a sample of US property/liability insurance firms, He et al. (2011) document that firms with a CEO change exhibit more favorable performance changes (measured by revenue and cost efficiency indicators) than their matching counterparts. The use of a frontier efficiency analysis by the authors is motivated by the fact that other performance measures, namely stock or accounting measures, do not allow to consider both public and private firms. He et al. (2011) results confirm previous evidence for publicly listed firms in Denis and Denis (1995) that accounting performance (measured by ROA) is higher after CEO changes. These results also complement evidence in He et al. (2011) who examine the impact of organizational structure on CEO turnover and find this latter to

³Independence here is understood as the CEO not chairing the BOD.

be less sensitive to firm performance in mutual insurers compared to stock insurers. This suggests that “managers are less effectively monitored in mutual companies than in stock companies,” as sustained by [McNamara and Rhee \(1992\)](#).⁴

Another important internal corporate governance mechanism is *managerial compensation*: extensive empirical evidence identifies a strong relation between firm performance and executives’ performance-based compensation, suggesting that compensation can align the interests of managers and shareholders ([Mayers and Smith 2010](#); [Milidonis and Stathopoulos 2011](#)). However, because of managerial risk aversion, this relation is theoretically nonoptimal ([Farinha 2003a](#)). In addition, the literature shows that managers tend to time stock-option grants to their advantage, suggesting that this device may not be completely effective. In a recent study, [Milidonis and Stathopoulos \(2011\)](#) ask whether “the executive compensation practices of US insurance firms encourage managerial risk taking? If so, could this drive an insurance firm toward default?” To answer these questions, the authors examine the relation between executive compensation and firm risk. Unlike previous studies that use accounting performance measures (i.e., ROA) for insurance firms (e.g., [Ke et al. 1999](#)), [Milidonis and Stathopoulos \(2011\)](#) focus on the distance to default and find that firms closer to default grant lower share-based, long-term incentive plans and high option-based compensation. These different compensation schemes have opposing effects on firm risk as option-based compensation is positively related to future firm default risk while share-based incentives are not.

Insider ownership has also been considered as a potential effective corporate governance mechanism that aligns the interests of managers and shareholders. [Morck et al. \(1988\)](#) and [McConnell and Servaes \(1990\)](#), among others, show that below a certain level, managerial ownership creates the necessary incentives for managers to increase firm value (incentive effect). However, beyond a certain threshold, managers become entrenched (entrenchment effect) and end-up rejecting value-enhancing projects that do not benefit them, which in turn adversely affects performance ([Miller 2011](#)). Many studies provide support for the managerial ownership incentive effect, and an equally important number finds no association of managerial ownership with performance. As suggested by [Cho \(1998\)](#) and [Himmelberg et al. \(1999\)](#), this mixed evidence may be due to the failure to control for the endogeneity of managerial ownership or for the simultaneous effect of other monitoring devices in the firm that can either substitute or complement each other. Looking at property/liability insurance firms [Downs and Sommer \(1999\)](#) show that managers are more likely to undertake highly risky activities when their stakes in the firm increase from low levels, but this relationship reverses after managerial ownership goes beyond the 45% threshold, indicating nonlinearity of the relationship between risk and managerial ownership. This confirms the evidence discussed above in [Morck et al. \(1988\)](#) and [Cho \(1998\)](#) that managerial ownership and firm performance exhibit a nonlinear relationship, with an incentive effect at low levels of managerial ownership and an entrenchment effect at higher levels of ownership.

Associated to managerial characteristics, few studies have recently pointed out the role of Directors and Officers’ (D&O) insurance as a signal of the firm’s corporate governance quality. [Holderness \(1990\)](#) takes a corporate governance perspective and argues that directors’ and officers’ (D&O) insurance may have an important governance role in publicly owned companies.⁵ Using a sample of UK firms, [O’Sullivan \(1997\)](#) tests Holderness’s monitoring hypothesis by examining the association between board composition, managerial ownership, external shareholder control, and the purchase of D&O. The results generally support the monitoring hypothesis. Very few studies focus

⁴Using the distinction in the organizational structure of property/liability insurance companies, [Mayers et al. \(1997\)](#) document a larger proportion of outside directors in mutual companies compared to stock companies.

⁵As reported by [Kang \(2011\)](#), as many as 95% of Fortune 500 companies maintain D&O liability insurance.

on D&O insurance premiums and the relation between insurance purchase and firm value⁶: if D&O premiums are a signal of corporate governance quality, they should empirically be negatively related as lower premiums should characterize better governed firms. Indeed, when Core (2000) tests whether D&O insurance premium is commensurate with the firms' corporate governance practices, he finds that it does.⁷

As argued in Jensen and Meckling (1976), small shareholders in widely held corporations may lack the motivation to monitor management. To avoid this free-riding problem, *large shareholders and block-holders* have been considered as an alternative effective governance mechanism given the large stakes they usually hold in the firm. The empirical evidence is generally supportive of this conjecture and shows that large shareholders are associated with better performance and higher firm value. They are also positively associated to managerial turnover which is consistent with an effective monitoring role. Some mixed results however are documented outside the USA, particularly in countries where concentrated ownership dominates, as large shareholders are found to be entrenched once their stake goes beyond a certain threshold (Claessens et al. 2002). In the insurance industry, Cheng et al. (2011) investigate the link between risk taking of life/health insurers in relation to their institutional ownership to determine whether market discipline from institutional investors serves as a substitute for regulation.⁸ After controlling for the endogeneity of risk and institutional ownership stability by using a system of simultaneous equations, they find that institutional ownership stability reduces total risk through an increase in leverage and underwriting risk and an increase in investment risk. Their evidence is in accordance with the incentive role of institutional investors. More recently Cheng et al. (2011) report that institutional investors owned 54% of life/health insurers' stocks and 59% of property/casualty insurers' stocks over the period 1992–2007. The authors then show that these block-holders contribute to reduce market risk, as well as the investment and underwriting risk of property/casualty insurance companies. The literature offers several arguments for such a negative relation: in particular, institutional investors are more likely to put pressure on managers so that they reduce risk and the overall cost of capital of the firm (Pound 1988; Cebenoyan et al. 1999). Additionally, as argued by Cheng et al. (2011), institutional investors are likely to pressure managers to reduce risk in order to satisfy both shareholders and regulators. Finally, as their wealth is generally highly concentrated, institutional investors are generally more risk averse and thus have additional incentives to play an active monitoring role in overseeing managers' activities.⁹ The specific impact of institutional investors on investment risk and underwriting risk is discussed in several previous studies including Staking and Babbel (1995), Cummins and Sommer (1996), and Baranoff and Sager (2003). The authors generally assert that, given their expertise and their long-term profile, institutional investors can control investment risk, as well as the underwriting activities and risk of the companies. Additional evidence on the monitoring function of institutional investors is provided by Pagash and Warr (2011) who find that firms with institutional ownership are more likely to adopt enterprise risk management and to hire a Chief Risk Officer (CRO). In addition, they show that when the CEO has incentives to take risk, the firm becomes more likely to hire a CRO.

Lastly, *debt and dividend policies* have been shown to have a monitoring effect as they subtract the free cash flows generated by the firm from the discretion of managers, thus reducing the equity agency

⁶This lack of evidence is largely due to the fact that firms, other than in Canada and the USA, are not required to disclose information about their D&O insurance.

⁷In an earlier study, Bhagat et al. (1987) examine stock price performance around the announcement of the purchase of D&O insurance and find no evidence that D&O insurance purchase adversely affects shareholders' wealth.

⁸Previous studies on the link between corporate governance and risk taking include John et al. (2008), Laeven and Levine (2007), and Sullivan and Spong (2007). Available empirical evidence documents that corporate governance, and particularly the audit quality, has a mitigating effect on risk taking (Firth and Liao-Tan 1998).

⁹Please refer to Sullivan and Spong (2007) for instance.

costs (Farinha 2003b). Indeed, by imposing a fixed stream of debt repayments on the firm, debt plays a disciplinary role that ensures management pursues shareholders' value maximization. The literature also shows that the terms of the debt contract and protective covenants protect bondholders from expropriation and financial distress (Agrawal and Knoeber 1996). Based on the same principle, by returning the available "free cash-flow" to shareholders as extraordinary dividends, dividend policy plays a disciplinary role leading managers to enhance firm performance and maximize shareholders' wealth (Crutchley and Hansen 1989). Studies in the insurance industry that focus on these issues are practically inexistent, with the notable recent exception of Zou et al. (2009).¹⁰ The authors examine the differences in dividend payout ratios between mutual and stock property–liability insurers in the USA and find that the organizational forms of insurance firms condition corporate dividend decisions. Specifically, their results suggest that mutual insurers have a lower dividend payout ratio than stock insurers and that the former adjust this ratio toward a long-run target level more slowly than the latter. These results are in accordance with the higher greater agency costs of equity in mutual insurers (as discussed below in Sect. 26.3).

Like most public firms, insurance companies involve a variety of stakeholders that exhibit differing incentives and objectives. However, unlike typical public nonfinancial firms, insurance firms may involve particular stakeholders that do not exist elsewhere (Cole et al. 2011). Indeed, regulators and non regulatory groups (e.g., agents, reinsurers) generally participate in monitoring insurance companies: Garven and Lamm-Tennant (2003) and Doherty and Smetters (2005) show that reinsurers have an incentive to monitor the behavior of insurers to avoid financial distress "and minimize excessive taxes" (Cole et al. 2011; Cole and McCullough 2006). Insurance agents can also act as monitoring agents as shown by Regan (1997) and Cole et al. (2011).

A general conclusion that emerges from the above discussion is that the literature fails to identify a universally adopted device that is effective in monitoring managerial discretion. Each mechanism may provide benefits but at a cost, which may explain why corporate governance characterizes firms differently across industries. In addition, several of these mechanisms may substitute to each other or complement each other making it more difficult to come up with a general recommendation. In a contemporaneous study, Cole et al. (2011) are first to control for the joint determination of a variety of stakeholders acting as monitors to insurers (i.e., reinsurers, agents, outside board members and regulators) in determining risk taking. Their results show that the impact of some stakeholders offsets the impact of others, although overall all stakeholders contribute to reduce firm risk measured by Best's capital adequacy ratio and the variance in the return on assets.

In addition to these internal mechanisms, firms also benefit from additional potential monitoring devices that are external to the firm, as discussed in the next section.

26.2.2 External Mechanisms of Corporate Governance

The literature identifies several external mechanisms that can encourage managers to align their interests with shareholders and commit to a value-maximizing behavior. They include the threat of takeover (Fama and Jensen 1983a, 1983b; Jensen and Meckling 1976), rating agencies, and the legal environment:

The *takeover market* has been considered in the literature to act as a performing disciplining device, particularly in the USA. Indeed, in few other countries, with the exception of the UK, does one find a highly efficient takeover market. The nature of corporate ownership that tends to be concentrated rather than diffuse (as in the USA and the UK) hinders the use of takeovers. In addition,

¹⁰One earlier contribution on the subject dates back to the 1980s (Cheng and Forbes 1980).

capital markets' lack of liquidity and regulation may limit the use of takeovers as a disciplining tool. Nevertheless, the existing studies on USA and UK markets show that an active hostile takeover market is indeed efficient as a watchdog device (Denis and McConnell 2005). In an attempt to provide evidence on the effectiveness of corporate control, Cummins and Weiss (2004) examine M&As in the European insurance market and study the stock price impact of M&A transactions on target and acquiring firms. Their analysis shows negative cumulative average abnormal returns for acquirers and substantial positive abnormal returns for targets. Splitting the sample into cross-border and domestic transactions reveals that cross-border transactions are value-neutral for acquirers and value-creating for targets. More recently, Cummins and Xie (2008) look at the productivity and efficiency of acquirers and targets involved in M&A transactions in the US property–liability insurance industry between 1994 and 2003. Using data envelopment analysis (DEA) and Malmquist productivity indices, the authors show that “acquiring firms achieved more revenue efficiency gains than non-acquiring firms, and target firms experienced greater cost and allocative efficiency growth than non-targets.” The results also reveal that “financially vulnerable insurers are significantly more likely to become acquisition targets, consistent with corporate control theory.” These results are in line with those in Cummins et al. (1999) who analyze the US life insurance industry.

There are two types of *ratings for insurance companies* to measure their default risk: (1) financial strength ratings (FSRs), which measure the overall ability of the insurance firm to pay future financial obligations, and (2) DRRs, which rate the creditworthiness of the firm with respect to debt. Halek and Eckles (2010) examine the information value contained in insurer analysts' rating changes by studying their effects on stock returns. They find an asymmetric reaction of stock prices to rating changes. While upgrades have no significant impact, downgrades result in lower returns. The results seem to vary depending on the rating agency “as share prices react more strongly to A.M. Best and S&P downgrades than to Moody's.” Although the literature for publicly listed nonfinancial firms points to the importance of analysts' activity as a monitoring device that impacts value, there remains a void in the insurance literature regarding this issue. One reason may be as extensively discussed by Milidonis and Stathopoulos (2011) that these ratings as measures of firm default risk may not be appropriate especially given changes in the ratings' calculations and standards for FSR over time. Also, the market for FSRs is almost a monopoly as A.M. Best has been the sole provider of ratings from 1899 until the 1980s. In contrast, the market for DRRs is more competitive with several active rating agencies that publish DRRs, such as S&P, Moody's, and Fitch. In any case, the authors underscore the limitations of these ratings especially for panel studies.

Recent studies point to the importance of the *legal environment including investor protection and creditor protection* in ensuring that shareholders' rights are enforced. For instance, the literature provides evidence that the extent of minority shareholders' rights and legal enforcement of rules contribute to reduce corporate earnings' management by insiders. Firm value as well as firm liquidity (i.e., bid-ask spread) are also found to be positively associated with the level of protection of minority shareholders (La Porta et al. 2000, 2002). New insights from recent international corporate governance studies suggest that the relative inefficiency of external governance mechanisms in several countries, specifically the legal environment, leads local firms to compensate with ownership concentration, suggesting that ownership concentration and the legal system act as substitutes (Shleifer and Vishny 1997; Denis and McConnell 2005). The interaction of all these mechanisms, both external and internal to the firm, makes the task of disentangling their incentive effects more difficult. To the best of our knowledge, these issues remain yet to be explored in the insurance sector across countries.

There is rare international out-of-sample evidence on corporate governance impact on performance in the insurance industry compared to the literature on international corporate governance of typical public firms. One recent exception relates to the risk taking behavior of European insurance companies from UK and Germany. Specifically, Eling and Marek (2011) are able to provide evidence that controls for the differences between the market-based UK corporate governance environment and the control-based system that prevails in Germany. Using a sample of 276 firms between 1997 and 2009, they

proxy risk taking by asset risk and product risk and focus on stock insurance companies. Their corporate governance indicators include executive compensation, supervisory board compensation and independence, as well as the number of board meetings and ownership structure. The study concludes that UK insurance firms engage in more risk taking than their German counterparts and that large shareholdings and concentrated ownership contribute to increase risk taking.

Overall, we find that there has been little attention in the insurance literature devoted to the impact and effectiveness of external mechanisms as cross-country studies are virtually inexistent. Studies on the monitoring effect of rating agencies are also scarce. Although most existing studies focus on internal mechanisms, there is yet area for research regarding the potential impact of debt and dividend policies as solutions for agency conflicts. More evidence is also warranted about the impact and effectiveness of managerial compensation design.

26.3 A Particular Governance Structure in the Insurance Industry and Its Implications

A particular feature of the Property/Liability insurance industry in terms of corporate governance has generated a large number of studies. Specifically, insurance firms in the sector exhibit different governance characteristics, particularly their *organizational structure* (mutual versus stock insurance companies). Agency theory arguments hold that mutual insurance companies are better able to control conflicts of interest between policyholders and owners whereas stock insurance companies control better the conflicts between owners and managers (Mayers and Smith 1992; Cummins et al. 2007).¹¹ Consistent with these arguments, He and Sommer (2011) sustain that insurance companies are subjected to different governance systems: mutual company managers have less discretion and are subject to substantially fewer control mechanisms being primarily internally monitored by the BOD, while stock insurers' managers are monitored by both internal *and* external control mechanisms. He and Sommer (2011) precise that "in stock firms managers are subject to managerial ownership, block ownership, institutional ownership and takeover" while mutual company managers are precluded from such monitoring mechanisms.

Lai and Lee (2011) exploit the particular organizational structure of the US PC insurance industry to assess the link between corporate governance and risk taking (captured by underwriting risk, leverage risk, and investment risk, in addition to a measure of total risk). The authors argue that "the stock organizational structure may provide incentives for risk taking to increase the wealth of shareholders." Indeed, shareholders, who have limited liability, are more likely to take risk in order to maximize firm value and hence directly benefit from increased earnings. The costs of insolvency instead would be shared with policyholders (Galai and Masulis 1976). In the mutual organizational structure, it is "policyholders who bear the consequences of insolvency, and thus maintain a low level of risk taking" (Cummins and Nini 2002; Ho et al. (2011). Lai and Lee (2011) results confirm indeed that mutual insurers have lower underwriting risk, leverage risk, investment risk, and total risk than stock insurers. Most importantly, they find that CEO duality is related to lower leverage and higher total risk. Controlling for BOD size shows that all types of risks (i.e., underwriting, leverage, investment and total risk) are higher when BOD size increases. A lower percentage of independent directors also results in higher investment risk and higher total risk. Earlier studies by Mayers and Smith (1992) and Smith and Stutzer (1990) all suggest that the stock organizational structure is associated with risky insurance activities. Stock insurers will engage in riskier activities if

¹¹See Mayers et al. (1997), Lamm-Tennant and Starks (1993), and Lai and Limpaphayom (2003), among others.

the underwriting risk is borne by shareholders thus encouraging managers to take more risk (Cummins et al. 2007). Doherty and Dionne (1993) suggest however that the mutual form of insurance coverage may exhibit a high risk taking behavior because of its higher diversification structure.

26.4 Corporate Governance Reforms and Avenues for Future Research

Corporate governance is of particular importance in light of the recent financial crisis. Since the last accounting scandals that undermined investors' confidence, new regulations on corporate governance were made mandatory for public firms. The main regulatory change is the Sarbanes Oxley Act of 2002 (SOX hereafter). SOX identifies corporate governance best practices that need to be complied with by publicly listed companies. Specifically, public companies are now required to have a significant proportion of independent directors on their BOD to ensure that business decisions are made objectively and to the benefit of shareholders. To qualify as an independent director, one needs to have no business relationship with the firm and should not be employed by the firm on which BOD he is sitting. Sections of SOX also impose that the BOD has the following committees: one for audit, one for compensation, and one that addresses nominations and corporate governance issues. All these committees report to the BOD. Also a code of ethics needs to be implemented within the firm addressing issues such as potential conflicts of interests, confidentiality issues, and compliance with laws and regulations. In this respect, SOX Section 806 provides substantial protection to employee whistle-blowers who report events of company misconduct.

Although nonpublic insurance companies are not yet legally bounded to comply with SOX provisions, it is very likely that they will adopt part of these corporate governance best practices. In fact, reforms in corporate governance and disclosure policy are warranted from insurance companies, especially in light of the NAIC's proposed revisions to the Model Audit Rule which is based on aspects similar to SOX. These proposed revisions include creating independent audit committees whose members should be financially literate and implementing an internal control process over financial reporting as suggested by Section 404 of SOX, in order to ensure the transparency and reliability of the accounting information provided by the firm.¹² Outside the USA as well, and particularly in Europe, major changes in risk management and disclosure requirements, all of which relate to corporate governance, are expected when the Solvency II regime becomes effective.¹³ To the best of our knowledge, there is no empirical evidence yet on the impact of SOX on the profitability or risk taking behavior of insurance companies, except for a study by Lai and Lee (2011) that shows that "insurers have higher underwriting risk and total risk but lower leverage risk post-SOX." These results suggest that the change in regulation was an effective device in tackling the excessive risk behavior of insurers. This evidence is generalized to USA publicly traded companies, irrespective of their sector, by Barger et al. (2010).

In the aftermath of the crisis, regulators, investors, shareholders, and policyholders all alike question the effectiveness of the existing corporate governance system in overseeing insurance companies and their excessive risk taking. In this respect, Baranoff and Sager (2009) note that "during 2008, asset risk dominated the attention of life insurers as they grew to appreciate the true risks of their vast holdings of mortgage-backed securities (MBS)."

¹²The audit committee is also responsible for monitoring risk management activities.

¹³As defined on the web page of the Financial Services Authority (www.fsa.gov.uk): Solvency II is a fundamental review of the capital adequacy regime for the European insurance industry. It aims to establish a revised set of EU-wide capital requirements and risk management standards that will replace the current solvency requirements.

The measurement and characterization of the different aspects of risk require more in-depth studies. The literature on risk taking in insurance firms uses different measures of risk taking: market risk measures, accounting risk measures, risk based capital via cash flow simulations, and financial health of insurance firms. [Cole et al. \(2011\)](#) sustain that previous studies therefore capture only certain aspects of firm risk. Similarly, earlier studies used a variety of performance measures including cost and efficiency scores, accounting measures of performance, and stock price measures. Further research is warranted to answer questions pertaining to these measurement issues such as: (1) What is the best risk/performance indicator?¹⁴ (2) Can one build a measure of comprehensive risk exposure or is it better to keep the analysis on an individual risk measure?

These questions are of particular importance in light of the evidence in [Lai and Lee \(2011\)](#) who show that corporate governance variables have different impacts depending on the risk measure. Correcting for the endogeneity of corporate governance in performance and risk in these kinds of studies is also very important as emphasized by [Cheng \(2008\)](#). The recent evidence in [Cheng et al. \(2011\)](#) who control for this issue underscores the importance of tackling endogeneity in corporate governance studies.

Another area for future research is to expand the literature on the risk taking behavior of insurance firms after SOX. Section 404 of SOX requires extensive disclosure to investors, and effective internal control systems, to protect shareholder wealth. Several studies have been published on the impact of SOX on firm behavior and notably risk taking by managers. For instance, [Cohen and Lys \(2005\)](#) note that after enactment of SOX in 2002, managers have less incentives to take higher risk ([Barger et al. 2010](#)). [Kang and Liu \(2007\)](#) find that managers of firms with better corporate governance and less information asymmetry become more conservative in their investment choices after enactment of SOX. [Boyle and Grace-Webb \(2008\)](#) suggest that SOX has resulted in higher auditing costs, lower corporate investment, and less risk taking ([Litvak 2007](#)). [Downs and Sommer \(1999\)](#) find a positive relation between risk and managerial ownership in the insurance industry. The risk-reducing effect of institutional ownership on insurers is also more pronounced after 2001. The finding in [Cheng et al. \(2011\)](#) that institutional investors ownership stability can reduce insurer risk suggests that regulators may curtail excessive risk taking by incentivizing steady ownership by institutional investors. However, one needs to control for the joint determination of different monitoring groups (as in [Cole et al. 2011](#)). In the same vein, researchers should exploit the upcoming implementation of the Solvency II regime in Europe to expand the literature on the impact of deregulation on insurance firms in an international context.

Remuneration and executive compensation that have often been blamed during the crisis for the problems witnessed by major financial institutions also deserve more attention in future research. A step in this direction is found in [Mayers and Smith \(2010\)](#) who recently examine the link between outside directors and pay-for-performance sensitivity in mutual and stock insurers. They find that compensation changes are more sensitive to changes in performance when the proportion of outside directors on the board is higher, but only in Mutuals. Also related to executive compensation, the literature is lacking evidence on the potential incentives for earnings' management. A recent contribution in this respect is by [Eckles et al. \(2011\)](#) who investigate the impact of executive compensation and corporate governance on earnings' smoothing in the US insurance industry. The authors show that the degree of earnings' manipulation depends on corporate governance structures, especially board independence. Higher bonus payments are also found to contribute to earnings' management in insurance companies.

Finally, an alternative corporate governance mechanism, namely rating agencies, has been thrust in the spotlight during the recent financial turmoil. These agencies, under intensive debate on future

¹⁴[He et al. \(2011\)](#) provide a partial answer by stating that frontier efficiency scores are better adapted to a study of public and private insurance firms since most of them are private and stock prices are not available.

regulation, are perceived to have failed along two aspects: First, they are blamed for the lack of accurate information available to market participants. Also, they are blamed for failing to reduce the information asymmetries between investors and insiders. The role of rating agencies as a potential corporate governance mechanism has received little attention (Frost 2006), especially in the insurance industry (Pottier and Sommer 1999), although we believe it definitively deserves further investigation.

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Chapter 27

Systemic Risk and the Insurance Industry

J. David Cummins and Mary A. Weiss

Abstract This chapter examines the potential for the US insurance industry to cause systemic risk events that spill over to other segments of the economy. We examine *primary indicators* that determine whether institutions are systemically risky as well as *contributing factors* that exacerbate vulnerability to systemic events. Evaluation of systemic risk is based on a detailed financial analysis of the insurance industry, its role in the economy, and the interconnectedness of insurers. The primary conclusion is that the core activities of US insurers do not pose systemic risk. However, life insurers are vulnerable to intra-sector crises; and both life and property-casualty insurers are vulnerable to reinsurance crises arising from counterparty credit risk. Noncore activities such as financial guarantees and derivatives trading may cause systemic risk, and interconnectedness among financial institutions has grown significantly in recent years. To reduce systemic risk from noncore activities, regulators need to continue efforts to strengthen mechanisms for insurance group supervision, particularly for multinational groups.

27.1 Introduction

The financial crisis of 2007–2010 is a classic example of a systemic risk event, in which problems in one sector of the economy, in this case housing, spread to other sectors and lead to general declines in asset values and real economic activity. Because the crisis began in the financial industry and one of the major firms that played a role in aggravating the crisis was an insurer (American International Group (AIG)), questions have been raised about whether the insurance industry is a major source of systemic risk. Answering this question has important implications for policy-makers, regulators, managers, and investors. Indeed, the newly established Financial Stability Oversight Council is charged with determining whether there are nonbank financial institutions that should be designated as systemically important financial institutions (SIFIs).

The purpose of this chapter is to investigate whether the US insurance sector poses a significant systemic risk to the economy. Because systemic risk is discussed throughout the chapter, we begin with our definition of systemic risk, which is discussed in more detail below:

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Systemic risk is the risk that an event will trigger a loss of economic value or confidence in a substantial segment of the financial system that is serious enough to have significant adverse effects on the real economy with a high probability.¹

Importantly, an economic event is not considered systemic unless it affects a substantial segment of the financial system and leads to a significant decline in real activity. For example, an event such as the 1980s liability crisis, which had a significant effect on the property-casualty insurance industry, would not be considered systemic.

In our analysis of systemic risk, we identify *primary factors* that can be used to measure the degree of systemic risk posed by specific markets and institutions (i.e., size, interconnectedness, and lack of substitutability). We also identify *contributing factors* that increase the vulnerability of markets and institutions to systemic shocks. Next, data are presented on the macroeconomic role of insurers in the US economy and the recent financial history of the insurance industry in terms of leverage and insolvency experience. Because interconnectedness is one of the primary factors driving systemic risk, an important contribution of this study is to provide information on a form of interconnectedness unique to the insurance industry—reinsurance counterparty relationships. Finally, we draw conclusions regarding the potential for systemic risk events originating in the insurance industry.

An important distinction in our analysis is between the *core activities* of insurers, such as insurance underwriting, reserving, claims settlement, and reinsurance, and the *noncore* or *banking activities* engaged in by some insurers (such as AIG). Noncore activities include provision of financial guarantees, asset lending, issuing credit default swaps (CDS), investing in complex structured securities, and excessive reliance on short-term sources of financing.

Our analysis of the core activities of insurers focuses on the US life-health (life) and property-casualty (P-C) insurance industries.² However, our analysis of reinsurance counterparty exposure analyzes interrelationships between US licensed insurers and reinsurers worldwide. Our discussion of noncore activities provides data on the participation by insurers in the market for asset-backed (structured) securities and discusses more generally CDS, asset lending, and financial guarantees. By way of preview, the analysis suggests that the core activities of insurers are not a major source of systemic risk. However, to the extent that insurers engage in noncore activities, they become more susceptible to and could become a source of systemic risk.

The remainder of this chapter is organized as follows. Section 27.2 presents a review of the literature on systemic risk in the insurance industry. Section 27.3 provides a brief synopsis of the financial crisis of 2007–2010 to provide context for our analysis of the insurance industry. Section 27.4 further defines systemic risk and analyzes primary indicators that define systemically important institutions and markets and the principal contributing factors that exacerbate vulnerability to systemic shocks. Section 27.5 addresses the issue of whether US insurers are systemically risky in their core activities by analyzing the macroeconomic role of insurers, insurer insolvency experience, and reinsurance counterparty exposure. Based on the data presented, we analyze systemic risk in the insurance industry in terms of the primary and contributing factors. Section 27.6 analyzes the noncore activities of insurers in terms of their potential for causing systemic risk. Section 27.7 conducts

¹Our definition of systemic risk is analogous to the definition proposed in Group of Ten (2001, p. 126). Similar definitions have been proposed by other organizations. See, for example, Financial Stability Board (2009).

²Specifically, we focus on insurers that are regulated as life-health or P-C insurers by the National Association of Insurance Commissioners (NAIC). Thus, the health insurance operations of life-health insurers are implicitly included. We do not analyze firms regulated purely as health insurers by the NAIC, a category that includes health maintenance organizations (HMOs), Blue Cross-Blue Shield plans, and similar organizations. The latter organizations played little or no role in the financial crisis. Their business models, regulatory annual statements, and filing requirements also differ significantly from those of life-health and P-C insurers. The chapter also does not analyze the monolines, which are important but deserve to be analyzed separately.

an analysis of business segments and derivatives activity for a sample of 13 systemic insurers and ten nonsystemic insurers used as a control group to search for significant differences between systemic and nonsystemic insurers, where systemic insurers are those identified as systemic in [Billio et al. \(2011\)](#) and [Acharya et al. \(2010\)](#). Section 27.8 concludes and provides some directions for future research.

27.2 Literature Review

There have been a few prior studies of systemic risk in the insurance industry. [Swiss Re \(2003\)](#) investigates whether reinsurers pose a major risk for their clients, the financial system, or the economy. The study examines two major channels through which reinsurers could create systemic risk—lack of reinsurance cover and insolvencies of primary insurers and banks triggered by reinsurer defaults. The study concludes that reinsurance insolvencies do not pose a systemic risk because primary insurers spread their reinsurance cessions across several reinsurers and the probability of reinsurer default is low. The conclusion is that “conditions for systemic risk...in terms of lack of cover, insolvency, or links to banks or capital markets, do not exist.” However, the study concedes that reinsurers are linked to the banking sector via credit derivatives, the same instruments that brought down AIG.

A study by the [Group of Thirty \(2006\)](#) also investigates the degree to which the reinsurance sector may pose systemic risk. The study investigates three potential channels through which such a shock might impinge on the real economy: through its effects on the primary insurance sector, the banking sector, and the capital markets. The study concludes that “there is no evidence that the failure of an insurance or reinsurance company in the past has given rise to a significant episode of systemic risk.” The study presents the results of a “stress test” projecting the results of reinsurer failures equivalent to 20% of the global reinsurance market. The conclusions are that even failures of this magnitude would be unlikely to trigger widespread insolvencies among primary insurers and that the effects on the real economy would be minimal.

[Bell and Keller \(2009\)](#) investigate the systemic risk of the insurance industry. They point out that, unlike banks, insurers do not take deposits and do not play a role in the monetary or payment systems. The study concludes that “classic insurers therefore do not present a systemic risk and, as a consequence, are neither ‘too big’ nor ‘too interconnected to fail’.” However, they argue that insurers engaging in nontraditional activities such as credit derivatives can pose systemic risk, which can be controlled through more rigorous risk-based capital requirements.

[Harrington \(2009\)](#) conducts an extensive study of systemic risk in insurance, focusing on the Federal bailout and takeover of AIG. He concludes that “the AIG crisis was heavily influenced by the CDS written by AIG Financial Products (AIGFP), not by insurance products written by regulated insurance subsidiaries. AIG also ran into major problems with its life insurance subsidiaries’ securities lending program.” He also concludes that systemic risk is relatively low in P-C insurance, compared to banking, because P-C insurers have much lower leverage ratios.³ However, he concedes that the potential for systemic risk is higher for the life insurance industry due to higher leverage, susceptibility to asset declines, and the potential for policyholder withdrawals during a financial crisis.

³Although AIG clearly was treated by policy-makers as a systemic institution during the crisis, experts continue to disagree about whether the AIG crisis was truly a systemic event ([Harrington 2009](#)). We do not have a definitive answer to the counterfactual question—if AIG had been allowed to fail, would it have created significant spillover effects to banks, insurers, and the real economy? It is clear that AIG had substantial counterparty exposure to major banks and that European banks would have had to bolster their regulatory capital if AIG had failed. Further research is needed to measure the extent of the exposure and the possible effects if AIG had not been bailed out.

The [Geneva Association \(2010\)](#) examines the role played by insurers during the financial crisis as well as the potential for insurers to cause systemic risk. The study concludes that insurers are significantly different from banks in terms of their longer-term liabilities and strong operating cash flow. The study concludes that insurers did not play a major role in the financial crisis aside from the monolines and insurers engaging in nontraditional activities such as CDS. Two noncore activities are identified as potential sources of systemic risk: (1) derivatives trading on noninsurance balance sheets, as in the case of AIGFP and (2) mis-management of short-term funding from commercial chapter or securities lending.

[Grace \(2010\)](#) conducts a series of tests on insurer stock prices to help determine “whether insurers contribute to systemic risk or whether they are potential victims of systemic risk.” He conducts an event study of the reaction of insurer stock prices to seven events related to the financial crisis, including the Lehman and AIG crises. He conducts Granger causality tests to determine whether AIG and other insurers receiving Federal bailout funds influenced the broader stock market. Finally, he simulates the relationship among insurer stock returns over time using an error-corrected vector auto regression model. The findings suggest that AIG was systemically important but that generally the insurance industry is not a significant source of systemic risk.

[Baluch et al. \(2011\)](#) investigate the role of the insurance industry in the financial crisis, with an emphasis on European markets. Their analysis reveals significant correlation between the banking and insurance sectors and finds that the correlation increased during the crisis period. They indicate that the greatest impact of the crisis was felt by (1) specialist finance guarantee insurers (such as US monolines); (2) insurers heavily engaged in capital market activities such as AIG and Swiss Re; (3) bancassurers; and (4) to a lesser extent, credit and liability insurers. They conclude that systemic risk is lower in insurance than in banking but has grown in recent years due to increasing linkages between banks and insurers and growing exposure to nontraditional insurance activities.

Although the prior literature raises few concerns regarding systemic risk originating from insurance, there are several reasons to evaluate the issue in more detail. First, recent “micro” analyses of interconnectedness of financial firms suggest that the linkages between banks, insurers, hedge funds, and other financial firms may be more significant than prior research seems to suggest. [Billio et al. \(2011\)](#) utilize monthly stock returns to analyze interconnectedness of financial firms. The study concludes that “a liquidity shock to one sector propagates to other sectors, eventually culminating in losses, defaults, and a systemic event.” The study also finds that financial firms have become more highly interrelated and less liquid during the past decade. Similarly, [Acharya et al. \(2010\)](#), also using stock price data, find that several insurers ranked highly based on an econometric measure of systemic risk when compared to systemically important banks. The implications of these two chapters are considered in more detail below.

A more recent micro-level analysis by [Chen et al. \(2014\)](#) estimates systemic risk in the banking and insurance industries using a methodology developed by [Huang et al. \(2009\)](#). Systemic risk is measured using intra-day stock price data and daily-frequency market value data on CDS spreads. Using the systemic risk measure, they examine the interconnectedness between banks and insurers with Granger causality tests. The results show significant bidirectional causality between insurers and banks. However, after correcting for conditional heteroskedasticity, the impact of banks on insurers is stronger and of longer duration than the impact of insurers on banks. Stress tests confirm that banks create economically significant systemic risk for insurers but not vice versa. Of course, this finding applies to the sample as a whole (i.e., insurers in general) and does not rule out the possibility that individual insurers could create systemic risk through noncore or other activities.

A second reason for conducting further analysis of the US insurance industry is that most prior studies have been oriented towards the global insurance and reinsurance industries rather than conducting an in-depth analysis of the US industry (e.g., [Swiss Re 2003](#); [Group of Thirty 2006](#); [Bell and Keller 2009](#); [Geneva Association 2010](#); [Baluch et al. 2011](#)). [Harrington \(2009\)](#) focuses on AIG rather than the US insurance market in general. A third rationale for conducting further

analysis of this issue is that several of the prior studies on the topic have been published or sponsored by the insurance industry (e.g., [Swiss Re 2003](#); [Bell and Keller 2009](#); [Geneva Association 2010](#)). Therefore, it is important to provide an independent, third party analysis. The fourth reason to conduct additional analysis of systemic risk in the US insurance industry is that the reinsurance counterparty exposure of US-licensed insurers has rarely been investigated systematically in any detail.⁴ Interconnectedness among insurers may pose a significant risk to the insurance sector with potential systemic implications.

27.3 The Financial Crisis of 2007–2010

The financial crisis that gripped US and world markets from 2007 through 2010 was triggered by a liquidity shortfall in the US banking system caused by the overvaluation of assets. The crisis resulted from the collapse of the global housing bubble, which peaked in the USA in 2006 and led to sharp declines in the value of securities tied to real estate, particularly mortgage-backed securities (MBS) and collateralized debt obligations (CDOs). The crisis is generally considered to be the worst financial meltdown since the Great Depression of the 1930s. It spread far beyond the housing and mortgage markets, leading to a general credit crunch and a loss in value of the US stock market of more than \$8 trillion in 2007–2008 ([Brunnermeier 2009](#)). Real gross domestic product (GDP) in the USA declined by 0.3% in 2008 and declined by 2.6% in 2009, increasing again in 2010–2011 (BEA 2012). Likewise, real GDP in the European Union declined by 4.1%, and GDP of the newly industrialized Asian nations declined by 0.81% in 2009.⁵ The spillover of the housing collapse into the broader credit market, the stock market, and the real economy is a classic example of systemic risk, as explained in more detail below.

In analyzing whether the insurance industry is systemically risky, it is helpful to briefly summarize how the housing and mortgage crises spread to other parts of the economy, in order to understand whether an insurance crisis could spread to other sectors. The housing bubble was caused by the availability of easy credit, resulting from a low interest rate environment and large capital inflows into the USA from foreign countries, particularly from Asia. The low interest rates resulted both from US monetary policy and the capital inflow from abroad. The foreign capital inflows were driven in part by the high US current account trade deficit, which required the US to borrow money from abroad, driving interest rates down ([Bernanke 2005](#)).

The easy credit conditions encouraged debt-financed consumption in the USA and fueled the housing boom. Borrowers assumed difficult mortgages and home-buyers took out home equity loans in large volume, assuming that housing prices would continue to rise and they would be able to refinance on favorable terms. During the buildup to the housing collapse, banks had been moving from the traditional banking model, where banks make loans that are held to maturity, to the “originate and distribute” banking model, in which loans are pooled and resold through securitization ([Brunnermeier 2009](#)). The originate and distribute model weakened incentives for originators and lenders to underwrite and monitor loans, and the parallel development of securitization increased the worldwide demand for MBS and CDO securities, facilitating the widespread distribution of these asset-backed securities (ABS). The result was a weakening of underwriting standards and dramatic expansion of subprime lending. Housing prices began to decline in 2006, and mortgage delinquency rates more than doubled between 2006 and 2008 ([Mortgage Bankers Association 2010](#)).

⁴The exception is a single chapter on P-C insurance by [Park and Xie \(2011\)](#), which is briefly discussed below. Life insurance counterparty relationships have not previously been analyzed.

⁵Global GDP data are from the International Monetary Fund, World Economic Outlook Database, April 2011 (Washington, DC).

As mortgage delinquency rates continued to rise, MBS, particularly those backed by subprime mortgages, began to experience defaults and ratings downgrades. The resulting uncertainty about the value of structured securities and the reliability of financial ratings led to the freezing of the commercial chapter market in mid-2007, as banks were unsure about the exposure of potential counterparties to mortgage-related asset problems. This created what amounted to a “run” on the *shadow banking system*, consisting of investment banks, hedge funds, and other institutions, which were heavily reliant on short-term borrowing to finance their operations.⁶ As defaults and asset write-downs continued in 2008, the monoline insurers, which insured municipal bonds and structured financial products, began to be downgraded, threatening the bond ratings for hundreds of municipal bonds and ABS and putting further pressure on credit markets.

Among the first major casualties of the deteriorating market was Bear Stearns, which experienced a run by its hedge fund clients and other counterparties, leading to its Federally backed absorption into JPMorgan Chase in 2008. In September of 2008, problems with subprime mortgages led to the Federal takeover of Fannie Mae and Freddie Mac, government-sponsored enterprises, which at the time owned or guaranteed about half of the outstanding mortgages in the US market (Wallison and Calomiris 2008). Later that month, Lehman Brothers was forced into bankruptcy and AIG experienced a “margin run” (Gorton 2008), leading to its bailout by the US government.⁷ Shadow bank runs also contributed to failures or severe financial deficiencies of other major institutions such as Washington Mutual, Wachovia, and Merrill Lynch. Thus, the crisis of 2007–2010 can be viewed as surprisingly similar to a classic bank run, with the exception being the important role played by securitization, the role played by excessive leverage, the degree of interconnectedness of institutions, and the mismatch of asset-liability maturities (Brunnermeier 2009). Internationally, the dominance in European countries of a few large banks exacerbated the spread of the crisis.⁸

It is also interesting to consider the extent to which the recent crisis is unique. Bardo and Landon-Lane (2010) identify five global financial (banking) crises since 1880 and conclude that there are many similarities among the crises.⁹ What seems to be unique about the recent crisis is the extent to which financial innovation in terms of securitization, derivatives, and off-balance sheet (OBS) entities played an important role. These developments were facilitated by technological advances and, in many advanced economies, deregulation of the financial industry. Financial innovations were internationally linked due to the globalization of financial markets that began in the 1970s. In earlier crises, stock and bond markets were globally linked but the linkages are much stronger today and span virtually all financial markets. The interconnections between banking and insurance markets are also more

⁶The shadow banking system consists of financial intermediaries that provide banking-like services without access to central bank liquidity or explicit public sector credit guarantees. Shadow banks are less stringently regulated than commercial banks. Shadow banks include finance companies, structured investment vehicles, hedge funds, asset backed commercial chapter conduits, money market mutual funds, securities lenders, and government-sponsored enterprises. For further information, see Pozsar et al. (2010).

⁷AIG had issued large volumes of credit default swaps through a subsidiary, AIG Financial Products. As mortgage backed securities default rates increased, AIGFP faced margin calls from its counterparties. It also had engaged in asset lending operations with many of the same counterparties, who demanded that the positions be closed out as the crisis unfolded (Harrington 2009).

⁸These banks frequently had crossholdings with large (dominating) insurers which contributed to the under-performance of banking stocks.

⁹One similarity is that international financial crises tend to occur when the USA is involved, both because of the size of the US economy and because the US banking system has always been crisis prone. US banking regulation is inefficient and unstable, including a patchwork of regulatory institutions and a dual Federal-state regulatory system. Financial globalization was also a common factor in financial crises, even in the nineteenth century, although globalization is much more pervasive today than in the past. The international monetary regime also has been important in the proliferation of crises both before and after the era of the gold standard and fixed exchange rates. Finally, asset booms and busts (“bubbles”) fueled by capital inflows and sudden stops are also a factor in common to most crises.

extensive today than during earlier financial crises. Because the unique elements driving the recent crisis still exist, there is a strong possibility of a similar crisis developing in the future unless enhanced global regulation is developed.

27.4 Systemic Risk: Definition, Primary Indicators, and Contributing Factors

This section further analyzes the definition of systemic risk and identifies primary risk factors for systemically important activities. We emphasize that *instigating* or *causing* a systemic crisis is not the same as *being susceptible* to a crisis. To instigate a systemic crisis the shock or event must first emanate from the insurance sector due to specific activities conducted by insurers and then spread to other financial sectors and the real economy.

27.4.1 Definition of Systemic Risk: Further Analysis

Embedded in our definition of systemic risk, given in the introduction, are two important criteria: (1) Economic shocks become systemic because of the existence of spillover effects whereby there is a contagious loss of value or confidence that spreads throughout the financial system, well beyond the locus of the original precipitating shock. Thus, the failure of one financial institution, even a very large one, which does not spread to other institutions is not a systemic event. (2) Systemic financial events are sufficiently serious to have significant adverse effects on real economic activity. For example, events such as the US liability insurance crisis of the 1980s and Hurricane Andrew in 1992 would not be considered systemic events, even though they caused major disruptions of property- casualty insurance markets, because they did not have sufficient adverse effects on real economic activity.

The financial crisis of 2007–2010 is a clear example of a systemic event, which began in the housing market and spread to other parts of the financial system, resulting in significant declines in stock prices and real GDP. Other systemic events of the past quarter century include the Japanese asset price collapse of the 1990s, the Asian financial crisis of 1997, and the Russian default of 1998, which was associated with the fall of Long-Term Capital Management. All of these events were characterized by an abrupt loss of liquidity, discontinuous market moves, extreme volatility, increases in correlation and contagion across markets, and systemic instability ([World Economic Forum 2008](#)).

Systemic risk may arise from interconnectedness among financial institutions that cascades throughout the financial sector and/or from a significant common shock to which many financial firms have a large exposure ([Helwege 2010](#)).¹⁰ Traditionally, systemic risk has been considered important because it results in increases in the cost of capital or reductions in its availability, while being frequently accompanied by asset price volatility. Capital and volatility disruptions can have spillover effects on the economy by affecting demand and/or supply of goods for an extended period ([Financial Stability Board 2009](#)).

¹⁰The shock may emanate from mispricing of assets as in an asset bubble or from unexpected exogenous events such as changes in oil prices. Not all asset bubbles are associated with systemic risk (e.g., the dot com bubble).

27.4.2 Systemic Risk: Primary Indicators and Contributing Factors

This analysis distinguishes between primary indicators of systemic risk and factors contributing to vulnerability to systemic risk (Financial Stability Board 2009). The *primary indicators* are criteria that are useful in identifying systemically risky markets and institutions, whereas the *contributing factors* are criteria that can be used to gauge financial vulnerabilities and the capacity of the institutional framework to deal with financial failures. The primary indicators determine whether a market or institution is systemic, and the contributing factors determine vulnerability of the market or institution to systemic events. That is, it is possible for an institution to be systemically important but not relatively vulnerable. This discussion provides conceptual background for the analysis of the systemic importance and vulnerability of the US insurance industry.

27.4.2.1 Primary Indicators

The three primary indicators of systemic risk are: (1) size of exposures (volume of transactions or assets managed); (2) interconnectedness; and (3) lack of substitutability.¹¹

This section discusses the indicators and provides examples related to the financial crisis of 2007–2010. These factors have been identified as having a high *potential* for generating systemic risk, i.e., they are not necessarily associated with systemic risk in every instance. This is especially true of size. For example, a large firm may not pose a systemic problem if it is not interconnected or if its products do not lack substitutes.¹² Thus, interactions among the factors also are important in identifying systemically risky institutions.

The size of the firm helps to determine whether it is “too big to fail.” In fact, the term “too big to fail” came into existence from the bailout of Continental Illinois Bank and Trust Company of Chicago in 1984 (FDIC 1997). Continental Illinois faced bank runs from its wholesale depositors, prompting the FDIC to guarantee all liabilities of Continental Illinois through a direct infusion of capital. In general, size may be important in a failure if it is associated with large spillover effects. At the time of its failure, Continental Illinois was the seventh largest bank in the USA. Large financial institutions may be engaged in significant, large transactions with other financial institutions through interbank activities and securities lending, such that potential spillover effects into the general economy could occur with their failure.

The size of an institution is frequently measured by its assets or equity, in absolute terms or relative to GDP. However, the financial crisis of 2007–2010 demonstrated that conventional balance sheet measures of size may not capture an institution’s systemic importance. For example, the now defunct Financial Products division of AIG wrote hundreds of billions of dollars of credit default swap coverage with relatively little capitalization, suggesting that notional value of derivatives exposure and potential loss to a firm’s counterparties should also be considered when analyzing size. Gauges of

¹¹Our primary indicators are based on those identified in Financial Stability Board (2009). The International Association of Insurance Supervisors (IAIS) (2009) proposes a fourth factor, *timing*, based on the argument that systemic insurance risk propagates over a longer time horizon than systemic risk in banking. The International Monetary Fund (IMF) considers size, interconnectedness, leverage, and (risky) funding structure in assessing the systemic importance of institutions (IMF 2009). Our taxonomy also considers leverage and funding structures but classifies these as contributing factors rather than primary indicators.

¹²As pointed out in Financial Stability Board (2009, p. 9), “While size can be important in itself, it is much more significant when there are connections to other institutions. The relevance of size will also depend on the particular business model and group structure, and size may be of greater systemic concern when institutions are complex (see below). . . for example, well capitalized large institutions with simpler business models and exposures can be a source of stability in times of stress.”

size that may be more relevant than conventional measures are the value of OBS exposures of the institution and the volume of transactions it processes. Systemic risk associated with size can also arise from clusters of smaller institutions with similar business models and highly correlated assets or liabilities, such that the cluster has the systemic impact of a much larger firm. Thus, the term “too big to fail” is being replaced with “systemically important financial institution” or (SIFI) because conventional size measures do not provide adequate proxies for spillover effects.

Interconnectedness, the second primary risk factor, refers to the degree of correlation and the potential for contagion among financial institutions, i.e., the extent to which financial distress at one or a few institutions increases the probability of financial distress at other institutions because of the network of financial claims and other interrelationships. This network or “chain” effect operates on both sides of the balance sheet as well as through derivatives transactions, OBS commitments, and other types of relationships. Although the classic example of contagion occurs in the banking sector as a “run on the bank” that cascades throughout the system, conventional depositor-driven bank runs have probably been eliminated by deposit insurance. However, as we have seen, the financial crisis of 2007–2010 was driven by other types of runs on the shadow banking system involving inter-bank lending, commercial chapter, and the market for short-term repurchase agreements (“repos”). As pointed out by [De Bandt and Hartmann \(2000\)](#):

While the ‘special’ character of banks plays a major role, . . . systemic risk goes beyond the traditional view of single banks’ vulnerability to depositor runs. At the heart of the concept is the notion of contagion, a particularly strong propagation of failures from one institution, market, or system to another. . . . The way in which large value payment and security settlement systems are set up as well as the behavior of asset prices in increasingly larger financial markets can play an important role in the way shocks may propagate through the financial system. (p. 8).

The propagation of systemic problems through interconnectedness or contagion usually requires exposure to a common shock or precipitating event such as a depression in agriculture, real estate, or oil prices ([Kaufman and Scott 2003](#)). In the crisis of 2007–2010, the common shock was the bursting of the housing price bubble.

The third primary indicator of systemic risk is lack of substitutability, where substitutability is defined as the extent to which other institutions or segments of the financial system can provide the same services that were provided by the failed institution or institutions. In order for lack of substitutability to pose a systemic problem, the services in question must be of critical importance to the functioning of other institutions or the financial system, i.e., other institutions must rely on the services to function effectively. Examples of critical financial services for which substitutability is a problem are the payment and settlement systems. The payment system is defined as “a contractual and operational arrangement that banks and other financial institutions use to transfer. . . funds to each other” ([Zhou 2000](#)). The settlement system is the set of institutions and mechanisms which enable the “completion of a transaction, wherein the seller transfers securities or financial instruments to the buyer and the buyer transfers money to the seller” ([BIS 2003](#)). Settlement is critical in the markets for stocks, bonds, and options and is usually carried out through exchanges. Failure of significant parts of the payment and settlement system would bring the financial world to a standstill. During the financial crisis, the freezing of the interbank lending and commercial chapter markets were critical because there were no other significant sources of short-term credit for the shadow banks. Market-making (liquidity) is another service that is critically important and lacks substitutes.

In analyzing the systemic risk of the insurance industry, it is important to determine not only whether there are adequate substitutes for insurance but also whether insurance is actually critical for the functioning of economic markets to the same degree as payments, settlements, liquidity, and short-term credit. To create a systemic risk through lack of substitutability, a financial service must be part of the infrastructure which permits markets to function or be essential for the operation of many firms in the economy.

One quantitative indicator of substitutability is market concentration, measured by the market shares of the leading firms or the Herfindahl index. Concentration in investments—either by type

of asset or geographic location—may have spillover effects if the asset or geographic area becomes problematic. Ease of market entry is also important, including technological, informational, and regulatory barriers that prevent new entrants from replacing the services of financially troubled firms. Qualitative evaluations of the degree to which key financial sector participants depend upon specified services also are important in determining substitutability.

27.4.2.2 Contributing Factors

Although the number of factors contributing to systemic risk is potentially much larger, four factors are emphasized in this discussion: (1) leverage, (2) liquidity risks and maturity mismatches, (3) complexity, and (4) government policy and regulation. These measures can be considered indicators of the vulnerability of systemically important institutions to financial distress resulting from idiosyncratic or system-wide shocks.

Leverage can be measured in various ways, including the ratio of assets-to-equity or debt-to-equity. Ideally, a measure of leverage would include both on and off-balance-sheet (OBS) positions. Leverage can also be created through options, through buying securities on margin, or through some financial instruments. Leverage is an indicator of vulnerability to financial shocks and also of interconnectedness, i.e., the likelihood that an institution will propagate distress in the financial system by magnifying financial shocks. Highly levered firms are vulnerable to *loss spirals* because declines in asset values erode the institution's net worth much more rapidly than their gross worth (total assets) (Brunnermeier 2009). For example, a firm with a 10-to-1 assets to equity ratio that loses half of its equity due to a loss of asset value would have to sell nearly half of its assets to restore its leverage ratio after the shock.¹³ But selling assets after a price decline exacerbates the firm's losses. If many institutions are affected at the same time, the quest to sell assets puts additional downward pressure on prices, generating the loss spiral.¹⁴

Liquidity risk and asset-liability maturity mismatches also increase financial firm vulnerability to idiosyncratic and systemic shocks. Liquidity can be broken down into two categories—*market liquidity* (the tradability of an asset) and *funding liquidity* (the ability of the trader to fund its trades) (Brunnermeier and Pedersen 2009). Market liquidity risk arises if an institution holds large amounts of illiquid assets. Such positions are vulnerable if the institution encounters difficulties obtaining financing (funding liquidity risk), triggering the need to liquidate all or part of its asset holdings. Concentration in illiquid assets is especially problematical if other institutions also have significant exposure to the same classes of assets.

Liquidity risk is exacerbated by the extent of an institution's asset-liability maturity mismatch. One of the factors in the financial crisis of 2007–2010 was that shadow banks were financing long-term positions in MBS and other risky assets with short-term sources of financing. The shadow banks relied heavily on short-term commercial paper and short-term repurchase agreements (“repos”), whereby the bank raises funds by selling an asset and promising to repurchase it at a later date. A significant amount of shadow bank financing took the form of overnight repos. Use of these short-term financing vehicles exposed the shadow banks to *funding liquidity risk*, i.e., the risk that investors will stop

¹³With a 10-to-1 assets-to-equity ratio, a 5% decline in asset values would wipe out half of equity. If liabilities remained unchanged, the firm would need to sell about 47.4% of assets and use the proceeds to pay off liabilities in order to restore its assets-to-equity ratio to the pre-shock level.

¹⁴Excessive leverage played an important role in exacerbating the financial crisis of 2007–2010. In October of 2004, the Securities and Exchange Commission effectively suspended net capital regulations for the five leading investment banks. The banks responded by increasing leverage ratios to 20, 30, or even 40-to-1, purchasing mortgage backed securities and other risky assets. Three of the five banks—Bear Stearns, Lehman, and Merrill Lynch, eventually failed or encountered severe financial difficulties during the crisis.

investing in commercial chapter and other short-term investments, requiring the bank to liquidate positions in longer-term assets under unfavorable market conditions.

Related to liquidity is *optionability* or *marginability* of a firm's assets, liabilities, or derivatives positions. Optionability refers to the ease with which an institution's counterparties can reverse their positions and/or require the institution to post additional margin or collateral to such positions. In the case of AIG, declines in the value of securities covered by AIG's CDS portfolio led to demands by counterparties for additional collateral. Simultaneously, AIG also faced collateral calls from its asset lending counterparties, many of which were also CDS counterparties. Optionability is a function of the contractual relationships between counterparties. Some types of financial contracts (e.g., bank demand deposits) are optionable, while other types are not (e.g., P-C insurance policies). In the former case, depositors can demand their deposits at any time, whereas in the latter, the policyholder must have a legitimate claim, which is subject to an orderly settlement process.

Complexity of a financial institution and/or its asset and liability positions also can exacerbate vulnerability to financial shocks. Complexity has several important dimensions—(1) Complexity of the organization, including its group structure and subsidiaries. For example, diversified financial services firms offering banking, insurance, and investment products are more complex than single industry firms. (2) Geographical complexity. That is, firms operating internationally are more complex than those focusing only on one or a few national markets. Multinational firms are exposed to a wider variety of local and regional risk factors as well as multi-jurisdiction regulatory risk. (3) Product complexity. Firms that are highly exposed to new and complex financial products are more vulnerable to shocks. Such products expose firms to risks that may not be completely understood. Complexity played a major role in the AIG debacle during the financial crisis. AIG was a large and complex organization, and its Financial Products division was heavily involved in complex CDS operations without fully understanding the risks. The complexity of the organization and its products impeded monitoring by both management and regulators, contributing to the crisis.

Related to complexity is opacity, i.e., the degree to which market participants have access to information about transactions and positions taken by an institution or trader in specific markets and instruments. Because CDS transactions are not cleared through an exchange, the volume and pricing of these transactions is opaque, preventing markets from adjusting to overly levered positions such as that taken by AIGFP. Complex, multinational organizations are inevitably more opaque than focused national or regional organizations.

Government policy and regulation also can contribute to financial system fragility. For example, deposit insurance and insurance guaranty fund protection not only reduce the probability of runs but also create moral hazard for banks and insurers, increasing the risk of financial distress (Acharya et al. 2009). Regulation can also create other types of adverse incentives. AIG sold large quantities of CDS to European banks that were using the contracts to reduce their required capital through regulatory arbitrage. The complexity and opacity of AIGFP contributed to creating a regulatory blind-spot that permitted the subsidiary to operate with excessive leverage. Further, regulation intended to enhance the solvency of the regulated financial institution actually can exacerbate a crisis. For example, an increase in capital requirements can occur in times of financial distress, resulting in asset sales or further restrictions on the ability to create credit. That is, capital requirements can be pro-cyclical.

27.5 Systemic Risk in the Core Activities of Insurers: An Empirical Analysis

This section presents empirical information on the systemic importance of the insurance industry, emphasizing the US life and P-C industries. The section begins by considering the macroeconomic importance of the insurance industry in terms of contribution to GDP and a source of investable funds

Table 27.1 World insurance: premiums, penetration, and density by region, 2011

| Region | Nonlife insurance | | | | Life insurance | | | |
|-------------------------------|-------------------|---------------------------|-------------------|---------------------|----------------|---------------------------|-------------------|---------------------|
| | Premiums | Share of world market (%) | Premiums % of GDP | Premiums per capita | Premiums | Share of world market (%) | Premiums % of GDP | Premiums per capita |
| America | 825,230 | 41.9 | 3.70 | 878.3 | 654,935 | 24.9 | 2.94 | 697.1 |
| North America | 736,152 | 37.4 | 4.41 | 2,117.9 | 589,737 | 22.4 | 3.53 | 1,696.7 |
| Latin America and Caribbean | 89,078 | 4.5 | 1.59 | 150.5 | 65,197 | 2.5 | 1.17 | 110.1 |
| Europe | 713,699 | 36.2 | 3.01 | 802.5 | 937,168 | 35.7 | 4.06 | 1,083.2 |
| Western Europe | 641,630 | 32.6 | 3.20 | 1,187.6 | 916,297 | 34.9 | 4.74 | 1,759.5 |
| Central and Eastern Europe | 72,069 | 3.7 | 2.03 | 222.3 | 20,871 | 0.8 | 0.59 | 64.4 |
| Asia | 356,180 | 18.1 | 1.59 | 85.4 | 941,958 | 35.9 | 4.26 | 228.5 |
| Japan and Industrialized Asia | 207,727 | 10.5 | 2.53 | 964.0 | 703,793 | 26.8 | 8.77 | 3,333.8 |
| South and East Asia | 118,792 | 6.0 | 1.04 | 33.1 | 228,060 | 8.7 | 2.00 | 63.5 |
| Middle East and Central Asia | 29,662 | 1.5 | 1.10 | 92.2 | 10,105 | 0.4 | 0.38 | 31.4 |
| Africa | 21,782 | 1.1 | 1.16 | 20.9 | 46,298 | 1.8 | 2.46 | 44.3 |
| Oceania | 52,628 | 2.7 | 3.15 | 1,460.3 | 46,810 | 1.8 | 2.80 | 1,298.9 |
| <i>World</i> | 1,969,519 | 100.0 | 2.83 | 283.2 | 2,627,168 | 100.0 | 3.77 | 377.8 |

Source: [Swiss Re \(2012b\)](#).

Note: All monetary valued statistics are in US dollars (millions).

for credit and equity markets. We then conduct a comparative analysis of the financial statements of banks and insurance companies to gauge leverage and liquidity risks. Historical insolvency data on US insurers is presented to gauge the vulnerability of insurers to financial distress. An analysis of the causes of insolvencies provides information on sources of insolvency risk in the industry. Finally, we conduct an analysis of intra-industry interconnectedness in the insurance industry by analyzing the exposure of insurers to reinsurance counterparties, a form of interconnectedness unique to the insurance industry.

27.5.1 The Macroeconomic Importance of Insurance: Size Risk

Analyzing the macroeconomic role of the insurance industry is helpful in determining whether insurance poses a systemic risk due to the volume of transactions or sources of investable funds for other economic sectors. World life and nonlife insurance premiums are shown in Table 27.1. World life and nonlife insurance premiums in 2011 were \$4.6 trillion, 57% life and 43% nonlife. North America is the world's largest nonlife insurance market, accounting for 37.4% of total nonlife premiums, and Western Europe is the largest life insurance market, accounting for 34.9% of premiums. Insurance premiums represent 6.6% of world GDP ([Swiss Re 2012b](#)). In terms of total premium volume, therefore, insurance is important, but insurance premium payments are small compared to GDP.

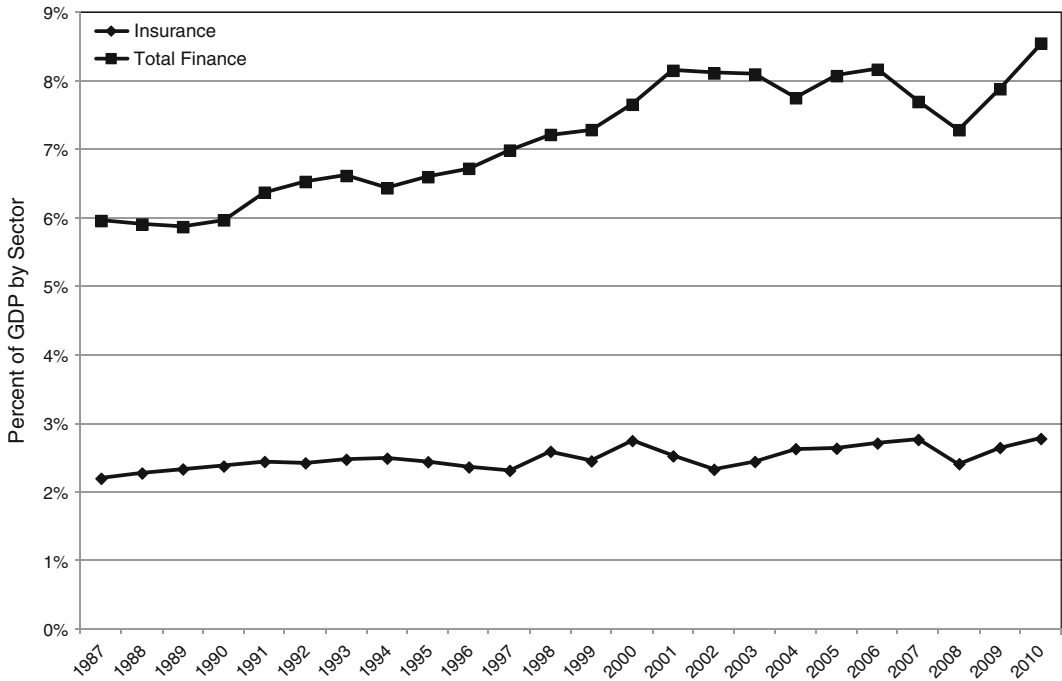


Fig. 27.1 US GDP attributable to financial services. *Source:* US Department of Commerce, Bureau of Economic Analysis

Although comparing premiums to GDP is useful to measure the relative importance of the insurance industry, premiums do not measure the contribution of insurance to GDP. Rather, the contribution to GDP is the value-added by the insurance industry. The percentages of US GDP attributable to insurance and other financial services are shown in Fig. 27.1. The lower line in the figure represents the contribution of the insurance industry to GDP and the upper line represents the contribution of the total financial services industry to GDP, where financial services are defined to exclude real estate and leasing. Insurance contributes between 2 and 3% of GDP, with a slight upward trend during the past 2 decades. Financial services in general represented about 6% of GDP in 1987, increasing to 8.2% by 2006. The GDP contribution of financial services declined during the crisis to 7.3% in 2008, but rebounded to 8.5% by 2010. In conclusion, insurance is a relatively small contributor to overall GDP, representing about one-third of the GDP contribution of the overall financial services sector.¹⁵

To measure the importance of the insurance industry as a source of credit, the major holders of outstanding US credit market debt are shown in Table 27.2. About \$54.2 trillion in credit market debt was outstanding in 2011.¹⁶ The major holders of credit market debt in 2011 were banks (19.0%), the “rest of the world” (non-US investors) (15.8%), domestic nonfinancial sectors (13.7%), and government-sponsored enterprises (GSEs) (13.7%). By this measure too, insurers are important but

¹⁵GDP data are from US Department of Commerce, Bureau of Economic Analysis (<http://www.bea.gov/industry/gdpbyind.data.htm>). Financial Services data considered here include all financial services except real estate and rental and leasing.

¹⁶Data on credit market debt outstanding are from the Federal Reserve Flow of Funds accounts, Table L1, <http://www.federalreserve.gov/datadownload/>). GSE total includes agency and GSE- backed mortgage pools.

Table 27.2 Major holders of US credit market debt outstanding

| Debt outstanding/ holders | 2007 | 2008 | 2009 | 2010 | 2011 |
|--|------------|------------|------------|------------|------------|
| Total credit market debt outstanding | 50,897,595 | 53,284,873 | 53,188,738 | 53,396,719 | 54,243,010 |
| Percent held by: | | | | | |
| Domestic Nonfinancial sectors | 14.1% | 13.1% | 14.1% | 14.7% | 13.7% |
| Of World | 14.3% | 14.1% | 14.5% | 15.7% | 15.8% |
| Monetary authority | 1.5% | 1.9% | 3.7% | 4.2% | 4.9% |
| Banks ^a | 20.2% | 19.9% | 18.8% | 19.0% | 19.0% |
| Credit unions | 1.3% | 1.3% | 1.4% | 1.4% | 1.5% |
| Property-casualty insurers | 1.7% | 1.6% | 1.7% | 1.7% | 1.7% |
| Life insurers | 5.6% | 5.4% | 5.7% | 5.9% | 6.1% |
| Private pension funds | 1.7% | 1.8% | 2.0% | 2.1% | 2.1% |
| State and local government pension funds | 1.6% | 1.6% | 1.6% | 1.5% | 1.5% |
| Money market mutual funds | 3.8% | 5.0% | 3.8% | 3.0% | 3.0% |
| Mutual funds (including closed end and ETFs) | 4.7% | 4.6% | 5.5% | 6.2% | 7.0% |
| ABS issuers | 8.7% | 7.6% | 6.1% | 4.2% | 3.6% |
| Finance companies | 3.6% | 3.3% | 2.9% | 2.9% | 2.7% |
| GSEs & Agency and GSE pools | 14.3% | 15.0% | 15.2% | 14.0% | 13.7% |
| All others | 3.0% | 3.9% | 3.1% | 3.5% | 3.6% |

^aIncludes US chartered depository institutions, foreign banking offices in the USA, and banks in US-affiliated areas.

Note: Outstanding debt in millions of dollars.

Source: Federal Reserve Flow of Funds Accounts (Washington, DC: Board of Governors of the Federal Reserve System).

Table 27.3 Holdings of financial assets by insurers and commercial banks

| Asset/holdings | 2007 | 2008 | 2009 | 2010 | 2011 |
|-----------------------------------|------------|------------|------------|------------|------------|
| Treasury securities | 5,099,199 | 6,338,184 | 7,781,929 | 9,361,488 | 10,428,308 |
| Banks ^a | 2.2% | 1.5% | 2.3% | 3.0% | 2.3% |
| Property-casualty insurers | 1.4% | 1.0% | 1.1% | 1.0% | 0.9% |
| Life insurers | 1.4% | 1.7% | 1.7% | 1.7% | 1.6% |
| Agency and GSE securities | 7,397,749 | 8,166,697 | 8,106,793 | 7,598,157 | 7,577,392 |
| Banks ^a | 16.1% | 16.1% | 18.1% | 20.6% | 22.0% |
| Property-casualty insurers | 1.7% | 1.4% | 1.4% | 1.5% | 1.6% |
| Life insurers | 5.2% | 4.5% | 4.6% | 4.9% | 5.1% |
| Municipal securities | 3,448,076 | 3,543,420 | 3,697,882 | 3,795,591 | 3,743,366 |
| Banks ^a | 5.9% | 6.3% | 6.2% | 6.8% | 8.0% |
| Property-casualty insurers | 10.8% | 10.8% | 10.0% | 9.2% | 8.8% |
| Life insurers | 1.2% | 1.3% | 2.0% | 3.0% | 3.3% |
| Corporate and foreign bonds | 11,543,006 | 11,118,323 | 11,576,850 | 11,538,517 | 11,586,995 |
| Banks ^a | 9.4% | 9.5% | 7.9% | 6.8% | 6.8% |
| Property-casualty insurers | 2.5% | 2.4% | 2.6% | 2.8% | 3.1% |
| Life insurers | 16.1% | 16.3% | 16.6% | 17.6% | 18.4% |
| Corporate equities | 25,580,900 | 15,640,457 | 20,123,185 | 23,249,520 | 22,522,227 |
| Banks ^a | 0.3% | 0.2% | 0.3% | 0.3% | 0.3% |
| Property-casualty insurers | 0.9% | 1.2% | 1.1% | 0.9% | 1.0% |
| Life insurers | 5.7% | 6.4% | 6.0% | 6.0% | 6.4% |
| Multifamily residential mortgages | 784,628 | 837,675 | 846,965 | 837,772 | 844,214 |
| Banks ^a | 33.3% | 33.5% | 32.0% | 30.8% | 29.8% |
| Property-casualty insurers | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Life insurers | 6.6% | 6.2% | 5.7% | 5.6% | 5.9% |
| Commercial mortgages | 2,447,855 | 2,566,445 | 2,478,077 | 2,314,001 | 2,232,357 |
| Banks ^a | 54.9% | 56.8% | 57.3% | 57.0% | 56.2% |
| Property-casualty insurers | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% |
| Life insurers | 10.3% | 10.4% | 10.4% | 10.9% | 11.8% |

^aIncludes US chartered depository institutions, foreign banking offices in the USA, and banks in US affiliated areas. Credit unions are excluded.

Note: Asset holdings are in millions of dollars.

Source: Federal Reserve Flow of Funds Accounts (Washington, DC: Board of Governors of the Federal Reserve System).

not among the leading sources of credit market debt—insurers hold 7.8% of outstanding debt (6.1% by life insurers and 1.7% by P-C insurers).

More details on the role of insurers in the securities markets are provided in Table 27.3, which shows the percentage share of banks and insurers in the markets for various types of assets. P-C insurers are not a very important source of funds in any of the asset categories shown, with the exception of municipal securities, where they account for 8.8% of outstanding asset holdings in 2011. Life insurers are more important, accounting for 18.4% of corporate and foreign bonds, 11.8% of commercial mortgages, and 6.4% of equities in 2011.

Although insurers are important in some asset markets (Table 27.3), this does not necessarily imply that they pose a systemic threat to the stability of these markets. As discussed further below, insurer liabilities are relatively long-term and generally not optionable, in comparison with banks and shadow banks. Moreover, liquidations of insolvent insurers tend to be orderly and take place over long periods of time. Hence, the probability is very low that an insurer would need to liquidate a large quantity of assets quickly. Thus, by this measure as well, the insurance industry does not pose a systemic threat solely because of its size.

27.5.2 *Financial Risk: Maturity Structure, Leverage, and Counterparty Risk*

Information on the balance sheets of insurers and banks is presented in Table 27.4, which shows the principal assets and liabilities for 2011. Table 27.4 shows that insurers pose lower size risk to the economy than commercial banks. Total assets of life and P-C insurers are about \$7.1 trillion, about half of insured commercial bank assets of \$12.6 trillion.¹⁷

Table 27.4 shows that P-C insurers hold 57.3% of their assets in bonds.¹⁸ Life insurers hold 71.9% of their general account assets in bonds.¹⁹ Both P-C and life insurers are long-term bond investors with average bond maturities of 6.3 years and 10.2 years, respectively, in 2011.²⁰ P-C insurers have about 14.8% of assets in common and preferred stocks and about 15.5% in reinsurer receivables, agents' balances, and other nonearning assets. P-C insurers hold only about 1% of assets in mortgages and real estate. Life insurers have 9.8% of general account assets in mortgages and real estate and only 2.3% in stocks (outside of separate accounts). In contrast to the mostly bond and stock portfolios of insurers, banks hold 23.7% of assets in non-real-estate loans and 29.2% in mortgages, real estate, and real estate loans. This is noteworthy because bonds and stocks tend to be highly liquid, whereas loans and mortgages are illiquid. Life insurers also hold significant amounts of illiquid assets, however, as discussed below.

On the liability side of the balance sheet, loss and policy reserves account for 79.8% of liabilities for property-casualty insurers and 88.5% of non-separate account liabilities for life insurers.²¹ Thus, insurers are primarily funded through long-term sources that cannot be withdrawn on demand by policyholders. For banks, on the other hand, 82.5% of liabilities represent deposits, most of which are short-term and withdrawable on demand, such that banks have higher liquidity risk and maturity mismatch risk than insurers.

Thus, an important conclusion is that asset and liability maturities are both long-term for insurers, whereas banks have short-term liabilities and longer-term assets. In addition, a high proportion of bank liabilities are instantaneously payable, such that depositors can cash out their accounts at any

¹⁷The bank data in Table 27.4 are for FDIC insured commercial banks. The total assets of US chartered depository institutions including foreign banking offices in the USA, banks in US-affiliated areas, and bank holding companies, were \$14.6 trillion at the end of 2011 (see US, Board of Governors of the Federal Reserve System, <http://www.federalreserve.gov/datadownload/>). Therefore, insurer assets are about half of total bank assets.

¹⁸The statistics on the US insurance industry presented in this chapter are based primarily on industry totals and therefore ratios and percentages are weighted averages. For a few key variables, we also provide some information on the values of the variables at various percentiles. Tables giving percentiles for other key variables are available from the authors.

¹⁹Life insurers' assets are divided between the *general account*, which consists of assets backing policies sold by the company, and *separate accounts*, which represents funds under management by insurers. Most separate account assets come from corporate pension plans, individual retirement accounts, and variable (investment linked) contracts. Life insurers are asset managers but not risk-bearers for separate accounts, where there generally is no mortality or longevity risk taken by the insurer and the investor bears the investment risk. P-C insurers have a smaller amount of separate accounts with similar characteristics, mostly associated with management of captive insurance companies for corporate clients.

²⁰Average maturities have been consistently high over time. Insurer bonds also have high financial ratings. In 2011, 97.1% of P-C insurer bonds were in the top 2 (out of 8) NAIC rating categories (at least A rated according to financial rating firm categories); and 93.4% of life insurer bonds were in the top 2 categories. This is at least partly attributable to the NAIC's risk-based capital system, which requires insurers to hold more capital if they invest in lower rated bonds. Bond data are from the NAIC annual statement database. Tables on bond maturities and ratings are available from the authors on request.

²¹For P-C insurers, average maturity of loss reserves in 2011 is 2.55 years, based upon Schedule P, Part 3—Summary from A.M. Best Company (2012b), but the maturity is much longer for lines such as general liability, medical malpractice, and workers' compensation. Life insurer reserves are also known to be relatively long-term (Saunders and Cornett 2008, p. 71). However, the maturity cannot be calculated directly from information disclosed in the NAIC annual statements and requires access to information on the underlying cash flows.

Table 27.4 Balance sheets for property-casualty insurers life-health insurers, and commercial banks: 2011

| | Property-casualty insurers | | Life-health insurers | | Commercial banks | |
|---|----------------------------|-----------------------|----------------------|--------------------------|------------------|---------------|
| | Dollars | % Assets ^a | Dollars | % GA Assets ^a | Dollars | % Assets |
| Assets: | | | | | | |
| Bonds | \$931.1 | 57.3 | \$2,611.5 | 71.9 | \$2,528.4 | 20.0 |
| Stocks | \$240.4 | 14.8 | \$82.0 | 2.3 | \$12.9 | 0.1 |
| Loans (non-real estate) | | | | | \$2,990.5 | 23.7 |
| Mortgage and real estate loans | \$5.0 | 0.3 | \$332.9 | 9.2 | \$3,541.4 | 28.0 |
| Real estate Assets in trading accounts | \$10.5 | 0.6 | \$20.9 | 0.6 | \$153.0 | 1.2 |
| Cash and equivalents | \$76.3 | 4.7 | \$99.0 | 2.7 | \$713.4 | 5.6 |
| Other invested assets ^b | \$110.8 | 6.8 | \$313.0 | 8.6 | \$1,196.3 | 9.5 |
| Total invested assets | \$1,374.1 | 84.6 | \$3,459.3 | 95.2 | \$1,171.2 | 9.3 |
| Reinsurance receivables | \$43.1 | 2.7 | \$38.2 | 1.1 | \$12,307.2 | 97.4 |
| Other assets | \$207.7 | 12.8 | \$136.0 | 3.7 | | |
| Total assets (non-SA) | \$1,624.9 | | \$3,633.5 | | \$332.5 | 2.6 |
| Separate accounts | \$1.7 | | \$1,849.4 | | | |
| Total assets | \$1,626.6 | | \$5,482.9 | | \$12,639.7 | |
| Liabilities and equity: | | | | % Non SA ^a | | % Liabilities |
| Reserves | \$839.6 | 79.8 | \$2,936.8 | 88.5 | | |
| Deposits | | | | | \$9,253.9 | 82.5 |
| Borrowed funds | | | | | \$1,185.8 | 10.6 |
| Subordinated notes | \$11.3 | 1.1 | \$16.3 | 0.5 | \$131.8 | 1.2 |
| All other liabilities (non-SA) ^a | \$201.3 | 19.1 | \$365.3 | 11.0 | \$645.2 | 5.8 |
| Total liabilities (non-SA) ^a | | | \$3,318.4 | | | |
| Separate accounts | | | \$1,845.4 | | | |
| Total liabilities | \$1,052.2 | 100.0 | \$5,163.8 | | \$11,216.7 | 100.0 |
| Total equity | \$574.4 | 54.6 | \$319.1 | 9.6 | \$1,423.1 | 12.7 |
| Total liabilities and equity | \$1,626.6 | | \$5,482.9 | | \$12,639.7 | |

^aGA stands for general accounts and SA stands for separate accounts.

^bFor life insurers, other invested assets include \$128.9 billion in contract loans (loans against insurance policies).

Note: Dollars in billions. Stock amounts include preferred stock. For P-C insurers, loss reserves include loss adjustment expense reserves, unearned premium reserves, and reinsurance payable. For life-health insurers, reserves include reserves for life, annuity, accident and health, and policy claims plus unearned premiums. Real Estate includes premises of insurers and banks. Deposits include interest and non-interest bearing deposits.

Source: Life-Health data are from A.M. Best Company, *Best's Aggregates & Averages: Life/Health*, 2012 edition. P-C Insurance data are from A.M. Best Company, *Best's Aggregates & Averages: Property/Casualty*, 2012 edition. Commercial Bank data are obtained from the Federal Deposit Insurance Corporation and apply to FDIC insured banks.

time. Liabilities in P-C insurance do not have this feature—to obtain payment from the insurer, the claimant has to experience an insured loss and present a claim for payment. Therefore, it is not possible to have a “run” on a P-C insurer.

Most life insurance liabilities are also long-term and not putable, with the exception of life insurance cash values and some types of variable annuities. Hence, there is a possibility of a run on a life insurer. However, runs on life insurers are unlikely to occur and also unlikely to be systemic if they did occur. Runs on life insurers are unlikely for several reasons. Life insurance policyholders are covered by state guaranty funds, providing protection against losses from insurer insolvencies. In addition, most life insurance policies have early withdrawal penalties, and there are also usually tax penalties for withdrawing funds from life policies and annuities (Haefeli and Ruprecht 2012). If a run were to occur, it would likely focus on financially weak life insurers, not the sector in general.²² No runs on US life insurers occurred during the recent financial crisis.

Although insurer assets are generally liquid and of high quality, there are some danger signals, especially with respect to the life insurance industry. The middle section of Table 27.5 breaks out insurer assets in more detail. The table reveals that life insurers hold 26.5% of their bonds (19.0% of assets) in MBS and other ABS, including pass-through securities, CMOs, and REMICs. The amounts invested in MBS and ABS represent 216.6% of life insurer equity capital (policyholders surplus). Life insurers also invest heavily in privately placed bonds, which tend to pose significant liquidity risk. Total holdings of private placements represent 25.6% of life insurer bond portfolios and 209.5% of equity capital. Thus, MBS, ABS, and single issuer private placements represent a total of 378.5% of life insurer surplus. These numbers are relevant because ABS and MBS were especially problematical during the financial crisis, and private placements are relatively illiquid. Thus, even minor problems with asset defaults and liquidity demands could significantly threaten the solvency of many life insurers.

P-C insurers are much less exposed to MBS and privately placed bonds. For P-C insurers, MBS and ABS securities represent only 30.6% of surplus, and private placements represent only 12.9% of surplus. Hence, life insurers face higher exposure to housing markets and significant asset liquidity risk, in comparison with P-C insurers.

Somewhat offsetting their asset liquidity risk, life insurers receive a significant amount of net cash from operations, defined as premiums plus investment income net of benefit payments, expenses, and taxes. Life insurers’ net cash from operations represents 30.6% of benefit payments and 49.5% of equity capital (Table 27.5). Thus, life insurers could withstand significant increases in benefit payments without liquidating assets, partially explaining their heavy concentration of investments in privately placed bonds. However, it is not clear whether the coverage of cash flow to surplus is sufficient to completely offset their asset liquidity risk. P-C insurers also have significant net cash from operations but, as mentioned, do not face significant liquidity risk.²³

²²The only known run involving US life insurers occurred in 1991 when six life insurers failed after substantial investment losses, primarily in commercial mortgages and junk bonds. These insurers were already financially weak prior to the precipitating investment losses, and the runs did not spread to financially sound insurers (Harrington 1992). Even during the Great Depression of the 1930s, when retail bank runs were a problem, life insurer insolvency problems were minimal. During the period 1929–1938, net losses from life insurer insolvencies were about 0.6 of 1% of industry assets, and 30 of the 45 states where life insurers were domiciled (accounting for 85% of industry liabilities) did not record a single life insurer insolvency (Mills 1964).

²³For life insurers, the ratio of net cash flow to benefits dropped significantly at the outset of the crisis (to 13.5% in 2007) but then rebounded to normal levels in 2008–2011. In 2008–2011, the ratio of net cash flow to benefits declined significantly for P-C insurers in comparison with prior years (the ratio was 38.3% in 2006 and 31.2% in 2007). In part, this reflects lower premium growth associated with the “soft” part of the underwriting cycle. Tables showing the net cash flow ratios from 2000 to 2011 are available from the authors. The discussion of the reinsurance data in Table 27.5 is deferred to later in the chapter.

Table 27.5 Aggregate insurer financial statement information: 2011 (Dollar amounts in billions)

| | Life-health | | | Property-casualty | | |
|---|-------------|------------|-----------|-------------------|------------|-----------|
| | Amount | % Benefits | % Surplus | Amount | % Benefits | % Surplus |
| Balance sheet, income statement, and cash flow | | | | | | |
| Assets (excluding separate accounts) | 3,633.5 | | | 1,626.6 | | |
| Bonds (excluding separate accounts) | 2,611.5 | | | 931.1 | | |
| Stocks (excluding separate accounts) | 82.0 | | | 240.4 | | |
| Mortgage loans (excluding separate accounts) | 332.9 | | | 5.0 | | |
| Liabilities (excluding separate accounts) | 3,318.4 | | | 1,052.2 | | |
| Surplus | 319.1 | | | 574.4 | | |
| Total premiums and considerations (earned) | 630.7 | | | 443.5 | | |
| Total insurance in force (gross of reins.) | 43,151.5 | | | NA | | |
| Benefit and loss payments | 515.5 | | | 289.2 | | |
| | Amount | % Benefits | % Surplus | Amount | % Benefits | % Surplus |
| Net cash from operations | 157.8 | 30.6 | 49.5 | 20.7 | 7.2 | 3.6 |
| Key investments | Amount | % Bonds | % Surplus | Amount | % Bonds | % Surplus |
| Bonds: publicly issued | | 74.4 | 608.8 | | 92.1 | 149.2 |
| Issuer obligations | 1,403.4 | 53.7 | 439.8 | 703.0 | 75.5 | 122.4 |
| Residential | 331.5 | 12.7 | 103.9 | 108.8 | 11.7 | 18.9 |
| MBS Commercial | 129.8 | 5.0 | 40.7 | 24.8 | 2.7 | 4.3 |
| MBS Other loan backed | 78.0 | 3.0 | 24.5 | 20.7 | 2.2 | 3.6 |
| Total public ABS/MBS and loan backed | 539.3 | 20.7 | 169.0 | 154.3 | 16.6 | 26.9 |
| Bonds: privately placed | | 25.6 | 209.5 | | 7.9 | 12.9 |
| Issuer obligations | 516.8 | 19.8 | 162.0 | 52.7 | 5.7 | 9.2 |
| Residential | 10.3 | 0.4 | 3.2 | 3.5 | 0.4 | 0.6 |
| MBS Commercial | 31.3 | 1.2 | 9.8 | 4.6 | 0.5 | 0.8 |
| MBS other loan backed | 110.3 | 4.2 | 34.6 | 13.0 | 1.4 | 2.3 |
| Total private ABS/MBS and loan backed | 151.8 | 5.8 | 47.6 | 21.2 | 2.3 | 3.7 |
| Stock of banks, trusts, and insurers ^a | Amount | % Stock | % Surplus | Amount | % Benefits | % Surplus |
| | 4.1 | 5.0 | 1.3 | 31.3 | 13.0 | 5.4 |

(continued)

Table 27.5 (continued)

| | Life-health | | Property-casualty | | | |
|--|-------------|-----------|--------------------|--------|-----------|--------------------|
| | Amount | % Surplus | % DPW ^b | Amount | % Surplus | % DPW ^b |
| Reinsurance Premiums ceded: | | | | | | |
| To Nonaffiliates | 60.4 | 18.9 | 8.8 | 69.6 | 12.1 | 13.9 |
| To affiliates | 78.1 | 24.5 | 11.4 | 38.8 | 6.8 | 7.7 |
| Receivables and funds held by reinsurer ^c | 38.2 | 12.0 | | 43.1 | 7.5 | |
| Reserve credit taken (amount recoverable) ^d | | | | | | |
| From nonaffiliates | 209.6 | 65.7 | | 145.2 | 25.3 | |
| From affiliates | 309.5 | 97.0 | | 85.5 | 14.9 | |
| Reins. Ceded surplus relief | | | | | | |
| From nonaffiliates | 2.4 | 0.8 | | NA | NA | |
| From affiliates | 8.0 | 2.5 | | NA | NA | |
| | | % total | | | % total | |
| | Amount | In force | | Amount | In force | |
| Reinsurance ceded in force—nonaffiliated | 11,820 | 27.4 | | NA | NA | |
| Reinsurance ceded in force—affiliated | 12,193 | 28.3 | | NA | NA | |

^aFigures are from 2010 (obtained from the NAIC (2011a, b)).

^bDPW = direct premiums written.

^cThis item is from Assets page, row 16 of the NAIC annual statement, data obtained from *Best's Aggregates & Averages: Life/Health*, 2012 Edition and *Best's Aggregates & Averages: Property/Casualty*, 2012 Edition.

^dFor P-C insurers this is the net amount recoverable from reinsurers from Schedule F, Part 3, column 18. For life insurers it is reserve credit from Schedule S, Part 3, Sections 1 and 2. Data from SNL Financial Institutions database.

Note: Amounts are in billions of dollars. Benefit and Loss Payments are from the Cash Flow Statement, line 11. Data for bonds taken from the Summary Investment Schedule and Schedule D, Part 1A, Section 2.

Systemic risk due to interconnectedness also can arise to the extent that insurers invest in the stocks and bonds of other financial institutions. The exposure of US P-C insurers to bank and securities firm bonds is rather limited, although exposure is somewhat higher for life insurers. In 2010, bank bonds represented only 5.4% of the bond portfolio of P-C insurers, and bonds of other financial firms represent only 1.2% of P-C insurer bonds.²⁴ Banking and financial firm bonds represent 11.4% of equity for P-C insurers. Thus, defaults by financial firms do not pose a serious threat to P-C insurers. Life insurers have 8.0% of their bond portfolio invested in bank bonds and 1.7% invested in the bonds of other financial firms. Bank and finance bonds represent 62.1% of equity for life insurers. Hence, life insurers do face a potential threat from bond default by financial firms, although massive defaults would have to occur in order to pose an industry-wide threat to solvency. In 2008, less than 1% of stocks held by US insurers were invested in bank stocks and a negligible proportion in stocks of securities firms.

Regarding the importance of insurers as sources of funds for other financial institutions, US insurers held approximately 9.4% of banks' "other borrowed money" in 2008. However, as noted above, borrowed money is not the primary source of financing to banks, amounting to less than 10% of liabilities. US insurers held 14.1% of securities firms' outstanding corporate bond debt in 2008, but bonds represent only 11.2% of securities firms' financing (liabilities). US insurers hold only negligible portions of securities firms' and banks' stock outstanding. Hence, interconnectedness risk from security holdings in other types of financial firms does not seem to be a significant problem for US insurers.

As indicated earlier, cross-holdings between banks and insurers can be substantial in Europe, and bancassurance is more common than in the USA. Thus, in Europe a systemic link can exist between insurers and banks such that a large event for an insurer can spread to an affiliated bank and vice versa. For example, Allianz owned Dresdner Bank from 2001 to 2008. Multibillion write-downs by Dresdner Bank adversely affected Allianz's equity and balance sheet as well as some of its key capital ratios (Baluch et al. 2011).

The capitalization ratios of insurers and banks are presented in Fig. 27.2. The figure shows book value equity capital-to-asset ratios for life insurers, P-C insurers, and commercial banks for the period 1985–2011. One important conclusion from Fig. 27.2 is that P-C insurers are much more highly capitalized than life insurers or banks, and their capital-to-asset ratios have been increasing over time. The capital-to-asset ratio for P-C insurers was 27.8% in 1985, increasing to 39.6% by 2011. Of course, one reason P-C insurers hold more capital than life insurers or banks is that they are subject to catastrophe risk from events such as hurricanes and earthquakes.²⁵ The capital-to-asset ratio of life insurers has been in the range of 9.3–11.9% since 1992.²⁶ Due to the crisis, the ratio dropped to 8.7% in 2008 but recovered to 9.7% by 2011. The ratio for banks was slightly below the ratio for life insurers until 2002, but the bank and life insurer ratios have been comparable since that time. The banks' capital-to-asset ratio stood at 11.1% in 2011. Therefore, at the present time, banks and life insurers are comparably capitalized.

Defining leverage as the ratio of assets-to-equity, the 2011 leverage ratios of P-C insurers, life insurers, and banks are 2.5, 10.3, and 9.0. Excessive leverage is risky because it exposes a firm's equity to slight declines in the value of assets. For example, with leverage of 10.3, an asset decline of

²⁴The data in this paragraph and the following paragraph are from NAIC (2011a, b) and unpublished NAIC data.

²⁵More generally, it is important to exercise caution in comparing leverage ratios across industries or even across firms writing different lines of insurance because leverage ratios do not account for the risk of the underlying cash flows. Nevertheless, leverage ratios are valuable in identifying vulnerability to asset declines and other economic fluctuations and in measuring changes in industry exposure over time.

²⁶The capital-to-asset ratio for life (P-C) insurers was 45.6% (50.1%) at the 75th percentile and 13.6% (32.4%) at the 25th percentile in 2010. For life insurers, the unweighted averages differ significantly from the average based on overall industry totals because large life insurers have low capital-to-asset ratios in comparison with smaller firms.

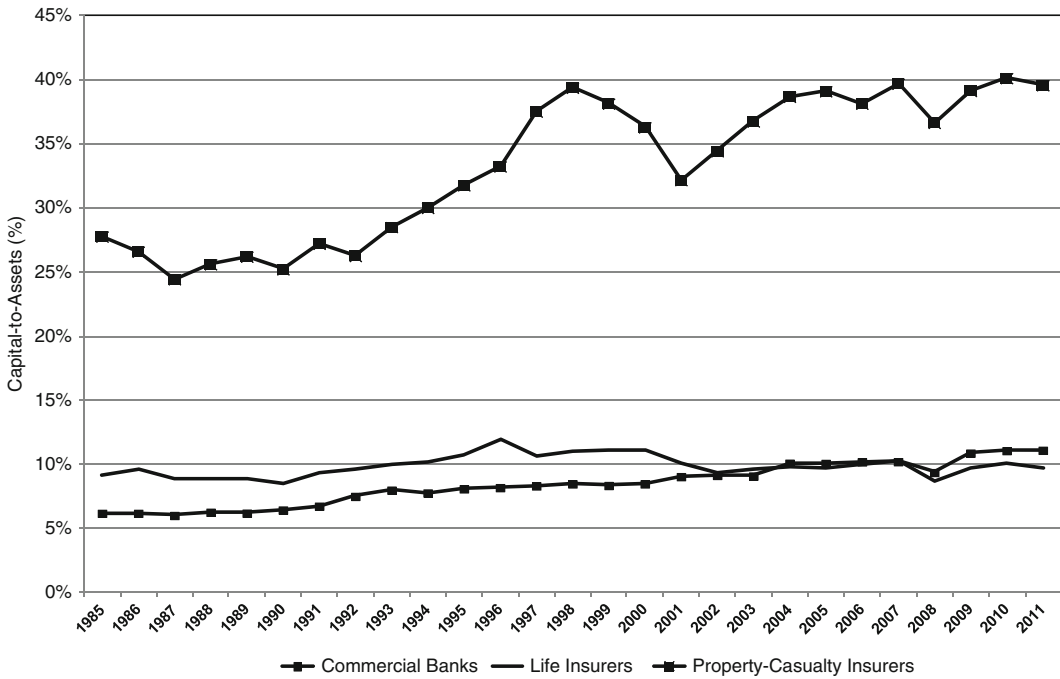


Fig. 27.2 Equity capital-to-asset ratios. *Source:* Board of Governors of the Federal Reserve System (property-casualty insurers), Federal Deposit Insurance Corporation (banks), American Council of Life Insurers (life insurers). Life ratio is capital plus asset valuation reserve divided by general account assets

9.7% could totally wipe out life insurer equity capital. Therefore, life insurers and banks face some risk from asset declines, although their leverage ratios have remained generally stable over time.

An alternative leverage ratio widely used in the insurance industry is the premiums-to-surplus ratio. The premiums-to-surplus ratios for life and P-C insurers from 1986 to 2011 are presented in Fig. 27.3. There has been a steady long-term decline in the premiums-to-surplus ratio for P-C insurers from 1.88 in 1986 to 0.79 in 2011. The ratio for life insurers has also trended downwards but increased sharply in 2008 because life insurers were more strongly affected by the financial crisis than P-C firms. The life insurer premiums-to-surplus ratio was 2.2 in 2008 but declined to 1.7 by 2011.²⁷ Thus, by this measure as well, life insurers are much more highly leveraged than P-C insurers.

Even though life insurers are more highly leveraged than P-C insurers, recent research reveals that life insurer capitalization is highly resilient to financial shocks. [Berry-Stoelzle et al. \(2011\)](#) show that the financial crisis and subsequent recession generated sizable operating losses for life insurance companies, yet the consequences were far less significant than for other financial intermediaries. The ability to generate new capital through external issuances and dividend reductions permitted life insurers to quickly restore equity capital to healthy levels. Notably, they find no evidence that insurers had difficulty generating new capital, unlike noninsurance financial service firms that required substantial amounts of public support.

²⁷For life (P-C) insurers, the premiums-to-surplus ratio was 2.3 (1.3) at the 75th percentile and 0.53 (0.59) at the 25th percentile in 2010.

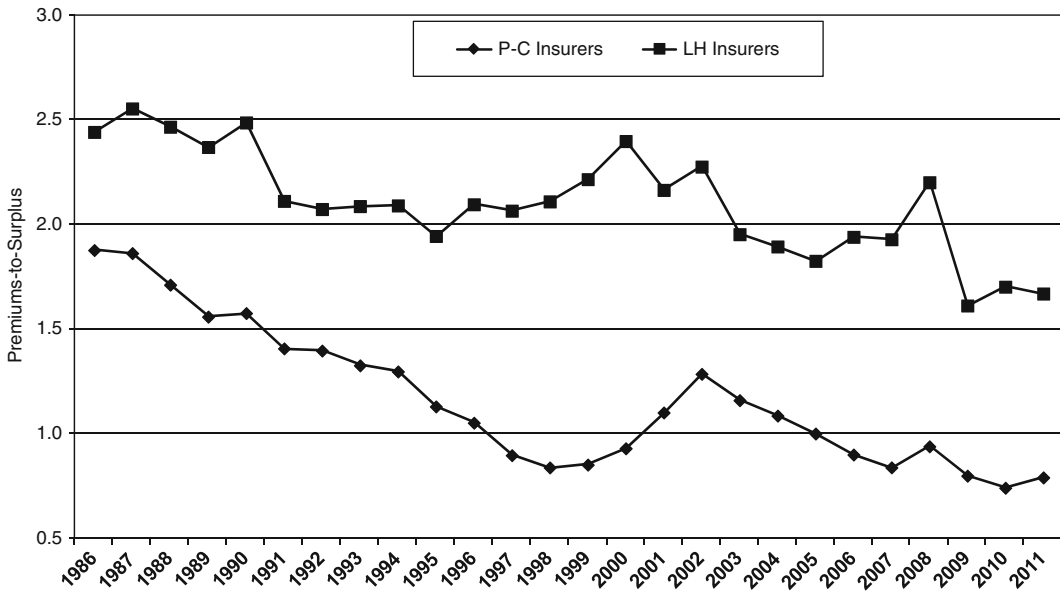


Fig. 27.3 Premiums-to-surplus ratios: life-health and property-casualty insurers. *Source:* A.M. Best Company (2012a, b), American Council of Life Insurance (2011)

27.5.3 Vulnerability to Crises and Insolvency Experience

The vulnerability of insurers and banks to financial turmoil can be clarified by investigating their stock price performance in the period spanning the crisis. Figure 27.4 shows insurer and bank stock indices for the period 12/31/2004 through 8/24/2010. The stock indices shown in the figure are the A.M. Best US life insurer index (AMBUL), the A.M. Best US P-C insurer index (AMBUPC), the Standard & Poor’s (S&P) bank stock index (BIX), and the S&P 500 stock index, representing the market.

The sharp decline in the bank stock index began earlier than the declines in the insurance stock indices and the S&P 500. The bank index peaked on February 20, 2007 and then began to decline as the subprime crisis unfolded. Another steep decline began in August 2007, reflecting the worldwide “credit crunch” and further announcements of losses on MBS. The next major decline in the bank index occurred in September and October of 2008 with the collapse of Lehman, Merrill Lynch, and AIG.

Insurance stock indices peaked later in 2007 than the bank index—October 31 for life insurers and December 6 for P-C insurers, and the S&P 500 index peaked on October 1, 2007. Unlike banks, the insurance stock indices did not experience major losses in value until the major stock market crash of October 2008. Another sharp decline occurred in January of 2009, as several British financial institutions experienced financial distress.

From peak-to-trough, for the period shown in Fig. 27.4, the life insurer index lost 85% of value and the bank index lost 88% of value. Banks and life insurers were hit harder than the market as a whole—the S&P 500 lost 57% of its value from peak-to-trough. P-C insurers fared relatively better during the crisis, losing “only” 47% of value, peak-to-trough. Both the assets and liabilities of P-C insurers were less exposed than those of banks and life insurers to elements of the crisis such as subprime mortgages and the credit crunch.

Outside of the USA, the effects of the crisis on global insurers and banks were very similar to each other. This similarity is most likely attributable to several factors: use of bancassurance models, large exposure to toxic assets, and exposure to liabilities underwritten backed by toxic assets. Within the

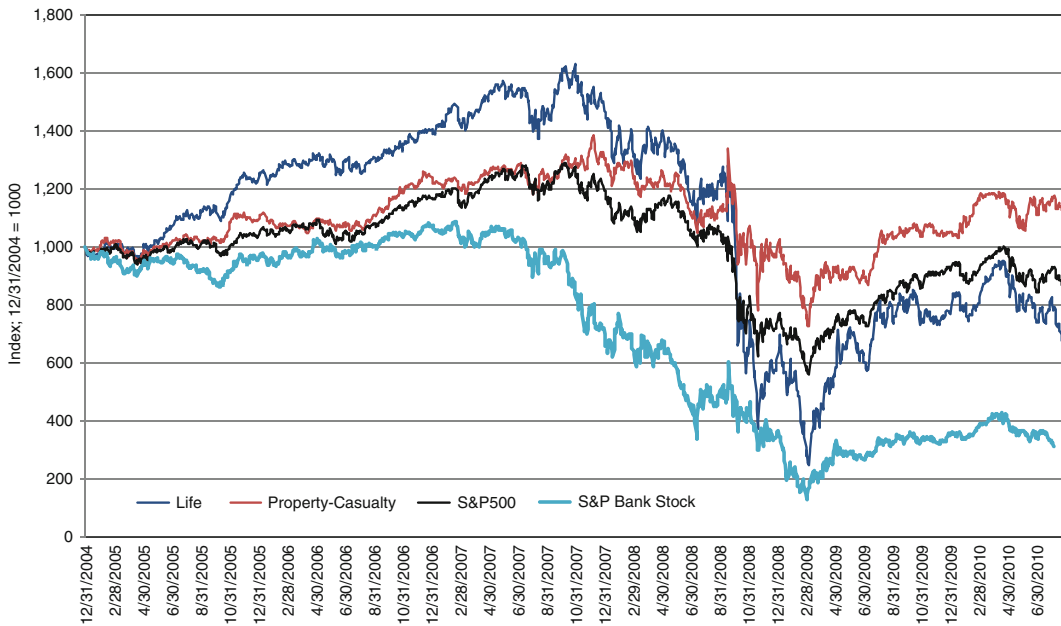


Fig. 27.4 US insurer and bank stock indices vs. S&P 500. *Source:* A.M. Best Company: A.M. Best U.S. life insurer index (AMBUL), A.M. Best U.S. property-casualty insurer index (AMBUPC). S&P bank stock index (BIX). <http://finance.yahoo.com/q?s=%5EBIX>

global insurance sector, from 2007 to 2009, life insurers, global composite insurers, global reinsurers and (non-UK) European insurers performed the worst. Asia-Pacific insurers, UK insurers, and US P-C insurers were the least affected. The effects of the crisis in the UK were not the same for insurers as for UK banks. A comparison of the performance of UK banks (FTBK Index) and UK insurers (FTIC Index) over the period 2004–2009 indicates that UK insurers outperformed banks. The most likely reason for this is higher quality assets and lower exposure to credit losses for the UK insurance industry.

Baluch et al. (2011) also examine correlations between banks and insurers performance over the period 2004–2009.²⁸ Using several selected large international banks and insurers they find the following correlations for 2004–2006, 2006–2007, and 2007–2009 to be 29.82%, 41.35%, and 55.50%, respectively. Thus, not only are banks' and insurers' performance correlated, but they also exhibit copula properties.

The failure rates of US insurers and commercial banks are shown in Fig. 27.5. Figure 27.5 confirms that life insurers and banks were much more strongly affected by the financial crisis than were P-C insurers.²⁹ The bank failure rate increased by a factor of 10, from 0.2% in 2007 to 1.9% in 2009–2010 and recovered somewhat to 1.6% in 2011. The life insurer failure rate rose by a factor of 5 from 0.19% in 2006 to 0.94% in 2009 but declined to 0.14% by 2011. By contrast, the P-C insurer failure rate in 2009–2010 was about the same as the failure rate in 2005–2006. During the crisis, the P-C failure rate remained significantly below earlier peaks in 1989–1993 and 2000–2003, which were driven by catastrophic events such as Hurricane Andrew and the 2001 terrorist attacks. Thus, historically,

²⁸The sample consisted of Goldman Sachs Group, Bank of America Corp., Citigroup Inc., Deutsche Bank, Credit Suisse Group, Allianz, Aviva PLC, Swiss Reinsurance Co. Ltd., Zurich Financial Services, and XL Capital Ltd.

²⁹The failure rate is defined as the number of failures divided by the total number of institutions.

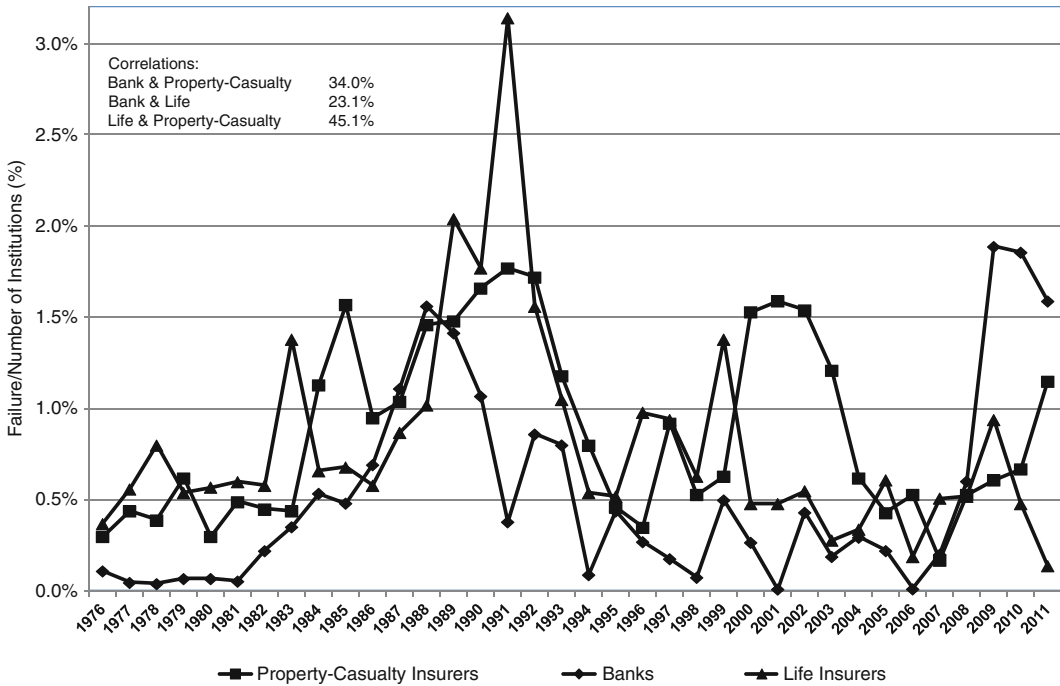


Fig. 27.5 Failure rates of US banks and insurers. *Source:* A.M. Best Company (2012a, b), Federal Deposit Insurance Corporation

underwriting events have created more insolvency risk for P-C insurers than financial crises, whereas banks and life insurers are more susceptible to financial market shocks. The bivariate correlations of the failure rates for the three types of institutions are statistically significant, providing evidence of susceptibility to common shocks (see Fig. 27.5). Failure rates of the two types of insurers are more highly correlated with each other than with bank failure rates.

The life insurer failure rate is explored in more detail in Fig. 27.6, which plots the life insurer failure rate versus life insurers’ after-tax profit margin, expressed as a percentage of revenues. Life insurers’ after-tax profits fell from about 4% in 2006–2007 to less than zero in 2008. Although profits recovered in 2009–2011, the life insurance failure rate continued to increase in 2009, because failures tend to lag economic developments. However, by 2011 the failure rate had fallen to its lowest rate in 35 years. The correlation between the after-tax profit margin, lagged one period, and the failure rate is -43.9%, indicating a strong relationship between insolvency risk and profitability.

The P-C insurer failure rate is plotted against the combined ratio (the sum of losses and expenses as a ratio to premiums) in Fig. 27.7. There is a strong correlation between the combined ratio and the P-C failure rate (the bivariate correlation is 63.7%), confirming that underwriting results are the principal driver of insolvencies for P-C insurers. The failure rate spiked in 2011, partially due to lingering effects of the financial crisis but remained well below earlier peaks associated with underwriting events.³⁰

To provide information on interconnectedness in the US insurance industry, the principal triggering events for life and P-C insolvencies are shown in Table 27.6, for the period 1969–2011. Table 27.6 shows that interconnectedness with reinsurers historically has not been a major factor in triggering

³⁰The 2011 spike in the P-C failure rate was due to a variety of factors, including the financial crisis, near-record catastrophe losses, and the “soft” phase of the underwriting cycle (A.M. Best Company 2012d; Swiss Re 2012a).

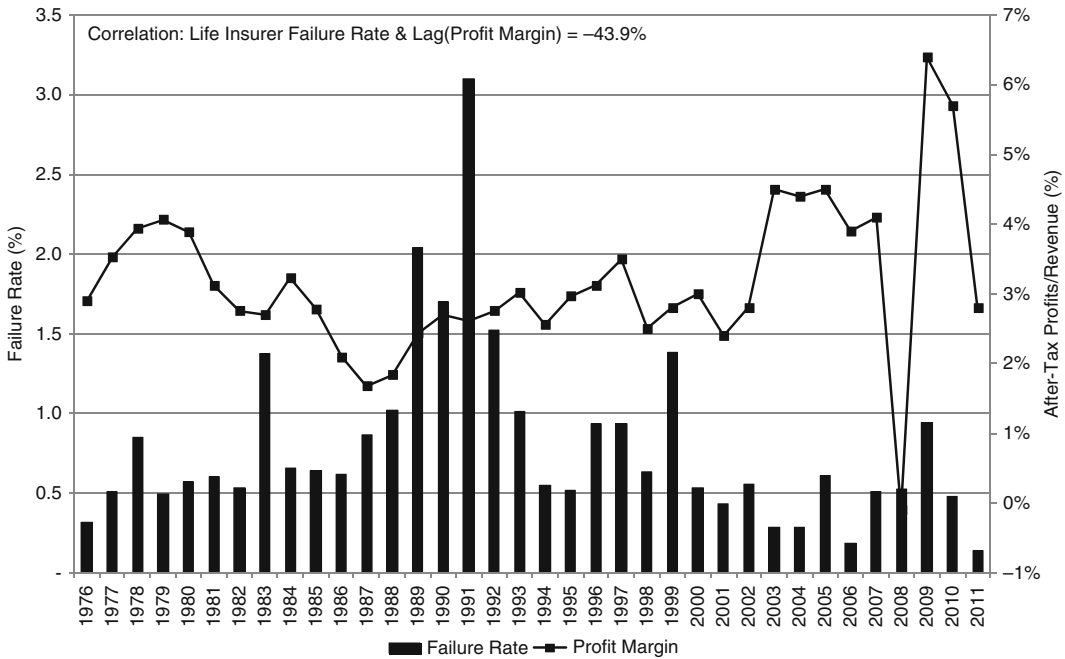


Fig. 27.6 Life insurer impairment frequency and after-tax profit margin. *Source:* A.M. Best Company (2012a). Failure is the ratio of the number of financially impaired insurers total number of insurers in the industry in a given year. Profit margin is after-tax net operating gain/total revenue

life insurer insolvencies. Only 2.1% of life insurer insolvencies were associated with the failure of reinsurers. However, life insurers have been vulnerable to interconnectedness with affiliates—affiliate problems are associated with 18.1% of life insurer failures. Life insurers are also susceptible to asset quality issues—investment problems trigger 15.0% of insolvencies. The primary triggers of life insurance insolvencies arise from bad management decisions such as under-pricing (29.1% of insolvencies), excessive growth (14.1% of insolvencies), and alleged fraud (8.8% of insolvencies). Likewise, for P-C insurers, under-pricing, excessive growth, and fraud together account for 62.5% of insolvencies. Interconnectedness with reinsurers and affiliates together are the triggering events for 11.5% of P-C insurer insolvencies.³¹ Unlike life insurers, P-C insurers are vulnerable to natural catastrophes, which account for 7.1% of failures. Therefore, except perhaps for life insurer affiliate problems, interconnectedness has not been a major cause of insurer insolvencies.

Insurers that are seriously financially impaired are handled in one of two ways in the USA. The insurer may be placed into receivership while the liabilities are “run-off.”³² As indicated above, loss payments under policies do not actually become due until some point in the future (often years), so the receiver operates the insurer to pay off (or run off) losses as they actually come due. Alternatively, especially for life insurers, the business of the insolvent insurer may be sold to another insurer, with the policies continued under the new insurer.³³ For a life insurer insolvency resolved by selling the insolvent insurer’s business to another insurer, the guaranty fund assesses an amount sufficient to

³¹Based on international data, *Swiss Re (2003)* also concludes that reinsurance failures historically have not been an important cause of insolvencies in the primary insurance industry.

³²An insolvent insurer is defined to be an insurer which is in receivership or liquidation.

³³In other words, life guaranty funds often replace policyholders’ coverage not policyholders’ cash.

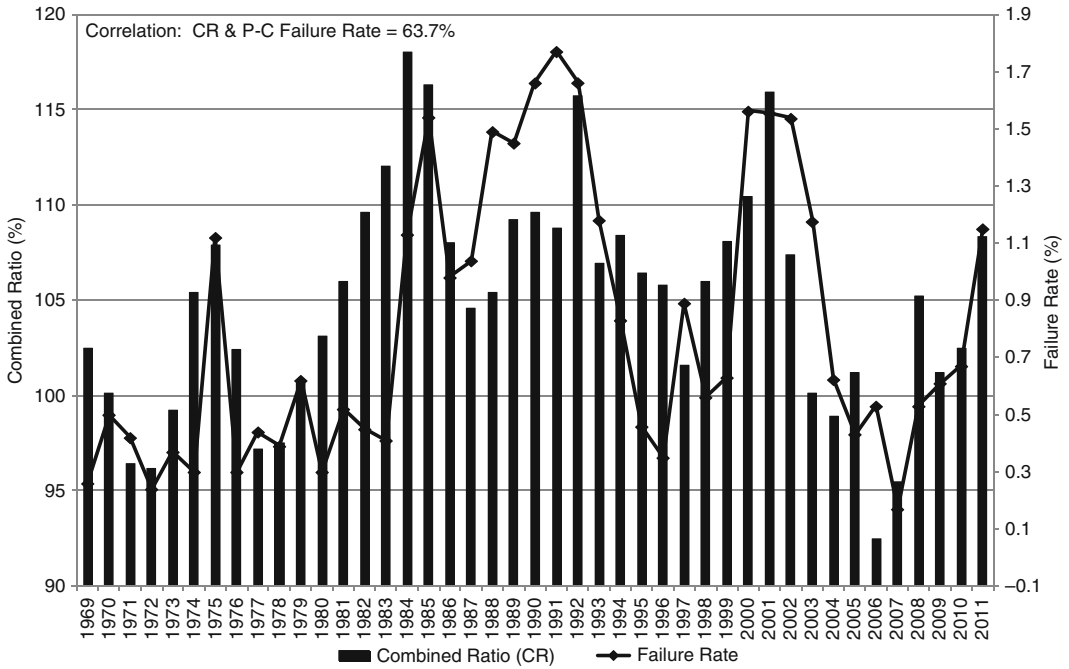


Fig. 27.7 Property-casualty insurer failure rate and combined ratio (CR). *Source:* A.M. Best Company (2012b). Failure rate is the ratio of the number of financially impaired insurers to total number of insurers in the industry in a given year

Table 27.6 Insurer insolvencies: primary triggering events. Life insurers (1969–2011) and property-casualty insurers (1969–2011)

| | Life-health | Property-casualty |
|--|-------------|-------------------|
| Inadequate pricing/deficient loss reserves | 29.1% | 41.9% |
| Affiliate problems | 18.1% | 8.3% |
| Investment problems (overstated assets) | 15.0% | 7.0% |
| Rapid growth | 14.1% | 13.1% |
| Alleged fraud | 8.8% | 7.5% |
| Miscellaneous | 8.1% | 8.3% |
| Catastrophe Losses | NA | 7.1% |
| Significant business change | 4.5% | 3.6% |
| Reinsurance failure | 2.1% | 3.2% |
| Average number of failures per year | 16.9 | 25.8 |

Note: Data are only on companies where the cause of impairment was identified.

Source: A.M. Best Company (2012a, b).

make the sale attractive to the acquirer. In P-C insurance it is necessary to have a valid claim, which is processed through an orderly settlement process, in order to obtain payment from the insurer. Some claims on life insurers do represent withdrawable assets, and there is some risk that many policyholders would surrender their policies as an insurer becomes financially distressed, causing a liquidity problem. However, insolvent insurers typically have substantial assets on hand to cover liabilities when they fail because losses are prepaid through premiums. Thus, liquidation of assets at

distressed prices usually does not occur nor are immediate settlements to all policyholders made at that time.³⁴

In many countries, a safety net exists to provide protection for policyholders of insolvent insurers in the form of guaranty funds. Each state in the USA operates a life insurance guaranty fund and at least one P-C guaranty fund. The typical funding approach in the USA is post-assessment³⁵—solvent insurers are assessed each year to cover shortfalls in loss payments for insolvent insurers, subject to annual maxima. Thirteen of the twenty seven member states of the European Union operate at least one insurance guaranty scheme, with prefunded programs being prevalent (Oxera 2007). There are restrictions on guaranty fund coverage, e.g., on maximum loss payable; and coverage generally does not apply to all lines of business.³⁶

US guaranty fund coverage and the state regulatory solvency resolution system in general apply to insurance companies that are US licensed and regulated. Hence, the creditors of AIGFP were not covered by US guaranty funds. If any of AIG's US licensed insurance subsidiaries had become insolvent as the result of their asset lending operations, the *policyholders* of the insurers but not the asset lending counterparties would have been covered by guaranty funds.

The assessment system is designed to place minimal stress on solvent insurers while protecting the policyholders of insolvent insurers. Guaranty funds in the USA have the ability to borrow against future assessments if losses covered by the guaranty fund in any 1 year would place a financial strain on solvent insurers. US guaranty funds have successfully paid claims of several large insolvent insurers, including Reliance, Executive Life, and Mutual Benefit Life. In 2010, the maximum annual assessment capacity of life insurers was \$10.3 billion, and the assessment capacity of P-C guaranty funds was \$6.7 billion.³⁷ Insolvencies larger than the annual assessment capacity could be financed because insurer insolvencies tend to be resolved over several years and because the shortfall between liabilities and assets typically is not very large.³⁸ Thus, assessments would be likely to continue until all claims are paid (Gallanis 2009).

Putting guaranty fund capacity in context, Metropolitan Life, the largest US life insurance company had \$235.2 billion in general account assets and \$13.5 billion in statutory equity at the end of 2011.³⁹ Thus, annual assessment capacity could be exhausted by a failure of Metropolitan Life that wiped out its equity and led to a sufficiently large shortfall of assets in comparison with liabilities. Thus, although the system has functioned effectively, “a completely unprecedented, worst-case crisis for the life industry could in theory challenge the liquidity of the guaranty system” (Gallanis 2009, p. 4), and similarly for P-C guaranty funds.⁴⁰

³⁴Policyholder claim/benefit payments are typically frozen for a period of time, except for death and financial need.

³⁵New York is an exception. The rationale for ex post assessments is that, unlike the obligations of the FDIC, insurance payments under policies are spread over many years in the future as claims arise.

³⁶In the USA small policyholders are typically protected by guaranty funds. Commercial insurance is covered also, but more than half of the states have a net worth restriction, such that if a company has net worth above some threshold (usually \$25–50 million) it is excluded from coverage. In addition, workers compensation insurance is always covered, while a few lines such as title insurance and mortgage guaranty insurance are not covered. For a description of guaranty funds and fund limitations in Europe, see Oxera (2007).

³⁷Life guaranty fund capacity is from the National Organization of Life & Health Insurance Guaranty Associations, <http://www.nolhga.com/factsandfigures/main.cfm/location/assessmentdata>. P-C guaranty fund capacity is from NCIGF (2011), <http://www.ncigf.org/>.

³⁸For example, in a life insurer insolvency, the shortfall in assets relative to liabilities is typically in the 5–10% range and seldom as high as 15% (Gallanis 2009, p. 7).

³⁹These figures are for Metropolitan Life Insurance Company, the largest insurer in MetLife Group. Data on general account assets are from the NAIC database. MetLife Group had total assets (including separate accounts) of \$612.8 billion and surplus of \$30.2 billion in 2011 (A.M. Best Company 2012a).

⁴⁰The largest P-C insurer in 2011 was National Indemnity, a member of the Berkshire-Hathaway Group, with assets of \$115.5 billion and equity of \$70.2 billion. Berkshire-Hathaway was the largest US P-C group, with assets of \$174.3

Table 27.7 provides statistics regarding guaranty fund assessments for the period 1988–2010. Because of the orderly resolution of insurer insolvencies, guaranty funds assessments in both life and P-C insurance historically have been quite small. The total amounts of assessments from life-health and P-C guaranty funds from 1988 to 2010 were \$6.3 billion and \$12.5 billion, respectively; and the average annual assessments were \$27.6 million for life insurers and \$544 million for P-C insurers. Annual assessments never exceeded 0.35% of total premiums for either life or P-C insurers. Thus, historically, the guaranty fund system has stood up very well; but the system has never been required to deal with a widespread solvency crisis in insurance markets.

27.5.4 *Interconnectedness: Reinsurance Counterparty Risk*

This section begins by providing information on reinsurance counterparty risk based on balance sheet and income statement aggregates. The discussion then turns to a more detailed analysis of reinsurance counterparty exposure at the individual firm level.

Underpinning this analysis is the fact that reinsurance is the primary source of interconnectedness in the insurance industry. On average, worldwide, 6% of risk is transferred to reinsurers from primary companies (Baluch et al. 2011). Reinsurer failures have not been a primary factor historically in US insurer insolvencies, and there is no evidence internationally that the failure of a reinsurer has ever led to a systemic event (Group of Thirty 2006).

Baluch et al. (2011) indicate that performance of insurers' and reinsurers' equity (measured in terms of daily stock returns) was mostly independent over the period 2007–2009.⁴¹ This study indicates also that the possibility of systemic risk arising from insurance and reinsurance networks could only occur if there were an exogenous, unanticipated shock that is much greater than has ever happened or if the reinsurer were part of a financial conglomerate such as a bank-insurer. That is, the bankruptcy of the reinsurer could result in a loss of confidence in the bank-insurer's creditworthiness.

Nevertheless, the reinsurance market has become increasingly concentrated over time, through mergers and acquisitions and organic growth (Cummins and Weiss 2000; Cummins 2007). In addition, interlocking relationships permeate the industry, such that reinsurers *retrocede* reinsurance to other reinsurers, who then retrocede business to still other reinsurers, in a pattern reminiscent of the counterparty interrelationships that brought down the shadow banking system.⁴² Worldwide, reinsurers retrocede approximately 20% of their business (Baluch et al. 2011). Thus, the reinsurance market is vulnerable to a *retrocession spiral* whereby the failure of major reinsurers triggers the failure of their reinsurance counterparties, who in turn default on their obligations to primary insurers, resulting in a crisis permeating the insurance industry on a worldwide scale.⁴³

billion and equity of \$95.1 billion in 2011 (A.M. Best Company 2012b). Because of its higher capitalization, an asset shortfall is unlikely; and any claim payments by guaranty funds would cover an extended period.

⁴¹However, correlations of 50% existed among returns between insurer's and reinsurer's equity. Baluch et al. (2011) attribute this correlation to the link these companies have with capital markets.

⁴²Some have likened the retrocession market to interbank lending and borrowing in the banking industry. As such it is sometimes thought to be a transmission mechanism for contagion and systemic risk within the reinsurance industry. But unlike MBS in the recent crisis, retroceders still retain part of the risk (to reduce adverse selection).

⁴³Vulnerability to spirals is also exacerbated by the increasing use of *ratings triggers* in the reinsurance contracts. A reinsurance policy with a ratings trigger allows the primary company to cancel the policy if the reinsurer experiences a rating downgrade below a threshold indicated in the policy. Triggering of this rating clause would likely place the reinsurer in runoff when it was already experiencing financial difficulty. Ratings triggers thus introduce significant elements of optionability into reinsurance counterparty relationships.

Table 27.7 Solvency record and guaranty fund assessments: 1988–2010

| Year | Life-health | | | | Property-casualty | | | |
|---------|-----------------|--------------|---------------------------|-----------------------------|-------------------|--------------|---------------------------|-----------------------------|
| | No. of Failures | Failure rate | Assessments (\$ millions) | Assessments (% of premiums) | No. of Failures | Failure rate | Assessments (\$ millions) | Assessments (% of premiums) |
| 1988 | 27 | 1.02 | \$80 | 0.0351 | 48 | 1.46 | \$465 | 0.2298 |
| 1989 | 55 | 2.04 | \$103 | 0.0421 | 49 | 1.48 | \$714 | 0.3418 |
| 1990 | 47 | 1.77 | \$198 | 0.0748 | 55 | 1.66 | \$434 | 0.1988 |
| 1991 | 82 | 3.14 | \$529 | 0.2006 | 60 | 1.77 | \$435 | 0.1948 |
| 1992 | 39 | 1.56 | \$735 | 0.2607 | 59 | 1.72 | \$384 | 0.1685 |
| 1993 | 25 | 1.05 | \$632 | 0.1977 | 41 | 1.18 | \$520 | 0.2152 |
| 1994 | 12 | 0.54 | \$843 | 0.2493 | 28 | 0.80 | \$498 | 0.1985 |
| 1995 | 11 | 0.52 | \$876 | 0.2493 | 16 | 0.46 | \$67 | 0.0256 |
| 1996 | 20 | 0.98 | \$574 | 0.1519 | 12 | 0.35 | \$95 | 0.0355 |
| 1997 | 18 | 0.94 | \$448 | 0.1104 | 32 | 0.92 | \$236 | 0.0854 |
| 1998 | 12 | 0.63 | \$275 | 0.0620 | 17 | 0.53 | \$239 | 0.0843 |
| 1999 | 26 | 1.38 | \$167 | 0.0341 | 20 | 0.63 | \$179 | 0.0620 |
| 2000 | 9 | 0.48 | \$149 | 0.0275 | 48 | 1.53 | \$306 | 0.1012 |
| 2001 | 9 | 0.48 | \$129 | 0.0268 | 49 | 1.59 | \$713 | 0.2168 |
| 2002 | 10 | 0.55 | \$71 | 0.0138 | 47 | 1.54 | \$1,184 | 0.3125 |
| 2003 | 5 | 0.28 | \$33 | 0.0064 | 37 | 1.21 | \$874 | 0.2106 |
| 2004 | 6 | 0.34 | \$90 | 0.0166 | 19 | 0.62 | \$953 | 0.2182 |
| 2005 | 10 | 0.61 | \$78 | 0.0145 | 13 | 0.43 | \$836 | 0.1910 |
| 2006 | 3 | 0.19 | \$25 | 0.0043 | 16 | 0.53 | \$1,344 | 0.2966 |
| 2007 | 8 | 0.51 | \$80 | 0.0132 | 5 | 0.17 | \$943 | 0.2085 |
| 2008 | 9 | 0.52 | \$58 | 0.0090 | 16 | 0.53 | \$385 | 0.0867 |
| 2009 | 13 | 0.94 | \$125 | 0.0240 | 19 | 0.61 | \$478 | 0.1122 |
| 2010 | 7 | 0.48 | \$42 | 0.0073 | 21 | 0.67 | \$219 | 0.0510 |
| Totals | 463 | | \$6,340 | | 727 | | \$12,503 | |
| Average | 20.1 | 0.91 | \$276 | 0.0796 | 31.6 | 0.97 | \$544 | 0.1672 |

Sources: A. M. Best Co. (2012a, b), National Conference of Insurance Guaranty Funds, National Organization of Life-Health Guaranty Funds, American Council of Life Insurers, *Life Insurance Fact Book* (2011).

Note: The failure rate is the number of insolvencies divided by the total number of insurers. Assessments% of premiums is guaranty fund assessments divided by total insurance premiums for life and property-casualty insurers, respectively. Life-health assessments are “Called” minus “Refunded.”

An example of a reinsurance spiral is the London Market Excess (LMX) spiral that unfolded in the late 1980s and early 1990s (Neyer 1990). The LMX spiral involved retrocessions of excess of loss reinsurance (primarily for property catastrophes) among Lloyd’s syndicates and the London Market in the 1980s in which reinsurers participated in different layers of the same exposures, often unknowingly. As reinsurance recoveries were triggered, losses worked their way through the “spiral,” often passing back and forth through the same reinsurers.⁴⁴ As catastrophe losses mounted,

⁴⁴Neyer (1990) explains how the spiral was created and unraveled. At the time, the London market was the ultimate source of risk-bearing capacity for high limit excess of loss property catastrophe reinsurance. Essentially, each London market reinsurer had a specified net capacity to bear risk. However, each reinsurer leveraged this capacity by retroceding business to other London market reinsurers, enabling it to actually write more reinsurance cover than its existing net capacity. The problem was that the retroceded business was often ceded back into the London market and passed eventually back to the originating reinsurer. Thus, the total amount of coverage written greatly exceeded the net capacity. Once a large loss occurred that stressed the true net capacity of the market, it was passed back and forth until the true net capacity was exhausted. Thus, the reinsurers thought they were diversifying by retroceding to other reinsurers but actually ended up buying into the retroceded business, creating fictitious capacity. (This discussion is based on a model of the LMX spiral; the actual spiral was somewhat more complicated.) The spiral had spillover effects well beyond the

the spiral began to unwind, resulting in the most severe financial crisis in Lloyd's 300-year history with losses exceeding \$8 billion in 1988–1992 (O'Neill et al. 2009). Although the LMX crisis was confined primarily to reinsurers and hence not systemic, reinsurance markets today are even more concentrated and interconnected, suggesting that spirals are a serious threat to insurance markets. Baluch et al. (2011) argue that if Lloyds had failed, the lack of cover for the types of risks typically underwritten by Lloyds would have caused “significant economic disruption.” Thus, analysis of reinsurance counterparty relationships is important in understanding systemic risk in insurance.

Recent research suggests that vulnerability of U.S. P-C insurers to reinsurance spirals is not very significant. Park and Xie (2011) conduct the first detailed examination on the likely impact of a major global reinsurer insolvency on the US P-C insurance industry by running scenario analyses by allowing one of the top three reinsurers (Swiss Re, Munich Re, and Berkshire Hathaway) to become insolvent. They trace the effects of such reinsurer defaults as they flow through the industry, using financial statement data on reinsurance counterparty relationships. Even under an extreme assumption of a 100% reinsurance recoverable default by one of the top three global P-C reinsurers, only about 2% of U.S. P-C primary insurers would suffer financial ratings downgrades and only 1% percent of insurers would become insolvent.

Insurers conduct reinsurance transactions with both affiliates and non-affiliates. Although non-affiliate reinsurance is generally considered to pose more counterparty risk than affiliate reinsurance, the analysis of insurer insolvency history shows that affiliate problems also can pose an insolvency threat to insurers. Therefore, this analysis considers reinsurance with both affiliates and non-affiliates. The analysis also focuses on primary insurer cessions into the reinsurance market rather than reinsurance assumed. Ceding reinsurance creates more counterparty risk than assuming reinsurance because the ceding insurer is dependent upon the reinsurer to pay claims, and the reinsurance counterparty usually holds the funds, unlike reinsurance assumed, where the assuming insurer usually holds the funds.

Several important financial statement variables measure an insurer's exposure to reinsurance counterparty risk. One measure that is important in both life and P-C insurance is reinsurance premiums ceded, and another measure that is important in life insurance is insurance in force ceded, where in force refers to the policy face value. Reinsurance receivables, which represent funds currently owed to the insurer under reinsurance transactions, are also an important measure of exposure.⁴⁵ One of the benefits of buying reinsurance is that the buyer is generally permitted to reduce its reserve liabilities to the extent of the reinsurer's liability, improving its leverage ratio and expanding its capacity to write insurance.⁴⁶ For life insurers, the result of the write-down is called the *reserve credit taken*, which represents estimated liabilities of the primary insurer that have been assumed by the reinsurer; and for P-C insurers the account is called *net amount recoverable from reinsurers*.⁴⁷

London market because it caused reinsurance supply to decline, raising prices of reinsurance and primary insurance around the world.

⁴⁵We use the term *reinsurance receivables* to refer to asset page item 16 in the NAIC life and P-C annual statements. It includes amounts receivable from reinsurers, funds held by or deposited with reinsured companies, and other amounts receivable under reinsurance contracts.

⁴⁶US insurers can take balance sheet credit for reinsurance as long as the reinsurer is “authorized,” i.e., licensed in the ceding insurer's state of domicile, accredited in the ceding insurer's state of domicile, or licensed in a state with substantially similar credit for reinsurance laws. Insurers can take credit for unauthorized reinsurance only if the reinsurer posts collateral, in the form of funds held in the USA or letters of credit from US banks. The NAIC and several individual US states have begun to liberalize collateralization rules, and the process is ongoing.

⁴⁷The difference between receivables, on the one hand, and reserve credit taken and net amount recoverable, on the other hand, is that receivables represent amounts currently owed and payable, whereas reserve credit taken and net amount recoverable largely represent estimated reserve liabilities for future losses. Reserve credit taken data for life insurers are from Schedule S on the NAIC annual statement, and reinsurance recoverables for P-C insurers are from Schedule F of the NAIC annual statement.

Because policyholder claims on an insurer are not affected by reinsurance, the insurer remains liable for the policyholder obligations if the reinsurer defaults even though the balance sheet credit for reinsurance can be substantial. Another item which is important for life insurers is *outstanding surplus relief*, representing surplus obtained through reinsurance transactions, usually recovery of pre-paid acquisition costs.

The relevant financial statement data relating to reinsurance are shown in the bottom section of Table 27.5, which is based on balance sheet and income statement aggregates for the industry. More details on counterparty exposure among insurers are provided below.

Table 27.5 shows that life insurers ceded \$60.4 billion in premiums to non-affiliates and \$78.1 billion to affiliates in 2011, representing in total 20.2% of direct premiums written and 43.4% of surplus. P-C insurers ceded \$69.6 billion of premiums to non-affiliates and \$38.8 billion to affiliates, representing in total 21.6% of direct premiums and 18.9% of surplus. Hence, life insurers' surplus exposure to reinsurance counterparty risk is higher than for P-C insurers, but counterparty risk from premiums ceded does not seem excessive for either type of insurer.

Reinsurance receivables represent about 12.0% of equity capital for life insurers and 7.5% of equity for P-C insurers (Table 27.5). Hence, purely in terms of current receivables, insurer equity is not seriously exposed to counterparty risk. However, when the reinsurance counterparty exposure for estimated future losses and benefits is included, the total is much higher. For life insurers, the reserve credit taken due to transactions with nonaffiliated reinsurers is 65.7% of surplus and the credit taken for affiliate reinsurance is 97.0% of surplus. Thus, insurer leverage gross of reinsurance is much higher than leverage net of reinsurance. P-C insurers are less exposed to nonaffiliated reinsurers in terms of the net reinsurance recoverable than life insurers (25.3% of surplus) and have even less net exposure to affiliated reinsurers (14.9% of surplus).⁴⁸ Finally, life insurers cede 27.4% of total insurance in force to nonaffiliated reinsurers and 28.3% to affiliates, for a total of 55.7% ceded. Thus, the degree of interconnectedness within the insurance industry due to reinsurance is significant, particularly for life insurers.

Summary statistics on reinsurance premiums ceded and reinsurance recoverable by company for the P-C insurance industry are shown in Table 27.8,⁴⁹ which is based on nonaffiliated reinsurance counterparties. At the median, P-C insurers cede 9.1% of direct and assumed premiums to the top four nonaffiliated reinsurers and only 13.1% to all nonaffiliated reinsurers. Reinsurance cessions are heavily concentrated in a few counterparties. At the median, insurers ceded 43.6% of total reinsurance cessions to the top counterparty, 87.6% to the top four counterparties, and 100% to the top ten counterparties. The Herfindahl index of premiums ceded at the median is 2,917, an index value equivalent to ceding equal amounts of reinsurance to 3.4 reinsurers. Concentration of recoverables in the top counterparties is also high. The proportion of the total recoverables owed by the top one, four, and ten counterparties at the median is 47.4%, 90.5%, and 100.0%, respectively. The Herfindahl index for recoverables at the median is 3,248, approximately equivalent to having recoverables equally divided among three counterparties.

Exposure of surplus to reinsurance recoverable from non-affiliates varies widely across the P-C industry (Table 27.8). At the median, exposure does not seem excessive—the ratio of reinsurance recoverable-to-surplus for all counterparties is 21.0%. However, at the 75th percentile, reinsurance recoverable-to-surplus from all counterparties is 52.2%. Therefore, at least one-fourth of P-C insurers could be seriously at risk if several large reinsurers were to fail.

The exposure to nonaffiliated reinsurance counterparties in the life insurance industry is shown in Table 27.9. Life reinsurance premium cessions are even more concentrated in the top counterparties

⁴⁸The SNL database used in compiling the reinsurance data in Table 27.5 nets out intra-group transactions.

⁴⁹Table 27.8 was compiled by ranking each ceding insurer's data by the amount ceded (or recoverable) from that ceding insurer's top counterparties. The counterparties therefore are not necessarily the same across ceding insurers.

Table 27.8 Property-casualty reinsurance premiums ceded to and recoverable from non-affiliated counterparties

| Section 1: Reinsurance Premiums Ceded | | | | | | | | |
|---------------------------------------|---------------------|-----------------------|-------------------------|-----------------------|-------------------|-------------------|--------------------|-----------------|
| | RPC Top Reinsurer % | RPC Top 4 Reinsurer % | RPC Top 10 Reinsurers % | Herfindahl Index, RPC | RPC Top 4 Re/DPWA | RPC Top 4 Re/DPWA | RPC Top 10 Re/DPWA | RPC All Re/DPWA |
| Average | 52.0 | 80.4 | 92.6 | 4, 168 | 10.1 | 15.6 | 17.8 | 19.5 |
| Max | 100.0 | 100.0 | 100.0 | 10, 000 | 95.2 | 95.2 | 95.2 | 95.3 |
| 99th | 100.0 | 100.0 | 100.0 | 10, 000 | 67.3 | 77.4 | 80.0 | 82.2 |
| 95th | 100.0 | 100.0 | 100.0 | 10, 000 | 39.3 | 55.3 | 60.1 | 62.2 |
| 75th | 78.9 | 100.0 | 100.0 | 6, 476 | 12.5 | 21.5 | 26.0 | 28.8 |
| median | 43.6 | 87.6 | 100.0 | 2, 917 | 4.9 | 9.1 | 10.9 | 13.1 |
| 25th | 26.0 | 64.1 | 89.3 | 1, 418 | 1.5 | 3.1 | 3.8 | 4.7 |
| 5th | 14.1 | 40.3 | 64.7 | 653 | 0.2 | 0.3 | 0.3 | 0.5 |
| 1st | 8.1 | 25.7 | 48.6 | 346 | 0.0 | 0.0 | 0.0 | 0.0 |
| Min | 4.1 | 12.9 | 23.7 | 126 | 0.0 | 0.0 | 0.0 | 0.0 |

| Section 2: Reinsurance recoverable | | | | | | | | |
|------------------------------------|----------------------|------------------------|-------------------------|----------------------|-----------------|-----------------|------------------|---------------|
| | RR Top Re % of Total | RR Top 4 Re % of Total | RR Top 10 Re % of Total | Herfindahl Index, RR | RPC Top Re/DPWA | RR Top 4 Re/PHS | RR Top 10 Re/PHS | RR All Re/PHS |
| Average | 53.8 | 82.3 | 93.5 | 4, 350 | 21.0 | 32.6 | 37.2 | 41.1 |
| Max | 100.0 | 100.0 | 100.0 | 10, 000 | 277.3 | 278.3 | 288.2 | 288.5 |
| 99th | 100.0 | 100.0 | 100.0 | 10, 000 | 179.2 | 224.6 | 236.6 | 249.6 |
| 95th | 100.0 | 100.0 | 100.0 | 10, 000 | 85.7 | 129.6 | 143.8 | 160.8 |
| 75th | 82.0 | 100.0 | 100.0 | 6, 907 | 24.1 | 40.5 | 46.7 | 52.2 |
| median | 47.4 | 90.5 | 100.0 | 3, 248 | 8.4 | 15.5 | 18.4 | 21.0 |
| 25th | 28.1 | 68.0 | 91.9 | 1, 578 | 2.5 | 4.7 | 6.1 | 6.7 |
| 5th | 14.5 | 41.9 | 69.2 | 677 | 0.3 | 0.5 | 0.6 | 0.6 |
| 1st | 8.6 | 26.5 | 49.8 | 367 | 0.0 | 0.1 | 0.1 | 0.0 |
| Min | 4.1 | 12.4 | 22.9 | 124 | 0.0 | 0.0 | 0.0 | 0.0 |

Source: National Association of Insurance Commissioners property-casualty annual statement database and ScheduleF.com

Note: Data are for 2008 in order to reflect insurer exposure during the crisis. RPC = reinsurance premiums ceded, DPWA = direct premiums written plus reinsurance assumed, RR = reinsurance recoverable, PHS = policyholders surplus. RPC Top x Reinsurers % = RPC to top x reinsurers as % of total RPC, RPC Top x Re/DPWA = RPC to top x reinsurers as % of total DPWA, RR Top x Re % of Total = RR from top x reinsurers as % of total RR, RR Top x Re/PHS = RR from top x reinsurers as % of PHS. Herfindahl indices are based on percentages of premiums ceded and receivables across counterparties.

than for P-C insurers. At the median, 53.0% of premiums are ceded to the top reinsurer, 93.5 % to the top four reinsurers, and 100.0% to the top ten. However, the premiums ceded at the median are not high for life insurers—the percentage of direct premiums and reinsurance assumed that is ceded to all reinsurers is only 11.3%. As a result, the ratios of reserve credit taken to surplus at the median also are not very high—e.g., 20.9% for the top four and 24.5% for all reinsurers. However, a substantial proportion of companies in the industry have very high ratios of reserve credit taken to surplus—at the 75th percentile, the ratio is 58.2% for the top reinsurer and 110.3% for the top four reinsurers. Thus, at least 25% of insurers would find their surplus severely eroded if a crisis developed in the reinsurance industry.

Table 27.9 Life insurance and annuity reinsurance premiums ceded and reserve credit taken, nonaffiliated counterparties

| Section 1: Reinsurance premiums ceded | | | | | | | | |
|---------------------------------------|-----------------------|-------------------------|--------------------------|-----------------------|-------------------|-------------------|--------------------|-----------------|
| | RPC Top Reinsurer % | RPC Top 4 Reinsurer % | RPC Top 10 Reinsurers % | Herfindahl Index, RPC | RPC Top 4 Re/DPWA | RPC Top 4 Re/DPWA | RPC Top 10 Re/DPWA | RPC All Re/DPWA |
| Average | 57.1 | 88.0 | 97.8 | 4,580 | 13.5 | 19.4 | 21.3 | 21.9 |
| Max | 100.0 | 100.0 | 100.0 | 10,000 | 100.0 | 100.0 | 100.0 | 100.0 |
| 99th | 100.0 | 100.0 | 100.0 | 10,000 | 99.6 | 100.0 | 100.0 | 100.0 |
| 95th | 100.0 | 100.0 | 100.0 | 10,000 | 59.3 | 75.2 | 79.6 | 83.9 |
| 75th | 78.9 | 100.0 | 100.0 | 6,400 | 16.3 | 25.4 | 27.8 | 29.5 |
| median | 53.0 | 93.5 | 100.0 | 3,943 | 4.9 | 9.5 | 10.9 | 11.3 |
| 25th | 34.7 | 79.6 | 98.6 | 2,130 | 1.5 | 2.6 | 3.0 | 3.2 |
| 5th | 20.1 | 57.2 | 85.6 | 1,115 | 0.2 | 0.4 | 0.4 | 0.4 |
| 1st | 14.4 | 43.7 | 75.3 | 769 | 0.0 | 0.0 | 0.0 | 0.0 |
| Min | 11.0 | 29.7 | 55.9 | 447 | 0.0 | 0.0 | 0.0 | 0.0 |
| Section 2: Reserve credit taken | | | | | | | | |
| | RCT Top Re % of Total | RCT Top 4 Re % of Total | RCT Top 10 Re % of Total | Herfindahl Index, RCT | RPC Top Re/PHS | RCT Top 4 Re/PHS | RCT Top 10 Re/PHS | RCT All Re/PHS |
| Average | 62.3 | 90.8 | 98.4 | 5,250 | 64.1 | 84.9 | 91.4 | 93.2 |
| Max | 100.0 | 100.0 | 100.0 | 10,000 | 500.0 | 500.0 | 500.0 | 500.0 |
| 99th | 100.0 | 100.0 | 100.0 | 10,000 | 500.0 | 500.0 | 500.0 | 500.0 |
| 95th | 100.0 | 100.0 | 100.0 | 10,000 | 381.5 | 454.2 | 457.3 | 471.0 |
| 75th | 90.6 | 100.0 | 100.0 | 8,250 | 58.2 | 110.3 | 122.5 | 123.0 |
| median | 61.5 | 97.6 | 100.0 | 4,644 | 11.7 | 20.9 | 23.8 | 24.5 |
| 25th | 38.0 | 85.8 | 99.6 | 2,580 | 2.8 | 5.4 | 6.0 | 6.0 |
| 5th | 20.6 | 61.8 | 89.9 | 1,240 | 0.1 | 0.1 | 0.1 | 0.1 |
| 1st | 13.6 | 39.7 | 77.7 | 650 | 0.0 | 0.0 | 0.0 | 0.0 |
| Min | 9.0 | 28.3 | 51.7 | 87 | 0.0 | 0.0 | 0.0 | 0.0 |

Source: National Association of Insurance Commissioners life insurance annual statement database.

Note: Data are for 2008 to reflect insurer exposure during the crisis. RPC = reinsurance premiums ceded, DPWA = direct premiums written + reinsurance assumed, RCT = reserve credit taken, PHS = policyholders surplus. RPC Top x Reinsurers % = RPC to top x reinsurers as % of total.

27.5.5 Do the Core Activities of Insurers Pose Systemic Risk?

This section analyzes whether the core activities of insurers pose systemic risk, i.e., whether an event originating in the insurance sector could spread to other parts of the financial sector or the real economy. To draw conclusions about systemic risk in insurance, we consider the primary indicators and contributing factors in the light of the data analysis presented above.

The first primary indicator of systemic risk is size. In terms of balance sheet aggregates, insurers are smaller than banks. Insurers have \$7.1 trillion of assets in 2011 including separate accounts and \$5.3 trillion excluding separate accounts, compared to \$12.6 trillion in the banking sector (Table 27.4). The largest US insurance group, MetLife, had \$612.8 billion in assets in 2011, compared with more than \$2.3 trillion for the top bank, J.P. Morgan Chase.⁵⁰ Insurance contributes about 3.0% to total US GDP, and insurers hold 7.8% of US credit market debt outstanding. Insurers hold more than 10% of financial assets only for municipal securities (P-C insurers hold 8.8% and life insurers hold 3.3%), corporate and foreign bonds (3.1% held by P-C insurers and 18.4% held by life insurers), and commercial mortgages (0.2% held by P-C insurers and 11.8% held by life insurers). However, because insurer insolvency resolutions are orderly and take place over lengthy periods of time, the amount of assets that would be liquidated in even the largest insurer insolvency would be small relative

⁵⁰The other three mega-banks are Bank of America, Citigroup, and Wells Fargo each of which had more than \$1 trillion of assets in 2012 (Standard & Poor's 2012a, b). The bank data are for March 2012.

to securities markets. Therefore, in terms of their core activities, insurers are not large enough to be systemically important, although the failure of a large insurer, such as a subsidiary of MetLife, could cause significant dislocations in insurance markets and possibly strain the liquidity of insurance guaranty funds.

Insurer core activities also do not seem to be systemically important in terms of the second primary indicator, interconnectedness. Unlike in many European countries, the cross-holdings of stocks and bonds between the US insurance and US banking industries are small, and neither industry provides a significant source of financing for the other. Thus, a commercial chapter-like credit crunch arising from the US insurance industry is highly unlikely. The bank failure rate has a bivariate correlation of 34% with the P-C insurer failure rate and 23% with life insurers, suggesting that banks and insurers are somewhat interconnected with respect to their susceptibility to common economic and financial shocks. Also, [Chen et al. \(2014\)](#) find banks create significant systemic risk for insurers but not vice versa, i.e., suggesting that insurers are victims rather than propagators of systemic risk.

Interconnection risk for core activities *within* the insurance industry is considerably higher than between insurance and banking, although risk confined within a specific sector is not systemic by definition. Life insurer liability write-downs (reserve credit taken) due to reinsurance are about 162.7% of surplus, but P-C write-downs are only 40.2% of surplus. However, non-affiliate write-downs are only 65.7% of surplus for life insurers and 25.3% of surplus for P-C insurers. About 25% of P-C insurers have reinsurance recoverables of more than 50% of surplus, and 25% of life insurers have reinsurance credit taken of more than 120% of surplus. Hence, an insolvency crisis in the reinsurance market potentially could cause intra-sector problems in the insurance industry. Nevertheless, purely from their core activities, insurers are not sufficiently interconnected with noninsurance institutions such that the reinsurance problems would spill over into the banking and securities industries. However, a reinsurance crisis could potentially cause spill-over risk due to interconnectedness of insurers and other institutions through insurers' noncore activities.

Is insurance a systemic threat due to lack of substitutability? For an activity to pose a systemic threat due to lack of substitutability, it is necessary not only that the activity not have substitutes but also that it is critical to the functioning of the economy. Banks pose substitutability problems because of their role in the payment and settlement systems, in transmitting central bank monetary policy, and in providing a critical source of liquidity and financing for consumers and businesses. Although insurance plays an important role in the economy, it does not suffer from lack of substitutability to the same extent as banking.

For life insurance, lack of substitutability does not pose a systemic problem. The bulk of financial transactions in life insurance relate to asset accumulation products rather than mortality/longevity risk bearing, and there are many substitutes for investing through life insurance and annuities. For mortality/longevity risks, which are unique to insurance, many insurers are available to fill coverage gaps created by the failure of one or a few firms, and hedging mortality risk is not central to the economy as are payments-settlement or monetary policy. Thus, life insurance has substitutes and is not critical to the functioning of other firms.

Unlike life insurance, P-C insurance exists primarily to provide risk management and risk-bearing services rather than serving an asset accumulation function. Certainly for individual insurance customers, there is no substitute for products such as automobile and homeowners insurance. However, even if the supply of individual P-C products were dramatically reduced, it is unlikely that real economic activity would be affected significantly. Even if several major insurers were to encounter severe financial difficulties, many other insurers are available to fill the coverage gap. The same would be true for small and medium-size commercial buyers. Large corporate buyers have many effective substitutes for P-C insurance, including self-insurance, captive insurance companies, and securitization of insurance-type risks ([Cummins and Weiss 2009](#)). There has been considerable debate in the finance literature about whether widely held corporations should even buy insurance, other than to access the risk management and claims settlement expertise of insurers and perform other corporate

risk management functions (MacMinn and Garven 2000). Thus, lack of substitutability does not seem to create a systemic risk as it relates to insurance. Because of the dominance of large insurers in the (non-UK) European market, substitutability may be more of a problem for P-C insurance there.

Nonetheless, some P-C insurance lines were harder hit by the financial crisis than other lines. These lines include errors and omissions insurance and directors and officers liability insurance. AIG, Chubb, XL, and Lloyd's of London are large writers of these coverages. Estimating the cost of such claims is very difficult because claims are hard to prove. However, there appears to be no shortage of supply in these lines at the present time, although prices for these products have risen. Credit insurance is another type of coverage hit hard by the crisis. According to Baluch et al. (2011), the economic downturn was reinforced by a decline in the supply of credit insurance. In fact, several governments, concerned about availability of credit insurance, have taken actions to safeguard credit insurance and trading activity.

Of course, even for those functions that are unique to insurance, ease of entry into the insurance industry means that supply is unlikely to be disrupted for a significant period of time. As mentioned, Berry-Stoelzle et al. (2011) show that substantial new capital flowed into the life insurance industry in response to the financial crisis, and Cummins (2008) shows that there has been substantial entry into the P-C insurance market, particularly in Bermuda.

Because the core activities of insurers generally do not lead to the identification of insurers as systemically important according to the primary indicators, the discussion of the contributing factors mainly relates to their role in creating financial vulnerabilities within the insurance industry. In this respect, we consider life and P-C insurers separately, except for regulation, where we discuss the regulatory framework more generally.

The first contributing factor is leverage. As we have seen, life insurers have higher leverage than P-C insurers. Life insurer capital-to-asset ratios are comparable to those of banks, both of which have been running at about 10%. Berry-Stoelzle et al. (2011) found that life insurers were able to recover quickly from losses sustained during the financial crisis by raising new capital, and insurer failure rates and guaranty fund assessments remain very low. Life insurers' reserve credit taken (162.7% of surplus on average) represents additional leverage that would come back onto life insurer balance sheets if there are reinsurance failures. Thus, life insurers have the potential for significantly higher leverage due to reinsurer defaults. However, reinsurer defaults have not played a significant role historically in causing insurer insolvencies, and no such defaults occurred during the financial crisis. Life insurer equity is exposed to erosion from asset fluctuation and default risk due to large holdings of MBS and ABS, but life insurers weathered the financial crisis in spite of these investments.

The second contributing factor is liquidity risk. As we have seen, life insurers also have high liquidity risk due to their heavy investment in privately placed bonds. Life insurers also suffer from the third contributing factor, complexity, especially in terms of offering life insurance and annuity products with embedded options such as minimum interest rate guarantees. Life insurers are also at least moderately exposed to optionability risk, due to the ability of policyholders to cash out their life insurance and annuity policies. The only contributing factor that does not seem to be a problem for life insurers is maturity risk, in that their asset and liability maturities seem to be well matched.

P-C insurers appear less financially vulnerable than life insurers in terms of the contributing factors. Their leverage ratios are low and have been improving over time; and they do not have much exposure to asset liquidity risk from ABS, MBS, or private placements. P-C insurers do have some exposure to reinsurance recoverables, indicating potential vulnerability to reinsurance spirals. However, Park and Xie (2011) provide evidence that even a large reinsurer insolvency would not significantly disrupt the P-C market. P-C insurers' core activities have low to moderate complexity, in comparison with complex banking products and life insurance products with embedded options. P-C insurers are vulnerable to catastrophe risk but have been able to withstand large catastrophes such as Hurricanes Andrew and Katrina in the past. Therefore, P-C insurers' vulnerability to intra-sector crises appears low although some insurers do have high exposure to nonaffiliated reinsurance (Table 27.8).

US insurance regulation, which tends to be very conservative, prevented insurers from engaging in the dramatic increases in leverage that occurred for the shadow banks during the period preceding the crisis. The effectiveness of regulation is demonstrated by the low insurance insolvency rates in the USA. Although US regulation is “Balkanized” and the cumbersome regulatory structure often impedes necessary reforms, Federal bank regulators did not perform well in the period leading up to the financial crisis, and it is not clear that Federal regulators would be more effective than state regulators. Although the lack of a single overseer does create problems in managing multi-state insolvency risk (Acharya et al. 2009), nationally significant insurers are reviewed every quarter by the NAIC, and those that appear to be performing poorly are prioritized for analysis by experienced regulators (the Financial Analysis Working Group).

Moral hazard is created by the existence of insurance guaranty funds because guaranty fund premiums are not risk-based. This feature of guaranty funds can lead to excessive risk-taking in insurers. However, moral hazard is mitigated somewhat by the fact that insurance guaranty funds have claim payment limits, giving policyholders an incentive to monitor insurers. Hence, relatively more market discipline is present for insurers than for other financial institutions such as banks (Harrington 2009). Moreover, the NAIC’s risk-based capital system penalizes insurers that take excessive risk, further reducing insurer incentives for risk-taking.

27.6 Systemic Risk and Noncore Activities

The core activities of P-C insurance companies involve providing various types of insurance coverages. The core activities of life insurers include providing asset accumulation products to consumers and businesses as well as insurance against mortality and longevity risk. In addition to their core products, insurers have undertaken a variety of noncore activities. Some of these activities have the potential to create interconnectedness with other financial institutions and nonfinancial sectors of the economy and thereby foster systemic risk.

Although insurer involvement in noncore activities is usually associated with the passage of the Gramm-Leach-Bliley Act in 1999, insurers expanded their operations beyond traditional core insurance products decades earlier.⁵¹ Insurers have invested in privately placed bonds at least since the 1970s, in direct competition with the bond underwriting functions of investment banks and also compete with banks in commercial mortgages. Life insurers introduced guaranteed investment contracts and single premium deferred annuities in the 1970s, competing directly with bank certificates of deposit. Beginning in the 1970s, many insurers also introduced proprietary mutual fund families to compete with banks and securities firms. Insurers also engage in investment management for consumer and business clients. Following Gramm-Leach-Bliley, a few insurers also acquired or established thrift institutions to offer banking services. Insurers have expanded into the provision of financial guarantees, asset lending, and CDS, as well as investing in ABS, MBS, and other complex structured securities. Insurers are active in trading derivatives such as foreign exchange and interest rate options. Insurers have entered the market for securitization, most prominently not only for catastrophe-linked securities but also for other types of risks.⁵² Some of these activities such as writing

⁵¹The Gramm-Leach-Bliley (Financial Services Modernization) Act repealed part of the Glass-Steagall Act of 1933, opening up the market among banks, securities firms, and insurers. The Glass-Steagall Act prohibited any one institution from acting as any combination of an investment bank, a commercial bank, and an insurance company.

⁵²Banks have also expanded into insurance and annuity markets. However, banks primarily serve as distributors of insurance products underwritten by unaffiliated insurance companies and not as insurance underwriters (Insurance Information Institute 2012). Therefore, such expansion does not seem to have systemic implications.

CDS and providing financial guarantees contribute to systemic risk, while others such as investing in MBS and ABS mainly increase the susceptibility of insurers to crises.

Detailed quantitative information on insurer noncore activities is not readily available. However, aggregate data on outstanding CDS by counterparty type are available from the Bank for International Settlements (BIS). The BIS data reveal that total CDS outstanding were \$58.2 trillion in the second half of 2007, declining to \$29.9 trillion by 2010 as a result of the financial crisis. The majority of CDS were held by reporting dealers, mainly large commercial and investment banks that have an active business with large customers (BIS 2007). Insurers held \$492 billion in CDS outstanding in 2007 and \$270 billion in 2010. Thus, insurers have remained active in the CDS market even after the AIG debacle. Although insurers represent a small part of the CDS market, \$270 billion is a large exposure relative to industry capitalization.

Insurers can be at risk from selling CDS, but insurers also purchase protection products to hedge risk from their own investment holdings (bonds and stocks), exposing insurers to counterparty credit risk. But CDS are frequently sold in the secondary market, so that a CDS may change hands many times (Baluch et al. 2011). It can turn out to be difficult to identify the counterparty to the trade in case of defaults so that unwinding the trade becomes difficult. Thus, insurers can experience significant credit risk, especially if the asset has a high notional value relative to assets.

Recent research on the stock prices of financial institutions provides evidence on the degree of interconnectedness within the financial industry. Billio et al. (2011) develop econometric measures of systemic risk and analyze stock price data on hedge funds, banks, brokers, and insurers for the period 1994–2008. They examine index returns on the four groups of financial institutions as well as the returns of the 25 largest entities in each group. They utilize principal components analysis to study the correlations among the four groups of institutions and Granger causality tests to analyze the direction of the relationships among the sample firms. They do not observe significant causal relationships between financial institutions in the first part of the sample period (1994–2000) but find that financial institutions have become significantly linked during the second part of the sample period (2001–2008). They find that the relationships are asymmetrical—the returns of banks and insurers have a more significant impact on hedge funds and brokers than vice versa. Insurers identified as systemically important include ACE, AIG, Progressive, and XL capital. The authors attribute the growing interrelationships among institutions to the existence of frictions in the financial system, including “value-at-risk constraints, transactions costs, borrowing constraints, costs of gathering and processing information, and institutional restrictions on short sales” (Billio et al. 2011, p. 10).

Acharya et al. (2010) develop an alternative measure of systemic risk, the *systemic expected shortfall*, which gauges the propensity of a financial institution to be undercapitalized when the system as a whole is undercapitalized. They analyze the stocks of the 102 financial institutions that had market capitalization exceeding \$5 billion as of June 2007 including four financial industry segments—depository institutions (29 firms), securities dealers and commodities brokers (10 firms), insurance companies (36 firms), and other financial institutions (27 firms). The period of analysis is 2006–2008. Their results indicate that “insurance firms are overall the least systemically risky, next were depository institutions, and most systemically risky are the securities dealers and brokers” (p. 21). In terms of specific insurers, AIG appears “more systemic” than Berkshire Hathaway. They also point out that the top three insurance companies in terms of systemic risk (Genworth, Ambac, and MBIA) were heavily involved in providing financial guarantees for structured products in the credit derivatives market.

Billio et al. (2011) and Acharya et al. (2010) reveal that financial firms are highly interconnected and that insurance firms can be a source of systemic risk. These studies strongly suggest that the interconnectedness among institutions extends beyond exposure to common shocks. The analysis presented in our chapter suggests that any systemic risk originating from the insurance sector is not attributable to the core activities of insurers. Rather, the interconnectedness between insurers and other financial firms is more likely attributable to the noncore or “banking-like” activities of insurers,

particularly large, publicly traded firms. Also playing a role are the financial market frictions identified by [Billio et al. \(2011\)](#).

Because noncore activities of insurance groups can create systemic risk, regulators need to improve the effectiveness of group supervision, particularly for global insurance-led financial groups ([Geneva Association 2012](#)). Large, global insurance groups not only have insurance subsidiaries that are regulated in the USA but also have financial subsidiaries located in other countries. Its London-based Financial Products division brought down AIG due to a failure of regulation, such that US insurance regulators did not have jurisdiction and US banking regulators failed to require adequate capitalization.⁵³ The NAIC, IAIS, and other regulatory bodies are currently working on improvements in group supervision. The key is to design a regulatory system that effectively encompasses both the core and noncore enterprises of the insurance sector and coordinates regulation across national boundaries. Given the limited information currently available on derivatives, asset lending, and other noncore activities of insurers, regulators should require more disclosure of these types of transactions. Disclosure enhances transparency and hence reduces the probability of the development of systemic crises. Regulators should also have the authority to regulate leverage by noncore subsidiaries of insurance firms.

Because of the importance of noncore activities in potentially creating systemic risk, it is useful to review the present and proposed future status of insurance group regulation. We focus primarily on the USA and briefly mention international efforts.

Historically, US insurance regulation has focused on the operations and financial results of insurers on a legal entity basis, i.e., most regulatory efforts have targeted individual insurers that are members of groups and unaffiliated single insurers rather than insurance groups. However, two NAIC model laws specifically relate to insurance holding companies. They are Model Law (ML) 440, Insurance Holding Company System Regulatory Act, and ML 450, Insurance Holding Company System Model Regulation with Reporting Forms and Instructions. In light of the financial crisis, modifications to these laws have been proposed, and holding company analysis became an accreditation requirement effective January 1, 2012. A new proposed model law with implications for group supervision, the Risk Management and Own Risk and Solvency Assessment (RMORSA) Model Law is also under consideration. We first consider the present regulatory rules under MLs 440 and 450 and then consider the proposed revisions to those laws and the key provisions of RMORSA as they relate to insurance groups.

An important objective of MLs 440 and 450 is to regulate transactions within the insurance group. Under ML 440, every insurer which is a member of an insurance holding company is required to register with the insurance commissioner. Transactions within an insurance holding company system to which a registered insurer is a party must satisfy legally specified requirements. Among other things, the terms of transactions within the holding company must be reasonable and fair. Pre-notification to the state commissioner and commissioner approval is required for specified transactions involving a registered insurer and any person in its holding company system. Such specified transactions include large sales, purchases, exchanges, loans, or investments; significant modification of reinsurance agreements; and any material transactions which the commissioner believes may adversely affect the interests of the insurer's policyholders. In addition, registered insurers must provide annual information in a prescribed format including capital structure, financial condition, the identity and relationship of every member of the insurance holding company as well as outstanding transactions and agreements between the insurer and its affiliates.

ML 450 is primarily directed towards providing rules and procedures necessary to carry out ML 440. Among other provisions, ML 450 requires insurance groups to file an annual "Insurance Holding

⁵³ AIGFP was under the regulatory authority of the US Office of Thrift Supervision (OTS). In retrospect, it is clear that OTS oversight was not adequate to prevent AIGFP's financial difficulties.

Company Registration Statement.” In the Registration Statement, the holding company is required to report a variety of information including disclosures regarding purchases, sales, or exchanges of assets; litigation or administrative proceedings pending or concluded within the past year; and financial statements and exhibits. In conclusion, currently existing model laws require the commissioner to be informed of material actions/transactions that affect domestically authorized insurers within insurance holding companies, including transactions with noninsurance affiliates, but commissioners do not have the authority to order an insurance subsidiary to provide other information on noninsurance affiliates.

State commissioners can take no direct action against noninsurance affiliates within an insurance holding company. However, state commissioners can place pressure on regulated insurance subsidiaries concerning holding company activities and the activities of noninsurance affiliates, e.g., state commissioners can place pressure so that the books and records of affiliates are provided to the commissioner. In particular, state insurance commissioners could have inquired about the activities of AIGFP even though AIGFP was not regulated by the state commissioners. If any resulting disclosures had raised questions about threats to the financial condition of AIG’s regulated US insurance subsidiaries, US regulators could have tightened regulatory requirements on the US subsidiaries, including requiring the subsidiaries to operate with increased capital.

Revisions to MLs 440 and 450 have been proposed and have already been adopted by nine states.⁵⁴ The overall focus of the proposed revisions is on enterprise risk management (ERM), corporate governance, and increasing regulatory authority to obtain information and regulate the activities of insurance holding companies. The most important change is the introduction of new guidelines for reporting enterprise risk (a required Enterprise Risk Report (ERR)). The ERR must indicate (among other things) any material developments regarding strategy, internal audit findings, compliance, or risk management that, in the opinion of senior management, could adversely affect the insurance holding company system. Under the revised model laws, the commissioner may order any registered insurer to produce records, books, or other information that are deemed reasonably necessary to determine the financial condition of the insurer, including information on noninsurance affiliates.

The RMORSA Model Act is a new model law, tentatively scheduled for implementation in 2015. The purpose of the model law is to provide the requirements for maintaining a risk management framework and to provide instructions for filing an annual ORSA Summary Report with the insurance commissioner. The ORSA requirement applies to the insurer or the insurance group of which the insurer is a member. At a minimum, the ORSA Summary Report should describe the risk management framework and provide an assessment of risk exposure, group risk capital adequacy, and prospective solvency assessment. The Report is to be supported by internal risk management materials and more detailed documentation. The goals of ORSA are to foster an effective level of ERM for all insurers and to provide a group-level perspective on risk management and capital.

In conclusion, the revisions to ML 440 and 450 along with the Risk Management and ORSA Model Act should provide insurance commissioners more complete information on the risks facing insurance holding companies. The ERR and the ORSA Summary Report, especially, should be instrumental in achieving this goal. The revisions to ML 440 clarify and strengthen regulatory authority to require information about noninsurance affiliates within an insurance holding company. The state insurance commissioner still would not have any direct control over noninsurance affiliates or affiliates outside of its geographic jurisdiction, but pressure can be brought to bear on the regulated affiliate if the state commissioner believes problems exist elsewhere in the group. The revisions of MLs 440 and 450 strengthen regulatory authority over the holding company and facilitate bringing pressures on regulated insurance subsidiaries to prevent spillovers of financial problems from noninsurance affiliates. However, because insurance in the USA is regulated by fifty-one separate

⁵⁴The revised model laws were put out for comment until the end of 2012. Whether the revised model laws become a requirement for accreditation will be decided after that.

jurisdictions, regulators need to carefully monitor the noninsurance subsidiaries of insurance-led groups and coordinate efforts to communicate any danger signals across regulatory jurisdictions. In addition, regulators need to develop stronger group-wide supervision to monitor primary indicators and contributing factors such as interconnectedness, leverage, and liquidity risk to prevent future systemic events.

An important new regulatory agency with potential authority over insurance holding companies is the Financial Stability Oversight Council (FSOC) established by the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010. The FSOC has three primary purposes (FSOC 2012): (1) To identify risks to the financial stability of the USA that could arise from the activities of large, interconnected bank holding companies or *nonbank financial companies* (emphasis added). (2) To promote market discipline, by eliminating expectations on the part of shareholders, creditors, and counterparties of such firms that the US government will shield them from losses in the event of failure. (3) To respond to emerging threats to the stability of the US financial system.

The FSOC has established a three-stage process for designating a nonbank financial institution as an SIFI. Stage 1 stipulates that the institution will be subject to further analysis if it has at least \$50 billion of consolidated financial assets and meets or exceeds any one of the several additional quantitative thresholds, including \$30 billion in gross notional CDS for which the nonbank financial company is the reference entity, \$3.5 billion in derivative liabilities, or \$20 billion of total debt outstanding. In Stage 2, FSOC will further analyze those companies triggering the Stage 1 thresholds using a broad range of information from existing public and regulatory sources. The final step, Stage 3, involves direct contact by FSOC with each nonbank financial institution that has passed through Stages 1 and 2 of the SIFI process to request additional information from the company. At the end of Stage 3, FSOC makes a final determination about designating the company as an SIFI. Institutions designated as SIFIs come under the regulatory authority of the Federal Reserve, which can impose “enhanced supervision and prudential standards, *whether they are banks or nonbanks*, and the ability to subject key market infrastructure firms to heightened risk-management standards” (US Department of the Treasury 2012) (emphasis added).

As of July 2013, the FSOC had designated two nonbanks as SIFIs, AIG and GE Capital and it had designated eight financial market utilities (FMUs) as systemically important, including the Clearinghouse Payments Company and ICE Clear Credit. Nevertheless, the FSOC clearly has the authority to designate additional nonbank financial institutions as SIFIs and subject them to additional regulation. As of the end of 2011, the top 26 US life insurance groups all exceeded the \$50 billion asset threshold under the SIFI Stage 1 criterion, but only five predominantly P-C groups exceeded the threshold (A.M. Best Company 2012a, b). It remains to be seen whether SIFI rules will be vigorously applied to nonbank financial institutions.⁵⁵

27.7 Analysis of Systemic and Nonsystemic Insurers

To provide further information on the noncore activities of insurance firms, we conduct additional analysis using two samples of insurers—a *systemic risk* sample and a *nonsystemic risk* sample. The systemic risk sample consists of insurers identified as SIFIs in Billio et al. (2011) as well as insurers

⁵⁵Another regulatory initiative that may have some relevance for US insurance groups is the effort by the IAIS to identify *globally systemically important insurers (GSII)*s (see IAIS 2012). This effort is in response to the task set by the G20 and the Financial Stability Board. The proposed assessment of GSII involves three steps: collection of data, methodological assessment of the data, and a supervisory judgment and validation process. However, because the IAIS has no direct statutory authority over insurers in particular countries, any regulatory consequences of an insurer’s identification as a GSII would have to be implemented by national regulatory organizations. Further analysis of the identification of SIFIs in insurance is provided in Geneva Association (2011).

Table 27.10 Compustat segment analysis for “systemic” and nonsystemic insurers

| Insurer | “Systemic” insurers | | Insurer | Nonsystemic insurers | |
|-----------------------------------|---------------------|---------------------------------|-----------------|----------------------|---------------------------------|
| | Number of segments | Segment Herfindahl ^a | | Number of segments | Segment Herfindahl ^a |
| ACE | 5 | 3,833.66 | Aetna | 3 | 8,598.61 |
| AIG | 10 | 2,382.92 | AFLAC | 4 | 6,478.42 |
| Ameriprise | 5 | 2,531.25 | Allstate | 3 | 7,220.48 |
| CIGNA | 5 | 6,737.81 | Assurant | 5 | 2,742.03 |
| Genworth | 7 | 3,912.75 | Chubb | 5 | 3,468.08 |
| Hartford | 10 | 1,894.37 | Cincinnati Fin | 6 | 4,016.54 |
| Lincoln National | 5 | 2,936.95 | CNA | 5 | 3,822.79 |
| Loews Corp | 9 | 2,173.66 | Protective Life | 6 | 2,553.81 |
| Metlife | 6 | 1,692.13 | Prudential | 8 | 4,574.45 |
| Principal Financial | 5 | 3,847.56 | Travelers | 3 | 4,124.50 |
| Progressive | 5 | 7,604.31 | | | |
| WR Berkley | 4 | 3,428.00 | | | |
| XL Capital | 5 | 4,739.31 | | | |
| Average | 6.23 | 3,670.36 | | 4.80 | 4,759.97 |
| Standard Deviation | 2.09 | 1,802.87 | | 1.62 | 2,006.09 |
| t-Tests: Systemic vs. Nonsystemic | | | | | |
| Number Segments | 1.851 | | | | |
| Segment Herfindahl | -1.349 | | | | |

^aSegment Herfindahl based on revenues by segment.

Source: Compustat Segments database.

ranked in the top 50 (out of 102 firms) in the [Acharya et al. \(2010\)](#) systemic risk ranking of financial firms (Appendix B of their chapter). A total of 13 insurance firms were identified as systemically risky based on these two sources. A control group of 10 insurers was selected, primarily consisting of insurers ranked below the top 50 firms in the [Acharya et al. \(2010\)](#) systemic risk ranking.⁵⁶ Because [Billio et al. \(2011\)](#) and [Acharya et al. \(2010\)](#) both focused on large publicly traded firms, the firms in the systemic and control samples are of comparable size and organizational form. The firms in the systemic and control samples are shown in Table 27.10.

Our additional analyses were conducted to try to identify characteristics differentiating systemic insurance firms from those identified as nonsystemic. The first analysis takes advantage of disclosure requirements expressed in Financial Accounting Standards Board (FASB) Accounting Standards Codification (ASC) 280, which deals with segment reporting.⁵⁷ ASC 280 requires publicly traded firms to disclose instances where “revenues from transactions with a single external customer

⁵⁶We omitted municipal bond insurers, brokers such as Marsh and Aon, and health care providers such as Humana. That is, the samples were designed to represent the mainstream life and P-C insurance industries. Berkshire-Hathaway was also omitted as atypical. Only one firm, Protective Life, was included in the analysis that does not appear in [Billio et al. \(2011\)](#) or [Acharya et al. \(2010\)](#). It was included because it is of comparable size to the other firms in the analysis and is regularly analyzed in other prominent sources such as [Standard & Poor’s \(2012a, b\)](#).

⁵⁷The predecessors to ASC 280 were Statement of Financial Accounting Standards (SFAS) 131 (1997), SFAS 30 (1979), and SFAS 14 (1976). ASC 280 states: “A public entity shall provide information about the extent of its reliance on its major customers. If revenues from transactions with a single external customer amount to 10% or more of a public entity’s revenues, the public entity shall disclose that fact, the total amount of revenues from each such customer, and the identity of the segment or segments reporting the revenues. The public entity need not disclose the identity of a major customer or the amount of revenues that each segment reports from that customer.”

amount to 10% or more of a public entity's revenues." Information on the disclosures is captured in Compustat's Segments database. By analyzing such disclosures for our sample of insurance firms, we attempt to determine whether systemic firms are more likely to have concentrated their activities in major customers or suppliers, thus increasing their interconnectedness with other firms in the economy.

In searching the Compustat segment files, we utilized procedures developed by [Fee and Thomas \(2004\)](#) and [Hertzel et al. \(2008\)](#).⁵⁸ After using these procedures to search for major customers of the systemic and nonsystemic insurers, we reverse the process and search for firms in all industries who list our sample insurers as major customers. The reverse procedure involves searching the entire Compustat segment database for firms listing the sample insurers as customers. Our analysis involved a search of Compustat from 1980 through 2010. The results indicate that only one of our sample of 23 insurance firms reported transactions with a customer of 10% or more of revenues. The firm was Loews, and its major customers were petrochemical firms (Loews has petrochemical subsidiaries as well as its insurance subsidiary CNA). The reverse search identified no firms who rely on any of the insurers for at least 10% of revenues.

The lack of instances where insurers have major customers or major suppliers is not surprising. The essence of insurance is diversification, and an insurer concentrating 10% or more of its premium writings in any one customer would not be engaging in prudent business practices, even if customers could be found that needed such large volumes of insurance. In terms of insurer suppliers, nearly 60% of insurer expenses are for personnel and related costs, and the entire insurance industry spends only about \$10 billion annually on equipment ([A.M. Best Company 2012a, b](#)), which is spread among numerous suppliers. Hence, large counterparty transactions do not create significant interconnectedness for insurers, except possibly for reinsurance, which we analyzed separately above.

Our second additional analysis compiled information on the number of business segments and revenues by segment in 2011 for the 23 firms in our case study samples. The results are summarized in [Table 27.10](#), which shows the number of segments and Herfindahl index based on segment revenues for the firms in the sample. The results indicate that the systemic firms had 6.2 segments on average whereas the nonsystemic firms had only 4.8 segments, and this difference is statistically significant at the 10% level. The Herfindahl index is lower for the systemic firms than for the nonsystemic firms (3670.4 versus 4760.0), but this difference is not statistically significant. Thus, there is some evidence that the systemic firms are involved in more businesses and are less concentrated across segments than the nonsystemic firms.

Because the use of derivatives played an important role in both the AIG debacle and the financial crisis in general, our third additional analysis is to compile data on the derivatives activities of our case study firms. The financial reporting of derivatives activities is governed by ASC 815, Derivatives and Hedging.⁵⁹ Among other items, ASC 815 requires public firms to separately report the gross notional amounts of derivatives held for hedging and non-hedging purposes and also to report net gains and losses from derivatives trading. ASC 815 also requires the reporting of OBS instruments and positions. This requirement is somewhat problematical, however, because it does not provide a standardized reporting format. As a result, the information contained in the 10K reports tends to be inconsistent across firms. In addition, some firms do not report numerical information, particularly on

⁵⁸The customer lookup procedure is complicated because ASC 280 does not require firms to disclose the names of major customers only their existence. Most disclose names but use abbreviations rather than full corporate names. Thus, identification of customers requires visual inspection as well as use of a text matching program to identify customers. For more information on the search process, see [Fee and Thomas \(2004\)](#) and [Hertzel et al. \(2008\)](#).

⁵⁹ASC 815 codifies the rules regarding reporting for derivatives, incorporating SFAS 161, which was issued in March 2008 to amend and expand the disclosure requirements of SFAS 133, which governed derivatives reporting prior to 2008.

OBS transactions, but rather include a verbal description of their activities.⁶⁰ Hence, the 10K reports are not as useful as they might be if reporting requirements were more consistent.

The derivatives activities reported by the samples of systemic and nonsystemic insurers are shown in Table 27.11. Based on averages, t-tests do not reveal any significant differences between the systemic and nonsystemic firms in terms of derivatives transactions. However, Prudential, which is classified as nonsystemic based on the systemic risk ranking in Acharya et al. (2010), has relatively high levels of derivatives holdings and is ranked 58th out of 102 firms in Acharya et al.'s systemic risk ranking. When the t-tests are recalculated omitting Prudential from the nonsystemic group,⁶¹ there are several significant differences between the systemic and nonsystemic insurers. The systemic firms on average have higher derivatives holdings both for hedging and non-hedging purposes than the nonsystemic firms. Based on total holdings, the systemic firms average \$75.8 billion in derivatives notional value compared to only \$4.1 billion for the nonsystemic firms (excluding Prudential). The fair value of derivative liabilities is also higher for the systemic firms than for the nonsystemic firms (\$2.3 billion on average versus \$0.25 billion). Hence, the systemic insurers do seem to utilize derivatives more intensively than the nonsystemic insurers (excepting Prudential).

In order to determine whether the firms in the systemic and nonsystemic samples differ in other important ways such as leverage, cash flow coverage, key investments, or the use of reinsurance, we conducted a fourth additional set of calculations. Specifically, we compiled the information in Table 27.5 for the firms in the systemic and nonsystemic samples.⁶² The results are presented in a table available from the authors. Again, Prudential proves to be an outlier in the nonsystemic group, so t-tests for differences between the two samples are conducted both including and excluding Prudential.

When Prudential is included in the nonsystemic sample, the only significant differences between the systemic and nonsystemic samples are for multi-class commercial MBS and total private ABS. For example, total private ABS/MBS represents 21.8% of surplus on average for the systemic risk sample but only 8.2% for the nonsystemic sample. This difference is statistically significant at the 10% level. When Prudential is excluded from the t-tests, the ratio of mortgage assets to surplus is significantly higher at the 10% level for the systemic firms than for the nonsystemic firms (59.2% versus 22.2%). The ratios of several categories of ABS/MBS to surplus are also significantly higher for the systemic firms when Prudential is excluded from the nonsystemic category, including total ABS/MBS to surplus, which is 106.8% for the systemic sample and only 43.9% for the nonsystemic sample (excluding Prudential).⁶³ Hence, the firms in the systemic sample tend to invest relatively more in mortgages and in ABS/MBS than the firms in the nonsystemic sample.

These case study analyses of insurers identified as systemic and nonsystemic provide some intriguing clues about insurer activities that can create systemic risk. The systemic insurers tend to operate in more business segments and use derivatives more intensively than nonsystemic firms.

⁶⁰The reporting is similar for embedded options inherent in many insurance and annuity products, especially variable annuities. Variable annuities are frequently sold with guaranteed minimum benefits such as the promise to return the buyers' purchase price on death or withdrawal even if the account balance has declined below the purchase price due to asset value fluctuations. Such guarantees expose the insurer to significant risk due to volatile or declining equity markets, changes in interest rates, or other economic fluctuations. Such guarantees are discussed qualitatively in the 10K reports of traded insurers, but little quantitative information is provided. Although no US life insurers encountered financial difficulties during the recent financial crisis as the result of such guarantees, regulators should require additional disclosures of guaranteed minimum benefits and other embedded options.

⁶¹Specifically, Prudential is excluded from the nonsystemic group and is not included in the systemic group.

⁶²The data year for the calculations is 2010, and the variables are expressed as ratios to surplus. Because most of the firms in our samples have life and P-C subsidiaries, the data for the two branches of the industry were aggregated for these firms before calculating the ratios. The data are from the NAIC annual statement database. Therefore, Loews was excluded from the systemic risk sample because its insurance operations are conducted through CNA.

⁶³The averages across firms in the sample are unweighted averages, so larger firms are not given higher weights.

Table 27.11 Asset and derivatives information from 10-K reports for “systemic” and nonsystemic insurers: 2011

| Category/Name | Total Assets | Capital/Assets | OBS Instruments & Guarantees | Net Gain (Loss) from Derivatives | Derivatives Holdings Notional Amounts | | Fair Value Derivative Assets | Fair Value Derivative Liabilities | Total Deriv Notional/Assets | Total Deriv Fair Value/Assets |
|----------------------------------|--------------|----------------|------------------------------|----------------------------------|---------------------------------------|------------|------------------------------|-----------------------------------|-----------------------------|-------------------------------|
| | | | | | Hedges | Non-Hedges | | | | |
| “Systemic” Firms | | | | | | | | | | |
| ACE | 87,505 | 28.0% | NP | -787 | 0 | 14,879 | 51 | 1,319 | 17.0% | 1.6% |
| AIG | 555,773 | 18.9% | 5,633 | 952 | 661 | 230,490 | 9,660 | 12,097 | 41.6% | 3.9% |
| AMERIPRISE | 133,986 | 8.2% | 3,374 | NR | 1,466 | NP | 3,319 | 3,879 | 1.1% | 5.4% |
| CIGNA | 51,047 | 16.3% | 1,117 | -3 | 1,276 | NP | 757 | 1,363 | 2.5% | 4.2% |
| Genworth | 114,302 | 15.5% | Descriptive | -99 | 14,571 | 13,520 | 1,530 | 1,190 | 24.6% | 2.4% |
| Hartford | 304,064 | 7.5% | Descriptive | 301 | 101,627 | 130,809 | 2,331 | 538 | 46.5% | 0.9% |
| Lincoln National | 202,906 | 7.0% | 4,395 | -426 | 4,527 | 46,833 | 3,151 | 3,473 | 25.3% | 3.3% |
| Loew’s | 75,375 | 30.9% | 0 | 0 | 7,22 | 1,553 | 130 | 62 | 3.0% | 0.3% |
| MetLife | 799,625 | 7.5% | Descriptive | 4,824 | 21,904 | 268,117 | 16,200 | 4,011 | 36.3% | 2.0% |
| Principal Financial | 148,298 | 6.8% | Descriptive | -196 | NP | NP | 1,171 | 1,860 | NA | 0.4% |
| Progressive | 21,845 | 26.6% | 4,165 | -99 | 15 | 1,648 | 1 | 76 | 7.6% | 0.1% |
| W.R.Berkeley | 18,488 | 21.7% | 328 | NR | 86 | 107 | 8 | 4 | 1.0% | 0.5% |
| XL Capital | 44,626 | 24.1% | Descriptive | NR | 2,648 | 1,641 | 147 | 63 | 9.6% | 2.1% |
| Average | 196,757 | 16.8% | 2,716 | 447 | 4,875 | 70,960 | 2,958 | 2,303 | 18.0% | 2.1% |
| Non-Systemic Firms | | | | | | | | | | |
| Aetna | 38,593 | 26.2% | 397 | -6 | NP | NP | 2 | 0 | NA | 0.0% |
| AFLAC | 117,102 | 11.5% | -257 | 146 | 146 | 5,345 | 375 | 531 | 4.7% | 0.8% |
| Allstate | 125,563 | 14.9% | 2,208 | -396 | 271 | 13,540 | 105 | 752 | 11.0% | 0.7% |
| Assurant | 27,115 | 18.5% | 3 | -1,304 | NP | NP | 8,521 | 3 | NA | 31.4% |
| Chubb | 50,865 | 30.6% | 8,090 | NR | NP | 340 | NP | 2 | NA | NA |
| Cincinnati Financial | 15,668 | 32.3% | 0 | -1 | NP | NP | NP | NP | NA | NA |
| CNA | 55,179 | 20.9% | Descriptive | 0 | NP | 46 | 12 | 1 | NA | 0.0% |
| Protective Life | 52,932 | 8.0% | Descriptive | -149 | 7 | 327 | 48 | 456 | 0.6% | 1.0% |
| Prudential | 624,521 | 6.1% | 1,118 | 2,294 | 10,608 | 210,100 | 10,764 | 5,111 | 35.3% | 2.5% |
| Travelers | 104,602 | 23.4% | 1,150 | -62 | NP | NP | NP | NP | NA | NA |
| Average | 121,214 | 19.2% | 1,589 | 58 | 2,758 | 38,283 | 2,832 | 857 | 12.9% | 5.2% |
| Average, ex Prudential | 65,291 | 20.7% | 1,656 | -222 | 141 | 3,920 | 1,511 | 249 | 5.4% | 5.6% |
| Systemic vs. Non-Systemic | | | | | | | | | | |
| t-test | 0.876 | -0.633 | 0.878 | 0.651 | 0.637 | 0.691 | 0.057 | 1.314 | 0.544 | -0.703 |
| t-test, excl Prudential | 1.993 | -1.041 | 0.758 | 1.254 | 2.313 | 2.064 | 0.751 | 2.235 | 2.224 | -0.684 |

Dollars are in millions. Data as of end of 2011. NR means information not reported separately. NP means information not provided. NA means information not available to calculate average. Descriptive means item described verbally. Source: 10K Reports of each insurer for 2011.

In addition, systemic insurers invest more heavily in mortgages and ABS/MBS than the nonsystemic firms. However, we do not find evidence that systemic firms are more heavily leveraged or have significantly lower levels of cash flow relative to benefits or surplus. Measurement of systemic risk for a larger sample of insurers using the techniques employed in [Billio et al. \(2011\)](#), [Acharya et al. \(2010\)](#), and/or [Chen et al. \(2014\)](#) would be required to provide more information on the characteristics of systemically important insurers. A larger sample would permit the analysis of the firm characteristics associated with systemic risk in a multiple regression context, providing the potential for more powerful statistical inferences.

27.8 Conclusion

This chapter examines the potential for the insurance industry to cause systemic risk events that spill over to other segments of the financial industry and the real economy. We examine *primary indicators* that can be used to determine whether markets, industries, or institutions are systemically risky as well as *contributing factors* that exacerbate vulnerability to systemic events. The chapter focuses primarily on the core activities of the US insurance industry.

The primary conclusion of the chapter is that the core activities of the US insurers do not create systemic risk. In terms of the primary indicators, through their core activities, insurers are not sufficiently large or interconnected with other firms in the economy to pose a systemic risk. Except for property-casualty (P-C) insurance for individuals and smaller businesses, lack of substitutability is not a serious problem in insurance. There are ample substitutes for life insurance asset accumulation products and for commercial P-C insurance for large firms. For personal P-C insurance, even the failure of several large insurers would not be likely to create a substitutability problem, because many other insurers could step in to fill the coverage gap.

Because the core activities of insurers are not systemically risky, the analysis of contributing factors mainly relates to their creation of vulnerability to intra-sector crises for insurers. Here we find that life insurers are more vulnerable to crises than P-C insurers. Life insurers are more highly levered than P-C insurers and are exposed to credit and liquidity risk due to their heavy investment in MBS and privately placed bonds. They also offer complex financial products with embedded derivatives. Nevertheless, insolvency rates in the life insurance industry remain low, and life insurers weathered the financial crisis successfully in spite of their exposure to ABS/MBS. Life insurers also demonstrated the ability to recapitalize quickly following the worst of the financial crisis.

Both life and P-C insurers are potentially vulnerable to reinsurance crises and spirals because of their exposure to reinsurance counterparty credit risk, the main source of interconnectedness for insurers. Because reinsurance counterparty credit risk is highly concentrated, a reinsurance spiral potentially could be triggered by the failure of one or more leading reinsurers, triggering an insolvency crisis in the insurance industry. Nevertheless, recent research provides evidence that the failure of a large reinsurer would be minimally disruptive to the US P-C insurance market, and reinsurance failures historically have not been an important causal factor in insurance insolvencies. We find that regulation is not an important source of sectoral risk with respect to insurer core activities.

As was demonstrated by the AIG debacle, the noncore activities of insurers do constitute a potential source of systemic risk, and interconnectedness among financial firms has grown significantly in recent years. Noncore activities include trading in derivatives (such as CDS), asset lending, asset management, and providing financial guarantees. Most of the noncore activities are beyond the traditional purview of insurance regulators and have not been rigorously regulated by banking authorities. Therefore, on a worldwide scale, regulators need to significantly improve their capabilities in group supervision. In the US regulators do have some authority to tighten capital requirements and other regulations for regulated insurers deemed vulnerable due to the activities of noninsurance

affiliates. Under proposed revisions to regulatory laws, regulators would have broad authority to require disclosures of information on the activities of noninsurance subsidiaries of insurance holding companies. Consequently, if the revisions are adopted, US regulators will have the information to prevent another AIG-type crisis, although they still will not have direct authority over noninsurance subsidiaries.

Additional research is needed to further explore systemic risk in the insurance industry. In terms of reinsurance spirals, further research is needed to examine the extent of the reinsurance relationships among insurers and to examine their impact on firm performance in a multivariate context. Further analysis of market level data on stock returns and credit default swap prices could help to provide further information on the interconnections between insurers and other types of financial institutions. This research could use multivariate analysis to analyze the reasons for the growing statistical interrelationships between insurers and other financial firms and the extent to which these relationships are systemic as opposed to reflecting susceptibility to common shocks. Additional research is also needed on the noncore activities of insurance groups. This probably would require detailed case studies of major insurance organizations and direct participation of the insurance industry or regulators.

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Chapter 28

Analyzing Firm Performance in the Insurance Industry Using Frontier Efficiency and Productivity Methods

J. David Cummins and Mary A. Weiss

Abstract This chapter reviews the modern frontier efficiency and productivity methodologies that have been developed to analyze firm performance, emphasizing applications to the insurance industry. The focus is on the two most prominent methodologies—stochastic frontier analysis using econometrics and non-parametric frontier analysis using mathematical programming. The chapter considers the underlying theory of the methodologies as well as estimation techniques and the definition of inputs, outputs, and prices. Seventy-four insurance efficiency studies are identified from 1983 to 2011, and 37 chapters published in upper tier journals from 2000 to 2011 are reviewed in detail. Of the 74 total studies, 59.5% utilize data envelopment analysis as the primary methodology. There is growing consensus among researchers on the definitions of inputs, outputs, and prices.

28.1 Introduction

An important development in modern economics has been the emergence of frontier methodologies for estimating efficiency and productivity. Traditional microeconomic theory assumes that all firms minimize costs and maximize profits and that firms that do not succeed in attaining these objectives are not of interest because they will not survive. Modern frontier efficiency analysis creates a framework to analyze firms that do not succeed in optimization and, as a result, are not fully efficient (Farrell 1957).¹ Efficiency is evaluated by comparing firms to “best practice” efficient frontiers formed by the most efficient firms in the industry. Two primary methodologies have been developed to estimate frontiers: (1) econometric approaches, including SFA (e.g., Greene 2008) and

¹In developing his efficiency concepts, Farrell drew upon earlier work by Debreu (1951). It took nearly 20 years following Farrell’s initial theoretical contribution for empiricists to develop methodologies to estimate efficiency. The most important contributions were the development of stochastic frontier analysis by Aigner et al. (1977), Battese and Corra (1977), and Meeusen and van den Broeck (1977) and the development of non-parametric mathematical programming frontiers by Charnes et al. (1978). Since that time, the growth in efficiency research has been explosive.

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(2) non-parametric approaches, most prominently data envelopment analysis (DEA), which utilizes linear programming techniques to estimate the frontier (e.g., Cooper et al. 2004; Färe et al. 2008; Thanassoulis et al. 2008).

The development of modern frontier efficiency methodologies has significant implications for insurance economics. Many studies have been conducted that compare insurance firms to other firms in the industry. Traditionally, this has been done using conventional financial ratios such as the return on equity, return on assets, expense ratios, etc. With the rapid evolution of methodologies for efficiency and productivity measurement, the conventional methods have become mostly obsolete, especially for analyses involving book values rather than market values. Frontier efficiency measures dominate traditional techniques in terms of developing meaningful and reliable measures of firm performance. They summarize firm performance in a single measure that controls for differences among firms in a sophisticated multidimensional framework that has its roots in economic theory.

The objective of this chapter is to provide the foundations for insurance economists to use in adapting their research to incorporate the frontier efficiency approach. The chapter also serves as a guide for those who are already conducting frontier efficiency analysis but are seeking guidance in using the methodology or defining inputs and outputs. We describe and analyze the principal methodologies that have been developed for measuring efficiency and productivity, defining the input and output concepts required to apply the methodologies to insurers, and reviewing the empirical literature on efficiency and productivity measurement in insurance. The literature review reveals that there have been many excellent contributions applying efficiency methodologies to insurance-related hypotheses, but there also have been some cases where researchers have made serious errors in utilizing the methodology, especially in the definition of inputs, outputs, and prices. It is much to be hoped that this chapter will prevent future researchers from repeating such mistakes.

The most basic efficient frontier is the production frontier, which is estimated based on the assumption that the firm is minimizing input use conditional on output levels.² Production frontiers can be estimated even if data on input and output prices are unavailable. If data on input prices are available, it is also possible to estimate the cost frontier, usually based on the assumption that the firm is minimizing costs conditional on output levels produced and input prices. Ultimately, of course, the firm also can optimize by choosing its level of output. If output prices are available, revenue and profit frontiers can be estimated. Revenue frontiers assume that the firm maximizes revenues by choosing its output quantities holding constant input quantities and output prices. In profit efficiency analysis, the firm maximizes by choosing both its inputs and outputs, contingent only on input and output prices.³ Cost, revenue, and profit efficiency can be decomposed into technical efficiency (whether the firm is operating on the production frontier) and allocative efficiency (whether the firm is choosing the optimal inputs or outputs). Finally, sophisticated methods such as Malmquist indices have been developed for measuring total factor productivity (TFP) change as well as efficiency change over time.

Frontier efficiency methods are useful in a variety of contexts. One important use is for testing economic hypotheses. For example, both agency theory and transactions cost economics generate predictions about the likely success of firms with different characteristics in attaining objectives such as cost minimization or profit maximization. Firm characteristics that are likely to be important include organizational form, distribution systems, corporate governance, and vertical integration. Frontier methodologies have been used to analyze a wide range of such hypotheses.

²This definition applies to an *input-oriented* frontier. It is also possible to estimate output-oriented measures of efficiency by maximizing outputs produced conditional on inputs used. Most efficiency analyses in insurance and other financial industries are input oriented, and most of the discussion in this chapter assumes an input-orientation.

³This discussion applies to *standard* cost, revenue, and profit efficiency analysis. Non-standard functions also are used for purposes such as studying revenue or profit scope economies (see Berger et al. 1997). Although frontier analysis is typically conducted under the assumption that the industry is competitive, efficiency also can be measured for non-competitive industries, public utilities, or government entities (Cooper et al. 2004).

A second important application of frontier methodologies is to provide guidance to regulators regarding the appropriate response to problems and developments in an industry or the overall economy. For example, both the banking and insurance industries have experienced waves of mergers and acquisitions (M&As). Frontier methodologies can be used to determine whether consolidation is likely to be beneficial or detrimental in terms of the price and quality of services provided to consumers. The efficiency of insurer operations also is an important regulatory issue, as in the debate over the price of automobile insurance. A third application of frontier methodologies is to compare economic performance across countries.

A fourth application is to inform management about the effects of new strategies and technologies. Although firms currently employ a variety of benchmarking techniques, frontier analysis can provide more meaningful information than conventional ratio and survey analysis, which often overwhelms the manager with masses of statistics that are difficult to summarize. Frontier analysis can be used not only to track the evolution of a firm's productivity and efficiency over time but also to compare the performance of departments, divisions, or branches within the firm.

This chapter is organized as follows. Section 28.2 discusses the concepts of efficiency and productivity, whereas Sect. 28.3 provides an overview of estimation techniques. Section 28.4 discusses the measurement of inputs, outputs, and prices as well as some additional methodological issues and problems. Section 28.5 provides a review of the insurance efficiency literature, and Sect. 28.6 concludes.

28.2 The Concepts of Efficiency and Productivity

This section provides an introduction to the economic concepts of efficiency and productivity. In general, *efficiency* refers to the success of the firm in minimizing costs, maximizing revenues, or maximizing profits, conditional on the existing technology. *Productivity* refers to changes in technology over time, such that firms can produce more output utilizing a given amount of inputs (technical progress) or less output utilizing a given amount of inputs (technical regress). The remainder of this section elaborates upon these concepts.

28.2.1 Economic Efficiency

The concept of economic efficiency flows directly from the microeconomic theory of the firm. We adopt the perspective of a privately owned firm operating in a competitive industry. Under these assumptions, the objective of the firm is to maximize profits by minimizing costs and maximizing revenues. Therefore, we recommend estimating *cost efficiency*, *revenue efficiency*, and *profit efficiency*. Cost minimization involves the minimization of input usage conditional on the outputs produced, and revenue maximization involves maximization of outputs conditional on the inputs used. Firms that minimize inputs conditional on outputs are said to have achieved full *technical efficiency*. In cost minimization, it is also important to choose the optimal combination of inputs, i.e., to achieve *allocative efficiency*. Achieving technical and allocative efficiency is also important in revenue maximization, where technical efficiency is achieved by maximizing outputs given inputs and allocative efficiency by choosing the optimal combination of outputs. Profit efficiency involves the optimal choice of inputs and outputs, conditional on output and input prices.

Efficiency is measured relative to *best practice frontiers* consisting of the dominant firms in the industry. Technical, cost, and revenue efficiency vary between 0 and 1, with efficiency scores of 1 indicating fully efficient firms. As explained below, profit efficiency is usually not constrained

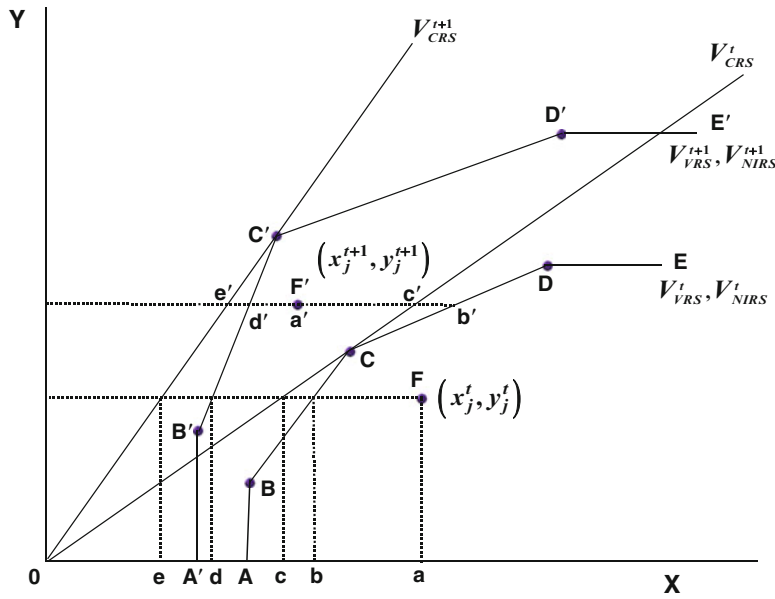


Fig. 28.1 Total factor productivity: single input, single output firm

between 0 and 1. Technical efficiency for firm i is the ratio of the inputs used by a fully efficient firm with the same output vector to the input usage of firm i , and cost efficiency is the ratio of the costs of a fully efficient firm with the same outputs and input prices to the costs of firm i . Revenue efficiency is the ratio of firm i 's revenues to the revenues of a fully efficient firm with the same inputs and output prices. Profit efficiency ratios are computed differently, as explained below.

Perhaps the most basic efficiency concept is that of the *production frontier*, which indicates the minimum inputs required to produce any given level of output for a firm operating at 100% efficiency. Production frontiers for a firm with one input (X) and one output (Y) are shown in Fig. 28.1. Frontiers for periods t and $t + 1$ are shown in the figure. In the present discussion, we focus on the period t frontiers. The production frontier labeled V_{CRS}^t in Fig. 28.1 is characterized by *constant returns to scale* (CRS) because of the linear relationship between input usage and output production. The frontiers labeled V_{VRS}^t and V_{NIRS}^t are *variable returns to scale* (VRS) and *non-increasing returns to scale* (NIRS) production frontiers. The VRS frontier is the line ABCDE, and the NIRS frontier is the line OCDE.⁴ The VRS frontier has *increasing returns to scale* (IRS) for input levels between the X -intercepts of points B and C , CRS at point C , and *decreasing returns to scale* (DRS) between points C and D . The NIRS frontier has CRS in the line segment OC and DRS in the line segment CD .

Efficiency can be illustrated with respect to firm j in Fig. 28.1, which is operating at point F with input–output combination (x_j^t, y_j^t) . This firm could operate more efficiently by moving to the frontier, i.e., by adopting the state-of-the-art technology. By moving to the VRS frontier, the firm achieves *pure technical efficiency*. The firm's level of pure technical efficiency is given by the ratio $0b/0a$, which is the reciprocal of its distance from the frontier, $0a/0b$. If the technology for producing with CRS exists in the industry, the firm can further improve its efficiency by moving to the CRS frontier. It is socially and economically optimal for firms to operate at CRS, providing the motivation for separating pure technical and scale efficiency. The firm's *scale efficiency* is given by the ratio $0c/0b$. Firms operating on the CRS frontier have achieved *technical efficiency*. The firm

⁴In Fig. 28.1, lines are labeled using capital letters. Firm operating points are represented by dots (•).

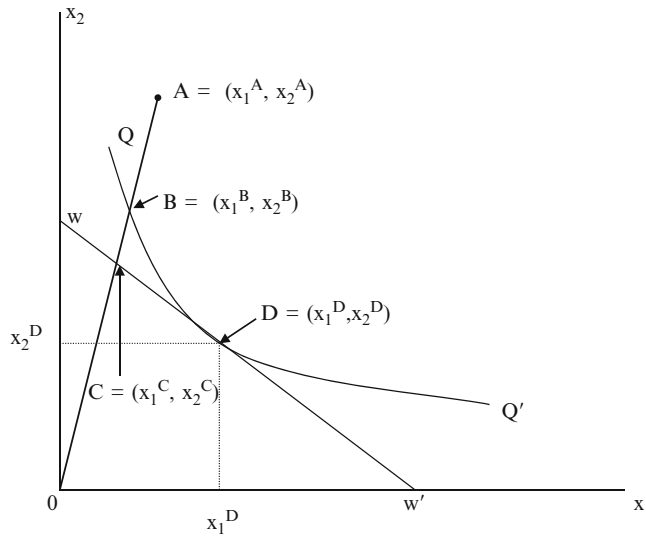


Fig. 28.2 Cost efficiency: Farrell technical and allocative efficiency

operating at point *C* is technically efficient, but the firms operating at points *B*, *D*, and *F* are not. Technical efficiency is the product of pure technical and scale efficiency:

$$\begin{aligned} \text{Technical Efficiency} &= \text{Pure Technical Efficiency} * \text{Scale Efficiency} \\ &= (0b/0a)*(0c/0b) = 0c/0a. \end{aligned}$$

In illustrating efficiency in Fig. 28.1, we have adopted an *input orientation*, meaning the optimization is achieved by minimizing inputs conditional on the level of output. It is also possible to estimate efficiency using an *output orientation*, moving to the frontier vertically from point *F* by maximizing output conditional on input usage. The choice of input versus output orientation is based on the microeconomic theory of the firm. In microeconomic theory, the objective of the firm is to maximize profits by minimizing costs and maximizing revenues. Cost minimization involves choosing the optimal amounts and mix of inputs to produce given output levels and mix, and revenue maximization involves choosing the optimal amounts and combination of outputs conditional on the input levels and mix. Hence, the input orientation is adopted to estimate technical efficiency in the cost minimization problem, and the output orientation is adopted for the revenue maximization problem. In a nonprofit firm or public utility, output-oriented technical and cost efficiency might be more appropriate; but for a private firm with a profit objective, the input orientation dominates in terms of consistency with economic theory. It also is possible to move to the frontier diagonally, for example, by choosing the shortest distance (e.g., [Frei and Harker 1999](#)), but this is not done very often.

Cost and allocative efficiency are illustrated in Fig. 28.2, using a diagram attributable to [Farrell \(1957\)](#). The diagram shows an isoquant for a firm with one output and two inputs, x_1 and x_2 . The isoquant QQ' in Fig. 28.2 represents the various combinations of the two inputs required to produce a fixed amount of the single output using the best available technology. Thus, firms operating on the isoquant are considered to be technically efficient. The optimal operating point is represented by the tangency (point *D*) between the isoquant QQ' and the isocost line ww' , the slope of which is determined by the prices (w_1 and w_2) of the two inputs (x_1 and x_2). A firm operating at this point is considered to be fully *cost efficient*. The firm operating at point $A = (x_1^A, x_2^A)$ exhibits both

technical and allocative inefficiency. It is technically inefficient because it is not operating on the best-technology isoquant. The measure of Farrell technical efficiency is the ratio OB/OA , i.e., the proportion by which it could radially reduce its input usage by adopting the best technology. However, this firm is also allocatively inefficient because it is not using its inputs in the correct proportions. Specifically, it is using too much of input 2 and not enough of input 1. The measure of allocative efficiency is thus the ratio OC/OB . Cost efficiency is then defined as follows:

$$\begin{aligned}\text{Cost Efficiency} &= \text{Technical Efficiency} * \text{Allocative Efficiency} \\ &= (OB/OA)*(OC/OB) = OC/OA\end{aligned}$$

28.2.2 Total Factor Productivity

TFP is defined as an index of total quantity of outputs produced divided by an index of total inputs used in the production process (Färe et al. 2008). TFP is a generalization of single factor productivity concepts such as labor productivity, where productivity is defined as total output divided by a single input.⁵ Productivity and efficiency are related. Productivity at a given time is determined by the optimal production technology available for use in producing outputs as well as the efficiency with which firms employ the technology.

The production frontier also can be used to illustrate changes in TFP, i.e., TFP growth. TFP growth is defined as the change in output production net of the change in input usage, i.e., TFP growth occurs when more output can be produced per unit of inputs consumed, where output production and input usage are defined using appropriate aggregation techniques. TFP growth has two major components—technical change and efficiency change. Technical change is represented by a shift in the production frontier, and efficiency change is represented by an index of a firm's efficiency relative to the present and past frontiers. If the firm is fully efficient, i.e., operating on the production frontier, which is the usual assumption in micro-economics, productivity growth and technical change are identical. However, if the firm is not operating on the frontier, i.e., is inefficient, then productivity growth can occur due to both improvements in efficiency and shifts in the production frontier. Of course, it is also possible for productivity to decline either because a firm becomes less efficient or the frontier shifts adversely (technical regress).

To illustrate the concept of TFP growth, consider the CRS frontiers for periods t and $t + 1$ in Fig. 28.1 for the single input-single output firm, labeled V_t^{CRS} and V_{t+1}^{CRS} , respectively. The frontier for period $t + 1$ lies to the left of the frontier for period t . This implies that productivity gains have been achieved between periods t and $t + 1$ because of technical change, i.e., a shift in the frontier. Efficient firms achieve TFP growth by moving from V_t^{CRS} to V_{t+1}^{CRS} . Inefficient firms can also achieve TFP gains by improving their efficiency. To see this, consider an inefficient firm operating at point (x_j^t, y_j^t) in period t and at point (x_j^{t+1}, y_j^{t+1}) in period $t + 1$. This firm has become more efficient between periods t and $t + 1$ because it is operating closer to the frontier in period $t + 1$ than in period t . In fact, in period $t + 1$, the firm is operating at a level of output that would have been infeasible in period t , i.e., it has also taken advantage of technical change to move its operating point to the left of the production frontier for period t . Thus, the firm has achieved TFP growth by improving its technology and by becoming more efficient.

⁵Single factor productivity indices are considered to be uninformative by economists because they take into account only one input, such as labor, and omit other important inputs, such as capital.

28.3 Methodologies for Measuring Efficiency and Productivity Change

This section discusses the principal methodologies that have been developed to measure efficiency and productivity change over time, emphasizing frontier approaches. We first discuss the two major classes of efficiency estimation methodologies—the *mathematical programming (nonparametric) approach* and the *econometric (parametric) approach*.

28.3.1 Mathematical Programming Methods

Mathematical programming approaches can be used to estimate both efficiency and TFP change. This section discusses the principal mathematical programming approaches to estimating efficiency and the Malmquist methodology for estimating productivity.

28.3.1.1 DEA Efficiency Estimation

The mathematical programming (non-parametric) approaches to estimating efficiency represent an empirical implementation of Shephard's distance function methodology (Shephard 1970). To analyze production frontiers, we employ both input and output-oriented distance functions (Färe et al. 1985). Suppose a firm uses input vector $x = (x_1, x_2, \dots, x_M)^T \in \mathfrak{R}_+^M$ to produce output vector $y = (y_1, y_2, \dots, y_N)^T \in \mathfrak{R}_+^N$, where T denotes the vector transpose. That is, there are M inputs and N outputs. A production technology which transforms inputs into outputs can be modeled by an input correspondence $y \rightarrow V(y) \subseteq \mathfrak{R}_+^M$, such that for any $y \in \mathfrak{R}_+^N$, $V(y)$ denotes the subset of all input vectors $x \in \mathfrak{R}_+^M$ which yield at least y . The input-oriented distance function for a given firm minimizes input consumption conditional on outputs:

$$D_I(y, x) = \sup\{\theta : \frac{x}{\theta} \in V(y)\} \quad (28.1)$$

where θ is a scalar, i.e., a radial distance estimate is provided. In the output-oriented case, technology is modeled by an output correspondence $x \rightarrow P(x) \subseteq \mathfrak{R}_+^N$, such that $P(x)$ denotes the subset of all output vectors obtainable from input vector $x \in \mathfrak{R}_+^M$. The output oriented distance function for a firm maximizes output conditional on inputs:

$$D_0(y, x) = \inf\{\theta : \frac{y}{\theta} \in P(x)\} \quad (28.2)$$

The input distance function is the reciprocal of the minimum equi-proportional contraction of the input vector x , given outputs y , i.e., Farrell's (1957) input-oriented technical efficiency $TE_I(y, x) = 1/D_I(y, x)$, and a similar interpretation applies for output-oriented efficiency.

The implementation that is used most frequently is *DEA*, which was originated by Charnes et al. (1978). The method can be used to estimate production, cost, revenue, and profit frontiers and provides a particularly convenient way for decomposing efficiency into its components.⁶ For example, cost efficiency can be conveniently decomposed into pure technical, scale, and allocative efficiency. DEA imposes somewhat less structure on the optimization problem than the econometric approach.

⁶Profit frontiers pose a somewhat different problem than the other types of DEA frontiers (Färe et al. 1994c, pp. 212–217).

The method is non-parametric, and neither functional form nor error term assumptions are required. Intuitively, the method involves searching for a combination of firms in the industry that dominate a given firm. These firms constitute the given firm’s *reference set*. If the reference set consists only of the firm itself, it is considered efficient and has an efficiency score of 1.0. However, if a dominating set can be found consisting of other firms, the firm’s efficiency is less than 1.0. The implication is that the firm’s outputs could be produced more cheaply (in the case of cost efficiency) by the “best practice” firms in the industry. In this section, we focus primarily on DEA, but we conclude the section with a discussion of the free disposal hull (FDH) methodology, which departs from DEA by dropping the convexity requirement.

In DEA, efficiency is estimated by solving linear programming problems. For example, technical efficiency for the cost efficiency problem is estimated by solving the following problem, for each firm, $s = 1, 2, \dots, S$, in each year of the sample period (time superscripts are suppressed):

$$(D_I(y_s, x_s))^{-1} = T_I(y_s, x_s) = \min \theta_s \tag{28.3}$$

Subject to

$$\begin{aligned} Y \lambda_s &\geq y_x \\ X \lambda_s &\leq \theta_s x_s \\ \lambda_s &\geq 0 \end{aligned}$$

where Y is an $N \times S$ output matrix and X an $M \times S$ input matrix for all firms in the sample, y_s is a $N \times 1$ output vector and x_s an $M \times 1$ input vector for firm s , and λ_s is an $S \times 1$ intensity vector for firm s (the inequalities apply to each row of the relevant matrix). Solving the problem with the constraint $\lambda_s \geq 0$ and no other restrictions on λ_s produces CRS efficiency estimates. The firms for which the elements of λ_s are non-zero constitute the reference set for firm s .

Technical efficiency is separated into pure technical and scale efficiency by reestimating problem (28.3) with the additional constraint $\sum_{i=1}^S \lambda_{si} = 1$ for a VRS frontier (this step estimates pure technical efficiency). Pure technical efficiency is defined as the distance of the firm’s input–output bundle from the VRS frontier (see Fig. 28.1), and the relationship $TE(x_s, y_s) = PT(x_s, y_s) * SE(x_s, y_s)$ can be used to separate pure technical and scale efficiency, where $SE(x_s, y_s)$ represents scale efficiency and $PT(x_s, y_s)$ pure technical efficiency.

Also solving the problem with the nonincreasing returns to scale (NIRS) technology is useful in determining the returns to scale characterizing each firm. For NIRS estimates, the constraint becomes $\sum_{i=1}^S \lambda \leq 1$. If $TE = PT$, i.e., the CRS and VRS technical efficiency estimates are equal, then $SE(x_s, y_s) = 1$ and CRS is indicated. If $SE \neq 1$ and the NIRS efficiency measure = PT, DRS is present; whereas if $SE \neq 1$ and the NIRS efficiency measure \neq PT, then IRS is indicated (Aly et al. 1990).

The cost frontier is specified as:

$$C(y_s, w_s) = \text{Min}_{x_s} \{w_s^T x_s : x_s \in V(y_s)\} \tag{28.4}$$

where $C(y_s, w_s)$ = the cost frontier for firm s with output–input vector (y_s, x_s) . A two-step procedure is used to estimate DEA cost efficiency. The first step is to solve the following problem for each firm $s = 1, 2, \dots, S$:

$$\min_{x_s} w_s^T x_s \tag{28.5}$$

Subject to

$$\begin{aligned} Y\lambda_s &\geq y_s \\ X\lambda_s &\leq x_s \\ \lambda_s &\geq 0 \end{aligned}$$

where T indicates vector transpose. The solution vector x_s^* is the cost-minimizing input vector for the input price vector w_s and the output vector y_s . The second step is to calculate cost efficiency for firm s as the ratio $\eta_s = w_s^T x_s^* / w_s^T x_s$, i.e., the ratio of frontier costs to actual costs. Thus, cost efficiency satisfies the inequality, $0 < \eta_s \leq 1$, with a score of 1 indicating full-cost efficiency.

Revenue efficiency is estimated analogously to cost efficiency. However, in this case we adopt an output-oriented rather than an input-oriented approach and maximize revenues rather than minimize costs. Then the revenue frontier is defined as (Fried et al. 2008):

$$R(x_s, p_s) = \text{Max}_{y_s} \{ p_s^T y_s : y_s \in P(x_s) \} \tag{28.6}$$

where $R(x_s, p_s)$ = the revenue frontier for firm s . DEA revenue efficiency is estimated as follows:

$$\text{max}_{y_s} \sum_{i=1}^N p_{si} y_{si} \tag{28.7}$$

Subject to

$$\begin{aligned} Y\lambda_s &\geq y_s \\ X\lambda_s &\leq x_s \\ \lambda_s &\geq 0 \end{aligned}$$

The solution vector y_s^* is the revenue maximizing output vector for the output price vector p_s and the input vector x_s . Revenue efficiency is then measured by the ratio $\kappa_s = p_s^T y_s / p_s^T y_s^* \leq 1$. Linear programming is used to solve the problem defined in (28.7).

The profit efficiency model solves the following problem:

$$\Pi(p_s, w_s) = \text{Max}_{x_s, y_s} \{ p_s^T y_s - w_s^T x_s \} \tag{28.8}$$

Thus, the profit efficiency measure allows the firm to optimize over both inputs and outputs, whereas cost efficiency minimizes over inputs and revenue efficiency maximizes over outputs. Unlike technical efficiency, cost, revenue, and profit efficiency are not radial measures, where the existing input and output vectors are multiplied by a scalar, but rather optimize over all n - outputs and/or m -inputs, allowing different combinations of inputs and outputs at the optimum.

Several profit efficiency models have been proposed in the DEA literature. One important model is specified in Cooper et al. (2000, (8.1)) based on a model originally proposed in Färe et al. (1985). The model solves:

$$\text{Max}_{x_s, y_s} p_s^T y_s - w_s^T x_s \tag{28.9}$$

subject to

$$\begin{aligned} Y\lambda_s &\geq Y_s \\ X\lambda_s &\leq x_s \\ \lambda_s &\geq 0 \end{aligned}$$

The i th row of y_s and j th row of x_s in the objective are defined by

$$\begin{aligned} y_{is} &= \sum_{k=1}^S y_{iks}\lambda_{ks}, \quad i = 1, \dots, N \\ y_{js} &= \sum_{k=1}^S x_{jks}\lambda_{ks}, \quad j = 1, \dots, M \end{aligned} \tag{28.10}$$

where on the right hand side of (28.10), y_{iks} = the ik th element of the i th row of Y , and x_{jks} = jk th element of the j th row of X . As in Cooper et al. (2000), we then estimate profits lost due to inefficiency as

$$\pi_s = (p_s^T y_s^* - w_s^T x_s^*) - (p_s^T y_s - w_s^T x_s) \tag{28.11}$$

where y_s^* and x_s^* , respectively, are the n element optimal output vector and m element optimal input vector obtained by solving the problem in expression (28.9). Thus, (28.11) provides a measure of the “profits lost (in the form of an ‘opportunity cost’) by not operating in a fully efficient manner” (Cooper et al. 2000, p. 222). In order to express profit inefficiency as a ratio to be more consistent with our other efficiency measures, we normalize π_j by dividing by the sum of actual costs and revenues, $(p_s^T y_s + w_s^T x_s)$ (see Cooper et al. 2004). We do not use optimal or actual profits as the denominator because optimal profits can be 0 and actual profits can be ≤ 0 . Therefore, unlike the efficiency ratios, profit inefficiency does not have to be between 0 and 1.

An alternative DEA profit efficiency model is specified in Färe et al. (2004) and Ray (2004). The profit setup solves the problem (28.9) without the restriction imposed by (28.10) but with the constraint:

$$\sum_{i=1}^S \lambda_{si} = 1 \tag{28.12}$$

The constraint (28.12) imposes VRS. The VRS constraint is necessary here because under CRS the solution is indeterminate, i.e., if (λ^*, x^*, y^*) is a solution, then for any arbitrary $t > 0$, $(t\lambda^*, tx^*, ty^*)$ is also a solution (Ray 2004). Imposing VRS eliminates this indeterminacy. Profit inefficiency is then estimated as in (28.11). As above, it can be normalized by dividing by the sum of actual costs and revenues (see also Färe et al. 2004).

Most DEA methods impose the condition that the efficient frontier be a convex set, with an exception being problems specified under CRS, where convexity is not imposed. While convexity sometimes is a reasonable assumption, there is no necessary mathematical or economic reason why it should always hold in practice. Deprins et al. (1984) criticize the DEA methodology for imposing convexity, contending that it leads to a poor fit to some observed datasets because it does not allow for local non-convexities. Intuitively, the convexity assumption allows a firm to be dominated by a convex combination of other firms even if there is no firm actually operating with the input–output vector of the “virtual” firm created by the convex combination.

Deprins et al. (1984) propose the elimination of the convexity assumption, using the FDH estimation technique. The FDH name comes from its retention of another major assumption of

DEA, free disposability, which implies, for example, that outputs do not decrease if some inputs are increased (strong disposability of inputs). The FDH method allows the frontier to have local non-convexities. It has been shown to envelop the data more closely than DEA, and FDH efficiencies tend to be higher than those for DEA with many more efficient firms (Cummins and Zi 1998). However, it is not at all clear that the increase in goodness of fit is economically meaningful, i.e., the frontier may indeed be convex for some industries. More research is clearly needed to resolve the convexity issue.

28.3.1.2 The Malmquist Productivity Index

We use the Malmquist index approach to analyze the TFP change of firms over time.⁷ The TFP change of a firm has two primary components: the shift in the production frontier over time, representing technical change, and the shift in the firm’s location relative to the production frontier over time, representing technical efficiency change. There are several other ways to measure the productivity change of a firm (such as the Fisher index or the Törnqvist index). We recommend the Malmquist index because it permits the separation of technical change from efficiency change and is consistent with the DEA efficiency estimation methodology.

We measure TFP change using input-oriented Malmquist productivity indices. In Malmquist index analysis, it is necessary to adopt an assumption with respect to the returns to scale of the underlying technology, with the choices generally being CRS and VRS. This assumption does not affect the overall Malmquist index, which is correctly measured by the ratio of CRS distance functions even when the underlying technology exhibits VRS (Ray and Desli (1997)) (R-D). However, the return to scale benchmark does affect the decomposition of the index into pure technical efficiency change, pure technical change, and scale change.

Because many insurance firms operate with IRS or DRS (Cummins 1999; Cummins and Xie 2013), we illustrate Malmquist analysis decomposition utilizing the VRS benchmark technology. The decomposition we discuss was developed by R-D (1997). However, our decomposition differs from theirs in that we adopt an input-orientation rather than an output-orientation, consistent with our preferred approach in the DEA analysis of cost efficiency.

To elucidate the Malmquist methodology and decomposition, we consider Fig. 28.1, which shows production frontiers for a single-input (X), single-output (Y) industry. The VRS production frontier is formed by firms operating at points B, C, and D in period t and points B', C', D' in period $t + 1$. The line $0V_{CRS}^t$ in Fig. 28.1 represents the CRS frontier in period t , and the line $0V_{CRS}^{t+1}$ represents the CRS production frontier in period $t + 1$. The line ABCDE represents the VRS frontier in period t , while the line labeled A'B'C'D'E' represents the VRS production frontier in period $t + 1$. Firm j produces at point F in period t and produces at point F' in period $t + 1$. Obviously, this firm is not on the CRS production frontier, and it is also VRS inefficient. Two changes have occurred to this firm between time t and time $t + 1$. First, the firm is using better technology in period $t + 1$ to produce its output. Second, the firm is operating closer to the frontier in period $t + 1$ than in period t , indicating a technical efficiency gain between the two periods.

Our Malmquist analysis is based on input-oriented distance functions, given by

$$D_r^t(x_s^p, y_s^p) = \sup \left\{ \phi_s^p : \left(\frac{x_s^p}{\phi_s^p}, y_s^p \right) \in V_r^t(y_s^p) \right\} = \frac{1}{\inf \{ \theta_s^p : (\theta_s^p x_s^p, y_s^p) \in V_r^t(y_s^p) \}} \quad (28.13)$$

⁷The Malmquist method is credited to Caves et al. (1982), for the theory, and to Färe et al. (1994a), for the empirical methodology. See also Färe et al. (1994b).

where $D_r^t(x_s^p, y_s^p)$ = the input-oriented distance function for firm s in period t relative to the production frontier in period p with returns to scale technology r , where $r = \text{CRS}$ for CRS, and $r = \text{VRS}$ for VRS; and x_s^p, y_s^p is the input–output vector for firm s in time period p , where $p = t$ or $t + 1$ in our example, and $s = 1, 2, \dots, S$. As in the DEA discussion, the production technology t , which transforms inputs into outputs, is modeled by an input correspondence $y^p \rightarrow V_r^t(y^p) \subseteq \mathbb{R}_+^N$. Notice that allowing the $p \neq t$ enables us to use distance functions to estimate the productivity changes of firm s over time.

Returning to Fig. 28.1, let $D_{\text{CRS}}^t(D_{\text{CRS}}^{t+1})$ represent the distance function relative to the CRS production frontier at time $t(t + 1)$, where (x_j^t, y_j^t) is the input–output combination of firm j at time t , and (x_j^{t+1}, y_j^{t+1}) is its input–output combination at time $t + 1$. Then, from Fig. 28.1, $D_{\text{CRS}}^t(x_j^t, y_j^t) = 0a/0c$ and $D_{\text{CRS}}^{t+1}(x_j^{t+1}, y_j^{t+1}) = 0a'/0e'$. Likewise, we can define $D_{\text{CRS}}^t(x_j^{t+1}, y_j^{t+1}) = 0a'/0c'$ and $D_{\text{CRS}}^{t+1}(x_j^t, y_j^t) = 0a/0e$. $D_{\text{CRS}}^t(x_j^t, y_j^t)$ and $D_{\text{CRS}}^{t+1}(x_j^{t+1}, y_j^{t+1})$ compare the period t and $t + 1$ input-output vectors to the same period’s production frontier and must have values ≥ 1 . However, if the frontiers shift over time, the distance function $D_{\text{CRS}}^t(x_j^{t+1}, y_j^{t+1})$ and $D_{\text{CRS}}^{t+1}(x_j^t, y_j^t)$ can be < 1 , implying that a given period’s input-output combination is infeasible using the other period’s technology.

A Malmquist index can be defined relative to either the technology in period t (written as M_{CRS}^t) or the technology in period $t + 1$ (written as M_{CRS}^{t+1}),

$$M_{\text{CRS}}^t = D_{\text{CRS}}^t(x_j^t, y_j^t)/D_{\text{CRS}}^t(x_j^{t+1}, y_j^{t+1}), \quad \text{or,} \quad M_{\text{CRS}}^{t+1} = D_{\text{CRS}}^{t+1}(x_j^t, y_j^t)/D_{\text{CRS}}^{t+1}(x_j^{t+1}, y_j^{t+1}) \tag{28.14}$$

M_{CRS}^t measures productivity growth between periods t and $t + 1$ using the period t reference technology, while M_{CRS}^{t+1} measures productivity growth between periods t and $t + 1$ using the period $t + 1$ reference technology. To avoid an arbitrary choice of reference technology, the Malmquist TFP index is defined as the geometric mean of M_{CRS}^t and M_{CRS}^{t+1} :

$$M_{\text{CRS}}(x_j^{t+1}, y_j^{t+1}, x_j^t, y_j^t) = [M_{\text{CRS}}^t * M_{\text{CRS}}^{t+1}]^{1/2} = [(0a/0c)(0c'/0a')(0a/0e)(0e'/0a')]^{1/2}. \tag{28.15}$$

A Malmquist index $>1(<1)$ implies TFP growth (decline).

As mentioned, we utilize the Ray-Desli (1997) VRS approach to decompose the Malmquist index into pure efficiency change (PEFFCH), technical change (TECHCH), and scale change (SCH), where $M_{\text{CRS}}(x_A^{t+1}, y_A^{t+1}, x_A^t, y_A^t) = \text{PEFFCH} * \text{TECHCH} * \text{SCH}$. The components for the input-oriented Malmquist index are given by the following formulas:

$$\text{PEFFCH} * \text{TECHCH} = \left(\frac{D_{\text{VRS}}^{t+1}(x_j^t, y_j^t)}{D_{\text{VRS}}^{t+1}(x_j^{t+1}, y_j^{t+1})} \right) \left[\frac{D_{\text{VRS}}^{t+1}(x_j^{t+1}, y_j^{t+1}) D_{\text{VRS}}^{t+1}(x_j^t, y_j^t)}{D_{\text{VRS}}^t(x_j^{t+1}, y_j^{t+1}) D_{\text{VRS}}^t(x_j^t, y_j^t)} \right]^{1/2} \tag{28.16a}$$

$$\text{SCH} = \left(\frac{D_{\text{CRS}}^t(x_j^t, y_j^t) D_{\text{VRS}}^{t+1}(x_j^{t+1}, y_j^{t+1}) D_{\text{CRS}}^{t+1}(x_j^t, y_j^t) D_{\text{VRS}}^{t+1}(x_j^{t+1}, y_j^{t+1})}{D_{\text{VRS}}^{t+1}(x_j^t, y_j^t) D_{\text{CRS}}^{t+1}(x_j^{t+1}, y_j^{t+1}) D_{\text{VRS}}^t(x_j^t, y_j^t) D_{\text{CRS}}^t(x_j^{t+1}, y_j^{t+1})} \right)^{1/2} \tag{28.16b}$$

The pure efficiency change component (PEFFCH), the expression in parentheses in equation (28.16a), compares the firm’s distance from the VRS frontier in period t to its distance from the VRS frontier in period $t + 1$. If the firm has moved closer to the frontier in period $t + 1$, this ratio will be >1 . In terms of Fig. 28.1, $\text{PEFFCH} = [(0a/0b)/(0a'/0d')]$. The technical change component in (28.16a) (TECHCH) measures the shift in the VRS frontier between periods t and $t + 1$ with respect to the operating points of firm j in the two periods. If the operating point in period t is further from the

frontier in period $t + 1$ than in period t , the implication is that the frontier has shifted to the left, implying that technology has improved, and likewise for the period $t + 1$ operating point. In fact, TECHCH is the geometric mean of the distances between the VRS frontiers in periods t and $t + 1$ and thus gives an indication of the degree of technological improvement between the two periods.

The scale change component of the input-oriented Malmquist index (28.16b) is somewhat complicated but can be envisioned intuitively as measuring the ratio of the distances between the VRS and CRS frontiers in periods t and $t + 1$, with respect to the operating points of firm j in the two periods. If the geometric mean distance between the CRS and VRS frontiers with respect to the period t operating point is greater than the geometric mean distance between the CRS and VRS frontiers with respect to the period $t + 1$ operating point, SCH will be > 1 , i.e., the firm's period $t + 1$ operating point is closer to CRS than its period t operating point. For example, the ratio $D_{CRS}^t(x_j^t, y_j^t)/D_{VRS}^t(x_j^t, y_j^t) = (0a/0c)/(0a/0b) = 0b/0c$ measures the distance between the period t VRS and CRS frontiers with respect to the period t operating point, and the ratio $D_{CRS}^{t+1}(x_j^t, y_j^t)/D_{VRS}^{t+1}(x_j^t, y_j^t) = (0a/0e)/(0a/0d) = 0d/0e$ measures the distance between the period $t + 1$ VRS and CRS frontiers with respect to the period t operating point. The geometric mean of the two distances is $[(0b/0c)(0d/0e)]^{1/2}$. The comparable ratios for the $t + 1$ operating point appear in the denominator, accounting for their being reciprocated in (28.16b). The overall scale efficiency component is given by $SCH = \{[(0b/0c)(0d/0e)]/[(0b'/0c')(0d'/0e')]\}^{1/2}$. The product of the three components equals the overall input-oriented Malmquist productivity index, $M_{CRS}(x_j^{t+1}, y_j^{t+1}, x_j^t, y_j^t)$.

Simar and Wilson (1998) design a further decomposition of scale change into scale efficiency change (SEFFCH) and scale technical change (STECHCH), where $SCH = SEFFCH * STECHCH$. The scale efficiency change component (SEFFCH) compares the firm's scale efficiency in period $t + 1$ to its scale efficiency in period t , with $SEFFCH > 1$ implying that the firm has become more scale efficient. STECHCH describes the change in the scale or shape of technology at the firm's operating points at times t and $t + 1$. As for the other components, $STECHCH > 1$ indicates an improvement in scale technical change between the two periods.⁸

Other methods for measuring productivity also have been developed. A prominent method is the index number approach (see Färe et al. 2008). Under the index number approach, TFP growth is defined as the difference between output and input growth. To use this approach, data for output and input quantities and prices are required. No parameters are estimated, but the index formula itself usually is derived from an assumed functional form for cost or production.

A popular non-frontier index is the *Divisia index* of TFP (Diewert 1981). The Divisia index of TFP growth can be derived from a translog aggregator (flexible) production function exhibiting CRS and profit maximizing competitive behavior. When used to measure TFP, productivity growth is assumed to be Hicks neutral.⁹ An alternative index, the "exact" index may be used if nonconstant returns to scale are known to exist. In cases where these assumptions are not reasonable, ex post regression analysis may be used to isolate the effect of such factors as size and regulation. To define the Divisia index, we first define the production function $y(t) = F[x(t), t] = A(t) \cdot f[x(t)]$, where $y(t)$ = the output at time t , $x(t)$ = the vector of inputs, and $A(t)$ = a cumulative shift factor for the production function at time t . Then the Divisia index of TFP growth is defined as¹⁰

$$\frac{dA(t)/dt}{A(t)} = \frac{dy(t)/dt}{y(t)} - \sum_{j=1}^M s_j(t) \frac{dx_j(t)/dt}{x_j(t)} \tag{28.17}$$

⁸For more details, see R-D (1997), Simar and Wilson (1998), and Cummins and Rubio-Misas (2006).

⁹Hicks neutrality means that the ratio of the marginal products of capital and labor for any ratio of capital and labor input is independent of time.

¹⁰For simplicity, we use only one output. However, the Divisia index can be defined for multiple outputs.

$$s_j(t) = \text{the } j\text{th input share} = w_j(t)x_j(t) / \sum_{j=1}^M w_j(t)x_j(t) \quad (28.18)$$

where $w_j(t)$ = price of the j th input and $s_j(t)$ = the j th input share. Hicks neutrality allows us to separate $A(t)$ from the function $f[x(t)]$ and thus to conveniently measure productivity growth.

The index approach is used typically in cases where direct econometric estimation of a cost or production function is infeasible because the functional form is not known and/or a sufficient number of observations to estimate the parameters in flexible functional forms are not available. The approach is sometimes used in analyzing national accounting data, such as insurance gross product originating because it is easy to compute (i.e., no estimation is conducted) (e.g., [Bernstein 1999](#)). For another insurance application see [Weiss \(1986\)](#).

28.3.2 *Econometric Frontier Efficiency Models*

The second major type of estimation technique for efficiency is the econometric approach; and within this class of methods, the vast majority of existing econometric efficiency applications utilize *SFA* ([Greene 2008](#)). The technique can be conceptualized in two stages: (1) the estimation of an appropriate function, such as a production, cost, revenue, or profit function, using an econometric method such as ordinary least squares, nonlinear least squares, maximum likelihood, or Bayesian estimation and (2) the separation of the estimated regression error terms into components, usually a two-sided random error component and a one-sided inefficiency component. This produces an estimate of efficiency for every firm in the sample. The technique allows firms to operate off the efficient frontier due to random error (“bad luck”) as well as inefficiency and filters out the bad luck component in estimating inefficiency. Thus, the two most important decisions that must be made in applying the econometric frontier efficiency methodology are the choice of functional form and the approach used to separate the random and inefficiency components of the error term. This section discusses these issues.

28.3.2.1 **Functional Form**

Ideally, researchers would be able to determine the exact form of the production function for the firms being analyzed. This is, in fact, possible for some physical production processes such as manufacturing chemicals or refining oil. However, in most industries, and especially in the service sector, the exact functional form is not known. In the past, this led economists to use various approximations such as the well-known Cobb-Douglas and constant elasticity of substitution (CES) production functions. One of the most important developments facilitating the development of stochastic frontier models was the introduction of the translog production function ([Christensen et al. 1973](#)). They reasoned that even though the functional form may be unknown, any function satisfying rather weak regularity conditions can be expanded as a Taylor series. They proposed the use of a second-order Taylor expansion in natural logarithms as an approximation of the unknown production function. An analogous derivation leads to the translog cost function. The translog has an advantage over earlier functional forms in that it allows returns to scale to change with output or input proportions so that the estimated cost curve can take on the familiar U-shape. The quadratic feature of the translog also can be a potential disadvantage, as explained below.

A general expression of a cost function is $C = f(y, w, t)$, where C is total cost, y is output, w is input price, and t is time. In most applications, y and w are vectors. The *cost frontier* is defined as the

minimum total cost function, i.e., the function that gives the minimum attainable cost for each level of output. The cost frontier is denoted $C^F = C^F(y, w, t)$. The translog cost function is

$$\ln C_{st} = \left[a_0 + \sum_{i=1}^N a_{y_i} \ln y_{sit} + \frac{1}{2} \sum_{i=1}^N \sum_{k=1}^N a_{y_i y_k} \ln y_{sit} \ln y_{skt} + \sum_{j=1}^M a_{w_j} \ln w_{sjt} + \frac{1}{2} \sum_{j=1}^M \sum_{f=1}^M a_{w_j w_f} \ln w_{sjt} \ln w_{sft} + \sum_{i=1}^N \sum_{j=1}^M \alpha_{y_i w_j} \ln y_{sit} \ln w_{sjt} \right] + v_{st} + \varepsilon_{st} \quad (28.19)$$

where $s = \{1, \dots, S\}$, i or $k = \{1, \dots, N\}$, and j or $f = \{1, \dots, M\}$ index firms, outputs, and inputs, respectively, C_{st} = observed total costs for firm s in year $t = \sum_j w_{sjt} x_{sjt}$, y_{sit} = amount of output i produced by firm s in year t , w_{sjt} = price of input j to firm s in year t , ε_{st} = a random error term, and v_{st} = an inefficiency error term. The estimation is usually conducted as a system of equations consisting of the cost function and the first-order conditions for cost minimization:

$$\partial \ln C_{st} / \partial \ln w_{sjt} = w_{sjt} x_{sjt} / C_{st} = \left[\alpha_{w_j} + \sum_{f=1}^M \alpha_{w_j w_f} \ln w_{sft} + \sum_{i=1}^N \alpha_{y_i w_j} \ln y_{ist} \right] + \omega_{sjt}. \quad (28.20)$$

where x_{sjt} = quantity of input j used by firm s in year t , and ω_{sjt} = a random error term. Linear homogeneity and symmetry restrictions are imposed in the estimation. Symmetry simply means that $\alpha_{y_j y_k} = \alpha_{y_k y_j}$ and $\alpha_{w_j w_f} = \alpha_{w_f w_j}$. Homogeneity means homogeneity of degree one in input prices, which requires that $\sum_{j=1}^M \alpha_{w_j} = 1$, $\sum_{j=1}^M \alpha_{y_i w_j} = 0$, and $\sum_{j=1}^M \alpha_{w_j w_f} = 0$.

Firms are assumed to share a common cost function given by the bracketed expression in (28.19). The stochastic nature of the frontier is modeled by adding a two-sided random error term, ε_{st} , to the cost equation. The realizations of these random errors differ across firms, but the errors are assumed to be independent, identically distributed, and beyond the control of individual firms. Hence, ε_{st} is not indicative of inefficiency. Inefficiency is captured by the additional error term in (28.19), v_{st} . Because inefficiency can only increase (not reduce) costs, v_{st} is a one-sided error term, $v_{st} \geq 0$, or more generally $v_{st} \geq \zeta$, where ζ = a non-negative parameter. The input shares are assumed to have a functional component common to all firms (the bracketed expression in (28.20)) and a random component captured by the two-sided error term $\sum_j \omega_{sjt} = 0$.

While the translog has been widely used in econometric efficiency studies, it has some limitations that have led some researchers to seek alternative forms for the cost function. One limitation is that the translog does not naturally allow any of the independent variables to be equal to zero. Although this is not a problem with regard to input prices, it can be a limitation for outputs if more than one output is present and some firms do not produce all outputs. This is especially problematical in studying economies of scope, where zeros for some outputs are required.

When zero outputs are present, one approach is to salvage the translog using somewhat ad hoc techniques such as setting all zero outputs to a small positive number or adding 1 to the value of all outputs (not just the output involving the zeros). Neither method is satisfactory. The approach of setting zero outputs to a small positive number has been shown to be unsatisfactory in studies of scope economies because quite different estimates of scope economies can be obtained, depending upon how close the number is to zero (Röller 1990). Bikker and Bos (2008) point out several other problems with scope estimation with logarithmic models. For example, if the sample contains both universal banks and other banks, only the former typically offer the full range of financial services.

Consequently, the estimates or economies of scope function tend to be biased upward. Limiting the sample to only those firms that have non-zero values of all outputs also is not a satisfactory solution because it fails to capture information from specialists and introduces survivor bias.

Because of the limitations of the ad hoc techniques for dealing with zero outputs, for many purposes it is advisable to use an alternative functional form. We discuss three alternatives that show up relatively often in the financial services literature. The simplest is the Fuss normalized quadratic, which replaces the logged values of outputs and input prices in (28.19) with the unlogged values of the variables (Diewert and Wales 1987). Homogeneity is imposed by dividing all variables by one of the input prices. A limitation of this form is that the results are not completely invariant to which input is chosen for normalization. An alternative is the generalized translog cost function, obtained by transforming the output variables using a Box–Cox transformation (Caves et al. 1980). That is, the $\ln(y_{sit})$ in (28.19) are replaced by the Box–Cox transformed variate defined as $y_{sit}^{(\varphi)} = (y_{sit}^{\varphi} - 1)/\varphi$, $\varphi \neq 0$. The Box–Cox model is the same as the translog if $\varphi = 0$ and thus fails to improve on the translog if φ is near 0.

Another functional form that seems ideally suited to the analysis of scope economies is the *composite function* (Pulley and Braunstein 1992). This is a more flexible functional form than the translog and deals effectively with zero outputs (Bikker and Bos 2008). This functional form consists of a quadratic component for outputs, linked through interaction terms with a log-quadratic component for input prices. The resulting functional form can be estimated linearly, log-linearly or using a Box–Cox transformation. This functional form has been used by Berger et al. (2000) to analyze economies of scope in the US insurance industry and by Hirao and Inoue (2004) to study scale and scope economies in the Japanese insurance industry.

A limitation of quadratic cost functions such as the translog is that they force the cost function to be U-shaped. The U-shape may be a problem if, for example, the actual cost curve exhibits CRS after output reaches the level where firms are no longer operating in the range of increasing returns to scale. The problem arises because the translog was developed as a local approximation to the true underlying cost function and thus may give misleading results when used globally. This problem cannot be solved by extending the Taylor series expansion to include higher order terms because the resulting function is still a local approximation. However, it is possible to impose constraints whereby the function becomes linearly homogeneous in output such that the dual production function exhibits CRS (Diewert and Wales 1987).

Several approaches have been proposed for solving the local approximation problem. One promising approach is the use of the Fourier flexible functional form, first proposed by Gallant (1982). This form arises from the expansion of the unknown true cost function as a Fourier series. The usual procedure is to append the Fourier (sine and cosine) terms to a standard translog, giving an extremely flexible function that does not force the estimated cost function to have a region characterized by DRS. The Fourier flexible form is a global approximation because the sine and cosine terms are mutually orthogonal over the $[0, 2\pi]$ interval, so that each additional term can make the approximating function closer to the true path of the data wherever it is needed.¹¹ A disadvantage is that the number of Fourier terms can become very large, causing degrees of freedom problems. Consequently, the method cannot

¹¹The orthogonality is perfect only if the data are evenly distributed over the $[0, 2\pi]$ interval, but in most applications to date, the Fourier terms lead to a significant improvement in the fit of the model.

be used for small datasets.¹² Applications of the Fourier functional form in insurance studies are Berger et al. (1997) and Fenn et al. (2008).

The translog functional form is also problematical in studies of profit efficiency even if zero outputs are not present, because observed profits are often negative. The two dominant conventional approaches to dealing with negative profits are to exclude observations with negative profits from the estimation and to add 1 plus the absolute value of the minimum profit observed in the sample to all observations. Neither method is satisfactory. The former does not produce efficiency estimates for firms with negative profits and can lead to biased estimates for the positive profit firms. The latter has an unknown effect on the parameter estimates because it is not possible to control the effect of the data manipulation on the regression error term structure. A solution proposed by Bos and Koetter (2011) is to replace the negative observations in the dependent variable (profits) with an indicator variable equal to 1 and to add a right hand side variable equal to 1 for positive profit observations and equal to the absolute value of profits for negative observations. The empirical application by Bos and Koetter (2011) demonstrates that their method improves the rank stability of the estimated efficiency scores and adds to the discriminatory power of their translog profit model.

28.3.2.2 Separating Inefficiency and Random Error

Two principal methods are used for separating the random and inefficiency components of the error term—(1) making distributional assumptions about the error terms and (2) averaging estimated residuals over time to “average out” the random component of the error (the “*distribution free*” approach or *DFA*). The general procedure for estimating efficiency under the first approach is to jointly estimate the parameters of the cost function (28.19) and the parameters of the assumed distributions of the error terms using maximum likelihood. The form of the likelihood function is determined by the distributional assumptions. The usual distributional assumptions are normal distributions for ε_{st} and ω_{sjt} (see (28.19) and (28.20)) and a truncated normal, exponential, or gamma distribution for v_{st} .¹³ Efficiency is then estimated by separating the random and inefficiency components of the residuals $z_{st} = \varepsilon_{st} + v_{st}$ from the maximum likelihood estimation. The separation technique involves finding the conditional probability distribution of v_{st} given z_{st} and finding the conditional expectation $E(\exp(-v_{st}|z_{st}))$ (see Greene 2008), providing an estimate of the ratio of frontier costs to actual costs for each firm in the sample.

The *distribution free* method developed by Schmidt and Sickles (1984) and Berger (1993) provides an alternative to the distributional assumption approach when several years of data are available. The cost function is estimated for the entire data period, either year by year or by pooling the data for all years. The residuals from the cost function estimation constitute a vector of random error terms for each firm, $z_s = \{z_{s1}, z_{s2}, \dots, z_{sT}\}$, $s = 1, 2, \dots, S$. The error term z_{st} is specified here as $z_{st} = \varepsilon_{st} + v_s$, i.e., the inefficiency component is assumed to be the same for all years. No distributional assumptions are required for ε_{st} or v_s . Rather, an estimate of the efficiency is extracted by averaging the estimated overall error, $z_{st} = v_s + \varepsilon_{st}$, over the sample period on the assumption that the random error ε_{st} will average out over time. Cost efficiency is then estimated for each firm as

¹²The recommended number of parameters is $N^{(2/3)}$ where N is the number of observations. For example, Berger et al. (1997) had 4,720 observations and 492 parameters including translog and first, second, and third-order Fourier terms. For relatively large data sets such as theirs and the even larger data sets used in many banking studies, the number of parameters is not a serious problem because the number of parameters as a proportion of the total number of observations is declining in N .

¹³For specificity, this discussion focuses on the translog, but a similar approach would apply for the other functional forms discussed above.

$$E[v_s | z_{s1}, \dots, z_{sT}] = \exp(\min_s(\bar{z}_s) - \bar{z}_s) \quad (28.21)$$

where \bar{z}_s is the average error term over the sample period for firm s and $\min_s(\bar{z}_s)$ is the minimum average error term for the firms in the sample. In addition to avoiding distributional assumptions, this method is also easier to implement than the distributional approach because it does not require the use of maximum likelihood methods.

The distributional assumptions approach has been criticized for potentially confounding efficiency estimates with the choice of inappropriate probability distributions. However, [Cummins and Zi \(1998\)](#) show that the efficiency rankings of firms in their sample of US life insurers are robust to the distributions assumed for the error terms. Further research is needed to determine whether this finding can be extrapolated to other datasets. The DFA method is not susceptible to errors stemming from incorrect distributional assumptions. However, it may give misleading results if the inefficiency component of the error term is not constant over time or if the number of available data years is not sufficient to average out the random error.

28.3.3 *Pros and Cons: Econometrics versus Mathematical Programming*

The choice of methodology for estimating efficient frontiers has generated controversy in the literature, with some researchers arguing for the econometric approach (e.g., [Berger 1993](#); [Greene 2008](#)) and others for the mathematical programming approach (e.g., [Cooper et al. 2004](#)). The econometric approach is usually called *SFA*. The primary advantage traditionally given for SFA in comparison with mathematical programming approaches such as DEA is that SFA allows firms to be off the frontier due to random error as well as inefficiency and, consequently, does not count purely random departures from the frontier as inefficiency. The primary advantage traditionally given for mathematical programming is that it is non-parametric and thus avoids misspecification of functional form or the probability distributions assumed for the error terms, which potentially confounds the efficiency estimates with specification error.¹⁴ The interpretation was that the DEA approach was non-stochastic and the SFA approach was parametric, and neither approach was considered robust to both statistical noise and specification error. However, over the past 10–15 years, “knowledge has progressed and distinctions have blurred. To praise one approach as stochastic is not to deny that the other is stochastic, as well, and to praise one approach as being nonparametric is not to damn the other as being rigidly parameterized. Recent explorations into the statistical foundations of the programming approach have provided the basis for statistical inference, and recent applications of flexible functional forms... have freed the econometric approach from its parametric straitjacket. Both techniques are more robust” than researchers previously believed ([Fried et al. 2008](#), p. 33). Because the properties of SFA models are well known, the remaining discussion mostly focuses on the recently developed knowledge about the properties of DEA.

As mentioned, recent theoretical work shows that DEA can be interpreted as a non-parametric stochastic frontier technique. Moreover, most DEA applications also allow for random error using second stage regression analysis. Consequently, allowing for random error is not necessarily a compelling rationale for the econometric approach.

DEA has several desirable properties: (1) DEA is non-parametric. It therefore avoids the choice of a functional form for the technical, cost, or revenue function and requires no distributional assumptions. Such assumptions can create specification errors. (2) DEA is individual-firm based, making it easy to

¹⁴The choice of distributional assumptions can be avoided by using the distribution free approach, but it is not clear that this approach yields efficiency estimates that are as accurate as the fully specified SFA approach or DEA.

decompose efficiency by firm, which is particularly convenient for studying scope economies. That is, DEA solves the optimization problem separately for each firm in the sample and thus optimizes over individual firms (Ray 2004, pp. 4–5). Econometric models, on the other hand, optimize over the sample as a whole, and the estimated function is assumed to apply to all units in the sample, with all of the differences among firms captured through the estimated residuals. Thus, DEA can produce estimates of important quantities such as economies of scale that apply to specific units of observations (firms), whereas econometric estimates of scale economies are based on the same parameter estimates for all units. (3) DEA provides a convenient way to decompose cost and revenue efficiency into their pure technical, scale, and allocative components. And (4) DEA can be applied in a meaningful way to situations where there are only a few decision making units, such as the divisions or departments of a firm, whereas econometrics requires larger samples to generate statistical reliability.

The DEA approach also has attractive statistical properties. First, as shown by Banker (1993), DEA is equivalent to maximum likelihood estimation. Second, DEA estimators are consistent and converge faster than estimators from other frontier methods (Grosskopf 1996). Third, DEA estimators are also unbiased if we assume that there is no underlying model or reference technology. If one believes in an underlying model, then the problem of bias in DEA estimates arises, but this bias decreases with sample size (Kittelsen 1999). Fourth, Banker and Natarajan (2008) show that DEA is a non-parametric stochastic frontier estimation methodology that performs better than parametric procedures in the estimation of individual decision making unit productivity. Finally, Banker and Natarajan (2008) also show that the two-stage approach utilized in many DEA applications, where DEA efficiency estimates are regressed on firm characteristics and other covariates, yields consistent estimates of the impact of these contextual variables on efficiency. They also show that the two-stage approach is consistent in a composed error framework, i.e., that DEA like SFA incorporates one and two-sided random errors.

The principal advantage of SFA over DEA is that SFA explicitly incorporates a random error term in the efficiency estimation model, while DEA does not. One consequence is that DEA is especially sensitive to measurement error. If one or a few organizations inputs are understated or its outputs overstated, those operating units can become outliers that distort the shape of the frontier and reduce the efficiencies of nearby organizations. The econometric approach is more efficient in dealing with outliers. Both DEA and SFA are susceptible to biases due to sample size but for slightly different reasons. For both methodologies, a small sample size can inflate efficiency estimates if relatively efficient firms have been omitted from the sample. The precision of DEA estimates is not affected by the sample size, but efficiency scores tend to decline as the sample size increases because there are more firms present that can enter a given firm's reference set. With SFA, coefficient estimates become less efficient and hence less reliable statistically as the sample size decreases.

A problem that affects both methodologies is imprecision in the measurement of inputs, outputs, and prices. This can occur due to data reporting or measurement errors but more commonly occurs because financial institution data are reported at a high level of aggregation. Hence, it might be desirable to measure insurance output at the line of business level or on an even more disaggregated basis, but such data may not be reported. In many countries, for example, data are available only for life and non-life insurance but not for more finely gradated line definitions. This problem may help to account for the relatively high inefficiencies reported in most insurance and banking efficiency studies. One possibility to increase measured efficiencies would be to utilize more finely divided output categories, which would reduce heterogeneity among firms arising from aggregating outputs with different characteristics.¹⁵

¹⁵For example, if many insurance lines are lumped together in a broad category such as non-life insurance, firms concentrating on lines of insurance with relatively high operating expenses will appear inefficient, whereas they would likely be measured as more efficient if compared against other firms specializing in high expense lines.

One area where SFA applications currently are ahead of DEA is in the estimation of profit efficiency. There have been many more profit efficiency studies utilizing SFA than DEA. As such, researchers have solved most of the practical problems of estimation of econometric profit frontiers and such estimations yield reliable and stable results. By contrast, there have been relatively few empirical DEA profit efficiency studies (e.g., [Färe et al. 2004](#); [Cummins et al. 2010](#)). DEA profit efficiency estimates can sometimes be unstable and give unrealistically small or large profit efficiencies. This situation can be expected to change as researchers gain more experience in estimating DEA profit efficiency and additional theoretical modeling takes place.

How important is the choice of an efficiency estimation methodology? Some clues are provided by the few studies that have applied a range of estimation methodologies to the same dataset. [Cummins and Zi \(1998\)](#) apply a variety of techniques to estimate the cost efficiency of US life insurers and find that econometric efficiency estimates are robust to the choice of distributional assumptions for the error term. The rank correlations among efficiency scores for the econometric methods are typically above 0.95. The rank correlations between the econometric and mathematical programming efficiency estimates are lower (around 0.67). They also find that FDH and DEA yield significantly different efficiency estimates. The rank correlations for cost efficiencies between DEA and FDH averaged about 0.6, and the rank correlations between FDH and the econometric methods also averaged about 0.6. More research is needed to analyze the consistency among the various methodologies and the economic significance of alternative efficiency scores.

[Eling and Luhnen \(2010a\)](#) conduct an extensive analysis of efficiency in the international insurance industry. They estimate DEA and SFA technical and cost efficiency using 6,462 insurance companies from 36 countries. They conclude that “the results of DEA and SFA and the economic insights that can be derived from them turn out to be very similar, both for technical efficiency and cost efficiency.” This result agrees with the few other studies that have considered multiple frontier efficiency methodologies. Thus, if applied correctly, DEA and SFA should yield similar results; and the choice between the two methods should be based on the objectives of the research and the advantages and disadvantages discussed above.

Mathematical programming is likely to be advisable if the objective is to study the performance of specific units of observation, because the optimization is conducted separately for each unit. Mathematical programming may be the only alternative for problems involving small numbers of observation units. However, with a small sample, there are fewer observations to form the dominating sets and hence efficiency is likely to be overestimated. For moderate sample sizes, DEA may give more reliable estimates than econometrics even for larger numbers of inputs and outputs. Of course, any efficiency estimation only provides an indication of “best practices,” i.e., the true frontier can never be estimated with real data.

There have been some potentially important methodological developments in mathematical programming analysis that have not yet been applied to insurance datasets. In particular, researchers have been developing explicitly stochastic non-parametric efficiency estimation methodologies. For example, [Post et al. \(2002\)](#) develop a non-parametric model that does not impose free disposability, convexity, or other potentially restrictive assumptions but allows for stochastic disturbances. [Kumbhakar et al. \(2007\)](#) propose a nonparametric stochastic frontier model based on local maximum likelihood. [Simar and Zelenyuk \(2011\)](#) extend [Kumbhakar et al. \(2007\)](#) by developing a stochastic DEA/FDH estimation technique that they argue makes the estimated frontier smoother, monotonic, and, if appropriate, concave. Another recent development is a new one-stage semi-non-parametric estimator that combines the nonparametric DEA-style frontier with a regression model of the contextual variables ([Johnson and Kuosmanen 2011](#)). [Johnson and Kuosmanen \(2011\)](#) show that the estimator is statistically consistent under less restrictive assumptions than required by the two-stage DEA-regression estimator. It would be useful to compare the results of these relatively new methodologies to SFA and DEA utilizing insurance databases.

28.4 Defining Outputs, Inputs, and Prices

An important step in efficiency analysis is the definition of inputs and outputs and their prices. The results can be misleading or meaningless if these quantities are poorly defined. This problem is especially acute in the service sector, where many outputs are intangible and many prices are implicit. Defining inputs also must be done with care in studies of the insurance industry, where data on the number of hours worked and number of employees usually are not available in public sources. In spite of the challenges, researchers have devised measures of inputs, outputs, and prices that produce economically meaningful results. This section discusses these measures.

28.4.1 *Outputs and Output Prices*

28.4.1.1 Measuring Financial Services Output

Insurers are analogous to other financial firms in that their outputs consist primarily of services, many of which are intangible. Three principal approaches have been used to measure outputs in financial services—the asset (intermediation) approach, the user–cost approach, and the value-added approach (Berger and Humphrey 1992). The intermediation approach treats financial firms as pure financial intermediaries, borrowing funds from one set of decision makers, transforming the resulting liabilities into assets, and paying out interest to cover the time value of funds used. In the intermediation approach, the inputs consist of borrowed funds, such as policy reserves, and the outputs are assets.¹⁶ The asset (intermediation) approach would be inappropriate for property–liability insurers because they provide many services in addition to financial intermediation. In fact, the intermediation function is somewhat incidental to property–liability (P–L) insurers, arising out of the contract enforcement costs that would be incurred if premiums were not paid in advance of covered loss events. This is true to a lesser extent for life insurers, where intermediation is the most important function. However, ignoring insurance outputs is likely to overlook important distinctions among insurers and thus give less accurate results than if a wider range of outputs were used. Accordingly, the asset approach is not likely to be appropriate for either P–L or life insurers.

The user–cost method determines whether a financial product is an input or output on the basis of its net contribution to the revenues of the financial institution (Hancock 1985). If the financial returns on an asset exceed the opportunity cost of funds or if the financial costs of a liability are less than the opportunity costs, then the product is considered to be a financial output. Otherwise, it is classified as a financial input. This method is theoretically sound but requires precise data on product revenues and opportunity costs, which are difficult to estimate.¹⁷ This approach is especially problematical for the insurance industry because insurance policies bundle together many services, which are priced implicitly.

The third approach to measuring output—the value-added approach—is the most appropriate method for studying insurance efficiency. The value-added approach considers all asset and liability categories to have some output characteristics rather than distinguishing inputs from outputs in a mutually exclusive way. The categories having significant value-added, as judged using operating

¹⁶Some recent chapters in the insurance literature have claimed to utilize the “intermediation approach” in defining outputs (e.g., Brocket et al. 2005). However, as discussed further below, their approach is actually not the intermediation approach but rather utilizes arbitrary and ad hoc sets of output variables.

¹⁷Efforts to apply the user–cost method in banking found that the classifications of inputs and outputs were not robust to the choice of opportunity cost estimates nor were they robust over time (see Berger and Humphrey 1992).

cost allocations, are employed as important outputs. Others are treated as unimportant outputs, intermediate products, or inputs, depending on their other characteristics. The following discussion focuses solely on the value-added approach.

28.4.1.2 Services Provided by Insurers

Because insurance outputs are mostly intangible, it is necessary to find suitable proxies for the volume of services provided by insurers. This section discusses the principal services provided, and subsequent sections discuss insurance output measurement.

Insurers provide three principal services:

- *Risk-pooling and risk-bearing.* Insurance provides a mechanism for consumers and businesses exposed to insurable contingencies to engage in risk reduction through pooling. Insurers collect premiums from their customers and redistribute most of the funds to those policyholders who sustain losses. The actuarial, underwriting, and related expenses incurred in operating the risk pool are a major component of value added in insurance. Policyholders may also have their risks reduced because insurers hold capital to cushion unexpected loss and investment shocks. Again, this creates value-added by increasing economic security.
- *“Real” financial services relating to insured losses.* Insurers provide a variety of real services for policyholders. In life insurance, these services include financial planning and counseling for individuals and pension and benefit plan administration for businesses. In property–liability insurance, real services include risk surveys, the design of coverage programs, and recommendations regarding deductibles and policy limits. Insurers also provide loss prevention services.
- *Intermediation.* Insurers issue debt contracts (insurance policies and annuities) and invest the funds until they are withdrawn by policyholders (in the case of life insurers) or are needed to pay claims. In life insurance, interest credits are made directly to policyholder accounts to reflect investment income; whereas, in property–liability insurance, policyholders receive a discount in the premiums they pay to compensate for the opportunity cost of the funds held by the insurer. The net interest margin between the rate of return earned on assets and the rate credited to policyholders represents the value-added of the intermediation function.

Insurance expense data presented in Table 28.1 helps to identify the main sources of value-added. In 2010, about 33 (25)% of operating expenses for life insurers (P–L insurers) were for agents’ commissions. Agents perform real services such as financial counseling and giving advice on coverages and deductibles. They also collect underwriting information and expand the size of the insurer’s risk pool. For life (P–L) insurers, about 37 (34)% of total expenses are for personnel costs for functions other than sales and claims settlement. These expenditures are for the underwriters, actuaries, and administrators that operate the insurance risk pool. For P–L insurers, a substantial share of expenses (14%) goes for claims settlement services, which include such real services as providing a legal defense against liability suits. Professional services including legal, accounting, and actuarial account for 3.3% of expenses for life insurers and 3.6% for P–L insurers. Thus, for life (P–L) insurers 73.3 % (76.6%) of expenses are for human services, leaving only about one-fourth of expenses for taxes, licenses, fees, equipment, rent, and advertising.

An estimate of the cost of equity capital is also shown in Table 28.1. Equity capital amounts shown in the table are the life and P–L industry aggregates for 2010. The estimated cost of capital is taken from Cummins et al. (2010). The estimated cost of capital is 40.0% of non-capital expenses for life insurers and 42.2% for P–L insurers, demonstrating the importance of including capital costs when analyzing insurer efficiency.

Breaking total expenses down by function, investment expenses account for 9.3% (1.7%) of total expenses for life (P–L) insurers, with the remainder composed primarily of underwriting and

Table 28.1 Expense analysis: US Life and Property–Liability Insurers, 2010

| Expense item | Life | | Property–liability | |
|---|------------|-------------|--------------------|-------------|
| | Amount | Percent (%) | Amount | Percent (%) |
| Commissions and brokerage | \$ 34,318 | 33.0 | \$ 44,829 | 25.1 |
| Claims adjustment | \$ 759 | 0.7 | \$ 24,202 | 13.5 |
| Employee salaries and benefits | \$ 38,647 | 37.2 | \$ 60,920 | 34.1 |
| Advertising | \$ 2,913 | 2.8 | \$ 5,132 | 2.9 |
| Postage, telecommunications, etc. | \$ 2,951 | 2.8 | \$ 4,267 | 2.4 |
| Professional services ^a | \$ 3,420 | 3.3 | \$ 6,406 | 3.6 |
| Equipment | \$ 4,091 | 3.9 | \$ 6,836 | 3.8 |
| Travel | \$ 1,193 | 1.1 | \$ 2,376 | 1.3 |
| Real estate and rent items | \$ 4,049 | 3.9 | \$ 5,630 | 3.2 |
| Taxes, licenses, and fees ^b | \$ 8,204 | 7.9 | \$ 11,269 | 6.3 |
| All other | \$ 3,361 | 3.2 | \$ 6,824 | 3.8 |
| Total expenses (in billions) ^a | \$ 103,906 | 100.0 | \$ 178,691 | 100.0 |
| Equity capital | \$ 314,755 | | \$ 580,452 | |
| Cost of capital ^c | 13.2% | | 13.0% | |
| Capital cost (Equity*cost of capital) | \$ 41,548 | | \$ 75,459 | |

^aFor life insurers includes legal fees and expenses, medical examination fees, inspection report fees, fees of public accountants and consulting actuaries, bureau and association fees, and collection and bank service charges. For property–liability insurers includes boards, bureaus, and associations; surveys and underwriting reports; audits of assureds' records; directors' fees; and legal and auditing.

^bNot including Federal or foreign income taxes.

^cEstimated cost of capital is from [Cummins et al. \(2010\)](#).

Note: All data are for 2010. Dollar amounts are in millions.

Source: *Best's Aggregates and Averages Life/Health: 2011 Edition*, (Oldwick, NJ), *Best's Aggregates and Averages Property/Casualty: 2011 Edition* (Oldwick, NJ).

marketing expenses for life insurers and underwriting, marketing, and claims adjustment expenses for property–liability insurers. These expenses along with the net interest margin between what insurers earn on their investments and what they credit to policyholders, is a measure of the value added by the intermediation function. A rough idea of the magnitude of the net interest margin can be obtained by observing that a 50 basis point margin on invested assets would be equivalent to 25% (4.5%) of total expenses for life (P–L) insurers. Thus, intermediation is significantly more important for life insurers than for P–L insurers.

28.4.1.3 Defining Insurance Output: Theoretical Foundations

Before turning to the specification of the variables used to represent insurer outputs in efficiency estimation, this section briefly considers the concept of insurance output from a theoretical perspective. The provision of real services poses no conceptual hurdles that need to be explored here. However, it is useful to explore the concept of the value-added from the risk-pooling/risk-bearing function in the context of the theory of insurance economics. The treatment of the intermediation function also requires some discussion.

In terms of insurance economics, the value-added from risk-pooling is measured by the Pratt-Arrow concept of the *insurance premium* ([Arrow 1971](#); [Schlesinger 2000](#)). The result is stated succinctly by [Arrow \(1971, p. 95\)](#):

Consider an individual faced with a random outcome Y and offered the alternative of a certain income, Y_0 . A risk averter would be willing to accept a value of Y_0 less than the mean value, $E(Y)$, of the random income; the difference may be thought of as an insurance premium.

More precisely, the insurance premium (value-added) is the amount which makes the individual just indifferent between retaining and insuring the risk, i.e., the insurance premium π is the solution to

$$U(W - \mu_L - \pi) = \int U(W - L)f(L)dL. \quad (28.22)$$

where $U(W)$ = utility function, with $U' > 0$, $U'' < 0$,

W = initial wealth (non-stochastic),

L = the loss (stochastic), with $L \geq 0$,

$f(L)$ = the probability of loss distribution, and $\mu_L = E(L)$.

Because of risk-aversion, the policyholder is willing to pay a positive amount (the insurance premium, π) in excess of the expected loss to eliminate the risk of loss. This creates “gains from trade” and justifies the existence of insurance markets. Thus, the value added by the insurance transaction is the maximum amount the policyholder is willing to pay above $E(L)$, i.e., π . After all, the consumer has the option of going uninsured and having risky wealth with expected value $(W - \mu_L)$. The amount she is willing to pay over and above the expected loss constitutes the value of insurance.

In a competitive market, the full amount of consumer welfare gain from insurance may not be observed, i.e., the market may be able to provide the insurance for a loading less than π . It is not possible to measure the unobservable consumers’ surplus that results. However, it should be clear that the amount paid in addition to the expected value is the measurable value-added by risk-pooling.

Although the term *insurance premium* is used in this discussion to be consistent with Arrow (1971), in the remainder of the chapter π is called the *loading* in order to avoid confusion with the standard terminology in the insurance literature, where the term *premium* is used to mean the total amount paid by the policyholder for insurance, i.e., the expected loss plus the loading.

Because premiums are usually paid in advance of loss payments, it is necessary to appropriately account for investment income when measuring insurance output, output prices, revenues, and profits. The correct approach for incorporating investment income can be illustrated by a simple one-period, two-date model of the insurance firm. The insurer is assumed to commit equity capital of S to the insurance enterprise at time 0. Premiums in the amount P are paid at time zero, and the premiums and equity are invested at rate of return r . Losses are paid at the end of the period (time 1). To avoid unnecessarily complicating the analysis, it is assumed that there are no taxes.¹⁸

The first concept to illustrate is the price of insurance, which corresponds to π in (28.22). Following the approach in Cummins (1990), the premium is:

$$P = [L(1 + e) + S\rho]/(1 + r) \quad (28.23)$$

where L = the expected loss,

S = equity capital committed to this policy,

e = insurer expenses expressed as a proportion of the expected loss, and

ρ = the risk premium received by equity holders for bearing insurance risk.

In this model, the quantity of insurer output is proxied by the present value of losses incurred, i.e., output = $L/(1 + r)$. This reflects the fact that the purpose of insurance is to redistribute funds from those members of the pool who do not have a loss to those who have losses. Thus, L is the total amount redistributed by the insurer and proxies for the amount of risk pooling. Insurer revenues are equal to total premiums received plus investment income earned, i.e., revenues = $P + r(P + S)$; and value-added is defined as revenues minus loss payments and the interest earned on equity, or

¹⁸Cummins (1990) generalizes the model to incorporate taxes.

$$\text{Value Added} = V = P + r(P + S) - rS - L = eL + \rho S \quad (28.24)$$

It is necessary to subtract out the investment income on equity because this amount will be earned by equity holders in any case. Equity holders have the option of writing no insurance and thus operating as a mutual fund so that merely investing the equity carries no opportunity costs associated with operating an insurance business. The additional costs resulting from placing the money at risk in the insurance business are reflected in the risk premium ρ . The total value-added, $eL + \rho S$, thus equals the insurer's expenses plus the owners' profit for bearing insurance risk. The price of insurance is defined as the value-added per dollar of output:

$$\text{Price} = [P - PV(L)]/PV(L) = [P - L/(1 + r)]/[L/(1 + r)] = e + (S/L)\rho \quad (28.25)$$

This result can easily be generalized to incorporate the intermediation function. This is done by discounting at a rate $r_P < r$ to obtain the premium, where $(1 + r) = (1 + r_P)(1 + m)$ and m is the net interest margin received by the insurer for performing the intermediation function. Continuing to use r as the investment income rate, it is easily shown that the value-added becomes:

$$V = m[L(1 + e)P + rS] + [eL + \rho S] \quad (28.26)$$

Expression (28.26) equals the value added from intermediation plus the value added by risk-pooling.

28.4.1.4 Defining Insurance Output in Practice

The discussion in this section focuses on output measurement using US data. The same general principles apply to data from other countries, but the specific variables sometimes differ because data availability and reporting requirements differ across countries. A broader discussion of outputs used in insurance efficiency studies is presented as part of the literature survey in Sect. 28.5.

Some efficiency studies have used premiums to measure output. This is inappropriate, however, because premiums represent price times the quantity of output not output (Yuengert 1993). As he points out, "systematic differences in price across large and small firms may lead to misleading inferences about average costs if premiums are used as an output proxy" (Yuengert 1993, p. 489). Thus, it is important to develop output measures that are consistent with the preceding discussion.

Because the products offered and data reported by life and P-L insurers differ significantly, different output definitions are adopted for the two market segments. Following Yuengert (1993) and Berger et al. (2000), the sum of incurred benefits and additions to reserves is usually used to measure life insurance output. Incurred benefits represent payments received by policyholders in the current year and are useful proxies for the risk-pooling and risk-bearing functions because they measure the amount of funds distributed to policyholders for insured events. Most life insurance and annuity products involve the accumulation of assets, and the funds received by insurers not needed for benefit payments and expenses are added to policy reserves. Additions to reserves thus are highly correlated with net new intermediation output.

Because life insurer products differ in the types of contingent events covered and in the relative importance of the risk-pooling, intermediation, and real service components of output, we suggest using five output variables, equal to the sum of incurred benefits and additions to reserves for the major lines of business offered by life insurers¹⁹—individual life insurance, individual annuities,

¹⁹In the NAIC life insurer annual statements, incurred benefits plus additions to reserves is line 20 in the Analysis of Operations by Lines of Business.

group life insurance, group annuities, and accident & health insurance. Insurers also provide services in connection with funds contributed by policyholders in previous years. To capture this element of intermediation, average invested assets for life insurers is usually included as an output variable. An approach that has not been utilized in the existing literature would be to separate incurred benefits from additions to reserves, giving rise to a total of ten insurance outputs if by line disaggregation is used. It would be interesting to test whether this might raise the average estimated efficiency scores.

In keeping with the value-added approach to output measurement, we define the prices of the five life insurance output variables as the sum of premiums and investment income minus output for each line divided by output.²⁰ This is consistent with the “unit price” of insurance, from the insurance economics literature, which interprets price as the amount required to deliver one unit of benefits. For the price of the intermediation output proxied by invested assets, we need a measure of the expected rate of return on the insurer’s assets. Because the expected return on bonds and notes generally is close to the actual income return, we use the ratio of actual investment income (minus dividends on stocks) to insurer holdings of debt instruments to represent the rate of return on that component of the portfolio. For stocks, we compute the expected return for a specified year as the 30-day Treasury bill rate at the end of the preceding year plus the long-term (1926 to the end of the preceding year) average market risk premium on large company stocks from [Ibbotson Associates \(2011\)](#).²¹ The expected portfolio rate of return for each insurer is a weighted average of the debt and equity returns, weighted by the proportion of the portfolio invested in debt securities and stocks.

For P–L insurers, it is possible to develop practical measures of price and output that correspond closely to the theoretical measures discussed above. Specifically, our proxy for the quantity of risk-pooling and real insurance services is the present value of real losses incurred ([Berger et al. 1997](#); [Leverty and Grace 2010](#)). Losses incurred are the losses that are expected to be paid as the result of providing insurance coverage during a particular year.

Because the timing of the loss cash flows differs by line of P–L insurance, we use as separate output measures the present values of personal lines short-tail losses, personal lines long-tail losses, commercial lines short-tail losses, and commercial lines long-tail losses, where the tail refers to the length of the loss cash flow stream. Lines of business are classified as short and long-tail based on Schedule P of the NAIC P–L regulatory annual statement. Cash flow patterns are estimated from data in Schedule P using the Taylor separation method ([Taylor 2000](#)). Discounting is conducted using US Treasury yield curves obtained from the Federal Reserve Economic Database (FRED) (Federal Reserve Bank of St. Louis). Average real-invested assets are used to measure the quantity of the intermediation output for P–L insurers.

The prices of the P–L insurance outputs are defined similarly to the prices of the L–H insurance outputs as: $p_i = [P_i - PV(L_i)]/PV(L_i)$, where p_i is the price of output i , P_i = premiums in line i , L_i = incurred losses in line i , and PV is the present value operator. The present value of losses is used in computing the price because premiums reflect discounting of loss cash flows. Using present values of losses maintains consistency by recognizing the time value of money both in the premium and loss components of the price. Multiplying the price, p_i , by the quantity of output, $PV(L_i)$, gives the value-added from the i th insurance output. The price of the P–L intermediation output is defined analogously to the price of the life insurer intermediation output.

Losses incurred inevitably differ from the expected loss estimates that went into calculating the premiums for the coverage year because losses are random and loss realizations generally are more or less than the expected value of loss. This does not necessarily reflect a problem in accurately

²⁰Insurers are required to allocate investment income by line in their regulatory annual reports, and we use the reported allocations in defining output prices. Premiums plus investment income appears as line 9 in the Analysis of Operations by Line of Business in the NAIC annual regulatory statement.

²¹Using this approach assumes that insurers have equity portfolios with a beta coefficient of 1.0.

measuring output, because insurers have actually provided more (less) output than anticipated if losses are higher (lower) than expected.²² Nevertheless, the randomness does create a potential “errors in variables” problem in the measurement of output prices. Two primary methods have been adopted to deal with the errors in variables problem: (1) Smoothing of outputs and output prices. The smoothing is designed to average out extreme fluctuations in the loss data and to correct for price outliers that arise for small insurers or insurers with small amounts of outputs in certain lines of business. One such smoothing methodology, described in [Cummins and Xie \(2008\)](#), involves moving extreme values to percentiles (such as the 10th and 90th) in a systematic way. Although arguing that smoothing often is helpful to reduce noise in the data, [Cummins and Xie \(2008\)](#) find that the efficiency scores with the smoothed and non-smoothed data are highly correlated (correlations greater than 90% for most types of efficiency). (2) Testing robustness by using premiums instead of losses as output; or, more appropriately, premiums multiplied by the long-term, company-specific loss ratio as a proxy for expected losses.

28.4.2 Inputs and Input Prices

Insurer inputs can be classified into three principal groups: labor, business services and materials, and capital. For some applications it also may make sense to split labor into agent labor and all other (mostly home office) labor because the two types of labor have different prices and are used in different proportions by firms in the industry (e.g., some firms use direct marketing in whole or in part, while others rely heavily on agents). In addition, there are at least three types of capital that can be considered—physical capital, debt capital, and equity capital. Because physical capital expenditures are a small proportion of the total (see [Table 28.1](#)), they are often lumped together with business services and materials. Insurance efficiency studies rarely utilize more than four inputs.

Theoretically, it is important to include the prices of all inputs, which when multiplied by inputs, totally exhaust operating costs. It is misleading and incorrect to omit an input that accounts for a significant proportion of operating expenses. The cost of equity capital is implicit and is not reported as part of insurer operating costs. Rather, it is incorporated in stockholder dividends and capital gains which go into the return on equity to stockholders and in the policyholder dividends and gains in book value of equity for policyholders of mutuals. Nevertheless, because of the important role played by equity capital, both theoretically and quantitatively, it is important to include the cost of capital when estimating total insurer costs. As discussed further below, this has long been recognized in both insurance and banking (e.g., [Cummins and Weiss 1993, 2000](#); [Hughes and Mester 1998](#)). Total insurer expenses thus include operating costs plus the cost of capital.

Because physical measures of input quantities are not publicly available for insurers in most countries, the approach usually taken in insurance efficiency studies is to impute the quantity of physical inputs by dividing the relevant insurer expense item by a corresponding price index, wage rate, or other type of deflator. For example, the quantity of labor is often measured by dividing the total expenditures on labor, from the regulatory annual statement, by the wage rate, i.e.

$$Q_{L_t} = X_{L_t}^c / w_{L_t}^c \quad (28.27)$$

²²In fact, paying claims following adverse loss fluctuations from catastrophic events and unusual accumulations of non-catastrophe claims is an important function of insurance and should be counted as output. An insurer’s reputation for paying catastrophic claims will lead to higher prices and profits in normal periods, compensating investors for paying catastrophic losses.

where Q_L = quantity of labor in period t ,

w_L^c = current dollar hourly wages, and

X_L^c = current dollar expenditures on labor,

where the superscript c refers to current dollars. The price of labor is then obtained as

$$w_{L_t} = w_{L_t}^c / p_t. \quad (28.28)$$

where w_{L_t} = constant dollar wage rate and

p_t = the consumer price index (CPI).

Multiplying Q_L by w_L then gives constant dollar labor expense $X_L = X_L^c / p_t$, such that the product of the constant dollar input quantity vector and the constant dollar input price vector yields total constant dollar costs.

For US studies, the wage rate for administrative labor is usually measured for life insurers using US Department of Labor (DOL) data on average weekly wages for Standard Industrial Classification (SIC) class 6311 before 2001 and North American Industry Classification System (NAICS) class 524113 since 2001 and for P–L insurers using DOL data on SIC class 6331 before 2001 and NAICS class 524126 since 2001. The current price of agent labor is measured using the DOL average weekly wage rate for insurance agencies and brokerages (SIC class 6411 and NAICS class 524210). Because wages vary by state, the ideal administrative wage rate would be a weighted average based on the amount of work performed in various locations. However, to do this accurately would require data on the locations and relative sizes of the insurer's processing operations, which are not publicly available. Two approximations that are often used for administrative labor are the wage rate for the state in which the company maintains its home office and a weighted average wage rate using the proportions of premiums written by state as weights. Neither measure is completely satisfactory. Most insurers either conduct their operations from a single home office or rely on regional (not state) offices. However, robustness checks conducted in several efficiency studies reveal that neither the efficiency scores nor the efficiency rankings are significantly affected by the definition of this variable (e.g., [Cummins et al. 1999](#)). Our view is that it makes more sense to use the wage rate for the state where the home office is located rather than the premium-weighted-average wage rate.

For agent labor, a weighted average wage variable is often used, with weights equal to the proportion of an insurer's premiums written in each state. The weighted average approach is more appropriate for agent labor than for home office labor because most agency services are provided at the local level, whereas most of the other tasks performed by insurance company employees take place at the home office or in regional offices.

Because unit prices are not available for materials and business services per insurer, a price index is used, defined as $p_{M_t} = w_{M_t}^c / w_{M_0}^c$, where p_{M_t} = materials and business services price index, $w_{M_t}^c$ = the (unobserved) price of one unit of materials and business services in period t , and $w_{M_0}^c$ = the price of materials and business services in a base period ($t = 0$). Then the quantity of input is obtained as

$$Q_{M_t} = X_{M_t}^c / p_{M_t} = X_{M_t}^c / (w_{M_t}^c / w_{M_0}^c) \quad (28.29)$$

where Q_{M_t} = quantity of materials and business services and

$X_{M_t}^c$ = current dollar expenditures on materials and business services.

The price of materials and business services is defined as p_{M_t} / p_t . Multiplying price times quantity yields constant dollar expenditures on materials and business services, i.e., $X_{M_t} = X_{M_t}^c / p_t$. The price index p_{M_t} for the materials and business services input is calculated as a weighted average of price indices for business services from the component indices representing the various categories of expenditures from the expense page of *Best's Aggregates and Averages*. The component price indices are from the DOL and the US Department of Commerce, Bureau of Economic Analysis.

Financial equity capital is also viewed as an important input under the financial theory of insurance pricing, where insurance is viewed as risky debt (Cummins and Danzon 1997). Under this theory, insurance prices are discounted in the market to reflect the expected costs of insurer default. Better capitalized insurers should receive higher prices for their products than riskier insurers, other things equal, because more capital implies a higher probability that losses will be paid if higher than anticipated. If the ultimate output of the insurance firm is economic security, equity capital is a necessary input to bring the firm as close as possible to the typical insurance demand theory assumption that claims are paid with certainty. Financial equity capital is quantitatively quite important for insurers, as shown in Table 28.1. Thus, failure to recognize the cost of equity capital is likely to distort the results of efficiency estimation (Hughes and Mester 1998).

Because most insurance efficiency studies are based on book value data, the quantity of financial equity capital usually is measured by the average of the beginning and end-of-year equity capital, deflated by the CPI. In P–L insurance studies this is sometimes adjusted by an estimate of the equity in the unearned premium reserves and other statutory balance sheet categories such as non-admitted assets whose treatment under statutory accounting principles (SAP) is not consistent with generally accepted accounting principles (GAAP). In life insurance studies using US data, the asset valuation reserve is usually included in equity capital.

The ideal cost of capital measure is the expected market return on equity capital. However, expected market returns cannot be calculated for most insurers because the majority of insurers are not publicly traded. A good proxy for the expected return on equity is the size-adjusted capital asset pricing model expected return (Cummins and Xie 2008), based on data from Ibbotson Associates (2011).²³ The cost of capital for year t is calculated as the 30-day Treasury bill rate at the end of year $t-1$, plus the long-term (1926 to the end of year $t-1$) average market risk premium on large company stocks, plus the long-term (the 1926 through end of year $t-1$) average size premium from Ibbotson Associates.²⁴ Following Ibbotson, insurers are grouped into four size categories based on equity capital. The largest size category has no size premium. For each of the smaller size categories, the Ibbotson long-term average size premium is added to the large firm expected return to give the price of equity capital.²⁵ Another approach to estimating the cost of equity is to compute the cost of capital for publicly traded insurers using the Fama-French three-factor model (Cummins and Phillips 2005). The results are then

²³Some earlier chapters utilized book value measures of the cost of capital, e.g., the average book return on equity (ROE) (net income divided by policyholders surplus) for the 3 or 5 years prior to the year of analysis. One problem with this approach is that it reduces the number of years for which efficiencies can be calculated by requiring at least 3 years prior to the start of the first year of efficiency analysis to compute average ROE. Another problem is that realized ROE can be negative, whereas the ex ante ROE must be positive. An alternative approach to ROE estimation is to estimate a regression equation with realized ROE as the dependent variable and variables such as leverage, business mix, and asset mix as independent variables. The cost of capital for a given firm is then estimated by inputting the firm's values of the regressors into the estimated regression equation.

²⁴Using this approach implicitly assumes that insurers have equity portfolios with market betas of 1.0. This is reasonable given that insurers are conservative investors.

²⁵More specifically, the firms in the sample are first ranked by size decile based on book values of equity capital. Firms are then placed into the following four categories, following Ibbotson Associates (2011): large-cap = deciles 1 and 2 (the largest size deciles), mid-cap = deciles 3 through 5, small-cap = deciles 6 through 8, and micro-cap = deciles 9 and 10. The cost of capital is then calculated as: $R_{it} = R_{f,t-1} + \text{Risk Premium}_{t-1} + \text{Size Premium}_{i,t-1}$, where R_{it} = cost of capital for firm i in year t and $\text{Size Premium}_{i,t-1}$ = the size premium for firm i based on the capitalization category of the firm. Researchers also have estimated efficiencies omitting the size premium and assigning the same cost of capital to each firm in a given year. It is important to run sensitivity analysis to see if using the size premium produces results that yield different conclusions.

averaged by A.M. Best Company financial rating category, and costs of capital are assigned to non-traded firms based on their Best's ratings.²⁶

Therefore, in most US insurance efficiency studies, the inputs consist of (at least one type of) labor, materials and business services, and financial equity capital. The input prices are measured as explained above. Multiplying the input quantity and input price vectors equals estimated total costs, which include insurer operating costs plus the estimated cost of capital.²⁷ The overall expenditure on capital is measured by average financial capital during the year multiplied by a decimal fraction representing the cost of capital (such as 0.132, Table 28.1).

Some researchers have also used debt capital as an input, measured either by borrowed funds and deposits from reinsurers (Cummins and Rubio-Misas 2006) or by policy reserves (Leverty and Grace 2010). The rationale for the use of debt capital is that insurers raise debt capital by issuing insurance and annuity policies and then "intermediate" this capital into invested assets. The use of debt capital as an input thus parallels the use of deposits as inputs in banking studies. However, debt capital is not always used as an input in insurance or banking studies because reserves for insurers and deposits for banks have some characteristics of both inputs and outputs. Additional research is needed to determine the sensitivity of the efficiency estimates to the use of the debt capital input.

In cases where reserves are used as an input, reserves should be deflated by the CPI but the current interest rate should be used as the input price. If I_t^c = current dollar interest expense, then $I_t^c = R_t^c r_t$, where R_t^c = current dollar value of reserves and r_t = the cost of debt capital (current interest rate). Then, constant dollar interest expense is obtained as follows:

$$I_t = I_t^c / p_t = R_t^c r_t / p_t = R_t r_t \quad (28.30)$$

where I_t = constant dollar interest expense and R_t = constant dollar value of reserves.

The interest payment made to policyholders for the use of policyholder-supplied debt capital (i.e., the cost of this type of debt capital) is implicit in the premium and in the dividend payments made by insurers to policyholders. This required return is a function of the credit quality of the insurer. The cost of policyholder-supplied debt capital is usually estimated as the ratio of total expected investment income minus expected investment income attributed to equity capital divided by average policyholder-supplied debt capital (e.g., Berger et al. 1997). Expected investment income attributable to equity capital equals the expected rate of investment return multiplied by average equity capital for the year.²⁸ An alternative approach developed by Cummins et al. (2009) is to measure the debt price for each insurance firm as the annualized interest rate equivalent to the rate on the term structure corresponding to the firm's credit quality and with maturity equal to the effective duration of the insurer's liabilities. The credit quality term structures are obtained from Bloomberg, and insurer credit quality is measured by Best's ratings.

²⁶Some researchers have used inappropriate measures of the cost of equity capital. For example, Jeng et al. (2007) utilize the debt-to-equity ratio as the cost of capital. Even though the debt-to-equity ratio is likely to be *correlated with* the cost of capital, it is not a price variable. Using this variable is likely to distort the efficiency estimates and is difficult to rationalize given that much better proxies are readily available.

²⁷The sum of the non-equity expenditures, i.e., labor and materials, is measured so that it will equal total insurer operating costs as reported on the expense statement.

²⁸This is based on the argument that investors will not supply capital to an insurer unless they receive a market return equal to the amount they could receive by investing in an asset portfolio that replicates the insurer's portfolio plus a risk premium for any additional costs associated with committing capital to the insurance business.

28.5 A Survey of Insurance Efficiency Research

This section provides a comprehensive survey of the research on productivity and efficiency in the insurance industry, focusing on studies that utilize modern frontier efficiency methodologies.

28.5.1 Insurance Efficiency Studies: Empirical Overview

Cummins and Weiss (2000) review 21 insurance efficiency studies spanning the period 1983–1999. Based on a comprehensive literature search, we identified 53 additional studies released from 2000 to 2011. We divided these studies into two quality tiers — upper tier and lower tier — primarily based upon the journal where the studies were published,²⁹ resulting in the identification of 37 upper tier and 16 lower tier studies. Eleven of the lower tier studies were published in the *Geneva chapters: Issues and Practices*. Other lower tier journals included the *China Economic Review* and the *Review of Islamic Economics*. The most common journals for the upper tier chapters are the *Journal of Risk and Insurance* (9 chapters), the *Journal of Banking and Finance* (9 chapters), *Applied Economics* (3 chapters), and the *Journal of Productivity Analysis* (3 chapters). Fifteen journals were represented by at least one chapter in the upper tier. The upper tier studies from 2000 to 2011 are reviewed later in this chapter. A summary of the lower tier studies is presented in an Appendix available from the authors.

Insurance efficiency studies can be classified in several ways based on (1) the economic issue or hypotheses investigated; (2) industry segment analyzed—life, non-life, or both; (3) definitions of outputs; (4) definition of inputs; (5) country or countries and time period covered by the sample; and (6) estimation methodology—DEA, SFA, DFA, a combination of methodologies, or other estimation techniques. Table 28.2 summarizes the existing empirical studies in terms of the principal classifications. The table includes all studies identified in this research or in Cummins and Weiss (2000) for the period 1983–2011 and includes both upper tier and lower tier publications.

According to Table 28.2, the largest number of studies by hypothesis have analyzed organizational form or corporate governance (20 studies), with market structure and the general level of efficiency over time accounting for another 12 studies in each category. Regulatory change accounted for 6 studies, and 5 studies analyzed economies of scale and/or scope. Eight studies primarily analyzed methodological issues. In terms of estimation methodology, 44 of the studies (59.5%) utilized DEA either as the only estimation methodology (40 studies) or in combination with another methodology such as SFA or the range-adjusted measure (RAM), a non-radial type of DEA.³⁰ There were 28 non-life studies, 21 life insurance studies, and 20 studies that analyzed more than one industry segment. Thirty-five of the 74 studies analyzed the USA, and 8 studies utilized multi-country data (mostly European).

In terms of insurance output definitions, 45 of the studies (60.8%) used losses, benefits, or losses and reserves as the output measure, 11 (14.9 %) used premiums, 4 studies used the number of policies, and 1 study used both premiums and losses. Other output definitions were used in only eight studies. Therefore, it seems clear that researchers have converged towards the use of losses and/or benefits as the primary measure of output. As discussed above, this is consistent with the economic theory of insurance and also avoids the use of premiums, which represent price times quantity, not quantity

²⁹For books and working chapters, the classification was based on the authors' evaluation of the studies themselves.

³⁰Unlike standard DEA, RAM is non-radial in the sense that it does not preserve the mix between inputs in movements toward the frontier. RAM was introduced by Cooper et al. (1999). For a general discussion of non-radial measures, see Fried et al. (2008).

Table 28.2 Classification of insurance efficiency studies by type

| Breakdown of studies by topic | Number | Studies by methodology | Number |
|---|--------|-----------------------------|--------|
| Scale and scope | 5 | DEA | 40 |
| Organizational form, corporate governance | 20 | SFA | 19 |
| Distribution systems | 4 | DFA | 7 |
| Regulation change | 6 | RAM | 2 |
| Market structure | 12 | Thick frontier | 1 |
| Mergers and acquisitions | 4 | DEA and RAM | 1 |
| General level of efficiency over time | 12 | SFA and DEA | 3 |
| Intercountry efficiency comparisons | 3 | SFA and DFA | 1 |
| Methodology issues | 8 | Total | 74 |
| Total | 74 | | |
| Studies by industry segment | | Studies by insurance output | |
| Life | 21 | Losses/benefits | 36 |
| Nonlife/P-L | 28 | Premiums | 11 |
| Life and nonlife | 18 | Number of policies | 4 |
| Microinsurer | 1 | Premiums and losses | 1 |
| Life, nonlife, and composite | 2 | Reserves | 1 |
| Other | 4 | Losses and reserves | 9 |
| Total | 74 | Claims | 4 |
| | | Other | 8 |
| | | Total | 74 |
| Studies by country | | Studies by year | |
| US | 35 | Before 1990 | 2 |
| Spain | 4 | 1990 | 1 |
| Taiwan | 4 | 1991 | 2 |
| Austria | 2 | 1992 | 0 |
| China | 2 | 1993 | 4 |
| Germany | 2 | 1994 | 0 |
| Greece | 2 | 1995 | 1 |
| Italy | 2 | 1996 | 2 |
| Japan | 2 | 1997 | 5 |
| Netherlands | 2 | 1998 | 3 |
| Thailand | 2 | 1999 | 4 |
| UK | 2 | 2000 | 2 |
| Finland | 1 | 2001 | 1 |
| France | 1 | 2002 | 2 |
| Malaysia | 1 | 2003 | 1 |
| Portugal | 1 | 2004 | 4 |
| Turkey | 1 | 2005 | 5 |
| Multicountry (mostly Europe) | 8 | 2006 | 2 |
| Total | 74 | 2007 | 2 |
| | | 2008 | 4 |
| | | 2009 | 5 |
| | | 2010 | 9 |
| | | 2011 | 13 |
| | | Total | 74 |

Note: DEA = data envelopment analysis, SFA = stochastic frontier analysis, DFA = distribution free approach, RAM = range adjusted measure, P-L = property-liability.

(Yuengert 1993). On average, during the 1990s there were 2.2 studies per year, and after 1999 the average number of studies almost doubled to 4.2 studies per year.

28.5.2 *Review of Top Tier Studies: Issues/Hypotheses Investigated*

Table 28.3 summarizes the issues investigated in the top tier efficiency studies. This section briefly reviews the principal chapters. Table 28.3 excludes studies covered in Cummins and Weiss (2000). A summary of all existing studies through 2011 is available from the authors.

28.5.2.1 Economies of Scale and Scope

Economies of scale are present if average costs per unit of output decline as the volume of output increases. The usual source of scale economies is the spreading of the firm's fixed costs over a larger volume of output. Fixed costs are present for insurers due to the need for relatively fixed factors of production such as computer systems, managerial expertise, and financial capital. Economies of scale also can arise if operating at larger scale permits managers to become more specialized and therefore more proficient in carrying out specific tasks. Operating at larger scale can reduce the firm's cost of capital if income volatility is inversely related to size. This source of scale economies may be especially important in the insurance industry due to the risk-reducing impact of the law of large numbers in insurance risk pools.

However, expansion of the firm also has the potential to create inefficiencies. As a company expands, it may see the efficiency benefits gradually eroded with additional costs arising from management inefficiency and the decreasing productivity of variable inputs. Internal communication and control of large organizations require expensive systems and extra tiers in the hierarchical management structure, which can lead to higher costs. Larger organizations also have more potential to create managerial conflict and agency costs. On the other hand, technological progress may have made the optimal scale of firms in an industry larger than before. Therefore, it is important for a firm to achieve optimal scale to realize the objectives of minimizing costs and maximizing revenues.

Many insurance efficiency studies estimate scale economies as a natural by-product of efficiency estimation, particularly when DEA is the estimation technique. However, only a few studies have estimated scale economies as the primary objective of the chapter. Cummins and Xie (2013) conduct an extensive analysis of scale economies in the US P-L insurance industry from 1993 to 2009, estimating scale economies using DEA and productivity growth using Malmquist analysis. The results show that the majority of firms in the six smallest size deciles operate with IRS, while a majority of firms in the four largest deciles operate with DRS. However, at least 6% of firms in every size decile operate with CRS, showing that it is possible even for large firms to realize CRS. They also find that the P-L industry experienced significant gains in TFP and that there is an upward trend in scale and allocative efficiency. More diversified firms and stock insurers were more likely to achieve efficiency and productivity gains. Higher technology investment is positively related to efficiency and productivity improvements. Similar analyses of the US life insurance industry are presented in Cummins (1999) and Cummins et al. (1999).

Bikker and Leuvensteijn (2008) analyze scale economies for Dutch life insurers from 1995 to 2003, and Bikker and Gorter (2011) measure scale economies for Dutch non-life insurers for the period 1995–2005. Utilizing SFA and a translog cost function, Bikker and Leuvensteijn (2008) find substantial scale economies, which are more pronounced for smaller firms. However, all existing insurers are far below the estimated (theoretical) optimal size, so that further consolidation in the Dutch life insurance market might be beneficial. Apparently, competitive pressure in the insurance

Table 28.3 Issues and Hypotheses Investigated with Efficiency Analysis: 2000–2011

| Topic/Author | Country | Type of Institution | Issue/Hypothesis | Selected Findings |
|--|-------------|---------------------|---|--|
| Scale and Scope Economies Cummins and Xie (2013) <i>Journal of Productivity Analysis</i> , forthcoming | US | P–L | Examines efficiency, productivity and scale economies in insurance industry. | Industry had significant TFP gains with upward trend in scale and allocative effc. More diversified firms, stock insurers, and groups more likely to achieve effc. and prod. gains. Higher tech. inv. positively related to effc. and prod. improvements. |
| Cummins et al. (2010) <i>Journal of Banking and Finance</i> | US | Life & P–L | Uses DEA to measure scope economies Conglomeration versus Strategic Focus hypotheses tested. | P&L insurers realize cost economies but more than offset by revenue scope diseconomies. Life insurers, cost, and revenue scope diseconomies. |
| Kasman and Turgutlu (2009) <i>Applied Economics</i> | Turkey | Life/nonlife | Analyzes cost efficiency and scale economies over 15-year period. | Small firms more cost efficient than larger firms Significant scale econ present for all size classes. |
| Berger et al. (2000) <i>Journal of Financial Intermediation</i> | US | Life & P–L | New methodology to measure scope economies Conglomeration versus Strategic Focus hypotheses tested. | Traditional method to measure scope misleading. Conglomeration benefits for large, personal lines, vertically integrated, profit efficient firms. Strategic Focus benefits for small, commercial lines, non vertically integrated, profit efficient firms. |
| Organizational form, Corporate Governance | | | | |
| Bikker and Gorter (2011) <i>Journal of Risk and Insurance</i> | Netherlands | Nonlife | Organizational Form and Focus Strategies. | Large Cost X-Inefficiencies. Stocks and mutuals have comparative cost adv. More specialized insurers have lower costs. |
| Chen et al. (2011) <i>Geneva Risk and Insurance Review</i> | US | P–L | Evaluate efficiency performance pre and post demutualization and compare to control group. | Demutualizing insurers have larger gains in cost efficiency and total productivity change than mutual control group. Efficiency improves after conversion. |
| He et al. (2011) <i>Journal of Risk and Insurance</i> | US | P–L | Investigates efficiency effects of CEO turnover (both voluntary and involuntary turnovers). | Firms with CEO turnover, especially a nonroutine turnover have more favorable performance changes than firms without a CEO turnover. |

| | | | | |
|--|--------------|---------------------|---|---|
| <p>Huang et al. (2011) <i>Journal of Risk and Insurance</i></p> | <p>US</p> | <p>P-L</p> | <p>Examines relationship between corp. governance and efficiency.</p> | <p>Significant relationship between efficiency and corp. governance (e.g., board size, director tenure, etc.). After Sarbanes-Oxley insurers became less efficient when they had more independent auditors.</p> |
| <p>Leverly and Grace (2012) <i>Journal of Risk and Insurance</i></p> | <p>US</p> | <p>P-L</p> | <p>Determines the extent that firm efficiency is linked to managers.</p> | <p>Manager fixed effects are important determinant of firm efficiency. Superior managers able to remove firm from regulatory scrutiny sooner than relatively inferior managers. More efficient managers re-duce chance of insurer becoming insolvent.</p> |
| <p>Ethemjants and Leverty (2010) <i>Journal of Money, Credit, and Banking</i></p> | <p>US</p> | <p>Life</p> | <p>Explains why life insurance industry is now mostly stock. Also investigates whether motivation to convert differs by type of conversion.</p> | <p>Efficiency, access to capital and tax savings are important determinants of shift to stock org. form in life insurance industry. Efficiency of stock org. form dominates mutual structure during sample period.</p> |
| <p>Jeng et al. (2007) <i>Journal of Risk and Insurance</i></p> | <p>US</p> | <p>Life</p> | <p>Efficiency and productivity changes before and after demutualization.</p> | <p>No efficiency improvement after demutualization relative to stock control insurers. Using financial intermediary approach, mutual efficiency improves after demutualization but declines before demutualization.</p> |
| <p>Jeng and Lai (2005) <i>Journal of Risk and Insurance</i></p> | <p>Japan</p> | <p>Life</p> | <p>Examines efficiencies for keiretsu, nonspecialized indep. firms and specialized indep. firms.</p> | <p>Efficiencies for three types same except Keiretsu more cost efficient. Productivity changes deteriorate over period. Value-added and fin. intermediary approach provide complementary (different) results.</p> |
| <p>Cummins et al. (2004) <i>Journal of Banking and Finance</i></p> | <p>Spain</p> | <p>All Insurers</p> | <p>Analyzes effects of organizational structure on efficiency-tests efficient structure versus expense preference hypotheses.</p> | <p>Stocks and mutuals operate on separate cost and revenue frontiers. Overall results consistent with efficient structure hypothesis.</p> |
| <p>Distribution Systems Klumpes (2004) <i>Journal of Business</i></p> | <p>UK</p> | <p>Life</p> | <p>Test polarization reg. that required insurers to use one of two distribution systems.</p> | <p>Independent adviser firms less cost and profit efficient than firms using co. reps. to distribute. Supports market imperfection hypothesis and implies polarization worsened efficiency. Telemarketing not more efficient than agents.</p> |

(continued)

Table 28.3 (continued)

| Topic/author | Country | Type of institution | Issue/hypothesis | Selected findings |
|--|-----------------------|-----------------------|---|---|
| Regulatory change | | | | |
| Mahlberg and Url (2010) <i>Journal of Banking and Finance</i> | Germany | Life & P-L | Efficiency increases expected due to additional competition from Single Market. | Dispersion declines for efficiency scores. Fails to confirm β -convergence in TFP scores. |
| Cummins and Rubio-Misas (2006) <i>Journal of Money, Credit, and Banking</i> | Spain | Life & P-L | Investigate consolidation and deregulation from EU's Third Generation Insurance Directives. | Unit prices declined significantly in life and P&L. No. of firms operating with DRS increased Avg firm size increased 275%. |
| Ennsfellner et al. (2004) <i>Journal of Risk and Insurance</i> | Austria | Life & Health Nonlife | Uses Bayesian SFA. | Deregulation had positive impact on production efficiency. |
| Mahlberg and Url (MU) (2003) <i>Empirical Economics</i> | Austria | All Insurers | Measures effects of market liberalization on tech. effic. and productivity development. | Avg. firm cost cutting potential of 34% due to tech. effic. Another 35% could be saved by adjusting to right size. Single market likely responsible for decrease in dispersion of effic. scores and more homogeneous TFP in last years of sample. |
| Market Structure | | | | |
| Choi and Elyasiani (2011) <i>Applied Economics</i> | US | P-L | Test foreign owned insurer performance in US P&L insurance market. | Foreign firms less profitable and less revenue efficient and less cost scale efficient, but more cost efficient and revenue scale efficient. |
| Berry-Stölzle et al. (2011) Working paper, Temple University | 12 European Countries | Nonlife | Tests Structure-Conduct-Performance (SCP), Relative Market Power (RMP) and Efficient Structure (ES) Hypotheses. | Results support Efficient Structure Hyp. Little or no support for SCP and RMP. |
| Xie (2010) <i>Journal of Banking and Finance</i> | US | P-L | Analyzes performance of IPO firms with private firms as benchmark. | IPO firms have no post-issue underperformance in efficiency, operations or stock returns. IPO firms experience improvement in allocative and cost efficiency and reduce fin. leverage and reinsurance usage. |

| | | | | |
|---|------------------------------|---------------------------------------|--|--|
| <p>Bikker and Leuvensteijn (2008) <i>Applied Economics</i></p> | <p>Netherlands</p> | <p>Life</p> | <p>Efficiency and competition linked, high efficiency is sign of competition and vice-versa.</p> | <p>Results point to lack of competition. Consolidation might result in significant cost savings.</p> |
| <p>Fenn et al. (2008) <i>Journal of Banking and Finance</i></p> | <p>14 European Countries</p> | <p>Life and Nonlife and Composite</p> | <p>Investigates effect of firm size on scale econ. and effect of firm size and market structure on X-efficiency.</p> | <p>Larger firms with high market shares more efficient. Most European insurers have IRS.</p> |
| <p>Weiss and Choi (2008) <i>Journal of Banking and Finance</i></p> | <p>US</p> | <p>P-L</p> | <p>Tests Structure-Conduct-Performance (SCP), Relative Market Power (RMP) and Efficient Structure (ES) Hypotheses for competitive vs regulated states.</p> | <p>Insurers in competitive and non-stringently regulated states may have market power but more efficient. Insurers in some regulated states less revenue and cost scale efficient than for competitive states.</p> |
| <p>Choi and Weiss (2005) <i>Journal of Risk and Insurance</i></p> | <p>US</p> | <p>P-L</p> | <p>Tests Structure-Conduct-Performance (SCP), Relative Market Power (RMP) and Efficient Structure (ES) Hypotheses.</p> | <p>Supports Efficient Structure hypothesis. First study to use revenue efficiency in a market structure study.</p> |
| <p>Cummins and Nini (2002) <i>Journal of Financial Services Research</i></p> | <p>US</p> | <p>P-L</p> | <p>Investigates use of capital to determine whether it is inefficient or legitimate response to market conditions.</p> | <p>Most insurers significantly over-utilized capital, leading to significant revenue and cost of capital penalties for inefficient firms.</p> |
| <p>Ryan and Schellhorn (2000) <i>Journal of Insurance Regulation</i></p> | <p>US</p> | <p>Life</p> | <p>Impact of RBC implementation on life insurers.</p> | <p>Industry X-efficiency largely unchanged with RBC.</p> |
| <p>Mergers and acquisitions</p> | <p>US</p> | <p>P-L</p> | <p>Determine relevance of efficiency scores and test hypotheses from corporate control production theory using market value data.</p> | <p>Efficient acquirers and targets have higher cumulative abnormal returns (CARs) but inefficient divesting firms have higher CARs.</p> |
| <p>Cummins and Xie (2009) <i>Managerial Finance</i></p> | <p>US</p> | <p>P-L</p> | <p>Examines efficiency and productivity changes for acquirers, targets, and non M&A firms.</p> | <p>M&As in P&L insurance value enhancing role in M&A. Acquiring firms had higher rev. effic. than non-acq. Targets had greater cost and allocative effic. growth than non-targets.</p> |

(continued)

Table 28.3 (continued)

| Topic/author | Country | Type of institution | Issue/hypothesis | Selected findings |
|--|-----------------------|---------------------|---|--|
| Intercountry Efficiency Comparisons | | | | |
| Biener and Eling (2011) <i>Journal of Risk and Insurance</i> | Emerging Countries | Microinsurer | First study to measure efficiency performance of microinsurers. Includes social function output variable. | Diverse efficiency and TFP results. Overall positive TFP, esp. technology improvements. Mergers and growth could solve IRS Group policies more efficient than individual. |
| Eling and Luhnen (2010a) <i>Journal of Banking and Finance</i> | 36 Countries | Life and Nonlife | Large number of insurers from many countries analyzed, some for first time. | Steady tech. and cost effic. growth. Big differences among countries. Expense pref. hyp. not supported for mutuals. Minor variations between DEA and SFA results. |
| Diacon et al. (2002) <i>Geneva Papers on Risk and Insurance</i> | 15 European Countries | Long-term | International comparison of long-term insurers (i.e., life, pensions, and health). | Avg Technical effic. declined over period. Insurers in UK, Spain and Sweden tend to have above avg. technical efficiency, but UK insurers have low levels of scale and mix efficiency. |
| Methodology Issues or Comparison of Techniques and Assumptions | | | | |
| Leverly and Grace (2010) <i>Journal of Banking and Finance</i> | US | P-L | Tests value-added versus flow approach for output estimation. | Effic. firms less likely to become insolvent using value added, but more likely to become insolvent using flow approach. Validates losses as output measure. |
| Cummins et al. (2009) <i>Journal of Productivity Analysis</i> | US | P-L | Tests whether risk management and fin. intermediation enhance cost efficiency. | Shadow prices for risk management and fin. intermediation estimated. Risk mgt and fin intermediation enhance efficiency of P-L insurers. |
| Kao and Hwang (2008) <i>European Journal of Operational Research</i> | Taiwan | Nonlife | Modifies DEA model by taking into account the series relationship of two subprocesses within whole process. | Model used is more reliable in measuring Taiwanese nonlife insurer efficiency than DEA. |
| Brockett et al. (2005) <i>Journal of Risk and Insurance</i> | US | P-L | New DEA approach (RAM DEA) financial intermediary approach to measuring output. | Stocks more efficient than mutuals, agency more efficient than direct. |
| Fuentes et al. (2001) <i>Journal of Productivity Analysis</i> | Spain | All insurers | Estimates Malmquist index for deterministic and stochastic frontier approaches. | Low rates of productivity growth and technical change in spite of rapid deregulation and expansion of activity. |

market has so far been insufficient to force insurance firms to exploit these existing scale economies. Utilizing thick frontier analysis, [Bikker and Gorter \(2011\)](#) find that the majority of firms operate with IRS but that the largest Dutch non-life insurers face DRS. The results suggest that scale efficiency for Dutch non-life insurers did not improve on average over their sample period.³¹

[Kasman and Turgutlu \(2009\)](#) measure scale economies for the Turkish insurance industry over the period 1990–2004. Their estimation uses SFA with a translog cost function. They find that small firms are more efficient than large firms. However, they find evidence of economies of scale in all class sizes and find no evidence of scale diseconomies for any insurer size category. They conclude that the Turkish insurance industry operates at a scale “below technological possibility.” They argue that consolidation would improve efficiency and competitiveness in the industry.

The issue of scope economies is also important because of the increasing prevalence of cross-industry mergers involving life insurers, P–L insurers, and other financial institutions. Because scope economies are studied less frequently than scale economies, it is useful to define the concept. For simplicity, we focus on the case of firms that produce at most two outputs. Cost scope economies for the two output case are defined as follows:

$$S_C = [C(y_1, 0; w) + C(0, y_2; w) - C(y_1, y_2; w)]/C(y_1, y_2; w) \quad (28.31)$$

where S_C = cost scope economies; $C(\bullet)$ = the cost function; y_1, y_2 = outputs; and w = vector of input prices. If $S_C > 0$, *cost scope economies* are present, i.e., it is more costly for specialist firms to produce the two outputs separately than for a joint firm to produce both outputs; and if $S_C < 0$, *cost scope diseconomies* are present, i.e., separate production is more efficient. Whereas scale economies result from spreading fixed costs over higher output volume, scope cost economies arise due to *production complementarities*, i.e., the joint use of some or all inputs. For example, a firm that writes both life and P–L insurance needs only one prospect list, which can be used in producing both types of insurance. Executive talent and brand names are other resources that can give rise to production complementarities.

Revenue scope economies (S_R) are defined analogously using the revenue function, except that the revenues from specialized production are subtracted from the revenues from joint production in the numerator of the ratio. Therefore, if $S_R > 0$, *revenue scope economies* are present and a joint producing firm will earn higher revenues by producing outputs y_1 and y_2 than would be earned by specialist firms producing these outputs; and if $S_R < 0$, *revenue scope diseconomies* are present, and specialists earn more than joint producers. Revenue scope economies arise due to *consumption complementarities*, e.g., customers may be willing to pay more to a joint producer because of the value of convenience or lower search costs that arise from buying more than one product from the same producer. Revenue scope diseconomies could arise if specialists provide higher quality products than joint producers, for example, because they are better able to tailor products to customers' specific

³¹In thick frontier analysis (TFA), a frontier is estimated for the lowest cost quartile of firms. This lowest cost quartile is considered a “thick frontier,” in which it may be reasonably assumed that the firms are of greater than average efficiency ([Berger and Humphrey 1991](#)). A cost function is also estimated for the highest average cost quartile, in which it may be reasonably assumed that the firms are of less than average efficiency. The differences between these two cost functions are separated into “market factors,” which are explained by differences in the available exogenous variables, and an “inefficiency residual,” which cannot be explained. The inefficiency residual is then decomposed among several types of inefficiencies. The exact maintained assumptions necessary to yield the thick frontier approach are that the error terms within the lowest and highest cost quartiles reflect only random measurement error and luck, while the differences between the lowest and highest cost quartiles reflect only inefficiencies and market factors. TFA analysis has gone out of fashion. It places heavy demands on the data and is difficult to use for small samples because half of the observations are not used.

needs. Profit scope economies are defined analogously to revenue scope economies and represent the net effects of production and consumption complementarities.

Berger et al. (2000) analyze scope economies across the life and P–L segments of the US insurance industry, estimating cost, revenue, and profit scope economies. They analyze firms that produce both life and P–L insurance as well as life insurance specialists and P–L specialists.³² They test the *conglomeration hypothesis*, which holds that operating a broad range of businesses leads to cost scope economies through sharing inputs in joint production and/or revenue scope economies through providing “one-stop shopping” to consumers who are willing to pay for the extra convenience. The competing hypothesis is the *strategic focus hypothesis*, which holds that firms can maximize value by focusing on core businesses and core competencies. Under this hypothesis, conglomeration is viewed as reflecting agency problems and managerial opportunism.

Berger et al. (2000) utilize a modified composite functional form. The composite is useful for this purpose because it admits zero outputs, unlike the translog. It is also more flexible than alternative functions such as the normalized quadratic. Their estimated cost, revenue, and profit functions are used to estimate scope economies at the 25th, 50th, and 75th percentiles of the data. The results show evidence of statistically significant cost scope economies for firms at the 25th percentile, the median, and the 75th percentile. At the 25th percentile and the median, significant revenue scope diseconomies wipe out the cost economies, leading to zero profit scope economies. However, there are no revenue economies or diseconomies for firms at the 75th percentile so that cost scope economies translate into profit scope economies for these firms. Thus, the overall conclusion is that profit scope economies are more likely to be realized for large insurers.

Cummins et al. (2010) estimate scope economies for the US insurance industry over the period 1993–2006, testing the conglomeration and strategic focus hypotheses. They estimate technical, cost, revenue, and profit efficiency utilizing DEA and test for scope economies by regressing efficiency scores on an indicator variable for strategic focus and control variables. P–L insurers realize cost scope economies, but they are more than offset by revenue scope diseconomies. Life insurers realize both cost and revenue scope diseconomies. Hence, they conclude that strategic focus is superior to conglomeration in the insurance industry.

28.5.2.2 Organizational Form and Corporate Governance

The hypotheses analyzed most frequently using frontier efficiency analysis relate to organizational form and corporate governance. In a study that investigates several issues, Bikker and Gorter (2011) analyze the Dutch non-life insurance industry. They estimate a translog cost function and use TFA to estimate efficiency. They observe that the Dutch non-life insurance industry has undergone “fierce consolidation” since the adoption of the European Union’s Third Generation Insurance Directives in 1994, leading to increased strategic focus and declining market shares for mutuals. Regarding organizational form, they test the expense preference hypothesis versus the efficient structure hypothesis. The former hypothesis predicts that mutuals are generally less cost efficient than stocks as the mutual ownership form provides weaker mechanisms for controlling owner–manager conflicts. The efficient structure hypothesis posits that stocks and mutuals are relatively successful in lines of business where they have comparative advantages. Their results support the efficient structure hypothesis with no support for the expense preference hypothesis.

³²Berger et al. (2000) develop an alternative to the traditional scope economy measures. They estimate separate functions for joint producers and specialists in order to allow for differences in technology between joint producing and specializing firms. For their data, scope estimates are significantly different using the alternative approach.

The expense preference and efficient structure hypotheses also are investigated by [Cummins et al. \(2004\)](#). They estimate efficiency for Spanish life and non-life insurers over the sample period 1989–1997 using DEA. Following [Cummins et al. \(1999\)](#), they utilize cross-frontier analysis, whereby they compare each type of firm (stocks and mutuals) to a frontier consisting of the set of firms with the alternative organizational form. This enables them to determine whether the outputs of a specific firm type could be produced more efficiently using the alternative production technology. They find that stocks are dominant for producing stock output vectors, smaller mutuals are dominant for producing their own output vectors, but large mutuals are neither dominant nor dominated. Thus, the results support the efficient structure but not the expense preference hypothesis.

[Jeng and Lai \(2005\)](#) analyze the efficiency of Kereitsu firms, non-specialized independent firms, and specialized independent firms in Japan for the period 1985–1994, using DEA. They find that Kereitsu firms are more cost efficient than other types of firms but otherwise find no efficiency differences by organizational form.

Three of the top tier chapters ([Chen et al. 2011](#); [Ehremjamts and Leverty 2010](#); [Jeng et al. 2007](#)) study the efficiency effects of demutualization. [Chen et al. \(2011\)](#) study US P–L insurers over the period 1990–2001 using DEA and Malmquist analysis. They find that demutualizing insurers have larger gains in cost efficiency and higher TFP change than the mutual control group. [Ehremjamts and Leverty \(2010\)](#) analyze the US life insurers for the period 1995–2004 to explain why the life industry has become dominated by stock insurers. They find that operating efficiency, tax savings, and access to capital are important determinants of the shift, that efficiency improves after conversion, and that the stock organizational form dominates the mutual form in terms of efficiency. [Jeng et al. \(2007\)](#) analyze the US life insurance industry over the period 1979–2001 using DEA. They find no efficiency improvement for converting insurers relative to control stock insurers.

Two top tier chapters—[He et al. \(2011\)](#) and [Huang et al. \(2011\)](#)—investigate corporate governance issues. [He et al. \(2011\)](#) investigate the efficiency effects of CEO turnover in the US property–liability insurance industry over the period 1995–2006 using DEA. They find that firms with CEO turnover, especially non-routine turnover, have more cost and revenue efficiency gains than firms without CEO turnover. [Huang et al. \(2011\)](#) analyze US P–L insurers over the period 2000–2007, using DEA to evaluate the relationship between corporate governance and efficiency. They find a significant relationship between efficiency and corporate governance variables such as board size, proportion of independent directors on the audit committee, and proportion of insiders on the board. They find that insurers became less efficient after adding more independent auditors to comply with the Sarbanes-Oxley Act.

[Leverty and Grace \(2012\)](#) analyze the US property–liability insurance industry over the period 1989–2000 using DEA. The objective is to examine whether managers impact firm performance when their firm is in distress. They utilize a manager–firm matched dataset which allows them to track managers (CEOs) across different firms over time. They find that manager fixed effects are important determinants of firm efficiency. They also find that superior managers are able to remove their firms from regulatory scrutiny sooner than relatively inferior managers, and more efficient managers reduce the probability that the firm becomes insolvent.

28.5.2.3 Regulatory Change

Four chapters focus on regulatory change. [Mahlberg and Url \(MU\) \(2003\)](#) and [Ennsfellner, Lewis, and Anderson \(ELA\) \(2004\)](#) investigate the effects of the European Union’s (EU) deregulation and the creation of a single market on the Austrian insurance industry. MU analyze the sample period 1992–1999, and ELA analyze 1994–1999. MU utilize DEA and Malmquist analysis, and ELA use Bayesian stochastic frontiers. MU find that Austrian insurers still have significant inefficiencies, in spite of the introduction of the single market. However, there were significant reductions in dispersion

of efficiency scores and more homogeneous TFP following the introduction of the single market. ELA find strong evidence that deregulation had a positive impact on production efficiency of Austrian insurers.

Mahlberg and Uri (2010) analyze the German insurance industry over the period 1991–2006, using DEA and Malmquist analysis. They define a narrowing of the dispersion of DEA-efficiency scores over time as σ -convergence and the catch-up process of firms with very low initial productivity level as β -convergence. They find declines in dispersion of German efficiency scores after the introduction of the single market (σ -convergence) but find no evidence of β -convergence.

Cummins and Rubio-Misas (2006) analyze deregulation, consolidation, and efficiency of the Spanish insurance industry for the sample period 1989–1998, spanning the introduction of the Third Generation Insurance Directives. The results show that many small, inefficient, and financially underperforming firms were eliminated from the market due to insolvency or liquidation. As a result, the market experienced significant growth in TFP over the sample period. Consolidation not only reduced the number of firms operating with IRS but also increased the number operating with DRS, implying that many large firms should focus on improving efficiency rather than additional growth.

28.5.2.4 Market Structure

Six top tier chapters investigate various aspects of market structure. Choi and Elyasiani (2011) utilize SFA to analyze the US P–L insurance industry over the sample period 1992–2000 with the objective of testing the performance of foreign-owned insurers relative to domestically owned insurers. They find that foreign firms are less revenue efficient and less cost scale efficient but that they are more cost efficient and revenue scale efficient than domestically owned firms.

Weiss and Choi (2008) and Berry-Stölzle et al. (2011) test the structure–conduct–performance (SCP), relative market power (RMP), and efficient structure (ES) hypotheses. Weiss and Choi (2008) analyze US P–L insurers over the period 1992–1998, and Berry-Stölzle et al. (2011) analyze non-life insurers in twelve European countries for the period 2003–2007. Weiss and Choi (2008) utilize SFA, and Berry-Stölzle et al. (2011) use DEA. In Weiss and Choi (2008), the SCP hypothesis is not supported in competitive and non-stringently regulated states because price is not positively related to concentration in these states. The RMP hypothesis appears to be supported in these states because there is a positive association between market share and prices. However, the price effect is at least partially offset because market share is positively related to cost efficiency in this set of states, providing some support for the ES hypothesis. None of the hypotheses are supported for stringently regulated states. Berry-Stölzle et al. (2011) support the ES hypothesis but provide little or no support for SCP or RMP. An earlier chapter by Choi and Weiss (2005) also supports the ES hypothesis but not SCP or RMP.

Fenn et al. (2008) utilize SFA to estimate efficiency of life and non-life insurers in fourteen European countries for the sample period 1995–2001. They find that most European insurers were operating with increasing returns to scale and that larger firms and those with high market shares tend to have higher levels of cost inefficiency.

Xie (2010) studies the performance of publicly held firms in the US P–L insurance industry by analyzing companies that issued initial public offerings (IPOs) from 1994 to 2005, using private firms as the benchmark. She finds that the likelihood of an IPO significantly increases with firm size and premium growth. IPO firms experience no post-issue underperformance in efficiency, operations, or stock returns; register improvement in allocative and cost efficiency; and reduce financial leverage and reinsurance usage. The findings support the hypothesis that firms go public for easier access to capital and to ease capital constraints.

28.5.2.5 Mergers and Acquisitions

Cummins and Xie (2008) analyze the productivity and efficiency effects of M&As in the US P-L insurance industry during the period 1994–2003 using DEA and Malmquist indices. The results provide evidence that M&As in P-L in insurance were value-enhancing. Acquiring firms achieved more revenue efficiency gains than non-acquiring firms, and target firms experienced greater cost and allocative efficiency growth than non-targets. Financially vulnerable insurers are significantly more likely to become acquisition targets, consistent with corporate control theory. Cummins and Xie (2009) estimate efficiency for the US P-L insurance industry over the sample period 1995–2003 using DEA. The objective is to determine the market-value relevance of frontier efficiency scores and to test hypotheses from corporate control theory by analyzing the market response to P-L insurer acquisitions and divestitures (A&Ds). The market-value response to A&Ds is estimated using a standard market model event study. Regression analysis is used to measure the relationship between abnormal returns and efficiency. Acquirers, targets, and divesting firms all have significant positive abnormal returns around announcement dates. Efficient acquirers and targets have higher cumulative abnormal returns (CAR) and inefficient divesting firms have higher CARs. The findings suggest that insurance A&Ds are driven primarily by value-maximizing motivations. This is one of the few chapters that relate efficiency to market values.

28.5.2.6 Inter-country Efficiency Comparisons

Diacon et al. (2002) estimate pure technical, scale, and mix (allocative) efficiency for 450 insurers licensed in 15 European countries for the sample period 1996–1999 using DEA specified with VRS. The sample consists of companies writing “long-term” insurance, defined as life, pensions, and health business. The results indicate that insurers in the UK, Spain, Sweden, and Denmark have the highest average levels of technical efficiency. UK insurers appear to have particularly low levels of scale and allocative efficiency.

Eling and Luhnen (2010a) estimate technical and cost efficiency for both life and non-life insurance using a sample consisting of 6,462 insurers from 36 countries over the period 2002–2006. Both DEA and SFA are used. They find steady growth in technical and cost efficiency in international insurance markets from 2002–2006, with large differences across countries. Denmark and Japan have the highest average efficiency, whereas the Philippines is the least efficient. Regarding organizational form, the results are not consistent with the expense preference hypothesis. The SFA efficiency scores are higher than the DEA scores, but the economic implications of the results using the two methodologies are similar.

Biener and Eling (2011) analyze twenty microinsurers from a sample of emerging countries in Asia, Africa, and Latin America. Utilizing DEA and Malmquist analysis, they estimate technical, allocative, scale, and cost efficiency and TFP for the period 2004–2008. The analysis of TFP shows an overall positive development of productivity over the sample period. They find that large and for-profit microinsurers are best able to improve performance when focusing on the use of state-of-the-art technology, whereas concentrating on cost-minimizing input combinations is appropriate to bring about efficiency improvements for small and nonprofit microinsurers.

28.5.2.7 Methodology Issues

As reported in Table 28.2, the usual approach in insurance efficiency studies is to define outputs using losses, benefits, or reserves, consistent with the economic theory of insurance. However, Brockett et al. (2005) propose an output definition approach which they incorrectly call the “financial

intermediary” approach. As mentioned above, there is a financial intermediation approach to output definitions in the banking literature which is not the same as the approach outlined by Brockett et al. (2005). Therefore, in discussing this issue, we refer to the Brockett et al. (2005) approach as the “flow” approach, following Leverty and Grace (2010). Brockett et al. (2005) define three outputs for insurance companies—the rate of return on investments, the liquid assets to liabilities ratio (claims paying ability), and a solvency ratio (a measure of the firm’s probability of insolvency).

Although having favorable values for these ratios is “desirable” in some sense, they are not good output variables for several reasons. Most importantly, none of them measures the volume of output produced. It would be possible for a firm with billions of dollars of premiums, assets, and losses to have the same or similar values of these ratios as a firm with only a few million dollars of premiums, assets, or losses. Hence, in the flow approach, a large firm with the same financial ratios as a small firm would be measured as using significantly more resources to produce the same quantity of output. In addition, many financial ratios exist that are used to gauge various aspects of a firm’s financial status, and the three chosen by Brockett et al. are rather arbitrary and not necessarily the best financial ratios to measure firm attributes. The Brockett et al. (2005) output measures are really quality measures rather than output measures. Quality can be taken into account in efficiency analysis, but this should be done appropriately and not by eliminating all measures of output volume.

In an important chapter, Leverty and Grace (2010) conduct empirical tests of the Brockett et al. (2005) output measures versus the standard measures used in most of the insurance efficiency literature. Specifically, they investigate the *value-added* approach to defining outputs that is used predominantly in the literature vs. the “flow” approach proposed by Brockett et al. (2005). They test the two approaches to defining output by estimating efficiency for US P–L insurers using DEA for the period 1989–2000 and find that the two methods for measuring P–L insurer output are not mutually consistent—hypothesis tests using both approaches tend to provide contrasting results. The value-added efficiency results are strongly related to traditional measures of performance such as ROA and ROE, while flow efficiency results are not related to these measures. Moreover, firms identified as highly efficient by the value-added approach are less likely to fail, while firms with high flow efficiency are more likely to fail. Thus, Leverty and Grace (2010) demonstrate that if a requirement of an efficiency approach is that it is consistent with traditional measures of performance and accurately predicts firm financial weakness, the value-added approach is the appropriate measure for insurer efficiency. They also find that the theoretical concern regarding the value-added approach’s use of losses as a measure of output is not validated empirically.

Cummins et al. (2009) innovate by investigating the role of risk management and financial intermediation in creating value for insurers by analyzing the cost efficiency of US P–L insurers for the sample period 1995–2003. Risk management and financial intermediation are key activities for insurers and are treated as endogenous in their econometric model. However, because the prices of risk management and financial intermediation services are not observable, these two activities are considered intermediate outputs and their shadow prices are estimated using an econometric methodology developed in the exhaustible resources literature (e.g., Halvorsen and Smith 1991). The shadow prices are then used to isolate the contributions of risk management and financial intermediation to insurer cost efficiency. The results reveal positive shadow prices for both activities, meaning that most insurers could reduce costs by increasing these activities.

28.5.3 *Outputs, Inputs, and Prices*

The outputs and output prices used in the extant insurance efficiency studies released from 2005–2011 are summarized in Table 28.4. Because output prices are not used in studies that analyze only technical or cost efficiency, not all of the studies define output prices.

Table 28.4 Output Definitions in Insurance Efficiency Studies: 2005–2011

| Study | Output Volume | Output Price | Lines of Business |
|---|---|--|--|
| Biener and Eling (2011) <i>Journal of Risk and Insurance</i> | Real Incurred Benefits + Additions to Reserves (life) | Output price not used | Total Life |
| | Real Value of Total Investments No. People Insured Relative to Total Population | | |
| Bikker and Gorter (2011) <i>Journal of Risk and Insurance</i> | Real Value of Losses Incurred plus alternate measure: Premiums | Output price not used. | Fire Health Motor Transport Misc. |
| | Total Investments | | |
| Chen et al. (2011) <i>Geneva Risk and Insurance Review</i> | Real Incurred Losses | Output price not used. | S-T Personal P-L S-T Commercial P-L L-T Personal P-L L-T Commercial P-L |
| | Real Invested Assets | | |
| Choi and Elyasiani (2011) <i>Applied Economics</i> | Alternative: Change in Policyholders' Surplus, Capitalization ratio, Investment yield, Δ Net Premiums, Δ Invested Assets, Ratio of Liquid Assets to Liab. | Output price not used. | |
| | Real PV Losses Incurred | (Premium-PV Losses Incurred)/ PV Losses Incurred | S-T Personal P-L S-T Commercial P-L L-T Personal P-L L-T Commercial P-L |
| | Real Invested Assets | Expected ROE + Realized ROR on investments (net of equity) | |

(continued)

Table 28.4 (continued)

| Study | Output volume | Output price | Lines of business |
|--|--|--|---|
| He et al. (2011) <i>Journal of Risk and Insurance</i> | Real PV Losses Incurred | (Premium-PV losses incurred)/ PV losses incurred | S-T Personal P-L S-T Commercial P-L L-T Personal P-L L-T Commercial P-L |
| Huang et al. (2011) <i>Journal of Risk and Insurance</i> | Real Average Invested Assets | Weighted Avg. expected returns on stocks and realized returns on other interest bearing assets | S-T Personal P-L S-T Commercial P-L L-T Personal P-L L-T Commercial P-L |
| Huang et al. (2011) <i>Journal of Risk and Insurance</i> | Real Losses Incurred | Output price not used. | S-T Personal P-L S-T Commercial P-L L-T Personal P-L L-T Commercial P-L |
| Leverty and Grace (2012) <i>Journal of Risk and Insurance</i> | Real Invested Assets PV Real Losses Incurred | (Premium-PV Losses Incurred)/PV losses incurred | S-T Personal P-L S-T Commercial P-L L-T Personal P-L L-T Commercial P-L |
| Pottier (2011) <i>Journal of Regulatory Economics</i> | Average Real Invested Assets Net Incurred Claims + Add. To Reserves | Expected Rate of Return on Assets Total Rev.- Net Inv. income)/ (Net Incurred Claims + Add. to Reserves) | Individual life Group life Individual Annuities Group Annuities Accident and Health |
| | Invested Assets | (Net Inv. Income- Interest on Deposit Funds)/Invested Assets (by Line) | |
| | Deposit Funds | Fee on Deposit Funds/Deposit Funds | |

| | | | |
|--|---|---|--|
| <p>Berry-Stölzle et al. (2011), Working paper, University of Georgia</p> | <p>Real Incurred Losses Total Invested Assets Life Real Incurred Benefits + Additions to Reserves</p> | <p>(Premium-incurred losses)/incurred losses Realized Investment Income (Premium + Inv. Income-Output)/Output (by line)</p> | <p>Total Nonlife</p> |
| <p>Cummins et al. (2010), <i>Journal of Banking and Finance</i></p> | <p>P&L Real PV losses incurred</p> | <p>(Premium-PV Losses Incurred)/PV Losses Incurred (by line)</p> | <p>Individual Life Individual Annuities Group Life Group Annuities Accident and Health</p> |
| | <p>Real Avg. Invested Assets</p> | <p>Weighted Avg, Expected debt returns + expected equity returns</p> | <p>S-T Personal P-L S-T Commercial P-L L-T Personal P-L L-T Commercial P-L</p> |

(continued)

Table 28.4 (continued)

| Study | Output Volume | Output Price | Lines of Business |
|--|--|---|--|
| Cummins and Xie (2013) <i>Journal of Productivity Analysis</i> | PV losses incurred | (Premium-PV Losses Incurred)/(by line) | S-T Personal P-L S-T Commercial P-L L-T Personal P-L L-T Commercial P-L |
| Eling and Luhnen (2010a) <i>The Geneva Papers: Issues and Practices</i> | Real Avg. Invested Assets | Weighted Avg. Expected debt returns + expected equity returns | Total Life |
| | Real Net Incurred claims + Additions to Reserves (nonlife) | Output price not used. | Total Nonlife |
| | Real Net Incurred Benefits + Additions to Reserves (life) | | |
| Erhemjants and Leverty (2010) <i>Journal of Money, Credit and Banking</i> | Real Value of Investments | Output price not used. | Individual Life |
| | Incurred Benefits + Addition to Reserves | | Individual Annuities |
| | | | Group Life |
| | | | Group Annuities |
| | | | Accident and Health |
| Leverty and Grace (2010) <i>Journal of Banking and Finance</i> | Real PV Real Losses Incurred | (Premium-PV Losses Incurred)/PV Losses Incurred | S-T Personal P-L |
| | | 3 Yr Avg Loss Ratio * Premium (as alternate price) | S-T Commercial P-L |
| | | | L-T Personal P-L |
| | | | L-T Commercial P-L |
| | Real Avg. invested assets | Real Expected ROR on Assets | |

| | | | |
|--|--|--|--|
| <p>Mahlberg and Uri (2010) <i>Journal of Banking and Finance</i></p> | <p>Real Life Net Benefits Incurred + Additions to Reserves Real life Policy Reserves</p> <p>Real Nonlife Net Losses Incurred + Add. to Reserves Real Nonlife Policy Reserves</p> <p>Real Exp Income from fin assets</p> <p>Real PV losses incurred</p> <p>Real Avg. Invested Assets</p> <p>Real PV losses incurred</p> <p>Intermediation (intermediate) Risk management (intermediate)</p> | <p>Real Unit price of Life Insurance Real Unit price of life insurance</p> <p>Real Unit price of nonlife insurance Real Unit price of nonlife insurance</p> <p>Real return on Long-term Bonds (Premium-PV Losses Incurred)/PV Losses Incurred</p> <p>Wgt avg. exp return on equities and realized ROR for other assets (Premium-PV losses incurred)/PV losses incurred</p> | <p>Total Life</p> <p>Total Nonlife</p> <p>S-T Personal P-L S-T Commercial P-L L-T Personal P-L L-T Commercial P-L</p> <p>S-T personal P-L S-T commercial P-L L-T personal P-L L-T commercial P-L</p> |
| <p>Xie (2010) <i>Journal of Banking and Finance</i></p> | | | |
| <p>Cummins et al. (2009), <i>Journal of Productivity Analysis</i></p> | | | |

(continued)

Table 28.4 (continued)

| Study | Output Volume | Output Price | Lines of Business |
|---|---|--|--|
| Cummins and Xie (2009) <i>Managerial Finance</i> | Real PV losses incurred | (Premium-PV losses incurred)/PV Losses Incurred | S-T Personal P-L S-T Commercial P-L L-T Personal P-L L-T Commercial P-L |
| Kasman and Turgutlu (2009) <i>Applied Economics</i> | Real Average Invested Assets (Losses Pd/Benefits Incurred) + Additions to Reserves | Wgt avg. exp return on equities & realized ROR for other assets Output price not used | Total Life and Nonlife |
| Bikker and Leuvensteijn (2008) <i>Applied Economics</i> | Real Invested Assets Annual Premiums No. of Policies Outstanding Total Insured Capital Sum Total of Insured Annuities Unit Linked Funds Policies Real PV Losses Incurred (some smoothing) | Output price not used. | Total Life |
| Cummins and Xie (2008) <i>Journal of Banking and Finance</i> | Real Avg. Invested Assets (avg. beg and end of year) | (Premium-PV Losses Incurred)/PV Losses Incurred Wgt avg. exp return on equities & realized ROR for other assets | S-T Personal P-L S-T Commercial P-L L-T Personal P-L L-T Commercial P-L |
| Fenn et al. (2008) <i>Journal of Banking and Finance</i> | Net Incurred Claims-Life | Output price not used. | Total Life |
| Kao and Hwang (2008) <i>European Journal of Operational Research</i> | Net Incurred Claims-Nonlife Underwriting Profit Investment Profit Direct Prem. Writ. (Intermediate) Reins. Premiums (Intermediate) | Output price not used | Total Nonlife Total Nonlife |

| | | | |
|---|---|---|--|
| Weiss and Choi (2008) <i>Journal of Banking and Finance</i> | Real PV Losses Incurred | (Premium-PV Incurred Loss)/PV Incurred Loss | S-T Personal P-L S-T Commercial P-L L-T Personal P-L L-T Commercial P-L |
| Jeng et al. (2007), <i>Journal of Risk and Insurance</i> | Real Invested Assets | Exp return on equities + realized ROR for other invested assets | Death Benefits Annuity Benefits Surrender Benefits Accident and Health Total Life Total Nonlife |
| Cummins and Rubio-Misas (2006), <i>Journal of Money, Credit and Banking</i> | Real P&L Losses Incurred Real Life Benefits Incurred Real Value Reins. Reserves Real Value Primary Ins. Reserves | Output price not used | Total P-L |
| Brockett et al. (2005) <i>Journal of Risk and Insurance</i> | Propensity for Solvency Liquid Assets/Liabilities Return on invested Assets Real PV Losses Incurred | Output price not used | S-T Personal P-L S-T Commercial P-L L-T Personal P-L L-T Commercial P-L |
| Jeng and Lai (2005) <i>Journal of Risk and Insurance</i> | Real Invested Assets Number of Policies Real Invested Assets | Exp Return on equities + realized ROR for other invested assets Output price not used. | Short-tail Lines Long-tail Lines Savings Type Lines |

Note: L-T = long-tail, S-T = short-tail, P-L = property-liability, PV = present value.

Losses, benefits, and reserves tend to be the most common measures chosen to represent insurance outputs. However, for countries other than the USA, output definitions are often driven by the data reported by insurers. Losses by line are not always available, leading some authors to utilize other variables such as premiums. Other variables also have been used. For example, [Jeng and Lai \(2005\)](#) in their study of Japanese insurers, use number of policies as an output measure. To represent the intermediation function, assets or invested assets is often used, although life insurance studies in the USA tend to use additions to reserves. The use of ratios such as the liquidity ratio, solvency ratio, and return on assets has not caught on, primarily because such variables do not measure output volume.

In measuring insurance output prices, the most common approach is to utilize a value-added definition of price equal to premiums minus output divided by output. For the price of the intermediation output, the usual approach is to utilize a weighted average of the expected return on stocks and the realized return on other investments. The expected return on stocks is usually estimated as the Treasury bill rate at the end of the prior year plus the long-term average risk premium on large company stocks from a source such as [Ibbotson Associates \(2011\)](#).

The inputs utilized in insurance efficiency studies released from 2005 to 2011 are summarized in [Table 28.5](#). As with outputs, the choice of inputs tends to be influenced by corporate reporting practices across countries. However, there is a high degree of uniformity in the inputs utilized in insurance efficiency studies. Out of the 29 studies summarized in [Table 28.5](#), 26 utilize equity capital as an input, and one additional study uses the sum of equity and debt capital. Debt capital is used as an input in 13 studies. Twenty-six studies utilize either a single labor input (10 studies) or agent and administrative labor as separate categories (16 studies). Twenty studies utilize materials and business services as an input. The most common set of inputs consists of administrative (home office) labor, agent labor, equity capital, and materials and business services.

As input prices, most US studies utilize insurance industry average weekly wages from the US Department of Labor, Bureau of Labor Statistics as input prices.³³ For non-US studies, researchers tend to use an insurance sector wage variable, where available, or a broader wage rate or index of labor costs if sectoral variables are not available. In US studies, a common approach for business services is to use a weighted average price index for various categories of nonlabor expenditures where the weights are taken from the expense page of the NAIC annual statement.³⁴ Another common approach is to utilize average weekly wages for SIC sector 73, business services. The corresponding NAICS sectors are 54 (Professional, Scientific, and Technical Services), 55 (Management of Companies and Enterprises), and 561 (Administrative and Support Services).

There is more diversity in the price of the equity capital input. The most prevalent approach both in US and non-US studies is to utilize an asset pricing model approach which estimates the cost of capital as the sum of a short-term interest rate plus an estimated expected market risk premium or premia. The most basic approach is to add a Treasury bill rate such as the 30 or 90-day rate to the average market risk premium on large company stocks, obtained from a source such as [Ibbotson Associates \(2011\)](#). The expected rate of return is sometimes adjusted for company market capitalization size quartile, again based on data from Ibbotson. Another approach used in several studies is to estimate the cost of capital using the Fama-French three-factor model for traded insurers (see [Cummins and Phillips 2005](#)), to tabulate the results by A.M. Best financial rating category, and then assign costs of capital to non-traded insurers based on their Best's ratings. For countries where market risk premium data are not readily available, an approach often adopted is to utilize the long-term (5, 10, or 20 year) average return on the country's principal stock index (e.g., [Bikker and Gorter 2011](#)). Some studies utilize book value equity return data to estimate the cost of capital. The best approach when adopting this method is

³³The appropriate SIC and NAICS categories for wages are discussed above in [Sect. 28.4.2](#).

³⁴For property-liability insurance, the expense page is the Underwriting and Investment Exhibit: Part 3— Expenses; and for life insurers, it is Exhibit 2—General Expenses.

Table 28.5 Inputs Used in Insurance Efficiency Research: 2005–2011

| Study | Input Type | Input Volume | Input Price |
|--|-----------------------------|--|--|
| Biener and Eling (2011) <i>Journal of Risk and Insurance</i> | Labor and business services | Operating expenses | Wage index from ILO main statistics, October inquiry |
| | Debt capital | Debt capital | J.P. Morgan emerging markets bond indices |
| | Equity capital | Equity capital | Total return of regional Morgan Stanley Capital Int'l emerging markets indices |
| Bikker and Gorter (2011) <i>Journal of Risk and Insurance</i> | Labor | Expenses | Uses avg. labor cost for Dutch ins. sector |
| | Financial Equity capital | Financial equity capital | Total Return on Amsterdam Stock Exchange (AEX) index (10 yr rolling avg) |
| | Debt capital | Debt capital | One year Dutch treasury bill rate |
| Chen et al. (2011)^a <i>Geneva Risk and Insurance Review</i> | Equity capital | Surplus | Debt to equity ratio |
| | Debt capital | Funds borrowed from policyholders | Total expected inv. income divided by avg. debt capital |
| | Administrative labor | Labor expense | Index avg weekly wages in Home State, SIC 6331 |
| Choi and Elyasiani (2011) <i>Applied Economics</i> | Agent labor | Agent expense | Index avg weekly wages for agent, SIC 6411 |
| | Materials | Materials expense | GDP deflator for business services |
| | Equity capital | Surplus (with adjustments) | Based on ROE regression |
| He et al. (2011) <i>Journal of Risk and Insurance</i> | Administrative labor | Expenditure on administrative labor | Avg weekly wage for SIC 6331/NAICS 524126 |
| | Agent labor | Expenditure on agent labor | Avg weekly wage for SIC 6411/NAICS 524210 |
| | Materials and bus. services | Expenditure on materials | Weighted avg. of price indices for bus. services for expense components from <i>Best's Aggregates & Averages</i> |
| | Financial equity capital | Average real surplus | Cost of capital by Best's rating category from Fama-French 3 factor model, estimated for publicly traded insurers |
| Huang et al. (2011) <i>Journal of Risk and Insurance</i> | Labor Business services | Labor cost | Labor index for avg. weekly wages for NAICS 524126 |
| | Equity capital | Agents costs + loss adj. expenses Surplus | Labor index of avg weekly wages for NAICS 54 Debt/equity in $t - 1$ |

(continued)

Table 28.5 (continued)

| Study | Input Type | Input Volume | Input Price |
|--|-----------------------------|--|--|
| Leverly and Grace (2012) <i>Journal of Risk and Insurance</i> | Administrative labor | Expenditure on administrative labor | Avg weekly wage of insurer's home office, SIC 6331 |
| | Agent labor | Expenditure on agent labor | Avg weekly wage rate for insurance agents, SIC 6411 |
| | Materials and bus. services | Expenditure on materials and bus serv | Avg weekly wage rate for business services, SIC 7300 |
| | Policyholder debt capital | Real loss reserves and real unearned | Total inv. income minus expected inv. income from equity divided by avg policyholder debt capital |
| | Financial equity capital | Premium Reserves | Avg 90 day T-Bill rate in year t plus long-term |
| Pottier (2011) <i>Journal of Regulatory Economics</i> | Home office labor | Average real surplus | Avg market risk premium on large Co. stocks |
| | Agent labor | Labor expense | Based on avg weekly earnings for L-H insurers |
| | Policyholder capital | Agent expense | Based on avg. weekly earnings for ins agencies |
| | Equity capital | Policy reserves + deposit funds | 4% 2005 1 year treasury rate plus long-horizon equity risk premium |
| | Equity Debt | Avg beg. and end of year value of capital and surplus | Expected ROE from regression |
| Berry-Stölzle et al. (2011) Working paper, University of Georgia | Equity | Surplus | Short-term risk-free rate |
| | Debt | Technical provisions | |
| | Administrative labor | Labor expenses | Average weekly wage rates for NAICS 524113 for L-H Insurers and 524126 for P-L insurers |
| | Agent labor | Agent expenses | Average weekly wage rates for NAICS 524210 agencies |
| | Materials Equity | Materials expenses | Weighted avg of price indices for non-wage expenses |
| Cummins and Xie (2013) <i>Journal of Productivity Analysis</i> | Equity | Real avg beg. and end of year Surplus (with adjustments) | Real 30 day T-bill rate from t-1 + long term avg. Market risk prem. on large co. stocks + size premium |
| | Administrative labor | Administrative labor expenses | Nat'l avg. weekly wage rate for SIC 6331 |
| | Agent labor | Agent labor expenses | Nat'l avg. weekly wage rate for SIC 6411 |
| | Business services | Business services expenses | Weighted Avg. of price indices for bus. services for expense components from <i>Best's Aggregates & Averages</i> |
| | Equity capital | Real avg beg. and end of year Surplus (with adjustments) | Fama-French 3 factor cost of capital estimated for traded Insurers, assigned to non-traded based on Best's ratings |

| | | | |
|--|---|---|--|
| <p>Eling and Luhmen (2010a) <i>Geneva Papers: Issues and Practices</i> Erhemjams and Leverty (2010) <i>Journal of Money, Credit, and Banking</i> Leverty and Grace (2010) <i>Journal of Banking and Finance</i></p> | <p>Debt capital Equity capital Labor Business services Policyholder debt capital Financial equity capital Administrative labor Agent labor Business services Equity Debt</p> | <p>Debt (policyholder) capital Equity (surplus) capital Consistent with prior literature</p> <p>Labor expense Agent expense Bus. services expenses Equity capital (surplus) Average policyholder debt capital</p> | <p>One year treasury bill rates (by country, by year) Return on MSCI stock market Index, by country, year Consistent with prior literature</p> <p>Avg weekly wage SIC 6331 Avg weekly wage SIC 6411 Avg weekly wage SIC 7300 90-day T-bill rate + long-term avg market Risk premium on large co. stocks (Expected investment income minus Inv. income for equity capital)/avg PH debt capital</p> |
| <p>Mahlberg and Uri (2010) <i>Journal of Banking and Finance</i></p> | <p>Adm. and distribution Debt capital Equity capital</p> | <p>Administrative and distribution costs Prov. for future tax payments or firm Pensions + Borrowings Equity capital</p> | <p>Deflator for financial business services Germany 1-year T-bill Rate Germany</p> <p>3 Mo. Money Market rate $t - 1$ + long-term equity prem. for German stocks</p> |
| <p>Xie (2010) <i>Journal of Banking and Finance</i></p> | <p>Administrative labor Agent labor Business services</p> | <p>Labor expense Agent expense Business services expense</p> | <p>Avg weekly wage SIC 6331 Avg weekly wage SIC 6411 Weighted avg of price indices for bus. serv. Based on total industry expenses by year Size adjusted CAPM</p> |
| <p>Cummins et al. (2009) <i>Journal of Productivity Analysis</i></p> | <p>Equity capital Administrative labor Agent labor Risk labor Materials/ bus. services</p> | <p>Average real equity capital Input volumes not used.</p> | <p>Avg weekly wages for Home Office State, SIC 6311 Wgtd avg. weekly wages for agents, SIC 6441 Avg. weekly wages from Home Office State, NAICS 52392 (Portfolio Management) Avg. weekly wages from Home Office State Bus. services-SIC 7300</p> |
| | <p>Debt Equity</p> | <p>Required return by policyholder, given insurer credit quality and liability duration Based on Fama-French 3 Factor Model</p> | |

(continued)

Table 28.5 (continued)

| Study | Input Type | Input Volume | Input Price |
|---|-------------------------|---|--|
| Cummins and Xie (2009) <i>Managerial Finance</i> | Administrative labor | Expenditure for labor | Avg. weekly wage rate for SIC 6331/NAICS 524126 |
| | Agent labor | Expenditure for agents | Avg weekly wage rate for SIC 6411/NAICS 524210 |
| | Materials/bus. services | Expenditure for materials and business services | Weighted avg. of price indices for bus. services for expense components from <i>Best's Aggregates & Averages</i> |
| | Financial equity | Average real surplus | Real 30 day T-bill rate from $t - 1 +$ long term avg. Market risk prem. on large co. stocks + size premium |
| Kasman and Turgutlu (2009) <i>Applied Economics</i> | Labor | Number staff employed | Real personnel Mgmt exp/No. staff (Gen'l exp personnel/Mgmt exp.)/total assets |
| | Business services | Sum of policyholder and equity capital | One year treasury bill rate |
| | Financial capital | Acquisition costs | Acquisition costs/total assets |
| | Acquisition Other | Other costs | Other costs/total assets |
| | Home Office labor | Home Office labor expense | Avg weekly wages for Home Office State, SIC 6331 |
| | Agent labor | Agent expense | Wgt. avg. of avg. weekly wages for agents, SIC 6411 |
| | Business services | Business services expense | Wgt. avg. of price indices for non-wage expenses |
| | Equity capital | Real Equity (average surplus) | Real 30 day T-bill rate from $t - 1 +$ long term avg. market risk prem. on large co. stocks + size premium |
| | Labor | Input volumes not used. | Insurance wage index |
| | Debt (Borrowing) | | ROR on long-term gov't bond |
| Equity | | Fixed input | |
| Technical reserves | | Fixed input | |
| Fenn et al. (2008) <i>Journal of Banking and Finance</i> | | | |
| | | | |

| | | | |
|---|---|--|--|
| Kao and Hwang (2008) <i>European Journal of Operational Research</i> | Operations Insurance | Operational exp.(salaries + operations) Insurance expense (acq. cost) | Input prices not used. |
| Weiss and Choi (2008) <i>Journal of Banking and Finance</i> | Labor Agent Materials Equity | Labor exp./ins. wage deflator Agent exp./agent wage deflator Materials exp./materials deflator Real equity (surplus) | Avg weekly wage rate SIC 6331 Avg weekly wage rate SIC 6411 Avg weekly wage rate SIC 7300 Expected ROE from regression analysis |
| Jeng et al. (2007) <i>Journal of Risk and Insurance</i> | Labor Business services Equity capital Labor | Commissions Business services Equity (book value) Labor expense | Wage deflator for SIC 6411 Wage deflator for SIC 7300 Debt/equity ratio for firm Avg. wage index for Spanish service sector |
| Cummins and Rubio-Misas (2006) <i>Journal of Money, Credit, and Banking</i> | Business services Debt Equity capital | Business services expense Borrowing and deposits Equity capital | Business services deflator (Spain) One-year Spanish treasury bill rate Total return on Madrid stock exchange index Input prices not used. |
| Brockett et al. (2005) <i>Journal of Risk and Insurance</i> | Surplus Change in capital Underwriting + inv. expense Policyholder capital Labor Agent Materials Equity | Surplus Change in capital Underwriting + inv. expense Policyholder capital Labor expense Agent expense Materials expense Real equity (surplus) | Avg weekly wage rate SIC 6331 Avg weekly wage rate SIC 6411 Avg weekly wage rate SIC 7300 Expected ROE from regression analysis |
| Jeng and Lai (2005) <i>Journal of Risk and Insurance</i> | Labor Business services Capital (debt + equity) | Number of personnel Number of policies Real debt + equity capital | Real personnel expenses per person Real service expense per policy (Real underwriting and investment profit)/(debt + equity) |

^a Also estimate efficiency using an alternative set of inputs.

Note: L-H = life health, P-L = property-liability, PH = policyholder, UPR = unearned premium reserve.

Table 28.6 Insurance Efficiency Studies-Methodologies and Average Efficiencies: 2004–2011

| Study | Country | Method | Efficiency Type | Type of Institution | Sample Period | No. of Insurers/year | Avg Efficiency Per Year |
|------------------------------------|--|----------------|--|--|--|--|--|
| Biener and Eling (2011) | Sample of emerging countries in Asia, Africa and Latin America | DEA | Technical Allocative Cost Scale | Microinsurer Microinsurer Microinsurer | 2004-2008 2004-2008 2004-2008 | 15 15 15 | 0.850 0.710 0.600 |
| Bikker and Gorter (2011) | Netherlands | Thick Frontier | Cost Scale | Nonlife Nonlife | 2004-2008 1995-2005 1995-2005 | 15 195 195 | Mostly IRS 0.170 0.930 |
| Chen et al. (2011) | US | DEA | Technical Allocative | P-L P-L | 1990-2001 1990-2001 | 540 540 | 0.964 0.892 |
| Choi and Elyasiyani (2011) | US | SFA | Cost Cost scale Revenue Rev. scale | P-L P-L P-L P-L | 1992-2000 1992-2000 1992-2000 1992-2000 | 2,881 2,881 2,881 2,881 | 0.798 0.874 0.730 0.910 |
| He et al. (2011) | US | DEA | Cost eff. chg Rev. eff. chg | P-L P-L | 1995-2006 1995-2006 | 557 557 | 1.037 0.998 |
| Huang et al. (2011) | US | DEA | Technical | P-L | 2000-2007 | 28 | 0.904 |
| Leverly and Grace (2012) | US | DEA | Cost | P-L | 2000-2007 | 28 | 0.799 |
| | | DEA | Cost | P-L | 1989-2000 | 1,018 | 0.352 |
| | | DEA | Scale | P-L | 1989-2000 | 1,018 | 0.898 |
| | | DEA | Pure tech. | P-L | 1989-2000 | 1,018 | 0.667 |
| | | DEA | Allocative | P-L | 1989-2000 | 1,018 | 0.590 |
| | | DEA | Revenue | P-L | 1989-2000 | 1,018 | 0.242 |
| Pottier (2011) | US | DEA | Cost Revenue Profit | Life Life Life | 2005 2005 2005 | 277 277 277 | 0.662 0.432 0.649 |
| Berry-Stölzle et al. (2011) | 12 mostly European | DEA | Cost Cost Scale Revenue Rev. scale | Nonlife Nonlife Nonlife Nonlife | 2003-2007 2003-2007 2003-2007 2003-2007 | 319 319 319 319 | 0.368 0.859 0.491 0.862 |
| Cummins et al. (2010) | US | DEA | Cost Revenue Profit Cost Revenue Profit | P-L P-L P-L P-L P-L P-L | 1993-2006 1993-2006 1993-2006 1993-2006 1993-2006 1993-2006 | 719 719 719 325 325 325 | 0.426 0.339 1.025 0.323 0.320 1.861 |

| | | | | | | | |
|--------------------------|--------------|---------|------------|------------------|-----------|-------|-------|
| Cummins and Xie (2013) | US | DEA | Cost | P-L | 1993-2006 | 784 | 0.510 |
| | | DEA | Pure tech. | P-L | 1993-2006 | 785 | 0.750 |
| | | DEA | Scale | P-L | 1993-2006 | 786 | 0.890 |
| | | DEA | Allocative | P-L | 1993-2006 | 787 | 0.770 |
| | | DEA | Revenue | P-L | 1993-2006 | 788 | 0.440 |
| Eling and Luhnen (2010a) | 36 countries | DEA | Technical | Life | 2002-2006 | 1,735 | 0.710 |
| | | DEA | Cost | Life | 2002-2006 | 1,735 | 0.380 |
| | | DEA | Technical | Nonlife | 2002-2006 | 3,566 | 0.500 |
| | | DEA | Cost | Nonlife | 2002-2006 | 3,566 | 0.590 |
| | | SFA | Technical | Life | 2002-2006 | 1,735 | 0.840 |
| | | SFA | Cost | Life | 2002-2006 | 1,735 | 0.590 |
| | | SFA | Technical | Nonlife | 2002-2006 | 3,566 | 0.810 |
| | | SFA | Cost | Nonlife | 2002-2006 | 3,566 | 0.740 |
| | | DEA | Technical | Life | 1995-2004 | 702 | 0.237 |
| | | DEA | Cost | Life | 1995-2004 | 702 | 0.120 |
| Leverly and Grace (2010) | US | DEA | Pure tech. | P-L | 1989-2000 | 1,300 | 0.790 |
| | | DEA | Scale | P-L | 1989-2000 | 1,300 | 0.934 |
| | | DEA | Allocative | P-L | 1989-2000 | 1,300 | 0.590 |
| | | DEA | Cost | P-L | 1989-2000 | 1,300 | 0.366 |
| | | DEA | Revenue | P-L | 1989-2000 | 1,300 | 0.206 |
| Mahlberg and Url (2010) | | DEA-RAM | | P-L | 1989-2000 | 1,300 | 0.983 |
| | | DEA | Cost | Life and nonlife | 1991-2006 | 138 | 0.293 |
| | | DEA | Revenue | Life and nonlife | 1991-2006 | 138 | 0.307 |
| | | DEA | Scale | P-L | 1994-2005 | 312 | 0.758 |
| | | DEA | Allocative | P-L | 1994-2005 | 312 | 0.668 |
| Xie (2010) | US | DEA | Technical | P-L | 1994-2005 | 312 | 0.554 |
| | | DEA | Cost | P-L | 1994-2005 | 312 | 0.373 |
| | | DEA | Revenue | P-L | 1994-2005 | 312 | 0.330 |
| | | SFA | Cost | P-L | 1995-2003 | 369 | 0.480 |
| | | DEA | Cost | P-L | 1995-2003 | 800 | 0.490 |
| Cummins and Xie (2009) | US | DEA | Revenue | P-L | 1995-2003 | 800 | 0.368 |

Table 28.6 (continued)

| Study | Country | Method | Efficiency type | Type of institution | Sample period | No. of insurers/year | Avg efficiency per year |
|--------------------------------|-----------------------|---------|-----------------|---------------------|---------------|----------------------|-------------------------|
| Kasman and Turgutlu (2009) | Turkey | SFA | Cost | Life/nonlife | 1990-2004 | 85 | 0.694 |
| Bikker and Leuvensteijn (2008) | Netherlands | SFA | Cost | Life | 1995-2003 | 96 | 0.724 |
| Cummins and Xie (2008) | US | DEA | Cost | P-L | 1994-2003 | 1,550 | 0.450 |
| | | DEA | Technical | P-L | 1994-2003 | 1,550 | 0.640 |
| | | DEA | Allocative | P-L | 1994-2003 | 1,550 | 0.710 |
| | | DEA | Scale | P-L | 1994-2003 | 1,550 | 0.930 |
| | | DEA | Revenue | P-L | 1994-2003 | 1,550 | 0.390 |
| Fenn et al. (2008) | 14 European countries | SFA | Cost | Life | 1995-2001 | 437 | 0.796 |
| | | SFA | Cost | Nonlife | 1995-2001 | 562 | 0.930 |
| | | SFA | Cost | Composite | 1995-2001 | 127 | 0.985 |
| | | SFA | Cost scale | Life | 1995-2001 | 437 | 0.733 |
| | | SFA | Cost scale | Nonlife | 1995-2001 | 562 | 0.776 |
| | | SFA | Cost scale | Composite | 1995-2001 | 127 | 0.860 |
| Kao and Hwang (2008) | Taiwan | DEA | Technical | Nonlife | Avg 2001-02 | 24 | 0.416 |
| Weiss and Choi (2008) | US | SFA | Cost | P-L | 1992-1998 | 1,188 | 0.810 |
| | | SFA | Revenue | P-L | 1992-1998 | 1,188 | 0.744 |
| | | SFA | Cost Scale | P-L | 1992-1998 | 1,188 | 0.877 |
| | | SFA | Rev. Scale | P-L | 1992-1998 | 1,188 | 0.911 |
| Jeng et al. (2007) | US | DEA | Cost | Life | 1979-2001 | NA | 0.803 |
| | | DEA | Technical | Life | 1979-2001 | NA | 0.953 |
| | | DEA | Allocative | Life | 1979-2001 | NA | 0.834 |
| Cummins and Rubio-Misas (2006) | Spain | DEA | Cost | Life and nonlife | 1989-1998 | 382 | 0.227 |
| | | DEA | Pure tech | Life and nonlife | 1989-1998 | 382 | 0.600 |
| | | DEA | Allocative | Life and nonlife | 1989-1998 | 382 | 0.412 |
| | | DEA | Scale | Life and nonlife | 1989-1998 | 382 | 0.893 |
| | | DEA | NA | Life and nonlife | 1989-1998 | 382 | 0.893 |
| Brockett et al. (2005) | US | DEA-RAM | NA | P-L | 1989 | 1,524 | NA |
| Choi and Weiss (2005) | US | SFA | Cost | P-L | 1992-1998 | 4,777 | 0.802 |
| | | SFA | Cost scale | P-L | 1992-1998 | 4,777 | 0.856 |
| | | SFA | Revenue | P-L | 1992-1998 | 4,777 | 0.729 |
| | | SFA | Rev. Scale | P-L | 1992-1998 | 4,777 | 0.918 |

| | | | | | | | |
|-----------------------------|---------|-----|-------------|-----------------|-----------|-----|-------|
| Jeng and Lai (2005) | Japan | DEA | Technical | Keritsu | 1985-1994 | 19 | 0.972 |
| | | DEA | Technical | NSIF | 1985-1994 | 19 | 0.976 |
| | | DEA | Technical | SIF | 1985-1994 | 19 | 0.911 |
| Cummins et al. (2004) | Spain | DEA | Tech stock | All Insurers | 1989-1997 | 298 | 0.310 |
| | | DEA | Cost-stock | All Insurers | 1989-1997 | 298 | 0.154 |
| | | DEA | Rev-stock | All Insurers | 1989-1997 | 298 | 0.209 |
| | | DEA | Tech-mutual | All Insurers | 1989-1997 | 49 | 0.408 |
| | | DEA | Cost-mutual | All Insurers | 1989-1997 | 49 | 0.232 |
| | | DEA | Rev-mutual | All Insurers | 1989-1997 | 49 | 0.357 |
| Ennsfelner et al. (2004) | Austria | SFA | Production | Life and health | 1994-1999 | 47 | 0.907 |
| | | SFA | Production | Nonlife | 1994-1999 | 53 | 0.719 |
| Klumpes (2004) | UK | SFA | Cost | Life | 1994-1999 | 40 | 0.655 |
| | | SFA | Profit | Life | 1994-1999 | 40 | 0.863 |

Note: Averages of reported scores shown for some studies. DEA = data envelopment analysis; FDH = free disposal hull; SFA = stochastic frontier approach, DFA = distribution free method, RAM = range adjusted measure, and P-L = property-liability.

to regress realized ROE data from a sample of companies over time on variables representing company characteristics. The cost of capital for a company is then estimated as the fitted value of ROE from the regression.³⁵

Debt capital in insurance usually represents policyholder supplied debt capital, such as reserves. The cost of this type of debt capital is often measured as total investment income minus expected investment income from equity capital divided by average policyholder supplied debt capital. As mentioned, an alternative approach developed by Cummins et al. (2009) is to grade the price of debt based on an insurer's duration of liabilities and credit quality as gauged by its financial rating. When data availability is a problem, researchers sometimes utilize interest rates such as the one-year Treasury bill rate to represent the cost of debt.

28.5.4 Average Efficiency Scores

Average efficiency scores based on the studies released from 2004 to 2011 are summarized in Table 28.6. The table shows the country or countries analyzed, the estimation methodology, the types of efficiency estimates, the sample period, number of observation units, and average efficiencies. Thirty-two studies are summarized in Table 28.6.

The first important observation based on Table 28.6 is that nearly all recent researchers have chosen to estimate efficiency using the econometric approach or mathematical programming but do not utilize both methods. Only one study during this observation period (Eling and Luhnen 2010a) used both SFA and DEA. This study confirms the results of prior research showing that SFA tends to give higher efficiency scores than DEA because SFA filters out part of the departure of observation units from the frontier as random error. The most common estimation technique is DEA, utilized as the sole or one of two estimation techniques by 22 studies. Of the remaining 10 studies, 9 utilize SFA and only one uses the TFA.

Fourteen of the 32 studies estimate cost and revenue efficiency, 2 estimate cost, revenue, and profit efficiency and one study estimates cost and profit efficiency. Thirteen studies estimate some combination of technical, scale, allocative or cost efficiency, 3 estimate only cost efficiency, 2 estimate only technical efficiency, and 1 study estimates production efficiency. Hence, it has become much less common to estimate only technical efficiency and not to estimate revenue and profit efficiency than in the earlier studies reviewed in Cummins and Weiss (2000).

Twelve studies estimate scale economies based on the cost frontier, and four also estimate scale economies with respect to the revenue frontier. Although it is somewhat difficult to generalize based on studies covering different countries and time periods, it is clear that scale efficiencies tend to be relatively high compared to other types of efficiency. Three of the 12 studies estimating scale efficiency relative to the cost frontier found average scale efficiency above 90%, 7 studies found scale efficiency between 85 and 89%, and 2 studies found scale efficiency between 75 and 80%. Revenue scale efficiencies also are relatively high—of the 4 studies that estimated revenue scale efficiency, the lowest scale efficiency score was 86%. The average among the studies for cost scale efficiency is 88%, and the average for revenue scale efficiency is 90%.

Allocative inefficiency is a more serious problem for insurers than scale inefficiency. Based on the eight studies that report allocative inefficiency, the lowest score is 59% and the average is 74%. Hence, failure to choose cost minimizing input quantities significantly reduces overall efficiency. Because cost

³⁵A few studies have utilized inappropriate measures of the cost of equity capital such as the debt-to-equity ratio (Jeng et al. 2007). Such mistakes are rare but inexcusable given the widespread availability of more appropriate cost of capital measures.

efficiency is the product of technical and allocative efficiency, it is expected to be lower than scale or allocative efficiency. Of the 31 estimates of cost efficiency presented in Table 28.6, the average is 53% and the median is 51%. Revenue efficiencies tend to be even lower—of the fifteen studies that estimate revenue efficiency, the average efficiency is 41% and the median is 36%. Profit efficiencies are more difficult to interpret because they do not have to be between zero and 1 in most DEA algorithms. Hence, some authors report average profit efficiency greater than 1. In such cases, the interest is more in the rankings of firms than in the scores themselves.

There tend to be significant lags between the end of the data period and the publication of an chapter or release of a working chapter. For the 32 chapters tabulated in Table 28.6, the average time from the end of the data period to release is 6.6 years, and the median is 6 years. The minimum time from the data period to release is 3 years and the maximum is 16 years. Delays usually occur due to data reporting lags, e.g., the NAIC data for a given year usually are not available until the middle of the following year, and it takes time to purchase, load up, and clean the data prior to use. However, data reporting lags account for at most 1 or 2 years. Another delay factor, of course, is the time required to do the research, including preparing the database, defining inputs, outputs, and other variables, conducting the estimation, and writing the chapter. For published chapters, the journal refereeing process can add another 1–3 years in delays. Finally, some researchers try to extract additional mileage out of existing databases by writing new chapters without going through the process of adding more years of data. These delays do not necessary detract from the value of the research, depending upon the stability of the market that is being analyzed, but delays much longer than 10 years do tend to be questionable.

28.6 Summary and Conclusions

Modern frontier efficiency and productivity methodologies have become the dominant approach to measuring firm performance using accounting data. These methodologies estimate “best practice” efficient technical, cost, revenue, and profit frontiers based on firm-level data. Frontier efficiency methods have been applied to analyze a wide range of industries and public entities in many different nations. Frontier methodologies can also be used to analyze change in TFP. The two primary methods for estimating efficient frontiers are the econometric approach and the mathematical programming approach. The econometric approach involves estimating cost, revenue, or profit functions, while the mathematical programming approach is a non-parametric approach implemented using linear programming. The mathematical programming approach provides a particularly convenient method for decomposing cost or revenue efficiency into pure technical, scale, and allocative efficiency.

There are many important applications of frontier efficiency methods. One important application is the measurement of scale and scope economies. Measuring scale and scope economies is particularly important when industry structure is changing rapidly due to mergers, acquisitions, insolvencies, or other factors. Another important application is to measure the change in TFP. TFP change can then be analyzed for correlations with various macro and micro- economic conditions to determine the drivers of productivity in an industry or economy. Frontier efficiency analysis also is useful in testing hypotheses about firm or industry structure, such as the effects of organizational form and product distribution systems, leading to a richer understanding of the issues than provided by conventional approaches.

Another use of efficiency analysis is in comparing performance of departments, divisions, or profit centers within a firm. Mathematical programming is particularly useful for this purpose because it is not as demanding in terms of degrees of freedom as the econometric approach and performs the optimization separately for each firm or operating unit. Regulators also can benefit from efficiency analysis. The Federal Reserve has used efficiency analysis to study the effects of bank branching,

mega-mergers, and other elements of banking industry structure. This type of analysis has been used in insurance to study industry consolidation, expense and rate regulation, solvency regulation, and mergers and acquisitions. Efficiency and productivity analysis also has been used in cross-national comparisons of efficiency of firms and other institutions.

An important trend in the literature is to estimate revenue and/or profit efficiency in addition to technical and cost efficiency. Technical and cost efficiency are useful in studying the efficiency effects of firm characteristics and of new policies, strategies, and technologies. However, the ultimate test of any organizational feature is its impact on the bottom line, i.e., ultimately on profit. A new strategy in one area of the firm may improve cost efficiency but may never find its way to the bottom line due to inefficiencies in other sectors of the firm. The only way to tell whether a program has met with ultimate success is to measure its effects on revenue or profit efficiency.

A wide range of under-researched insurance topics provide fruitful avenues for future research. Organizational form in the life insurance industry could be investigated using the cross-frontier approach to provide further tests of the expense preference and managerial discretion hypotheses. Analyzing the efficiency of life insurance distribution systems using cost and profit functions could determine whether unmeasured product quality differences exist in the life insurance industry. The effects of consolidation on efficiency in the property–liability insurance industry also would be an interesting topic. A further example of potential future research would be additional analysis of the effects of corporate governance on efficiency in the insurance industry. Finally, frontier methods continue to be useful in studying economies of scope across the financial services industry as mergers and acquisitions involving insurers, banks, mutual fund companies, securities dealers, and other types of financial services firms become more widespread.

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Chapter 29

Capital Allocation and Its Discontents

Daniel Bauer and George H. Zanjani

Abstract Capital allocation concerns an assignment of the capital of a financial institution to the various sources of risk within the firm. While the procedure is commonly applied within financial institutions for purposes of pricing and performance measurement, its necessity and feasibility are disputed within the academic literature. This chapter clarifies how incomplete markets and frictional costs can create conditions sufficient for capital allocation to play a role either as an input to or a by-product of the pricing process. It then reviews the various approaches to capital allocation, with particular attention paid to the theoretical foundations of the Euler (gradient) approach to capital allocation. Finally, the chapter illustrates the application of the Euler method using various popular risk measures in the context of an example from life insurance.

29.1 Introduction

Few areas of academic inquiry can claim so inauspicious a birth as the theory of capital allocation. [Merton and Perold \(1993\)](#) observed that allocation was generally “not feasible,” while [Phillips, Cummins, and Allen \(1998\)](#) deemed allocation to be “inappropriate” for insurance companies. Yet, despite such dim pronouncements from the halls of Harvard and Wharton, the capital allocation literature blossomed in the first decade of the new millennium.

To a newcomer, the propagation of the literature may be hard to understand. The arguments of [Merton and Perold \(1993\)](#) and [Phillips, Cummins, and Allen \(1998\)](#) were well founded and continue to resurface from time to time in skeptical articles. Capital allocation continues, however, because of the practical need: Pricing and performance measurement within insurance companies and other financial institutions are not possible in current practice without some allocation of capital—whether implicit or explicit.

This chapter starts by reviewing the rationale for capital allocation, as well as its limitations. Once we have established the justification for allocation, we then review the methods. It is here where the literature becomes diffuse, with many potential approaches to choose from. We focus most of our attention on what can fairly be called the mainstream approach to allocation—the gradient or Euler method (an allocation also implied by game theoretic approaches)—due not only to its

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widespread acceptance but also because of the respect it pays to the concept of marginal cost. Defining marginal cost, however, is a tricky enterprise—and, after presenting an example from life insurance, we conclude by discussing this weakness of capital allocation approaches along with future directions for research.

29.2 Allocation Defined

Consider an insurance company with capital K ,¹ assets A , and a set of N exposures denoted by q_i for $i = 1, \dots, N$. The variable q_i quantifies the extent to which the company is exposed to the i th source of risk, where the sources of risk could be lines of insurance, or individual contracts. The exposures are associated with random claims:

$$l_i(q_i). \quad (29.1)$$

An increase in exposure shifts the distribution of the claim random variable so that the resulting distribution has first-order stochastic dominance over the former. That is:

$$Pr(l_i(\hat{q}_i) \geq z) \geq Pr(l_i(q_i) \geq z) \quad \forall z, \hat{q}_i > q_i. \quad (29.2)$$

As a simple (and ubiquitous) example, imagine the exposure q_i representing an insurance company's quota share of a customer i 's loss \hat{l}_i , so that

$$l_i(q_i) = q_i \times \hat{l}_i. \quad (29.3)$$

The variable L represents the aggregate claims for the company, with the sum of the random claims over the sources adding up to the total claim:

$$\sum_{i=1}^N l_i = L. \quad (29.4)$$

Actual payments made (denoted by the random variable X) differ from the total loss claims made (L) because of the possibility of default and can be expressed as

$$X = \min(L, A). \quad (29.5)$$

Note we have omitted time in this specification for simplicity, as well as asset risk. This allows us to focus on the essence of the allocation problem with minimal complications and to interpret the allocations adding up over liability risks.

We can also decompose actual payments, where x_i represents the payment delivered to the i th source. Obviously, it must be the case that

¹By capital, we are referring to the equity of the firm—or the difference between the value of its assets and its liabilities. To fix ideas, we will adopt a common specification of the difference between the fair value of assets and the expected value of liabilities for examples. However, equity can be calculated in a number of different ways, depending on the accounting treatment accorded to assets and liabilities. As will become clear later, the important consideration for the allocation problem is the source of the costs to the firm, and the source could align with various definitions of capital. Thus, it is important to note that the allocation methods described herein could be applied just as easily to alternative definitions of capital.

$$\sum_{i=1}^N \mathbf{x}_i = \mathbf{X}. \quad (29.6)$$

The typical assumption in the literature is of equal priority in bankruptcy, so that

$$\mathbf{x}_i = \min \left(l_i, \frac{A}{L} l_i \right). \quad (29.7)$$

We will adopt that rule here for simplicity, although alternative rules could conceivably be adopted in the framework to follow. We may now think of allocating capital or assets to the N sources of risk, with k_i representing the capital per unit of exposure allocated to the i th source (and a_i representing a similar quantity for assets). Of course, it must be the case that

$$\sum_{i=1}^N q_i k_i = K \quad (29.8)$$

and

$$\sum_{i=1}^N q_i a_i = A. \quad (29.9)$$

These relations embody the so-called “adding up” property of an allocation. However, it is important to note that allocating capital or assets differs from allocating losses or actual payments in an important sense. The decomposition of the latter quantities into source-specific pieces is an obvious and unique one—following clearly from the claims made by, or payments made to, the respective sources. Allocating capital or assets, on the other hand, is not obvious and depends—as we will describe later—on the context of the problem (see also [Bühlmann 1985](#) for early related ideas).

29.3 Why Allocate?

29.3.1 Pricing and Performance Measurement

Let $P_i(q_i)$ represent the premiums collected from the i th source, with the amount collected depending on the exposure assumed, so that total premiums collected are

$$\sum_{i=1}^N P_i(q_i) = P. \quad (29.10)$$

We ignore underwriting expenses and define the total costs faced by the insurer as

$$V(\mathbf{X}) + C(A, q_1, \dots, q_N), \quad (29.11)$$

where $V(\mathbf{X})$ represents the fair financial value of the random claims payments, and $C(A, q_1, \dots, q_N)$ represents a frictional financing cost which could originate from tax or agency issues. This latter function can evidently accommodate a variety of different frictional cost assumptions. For example,

if capital is regarded as the source of frictional costs, a simple tax τ on capital (e.g., [Froot and Stein 1998](#)) could be represented as

$$C(A, q_1, \dots, q_N) = \tau(A - E[\mathbf{L}]) = \tau K. \quad (29.12)$$

One could also imagine frictional costs being represented by a tax on assets:

$$C(A, q_1, \dots, q_N) = \tau A. \quad (29.13)$$

In any case, fair pricing of insurance implies that:

$$P = V(\mathbf{X}) + C(A, q_1, \dots, q_N) \quad (29.14)$$

must hold in the aggregate. The key question is how to allocate the requisite aggregate to each of the N sources, and herein lies a controversy about capital allocation first identified by [Phillips, Cummins, and Allen \(1998\)](#). They studied an environment without frictional costs (i.e., $C(A, q_1, \dots, q_N) \equiv 0$) and with complete markets. In this setting, by-line pricing is straightforward:

$$P_i = V(\mathbf{x}_i) \quad (29.15)$$

with

$$\sum_{i=1}^N P_i = P = \sum_{i=1}^N V(\mathbf{x}_i) = V(\mathbf{X}). \quad (29.16)$$

The significance of this result is that the fair price for insurance for a given line is evidently independent of any by-source *allocation* of capital or assets. The valuation of the liabilities associated with the i th source depends on total assets as well as the extent of exposure to each of the risk sources:

$$\mathbf{x}_i(q_1, q_2, \dots, q_N, A) \quad (29.17)$$

but, importantly, it is not necessary to know anything beyond that.² This finding underscores an important point about capital allocation. Scholars studying insurance pricing in frictionless markets will find capital allocation unnecessary or arbitrary ([Sherris 2006](#))³—and with good reason. There is no need to allocate capital for pricing purposes unless there are frictional costs involved.

If, however, frictional costs are present—i.e., if $C(A, q_1, \dots, q_N) > 0$ —it becomes necessary to allocate them to lines of business. While $V(\mathbf{X})$ decomposes naturally into source-specific components, $C(A, q_1, \dots, q_N)$ may not, and it is this fundamental problem that motivates allocation. While this problem could in principle apply to other types of overhead expense, most recent interest has been directed at the topic of costs relating to capital, in which case the problem of frictional cost allocation ends up boiling down to one of capital allocation.

This is no blackboard curiosity. This is the same problem an actuary confronts when charged with pricing a multiline business to a target return on equity (ROE). The practical manifestation of

²Note that there is a one-to-one relationship between assets and capital once we are given a set of risk exposures. Thus, we could also have written $\mathbf{x}_i(q_1, q_2, \dots, q_N, K)$.

³Sherris notes that the *default value* can be allocated uniquely, but that the extension of this allocation to assets, while potentially appealing, is arbitrary.

a “frictional cost of capital” occurs in situations where the target ROE exceeds that implied by the underwriting betas associated with the insurer’s liability risks. Indeed, even the academic literature indicates a significant gap between the insurer’s cost of capital (see [Cummins and Phillips 2005](#)) and the estimated theoretical costs of bearing liability risks (to the extent that these can be measured with any precision at all—see, e.g., [Cox and Rudd 1991](#)). Regardless of the source of the difference, the gap between an insurer’s target ROE and the required rate of return on capital predicted by a model grounded in frictionless financial markets can be thought of as a frictional cost of capital that must be allocated to risks.

29.3.2 Value Maximization

[Merton and Perold \(1993\)](#) had a related objective in mind when considering capital allocation. Their interest lay in exploring the feasibility of a capital allocation rule for purposes of making value-maximizing business decisions. To fix ideas, imagine an insurer evaluating its profit function:

$$\Pi = \sum_{i=1}^N P_i(q_i) - V(X(q_1, q_2, \dots, q_N, A)) - \tau K \quad (29.18)$$

and wondering if an alternative mix of exposures—for example, exiting a business line or, perhaps, doubling volume in another—would yield an improvement. To answer this question, of course, some connection between exposures and capital is needed (e.g., setting capital according to a risk measure target), and Merton and Perold showed that it was not possible to develop a linear allocation rule (i.e., assigning k_i units of capital for each unit of exposure to the i th source, with $\sum_{i=1}^N q_i k_i = K$) that would account for the effects of diversification when considering inframarginal or supramarginal changes to the exposure portfolio.

While this finding was generally true, subsequent research would show that allocations *could* give accurate guidance when considering marginal changes to a portfolio. And it was this insight that spawned much of the literature on the topic that would follow.

29.4 Allocation Methods

Many authors have approached the allocation problem from different directions, yet it is reassuring that under certain assumptions—and putting aside relatively minor differences in presentation—most approaches end up in essentially the same place: the so-called Euler or Gradient Principle. For the special case of the allocation according to the so-called covariance principle, the close relationship of the different allocation methods was already pointed out by [Urban et al. \(2003\)](#). Also, [Albrecht \(2004\)](#) recognizes that different approaches lead to the Euler principle.

Of course, the foregoing characterization obscures much nuance and detail. In what follows, we start by introducing the Euler Principle as the most important approach among practitioners and the common ground for many allocation methods. We then attempt to provide the intuition for and the intellectual genesis of the various approaches to the capital allocation problem.

29.4.1 The Euler Principle

The key ingredient for the gradient method is a positively homogeneous risk measure. Formally, a risk measure ρ is a function mapping the random variable of total claims into a real number and can thus be expressed as

$$\rho(\mathbf{L}) = \rho\left(\sum_i l_i(q_i)\right) \quad (29.19)$$

although we sometimes directly write ρ as a function of the exposures as in $\rho(q_1, q_2, \dots, q_N)$. If now $\rho(a\mathbf{L}) = a \times \rho(\mathbf{L})$, $a \geq 0$, and $l_i(q_i) = q_i \times \hat{l}_i$, i.e., if the risk measure and individual loss distributions are (positively) *homogeneous*, then Euler's homogeneous function theorem yields

$$\sum_{i=1}^N \frac{\partial \rho}{\partial q_i} q_i = \rho. \quad (29.20)$$

Herein lies the basis for allocation, with the i th source receiving a per-unit allocation of capital equivalent to

$$\frac{k_i}{K} = \frac{\frac{\partial \rho}{\partial q_i}}{\rho}. \quad (29.21)$$

and the capital allocations “add up.”⁴ In the important special case where capital is determined by the risk measure constraint (i.e., when $\rho(\mathbf{L}) = K$),⁵ the capital allocations correspond to risk allocations: $k_i = \frac{\partial \rho}{\partial q_i}$. But this restriction is not necessary: As can be seen above, scaling by the risk measure in (29.21) effectively converts “risk shares” into capital shares.

It is important to note that, to this point, all we have described is a mathematical technique. The Euler principle yields an allocation method simply because the prescribed allocations add up. We have not provided a motivation for why one would want to apply the Euler principle, nor any reasoning to guide the choice of risk measure (beyond the requirement that the risk measure be homogeneous). It is at this point where the literature becomes diffuse—with motivations and guidance depending crucially on the particular context chosen.

This problem is illustrated by one of the seminal articles in the field. [Myers and Read \(2001\)](#) reckon that, given complete markets, default risk can be measured by the *default value*, i.e., the premium the insurer would have to pay for guaranteeing its losses in the case of a default. They reason further that “sensible” regulation will require companies to maintain the same default value per dollar of liabilities and effectively choose this latter ratio as their risk measure. Myers and Read verify the “adding up” property in this particular case and continue to demonstrate that this observation can be employed

⁴The literature often obscures the distinction between “capital” and “assets” in part because in some contexts (e.g., a hedge fund manager seeking to maximize risk-adjusted expected returns in a long-only asset portfolio) the distinction is unimportant. The distinction, however, is important for insurance, and from here on we will write about “capital” allocation, although the techniques described could just as easily be used to allocate assets or something else.

⁵It is useful here to provide an example verifying that this framework fits insurance applications. An example of the risk measure being defined so that $\rho(\mathbf{L}) = K$ is where capital is being set to satisfy $\rho(\mathbf{L}) = VaR_\alpha(\mathbf{L}) - E[\mathbf{L}]$ (where VaR_α represents the Value at Risk of the claim distribution at some threshold α). Of course, there is no requirement generally that $\rho(\mathbf{L}) = K$, but this condition will often prevail in real-world applications.

to uniquely allocate capital so as to preserve the risk measure target across lines of insurance when considering marginal changes to the risk portfolio.

However, because their analysis is confined to a particular risk measure, their findings depend on the unstated objectives of the “sensible” regulator and can only be uniquely implemented in a complete markets setting. Moreover, [Gründl and Schmeiser \(2007\)](#) show that the Myers–Read allocation leads to decisions that are suboptimal from a profit standpoint. While this is not so surprising when one considers that Myers and Read advanced the allocation as being driven by regulation (and not necessarily one consistent with insurer self-interest), the finding underscores the crucial role institutional context plays in risk measure selection. Using a particular risk measure may be justified when driven by regulatory fiat but may not necessarily align with economic self-interest.

As we will see, the broader literature has contemplated applying the Euler principle to a wider range of risk measures, but the underlying justification for using any particular measure has always remained murky. We will return to this issue in Sect. 29.5.

29.4.2 Axiomatic Approaches

Inspired by the axiomatic approach to risk measures of [Artzner, Delbaen, Eber, and Heath \(1999\)](#), [Denault](#) proposes a set of axioms that define a *coherent* capital allocation principle when $\rho(\mathbf{L}) = K$.⁶ Aside from the “adding up” property introduced above, he requires a *no-undercut* condition, *symmetry*, and *riskless allocation*. Here, the *no-undercut* condition means that no subportfolio of risks will require a smaller amount of capital on a stand-alone basis than the aggregated capital allocated to these risks. *Symmetry* means that when adding two risks to any disjoint subportfolio results in the same contribution to capital, their allocations must coincide; in other words, risks that are identical relative to all other risks in the portfolio should be treated the same. And, finally, *riskless allocation* means that the allocation of a deterministic “risk”—in excess of its “mean”—is zero (see also [Panjer 2002](#)).

This approach, however, yields an impractical result: In order for a *coherent* allocation to exist, the risk measure must necessarily be linear (see also [Buch and Dorfleitner 2008](#), who show that the problematic axiom is symmetry). The key issue here again traces back to the distinction between marginal and inframarginal changes to the portfolio. More precisely, the axioms above are framed in an indivisible setting where the focus is on (finite) subportfolios of a given (finite) portfolio. This framing effectively requires consideration of inframarginal changes to the total portfolio—a requirement which, as shown in [Merton and Perold \(1993\)](#), leads capital allocation to be an exercise in futility. [Denault \(2001\)](#) shows that this futility can only be overcome through the use of a linear risk measure.

As linear risk measures offer little practical relevance, [Denault \(2001\)](#) moved on to thinking about the more fruitful and practical setting of divisible portfolios and real-numbered portfolio weights—thereby effectively restricting attention to marginal changes in the portfolio. In particular, [Denault \(2001\)](#) proposes a set of five axioms in this divisible setting defining a “fuzzy” coherent allocation principle that exists for any given coherent, differentiable risk measure—and this allocation is given by the Euler principle applied to the supplied risk measure.

A similar though slightly more parsimonious and self-contained set of axioms—within the divisible setting—was proposed by [Kalkbrener \(2005\)](#): *Linear aggregation*, which combines the “adding up” and the *riskless allocation* properties; *Diversification*, which corresponds to the *no-undercut* property; and *Continuity*, which means that small changes to the portfolio should

⁶A risk measure is called *coherent* if it satisfies four properties: Monotonicity, subadditivity, (positive) homogeneity, and translation invariance. See [Artzner et al. \(1999\)](#) for details.

only have a small effect on the capital allocated to a subportfolio. He continues to show that these axioms already uniquely determine the allocation of capital to each subportfolio, and it is given by the (Gâteaux) derivative in the direction of the subportfolio—which is exactly the Euler principle. Furthermore, the existence of the capital allocation is equivalent to subadditivity and homogeneity of the underlying risk measure, which in turn are the defining characteristics of a *coherent* risk measure relative to a *monetary risk measure* (see e.g., Föllmer and Schied 2002).

Although Kalkbrenner's axioms seem intuitive at first glance, Meyers (2005) points out that the resulting allocation may not yield the appropriate choice from an “economic perspective” that is in line with the objectives of a profit-maximizing institution (see Meyers 2003 and below). The reason traces back to an implicit assumption about homogeneity of the underlying loss distributions embedded in the *linear aggregation* axiom.

This problem with the Euler principle was first identified by Mildenhall (2004), who noted that actuarial applications often involve inhomogeneous distributions—whose properties change as the volume is scaled up or down. To illustrate, the return distribution associated with a particular stock is homogeneous in the sense that the return distribution associated with, say, 100 shares simply follows from scaling up the distribution associated with a single share by a factor of 100; however, this is not true of the loss distribution associated with vehicles—where the distribution of losses associated with 100 vehicles is not (except in the case of perfect correlation across vehicles) a simple scaling up of the loss distribution associated with a single vehicle.

That said, even with inhomogeneous distributions, gradient allocation methods can be resurrected after generalization that takes into account “volumetric diversification” by adjusting the structure of the underlying vector space (Mildenhall 2006). However, note that capital allocated by this generalized gradient principle may not “add up.”

29.4.3 Game Theoretic Approaches

The *Shapley value* is a concept from cooperative game theory that assigns each player a unique share of the cost that adheres to several axioms (Shapley 1953). Although it therefore also technically constitutes an *axiomatic* approach, a distinction from the previous section is useful since the axioms here are more general and not tied to the specifics of capital allocation. In fact, the idea to rely on this concept for other allocation problems in insurance such as cost or risk allocation already occurs in Lemaire (1984) and Mango (1998). However, it is again Denault (2001) who formalized the application in the context of the capital allocation problem by aligning the general axioms with his specific allocation axioms introduced in the previous subsection. Thus, as pointed out there, the direct application of the Shapley value proves disappointing as it yields a linear risk measure. However, as the game theoretic analogue to moving from the indivisible to the divisible portfolio case in the previous subsection, relying on the theory of fuzzy cooperative games introduced by Aubin (1981) proves to be more practical and fruitful.

To illustrate the main idea, assume that the cost functional c of a cooperative game is defined via the risk measure ρ :

$$c(q_1, q_2, \dots, q_N) = \rho(q_1, q_2, \dots, q_N). \quad (29.22)$$

Then the core of the fuzzy game is defined as (see also Tsanakas and Barnett 2003)

$$C = \left\{ (k_1, k_2, \dots, k_N) \mid c(q_1, q_2, \dots, q_N) = \sum k_i q_i \ \& \ c(u) \geq \sum k_i u_i, \ u \in [0, q_1] \times \dots \times [0, q_N] \right\}. \quad (29.23)$$

Hence, the core consists of allocations such that for each (fractional) subportfolio the aggregated per-unit costs increase, which is a generalization of the *no-undercut* rule from above. It now turns out that if the cost function is subadditive, positively homogeneous, and differentiable—which is equivalent to requiring these properties from the underlying risk measure and requiring homogeneous loss distributions—the core consists of a single allocation only, namely that implied by the Euler method (cf. [Aubin 1981](#)).⁷ In particular, in this case the allocations coincide with the so-called *Aumann–Shapley* values, which satisfy axioms stemming from different backgrounds (see [Aumann and Shapley 1974](#), [Billera and Heath 1982](#), or [Mirman and Tauman 1982](#)):

$$k_i = \left. \frac{\partial}{\partial u_i} \int_0^1 c(\gamma u) d\gamma \right|_{u_j = q_j \forall j} . \quad (29.24)$$

Now obviously if $c(\gamma u) = \gamma \times c(u)$, i.e., if the underlying risk measure is homogeneous, this expression immediately reduces to the gradient allocation (29.20) and (29.21). In general, the Aumann–Shapley value aggregates the marginal contributions of each “slice” of a risk factor i , $[\gamma u_i, (\gamma + d\gamma) u_i]$, $\gamma \in [0, 1)$, when the risk portfolio is uniformly expanded.

The Aumann–Shapley value thus also serves as a starting point for generalizations. Specifically, to cope with the problem of inhomogeneous loss distributions, [Powers \(2007\)](#) demonstrates that although the Euler principle will not apply, the Aumann–Shapley value can be used for the risk-allocation problem. Similarly, it may offer a solution if the underlying risk measure does not satisfy the homogeneity condition. For instance, [Tsanakas \(2009\)](#) shows how to allocate capital with convex risk measures, although the absence of homogeneity is shown to potentially produce an incentive for infinite fragmentation of portfolios. The intuition for this rather undesirable feature is risk aggregation penalties within inhomogeneous convex risk measures.⁸

29.4.4 Economic Approaches: Profit Maximization

The relationship of the Euler principle to profit maximization was sensed in early work by [Tasche \(2004\)](#)⁹ and [Schmock and Straumann \(1999\)](#). More specifically, [Tasche \(2004\)](#) calls a capital allocation *suitable for performance measurement* if it satisfies the following property: If the marginal performance of risk i as measured by its return on allocated risk capital exceeds (respectively, falls below) the company’s total *risk-adjusted return on capital* (RAROC)—i.e., its return per unit of risk $\frac{\Pi}{\rho(L)}$ —then increasing (respectively, decreasing) the exposure by a small amount improves the overall performance of the portfolio. The author then continues to show that the only suitable allocation is given by the Euler principle. Similarly, [Schmock and Straumann \(1999\)](#) call an allocation *consistent* if all individual risk-adjusted returns are equal to the optimal risk-adjusted company return, which again yields Euler.

More formally, [Zanjani \(2002\)](#) derives the gradient solution in the context of a profit maximization problem where the firm’s policyholder/counterparty preferences are defined over a measure of the

⁷[Tsanakas \(2004\)](#) shows that for distortion risk measures, the gradient allocation also results if one allows for nonlinear portfolios, which give rise to a so-called *nonatomic core*.

⁸A risk measure is called *convex* if it satisfies three properties: Monotonicity, translation invariance, and convexity. See [Föllmer and Schied \(2002\)](#) for details.

⁹Although the final version was published in 2004, all the important ideas are already contained in a working paper version entitled “Risk Contributions and Performance Measurement” from 2000.

overall portfolio risk of the institution. Similarly, [Stoughton and Zechner \(2007\)](#) arrive at a gradient-based allocation by framing the institution's profit maximization problem with a capitalization constraint tied to a risk measure. To illustrate, consider the optimization problem

$$\max_{(K, q_1, \dots, q_N)} \left\{ \underbrace{\sum_{i=1}^N P_i(q_i) - V(X(q_1, q_2, \dots, q_N, K)) - C(K)}_{\Pi} \right\} \quad (29.25)$$

subject to

$$\rho(q_1, q_2, \dots, q_N) \times \vartheta_X \leq K, \quad (29.26)$$

where ϑ_X is an exchange rate that converts risk to capital, which is often chosen to be unity if risk is measured in monetary units. After eliminating Lagrange multipliers from the optimality conditions associated with this problem, one obtains

$$\frac{\partial \Pi}{\partial q_i} = \left(-\frac{\partial \Pi}{\partial K} \right) \times \vartheta_X \times \frac{\partial \rho}{\partial q_i} \quad (29.27)$$

at the optimal exposures and capital level. Hence, for the optimal portfolio, the risk-adjusted marginal return $\frac{\partial \Pi / \partial q_i}{\vartheta_X \times \partial \rho / \partial q_i}$ for each exposure i is the same and equals the cost of a marginal unit of capital $-\frac{\partial \Pi}{\partial K}$. In this context, the appeal of the allocation produced by the gradient method is its consistency with marginal cost (see also [Meyers 2003](#)), and for this reason, the gradient method is often claimed to be “economic” in nature. However, it is again important to stress that any economic content flows from the imposition of a risk measure constraint (29.2), and that this imposition may well be arbitrary.

An alternative economic foundation for capital allocation—that does not rely on the imposition of a risk measure—is offered by [Zanjani \(2010\)](#), who shows that economic capital allocation can be derived in a social planning problem when starting from primitive assumptions on risk and preferences. [Bauer and Zanjani \(2012\)](#) extend this line of reasoning by establishing the allocation consistent with economic self-interest—that is again resulting from profit maximization—but they explicitly take the preferences of the counterparties into account. This is achieved by attaching additional participation constraints to the problem (29.25) and keeping—or dropping—constraint (29.26), which is interpreted as an exogenously supplied solvency constraint from a regulator. The key idea is that it is not only external regulation but also the counterparties' preferences for capitalization that drive the company's capital allocation. The resulting allocation then is a weighted average of the Euler method applied to the exogenous risk measure and an internal allocation rule, where the weight depends on how much the imposed capital constraint differs from the level of capital held in an unregulated regime.

29.4.5 Alternatives to the Gradient Method Based on Risk Measurement

There are a number of alternative approaches based on risk measures that do not necessarily land at the Euler principle. One idea that first occurred in [Dhaene et al. \(2003\)](#) and was extended by [Laeven and Goovaerts \(2004\)](#) and [Dhaene et al. \(2011\)](#) is to derive allocations based on an optimization procedure. The idea is to choose an allocation such that the deviation of the individual losses and the allocated capital are maximally “close.” Specifically, Laeven and Goovaerts propose the optimization problem:

$$\min_{k_1, k_2, \dots, k_N} \rho \left(\sum_{i=1}^N (l_i(q_i) - q_i k_i)^+ \right) \text{ s.t. } \sum q_i k_i = K \quad (29.28)$$

to identify an allocation (k_1, k_2, \dots, k_N) , whereas [Dhaene et al. \(2011\)](#) consider the program:

$$\min_{k_1, k_2, \dots, k_N} \sum_{i=1}^N q_i E \left[\theta_i D \left(\frac{l_i(q_i)}{q_i} - k_i \right) \right] \text{ s.t. } \sum q_i k_i = K \quad (29.29)$$

where D is a (distance) measure and θ_i are weighting random variables with $E[\theta_i] = 1$.

While the former yields rather complex allocation rules, the approach by [Dhaene et al. \(2011\)](#)—when choosing D and θ_i adequately—gives rise to various allocation methods proposed in the literature. For instance, for $D(x) = x^2$ and $K = \sum E[\theta_i l_i(q_i)]$, they arrive at so-called *weighted risk capital allocations* $k_i = E[\theta_i l_i(q_i)]$ studied in detail by [Furman and Zitikis \(2008\)](#). For other choices, they uncover an array of other allocation principles, including several that can also be derived from the application of the Euler principle. Thus, while not unambiguously collapsing to the Euler principle, the approaches are yet again related.

29.5 Conceptual Issues with the Choice of Risk Measure

With few exceptions, most of the capital allocation approaches start with the choice of a risk measure. This fairly reflects the weight of the academic literature. It also reflects revealed preference among practitioners for the tractability of gradient methods applied to risk measures. Academics may concern themselves with all sorts of esoterica when analyzing capital allocation, but when it comes to actually implementing capital allocation, gradient methods applied to risk measures are hard to beat.

However, while ease of implementation may justify the special attention paid to approaches based on risk measures, it does not necessarily imply coherence of logic. We have yet to establish which risk measure is appropriate and, on a deeper level, whether it makes sense to be guided by risk measures at all.

To illustrate the latter point, is not clear why coherence of an allocation method should be specified via a risk measure as in [Kalkbrener \(2005\)](#), nor why the risk measure should specify the cost function of the cooperative game from [Denault \(2001\)](#), nor why the policyholders in [Zanjani \(2002\)](#) would assess company quality with a risk measure, nor why the bank in [Stoughton and Zechner \(2007\)](#) would constrain itself with a risk measure. As noted earlier, a risk measure constraint will not necessarily help a firm to improve its profitability (e.g., [Gründl and Schmeiser 2007](#)).

Of course, one could argue that risk measure constraints are driven by the dictates of rating agencies (on whom uninformed consumers rely for assessments of creditworthiness) or regulators, who set standards for companies via risk measure-based analytics. But such an argument inevitably leads one to question whether rating agencies and regulators should be using risk measures in this way. Does a regulator serve the public interest by setting standards with a risk measure, and, if so, which is the correct risk measure?

For the gradient method at least, much rides on the answer. The gradient method's claim of superiority rests entirely on the propriety of the risk measure. Without economic justification for the risk measure, it is not clear that the gradient method, despite its mathematical elegance, offers a superior allocation.

Thus, it is not surprising that much attention in the current discourse on capital allocation pertains to the choice of risk measure. Capital allocation scholars have largely joined other risk scholars in embracing so-called “tail” risk measures with the consequence that risk measures similar in concept

Table 29.1 Portfolio of the insurance company

| Term-life, face value 100,000.00 | | Endowment, face value 50,000.00 | | Annuities, 18,000.00 annually | |
|----------------------------------|--------|---------------------------------|--------|-------------------------------|--------|
| Age/term | Number | Age/term | Number | Age/term | Number |
| 30/20 | 250 | 40/20 | 500 | 60/35 | 250 |
| 35/15 | 250 | 45/15 | 500 | 70/25 | 250 |
| 40/10 | 250 | 50/10 | 500 | | |
| 45/5 | 250 | | | | |

to Expected Shortfall (ES) are rapidly gaining favor among academics and practitioners.¹⁰ Proponents of ES stress the theoretical appeal of coherence (Artzner et al. 1999) and the practical appeal of weighting tail events more heavily than VaR. The weighting of tail events can be taken further with the enhancement of a spectral weighting function (Acerbi 2002), a transformation that preserves coherence.

It is an open question, however, whether coherence offers a one-size-fits-all guide to risk measure selection. To illustrate, the capital allocation yielded in the economic model of the insurance company used in Bauer and Zanjani (2012) can only be implemented through the application of the gradient technique to a particular risk measure:

$$\rho(X) = \exp \{E^Q [\log \{X\}]\}, \quad (29.30)$$

where Q is a probability measure that shifts the entire probability mass to default states and includes weights determined by relative values placed on recoveries by the firm's policyholders. This risk measure, however, is not coherent.

The deeper point here is that, even if one accepts the inevitability of using risk measures for capital allocation, different foundational assumptions may point the way to different risk measures with different mathematical properties. This suggests that the appropriate risk measure for capital allocation based on the gradient method may depend very much on context.

29.6 An Example from Life Insurance

To illustrate the use of the capital allocation methods introduced above, we consider a life insurance company selling three product lines: Term-life insurance contracts with constant annual premium payments, endowment insurance contracts with constant annual premium payments, and life annuities. More specifically, we analyze the allocation problem for the stylized insurance company introduced in Zhu and Bauer (2011b), the portfolio of which is detailed in Table 29.1.

We assume that the required capital is calculated in a 1-year mark-to-market approach as

$$K = \rho(L^{\text{TEA}}), \quad (29.31)$$

where the “loss” is defined as

$$L^{\text{TEA}} = p(0, 1) \times (V_1 - A_1). \quad (29.32)$$

¹⁰Aside from minor subtleties in the case of noncontinuous distributions, the Expected Shortfall is identical to the Tail Value at Risk (TVaR) or Conditional Tail Expectation (CTE). We will treat them as synonyms for the purpose of this chapter.

$p(0, 1)$ denotes the price of a 1-year zero coupon bond, and A_1 and V_1 denote the values of the insurer’s assets consisting of all premiums paid and liabilities at time 1, respectively. Here it is assumed that the insurer allocates assets into 1-, 3-, 5-, and 10-year UK government bonds as well as an equity index (FTSE) at equal proportions, which are modeled via an extended Black–Scholes model with Vasicek stochastic interest rates calibrated to UK data between 6/1998 and 6/2008. We refer to [Zhu and Bauer \(2011b\)](#) for the model dynamics and parameters. In addition, we consider the required capital for companies that only have one or two lines of business, with corresponding losses denoted by L^{TE} for a company with term-life and endowment business only, L^{TA} for a company with term-life and annuity business only, L^{EA} for a company with endowment and annuity business only, L^T for a company with term-life business only, L^E for a company with endowment business only, and—finally—by L^A for a company with annuity business only.

For evaluating the insurance liabilities—in addition to the stochastic interest rate model—we need to make an assumption about the evolution of mortality. Following [Zhu and Bauer \(2011b\)](#), we use two different approaches: First, we assume that mortality evolves deterministically, so that (unsystematic) mortality risk only comes to effect in that the number of deaths within each cohort is sampled from a Binomial distribution—with a known mortality probability given via the corresponding generation life table for the England and Wales general male population compiled based on the Lee–Carter method. In what follows, we refer to this as the “deterministic case.” Second, in addition to unsystematic mortality risk as above, we consider aggregate (or systematic) mortality risk by sampling the generational life table at time 1, i.e., we allow mortality rates to evolve stochastically over the year. Specifically, we use the forward mortality factor model introduced in [Zhu and Bauer \(2011a\)](#). We refer to this as the “stochastic case.”

Based on each sampled scenario—that is a combination of stock return, interest rate, generational life table, and death counts for each cohort—we can then evaluate A_1 and V_1 (we refer to [Zhu and Bauer \(2011b\)](#) for further details). Since the assets at time zero consist of the premiums only, which—for each business line—are proportional to the corresponding insured amounts, and since the same is true for the liabilities, L^{TEA} can be represented as a linear combination of random variables corresponding to each business line with the amounts as the weights, i.e., the loss distributions are homogeneous in this case. More specifically, we can write

$$L^{TEA} = FaceVal^T \times \bar{L}^T + FaceVal^E \times \bar{L}^E + FaceVal^A \times \bar{L}^A, \tag{29.33}$$

where $FaceVal^i$ is the face value in business line $i \in \{T, E, A\}$ and \bar{L}^i is the corresponding normalized loss for a face value of 1. Obviously, we have $L^i = FaceVal^i \times \bar{L}^i, i \in \{T, E, A\}$. Thus, given a homogeneous risk measure, we can evaluate capital allocations via the Euler principle:

$$q_i k_i = FaceVal^i \times \frac{\partial \rho(L^{TEA})}{\partial FaceVal^i} \approx FaceVal^i \times \frac{\rho(L^{TEA} + \Delta_i \bar{L}^i) - \rho(L^{TEA})}{\Delta_i}, \tag{29.34}$$

where we choose $\Delta_i = 1\% \times FaceVal^i, i \in \{T, E, A\}$.

Tables 29.2 and 29.3 display our results for the deterministic and the stochastic mortality case, respectively. To keep the presentation concise, we only provide point estimates based on 100,000 simulations—we refer to [Zhu and Bauer \(2011b\)](#) for corresponding standard errors. In particular, we calculate capital allocations for four risk measures: (i) The standard deviation risk measure with parameter $a = 2$, that is,

$$\rho(X) = E[X] + a \times StDev[X]; \tag{29.35}$$

Table 29.2 Results for the deterministic mortality case

| Deterministic mortality | | Term insurance | Endowment insurance | Annuities | Total |
|-------------------------|-------------------|----------------|---------------------|-----------|------------|
| StDev | Cap Alloc. | 22,624 | 1,519,072 | 5,162,791 | 6,704,487 |
| | Percentage | 0.34% | 22.66% | 77.01% | 100.00% |
| | Cap Alloc. (adj.) | 22,614 | 1,518,365 | 5,160,389 | 6,701,368 |
| | Stand Alone | 227,136 | 2,165,157 | 5,352,843 | 7,745,136 |
| | Infr. Increase | 19,068 | 1,330,541 | 4,509,569 | 5,859,178 |
| 99% VaR | Cap Alloc. | 12,769 | 2,077,348 | 5,444,049 | 7,534,166 |
| | Percentage | 0.17% | 27.57% | 72.26% | 100.00% |
| | Cap Alloc. (adj.) | 13,249 | 2,155,460 | 5,648,752 | 7,817,461 |
| | Stand Alone | 337,442 | 2,692,282 | 5,908,572 | 8,938,296 |
| | Infr. Increase | 16,240 | 1,880,233 | 5,095,335 | 6,991,808 |
| 90% ES | Cap Alloc. | 20,675 | 1,512,979 | 4,209,552 | 5,743,206 |
| | Percentage | 0.36% | 26.34% | 73.30% | 100.00% |
| | Cap Alloc. (adj.) | 20,668 | 1,512,383 | 4,207,893 | 5,740,944 |
| | Stand Alone | 224,516 | 2,007,531 | 4,372,433 | 6,604,480 |
| | Infr. Increase | 17,555 | 1,351,388 | 3,710,757 | 5,079,700 |
| 99% ES | Cap Alloc. | 27,157 | 2,456,872 | 6,611,156 | 9,095,185 |
| | Percentage | 0.30% | 27.01% | 72.69% | 100.00% |
| | Cap Alloc. (adj.) | 27,149 | 2,456,105 | 6,609,092 | 9,092,346 |
| | Stand Alone | 384,072 | 3,121,017 | 6,832,316 | 10,337,405 |
| | Infr. Increase | 23,549 | 2,234,172 | 5,942,845 | 8,200,566 |

(ii) Value at Risk at the 99% level estimated by the empirical quantile; (iii) Expected Shortfall at the 90% level, that is,

$$\rho(X) = E[X|X \geq VaR_{90\%}(X)], \tag{29.36}$$

where again the Value at Risk is estimated by the empirical quantile; and (iv) Expected Shortfall at the 99% level. All of these risk measures are homogeneous so that we may apply the Euler principle. Formally, the standard deviation risk measure (29.35) yields the so-called covariance allocation principle:

$$k_i = E[\bar{L}^i] + a \times \frac{Cov(\bar{L}^i, L^{TEA})}{StDev(L^{TEA})}. \tag{29.37}$$

Value at Risk gives

$$k_i = E[\bar{L}^i | L^{TEA} = VaR_{\alpha}(L^{TEA})] \tag{29.38}$$

and the Expected Shortfall (29.36) yields (cf. Sect. 6.3 in McNeil et al. (2005) for derivations of these formulas)

$$k_i = E[\bar{L}^i | L^{TEA} \geq VaR_{\alpha}(L^{TEA})], \tag{29.39}$$

whereas our calculation via (29.34) only provides an easy-to-calculate approximation. In particular, our allocations from Tables 29.2 and 29.3 shown in the first lines for each considered risk measure do not perfectly add up to the capital K calculated according to (29.31)—which is shown in the last

Table 29.3 Results for the stochastic mortality case

| Stochastic mortality | | Term insurance | Endowment insurance | Annuities | Total |
|----------------------|-------------------|----------------|---------------------|-----------|------------|
| StDev | Cap Alloc. | -105,602 | 1,276,893 | 6,272,827 | 7,444,118 |
| | Percentage | -1.42% | 17.15% | 84.27% | 100.00% |
| | Cap Alloc. (adj.) | -105,544 | 1,276,192 | 6,269,383 | 7,440,031 |
| | Stand Alone | 375,020 | 2,182,978 | 6,519,600 | 9,077,598 |
| | Infr. Increase | -113,693 | 1,064,411 | 5,172,510 | 6,123,228 |
| 99% VaR | Cap Alloc. | -54,416 | 1,550,635 | 7,424,958 | 8,921,177 |
| | Percentage | -0.61% | 17.38% | 83.23% | 100.00% |
| | Cap Alloc. (adj.) | -54,067 | 1,540,694 | 7,377,356 | 8,863,983 |
| | Stand Alone | 467,622 | 2,706,795 | 7,668,752 | 10,843,169 |
| | Infr. Increase | -194,183 | 1,385,223 | 6,059,950 | 7,250,990 |
| 90% ES | Cap Alloc. | -106,402 | 1,253,615 | 5,355,359 | 6,502,572 |
| | Percentage | -1.64% | 19.28% | 82.36% | 100.00% |
| | Cap Alloc. (adj.) | -106,328 | 1,252,742 | 5,351,625 | 6,498,039 |
| | Stand Alone | 343,567 | 2,021,019 | 5,573,855 | 7,938,441 |
| | Infr. Increase | -112,988 | 1,068,368 | 4,404,135 | 5,359,515 |
| 99% ES | Cap Alloc. | -177,992 | 1,958,468 | 8,610,591 | 10,391,067 |
| | Percentage | -1.71% | 18.85% | 82.87% | 100.00% |
| | Cap Alloc. (adj.) | -177,930 | 1,957,784 | 8,607,585 | 10,387,439 |
| | Stand Alone | 544,508 | 3,149,934 | 8,957,039 | 12,651,481 |
| | Infr. Increase | -188,271 | 1,674,377 | 7,123,448 | 8,609,554 |

column of the third line for each risk measure. However, with the possible exception of Value at Risk, the approximation error is small and the calculated allocations are close to the “adjusted” allocations calculated based on K and the proportions shown in the respective second lines.

Comparing the proportional allocations in line 2 for each risk measure in the deterministic case (Table 29.2), we find that all principles yield rather similar allocations with a relatively small weight on the term business and the majority of capital allocated to the annuity business. In particular, the allocations based on 90% ES and 99% ES are very close.¹¹ Similarly, we observe rather congenious allocations for all considered risk measures in the stochastic case, with again the ES-based allocations being very similar. One minor difference between the allocations is the increased weight put on the annuities line within the covariance allocation relative to the other tail-based risk measures. This indicates that the combination of risk factors driving annuities plays a major role over the entire domain of the distribution—and in some ranges possibly even more so than in the tails.

One potentially surprising observation is that while in the deterministic case the capital contributions of each line are still positive, this is no longer the case under stochastic mortality. More precisely, although the total required capital increases for each risk measure relative to the deterministic case, the term-life insurance block now is allocated a negative amount of capital. The intuition is of course given by natural hedging effects between the different business lines: While liabilities from endowments and—especially—life annuities increase when survival probabilities increase systematically, the term-life insurance liabilities decrease since fewer term policyholders are going to decrease. The resulting

¹¹See also Asimit et al. (2012) for related theoretical results on the limiting behavior of ES-based allocations as the confidence level α approaches 1.

negative dependence between the term-life profits and losses and the remainder of the portfolio then turns out to be beneficial for the insurer.¹²

However, it is necessary to point out that the interpretation of negative allocations is not immediately clear when considering them in the context of the risk-adjusted return on capital (RAROC). A low—or even negative—RAROC now seems desirable from the insurer’s perspective since it implies only a small loss—or even a gain—on a business line together with a substantial capital relief, whereas a high RAROC implies large losses relative to the (possibly minor) capital relief. This challenge was already noted in [Tasche \(2004\)](#), who points out that in this case the RAROC should be interpreted as “the profit of a counterparty and should therefore—from the investor’s [insurer’s] point of view—be hold as small as possible.” In the present setting, one can for instance think of term-policyholders as counterparties providing the company with a hedge for which they want to be compensated—but of course the insurer wants this compensation to be as small as possible. Since we are evaluating risks by their RAROC, the largest acceptable return to be paid to the counterparties is the target return. Thus, pricing according to a given positive target RAROC is still possible, and in this case the company will be happy to sell term-life contracts under par—i.e., it is willing to incur a loss on the line since it benefits the company overall.

Of course this will not be the case for a company only offering term-life insurance. To illustrate, in the fourth line for each considered risk measure of [Tables 29.2 and 29.3](#), we provide the economic capital for single-line companies, $\rho(L^i)$, $i \in \{T, E, A\}$. Not surprisingly, we find that in all cases the stand-alone capital exceeds the allocated capital in the enterprise setting and, consequently, that the sum of the capital for the single-line companies exceeds the required capital for the multiline company due to diversification benefits.

It is important to bear in mind, however, that the calculated capital contributions are to be understood at the margin. As shown by [Merton and Perold \(1993\)](#), capital allocation is generally unfeasible at the inframarginal level. To illustrate, the fifth line for each considered risk measure in [Tables 29.2 and 29.3](#) provides the *inframarginal* capital increase when a company with two business lines decides to enter the remaining third business line. For instance, for calculating the inframarginal capital increase for the term business, we calculate

$$\rho(L^{\text{TEA}}) - \rho(L^{\text{EA}}) \quad (29.40)$$

with similar equations for the endowment and annuity lines. We find that the inframarginal increase always is smaller than the capital allocated within the Euler principle. The intuition is that each dollar increase of the new business line enjoys the full diversification benefits of the existing lines when the portfolio is changed inframarginally, whereas the Euler principle relies on a uniform (marginal) extension of the entire portfolio (see also [Eq. \(29.24\)](#) for the Aumann–Shapley value and the following discussion). In particular, we find that the resulting increases in capital *do not* add up to the total capital.¹³

¹²See also [Powers \(2007\)](#) in this context, who notes that “a negative value [...] simply means that the presence of member i serves to decrease (i.e., offset some portion of) the total portfolio’s risk.”

¹³While “adding up” in principle would be delivered by the Shapley value, as indicated in [Sects. 29.4.2 and 29.4.3](#), a *coherent* capital allocation via the Shapley value would require a linear risk measure.

29.7 Conclusion

Initial skepticism about the exercise of capital allocation was grounded in the notion of frictionless markets, where allocation is unnecessary and arbitrary. Once frictions are introduced, however, allocation becomes well defined, at least at the margin of the risk portfolio. The predominant allocation technique relies on calculating the gradient of a chosen risk measure of the portfolio.

In the end, allocation methods—regardless of provenance—must be judged on their ability to give an accurate picture of marginal cost of risk. The literature has firmly established that a fixed allocation makes sense when considering marginal changes to the risk portfolio but fails when considering infra- or supramarginal changes, so the best we can hope for is that the allocation “gets it right” on the margin.

A remaining problem, however, is that marginal cost often ends up being defined by the way we allocate capital—as opposed to the reverse, where marginal cost dictates how we allocate capital. The first approach is easy but self-referential in its justification. The second has its own pitfalls in that a great deal of information may be required to assess the “true” marginal costs of the firm. Going forward, we regard the challenge for the capital allocation literature as being to connect the mathematical techniques of allocation with the real operating objectives and constraints faced by the institution under consideration.

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Chapter 30

Capital and Risks Interrelationships in the Life and Health Insurance Industries: Theories and Applications

Etti G. Baranoff, Thomas W. Sager, and Bo Shi

Abstract This chapter summarizes the theory and empirics of capital structure for life insurers and health insurers. The large literature on explaining capital structure for nonfinancial firms is not explicitly applicable to insurers because of the differences in the structures, setting, and the premium financing of insurers. Nevertheless, the fundamental capital structure question is carefully adapted from the debt versus equity theories used for nonfinancial firms to the risk versus capital theories in insurance. The switch follows naturally from the customer-based model of insurer financing. The predictions of agency theory, transaction-cost economics, pecking order, debt–equity trade-off, bankruptcy cost, risk subsidy, and other theories are developed and summarized into the “finite risk” and “excessive risk” hypotheses. The interrelationships between the capital and risks of life and health insurers are examined in this light. For the last two decades, insurers operated under the finite risk paradigm, even during the 2008 financial crisis.

30.1 Introduction

In this chapter, we examine the empirical research on how life and health insurers manage the interrelationship between their capital and major risks. In particular, the literature investigates whether their management limits insurer risk or expands insurer risk and the determinants that affect the outcome. We also provide an extensive theoretical context for the empirics. That larger context is the theory and empirics of capital structure in relation to insurer risk-taking behavior. Capital structure itself is a vast field that has developed rapidly over the past several decades, but mostly for nonfinancial firms. We will not attempt to review the breadth of capital structure in detail but will focus upon the

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parts relevant to life and health insurers. Life insurers sell not only life products but also substantial annuity, reinsurance, and health products. Since the literature emphasizes the potential effect that product focus has on capital structure, the life industry, augmented with the more specialized health insurers, provides a natural spectrum of product foci for tests of the theory. The literature on property and casualty insurers is not included, except as it may illuminate life and health capital structure research. We concentrate mainly on the literature of the last two decades. We discuss the difficulties in adapting capital structure theory and empirics to life and health insurance from its origins in nonfinancial firms. We discuss the progress that has been made and further work to be done.

There are a number of different ways to organize the contributions in the capital structure literature for a review. The [Harris and Raviv \(1991\)](#) survey discussed later mentions several ways. One way to organize the literature for this review that we find illuminating is by the role of the key capital structure variable in the models of the contributions. This key variable is nearly always some version of the debt-to-equity ratio (leverage) or capital-to-assets ratio, or a closely related equivalent. Following the seminal article of [Modigliani and Miller \(1958\)](#), many contributions study the impact of the capital structure variable upon firm value, in the context of various frictions. In this stream of the capital structure literature, the leverage variable is potentially one of the determinants of firm value. Subsequently, another stream developed in which the focus shifted to the determinants of the leverage or capital ratio itself. Generally, the debt/equity decision (or leverage) variable is an effect rather than a determinant.¹ In particular, a major research theme became the question of whether firms set targets for their capital and move to close the gap between actual and target capital.² In this research stream, the effect of capital structure upon firm value is not addressed. In decoupling the capital ratio (leverage) variable from the firm value, the second stream of research implicitly implies that maximization of firm value may not be the only objective for capital structure management.³ Most of the work in the first two streams is oriented toward nonfinancial firms, either explicitly or implicitly.⁴

A third stream of research has grown out of the second stream. This body of research attempts to develop and to adapt capital structure models for the insurance industry. This chapter focuses upon the portion of the third stream oriented toward life and health insurers. This research emphasizes the interactions between capital ratio and insurer risks. Capital ratio may be either determinant or effect and is often both in simultaneous models. As in the second stream, the effect of capital structure upon firm value is not addressed explicitly. Each stream is elaborated in Sect. 30.2.

Among the issues that the life and health insurance stream of the capital structure literature addresses in this review are the following:

1. Do life and health insurers manage the capital ratio to balance an increase of risk in one area with a reduction of risk in another area, *ceteris paribus*?
2. Do life and health insurers manage the capital ratio and risks jointly? Or does the capital ratio follow risk—or vice versa?
3. Which life and health insurer risks are the most important for the capital structure management? In particular, is there evidence to support the transaction-cost economics notion that product risks are fundamental?
4. How does the capital structure management vary across subsectors of the industry? In particular, do life specialty insurers manage the capital structure like the health specialty insurers? What about large insurers versus small insurers and mutual insurers versus stock insurers?

¹Some research in this stream treats capital as interacting simultaneously with its determinants, but not with firm value.

²The foundation for targets is the trade-off theory which is described more in detail in Sect. 30.2.

³Arguably, this possibility may apply to the highly regulated insurance industry.

⁴There are a few examples of insurance contributions in the first stream, for example, [Staking and Babbal \(1995\)](#) and most recently, the study of [D'Arcy and Lwin \(2012\)](#), both for the property/casualty insurance industry.

5. How does financial crisis affect the capital structure management?
6. Do life and health insurers set targets for their capital ratio variable? If so, how rapidly do they close the empirical gap toward their targets?

In Sect. 30.5, we discuss what the literature has to say about these and other issues.

At the outset, the reader should be advised that capital structure theory was developed and tested on nonfinancial firms, with many authors explicitly excluding the financial sector for various reasons. This has resulted in standard capital structure theory and empirics bearing imbedded explicit and implicit assumptions that interfere with its application to insurers. Among the major distinctions between insurers and nonfinancial firms that pose hurdles to the straightforward application of capital structure theory and empirics to life and health insurers are the following:

1. The nature of debt is very different for an insurer than for a manufacturer. Most insurers have little conventional debt. An insurer's debt consists mainly of actuarial estimates of future claims payments (some regard it as contingent debt).⁵
2. Insurers are subject to a high degree of regulation. In particular, there are risk-based capital regulations that require a certain level of capital to meet various risk factors for assets held, products sold, etc.
3. Since most life and health insurance companies are not publicly traded, they lack market determinations of firm value. Moreover, life and health insurers report according to statutory accounting rules (SAP) rather than GAAP rules. SAP does not require that most assets be marked to market. So market values of capital, assets, and liabilities are not available for most insurers.

These three main factors and others interfere with the application of conventional capital structure theory and empirics to the financial sector. In Sect. 30.2, we examine the adaptation of capital structure theories to life and health insurers from nonfinancial firms.

Section 30.3 provides a brief empirical profile of the life and health insurance industries. This section provides context for understanding the significance of some of the theories presented in Sect. 30.2. For example, we see that the life insurance industry is quite heterogeneous in comparison with the health insurance industry. That is because the life industry includes insurers who specialize in health products in addition to life insurance, annuities, and reinsurance.⁶ Many of the empirical differences can be traced to product mix, in accordance with the theories of Sect. 30.2. For example, in 2008 the collective capital ratio of insurers who specialize in annuities (0.05) was only one-tenth of those who report as (0.50). The much higher capital ratio of health insurers reflects their greater need for a large risk buffer since the health insurance contract is incomplete and implicit as explained in Sect. 30.2.

Section 30.4 discusses the empirical metrics that have been used to capture the major risks of life and health insurers (product and asset/ investment risks). The most common measures are based on exposure to risk and on volatility. For example, product risk exposure metrics are often proportional to the level of premiums collected in given product lines as based on transaction-cost economics theory. Investment risk metrics may be based on weighted asset portfolio proportions such as the C-1 risk in the risk-based capital formula or on volatility of portfolio returns.

Section 30.5 presents a survey of the empirical literature on capital/risk literature for life and health insurers in the past two decades. Section 30.6 concludes with a set of generalizations that can be drawn from the empirical analyses and possibilities for further research.

⁵See *Staking and Babbel (1995)* for example.

⁶Since 2002, many insurers who had been filing annual reports (with the NAIC) as life insurers have been switching their filing status to "health insurer." Generally, the switching insurers already were predominantly specialized in health insurance before the transition.

30.2 Capital and Risks: Theoretical Development

As noted in the introduction, we organize the capital structure literature for this chapter into three streams based on the role of the key capital structure variable and application to insurers. The initial stream examines capital structure as a potential determinant of firm value. The second stream examines the determinants of capital structure, including the setting of targets for capital. Most of the first two streams exclude insurers. The third stream explicitly develops and adapts capital structure theory for insurers. Our discussion of the theory follows this organization. We emphasize the life and health insurer component of the third stream in our review but present a brief summary of the other two streams in order to establish the larger context.

30.2.1 Capital Structure for Nonfinancial Firms

[Modigliani and Miller \(1958\)](#) argued that the form of capital structure is theoretically irrelevant to *firm value*. In their analysis, capital is a *determinant* of firm value. If a firm were to swap debt for an equal amount of equity, the market value of the firm would be unaffected, *ceteris paribus*, absent frictions and market imperfections. There is a stream of the capital structure literature that retains this original formulation of leverage as a determinant of firm value. In the theory part of this stream, frictions and other conditions such as taxes, interest rate volatility, agency conflicts, asymmetric information, bankruptcy cost, and other theories are investigated that might cause alternative capital structures to affect firm value. In the empirical part of the stream, frictions and other conditions are investigated that in fact lead to alternative capital structures having an effect upon firm value. Within this line of work, there are contributions that formulate an optimal capital structure to achieve value maximization.

In a second stream of the capital structure literature, the focus shifts from capital structure as a determinant of firm value to the determinants of a firm's choice of capital structure. This work is implicitly agnostic regarding the objective of capital structure choice. The large-scale survey by [Harris and Raviv \(1991\)](#) reveals the evolution of the research focus.⁷ They reviewed over one hundred studies and identified theories of debt–equity choice based on agency costs, asymmetric information, product/input market interactions, and corporate control considerations, as well as the important class of tax-based theories.⁸ In brief, they concluded:

“... the models surveyed have identified a large number of potential determinants of capital structure... the theory has identified a relatively small number of ‘general principles’... Several properties of the debt contract have important implications for determining capital structure. These are the bankruptcy provision, convexity of payoffs of levered equity, the effect of debt on managerial equity ownership, and the relative insensitivity of debt payoffs to firm performance.”

In the further development of this stream, many researchers have investigated whether firms set targets for their capital (or leverage) and, if so, how fast actual levels converge toward the targets. Trade-off theories of capital structure assert that firms choose debt or equity by trading off the benefits of debt against its costs. Trade-off theories assert the importance of capital targets and predict that actual capital will revert toward target levels over time (cf. [Hovakimian et al. 2001](#); [Kayhan and Titman 2007](#)⁹). Alternative theories, such as the pecking order theory, market timing, and inertia hypotheses,

⁷Other useful partial reviews may be found in [Titman and Wessels \(1988\)](#), [Hovakimian et al. \(2001\)](#), and [Hovakimian et al. \(2004\)](#).

⁸Harris and Raviv excluded the literature on tax-based theories from their survey.

⁹Per [Kayhan and Titman \(2007\)](#), “although firms’ histories strongly influence their capital structures, over time their capital structures tend to move toward target debt ratios that are consistent with the tradeoff theories of capital structure.”

attribute the choice of debt or equity to other factors. According to the pecking order hypothesis, there is a preference order in the choice of financing: earnings most preferable, then debt, then equity, with a less preferred option employed only if a more preferred option is unavailable (Donaldson 1961; Myers and Majluf 1984). The market timing hypothesis states that the choice of debt or equity depends on managers' exploitation of information asymmetries to assess which option better benefits shareholders (Baker and Wurgler 2002). In the inertia theory, leverage fluctuates because managers do not rebalance debt and equity as stock prices change (Welch 2004). The pecking order, market timing, and inertia theories predict that capital generally does not revert to targets.

Empirically, some studies show that actual debt ratios of firms tend to converge over time toward their expected target debt ratios (e.g., Shyam-Sunder and Myers 1999; Hovakimian et al. 2001; Hovakimian et al. 2004¹⁰). The speed of closure is generally not fast. For example, Flannery and Rangan (2006), using a partial adjustment model, estimate annual closure of the gap between actual and target capital to exceed 30% and observe that this rate is much faster than in related research.

30.2.2 *Capital Structure for Life and Health Insurers*

Mainstream capital structure theory, as discussed immediately above, was developed in the context of nonfinancial firms. As a consequence, the theory carries explicit and implicit assumptions about the nature and business environment of firms to which the theory applies. In fact, most capital structure studies routinely exclude the financial sector from their purview (e.g., all of the literature cited above) because of concerns about the validity of the assumptions. Cited reasons for exclusion include that financial firms utilize different mechanisms to finance operations than nonfinancial firms, that financial firms are more subject to regulation, that substantially fewer financial firms are publicly traded, and that the accounting mechanisms are different. These are good reasons to separate financial firms from nonfinancial firms in the analysis of capital structure. But they also motivate closer examination of the financial sector to see how capital structure theories, including target capital theories, and models may be modified to apply there.

In order to understand how to develop capital structure models for the life and health insurance industries, it is necessary to understand the key attributes of the life and health insurance industries that are relevant to capital structure models.

First, as noted above, the insurance industry is highly regulated for its financial solvency and adequacy and fairness of rates. In particular, adherence to the life risk-based capital laws and the health risk-based capital laws is required of all insurers. These laws constrain insurer discretion in managing the interrelationship between capital and risks. The intention is to guarantee that life and health insurers have adequate capital, per regulatory formulae, to buffer their investment risks and protect their solvency. Thus, life and health insurers are not free to pursue unbounded value maximization. In practice, these regulations are more constraining for financially troubled insurers than for healthy insurers. Also in practice, life and health insurers may pursue a blended goal of insolvency risk minimization and value maximization.

Second, it is imperative to note that few life or health insurers are publicly traded. The first stream of capital structure research addresses the effect of different capital structures on firm value. A tacit

¹⁰Hovakimian et al. (2004) show that firms that issue both debt and equity offset the deviation from the target leverage that results from earnings and losses. Their result is also consistent with dynamic trade-off theories. Among others is the study of Leary and Roberts (2005), who examined whether a firm dynamically rebalances its capital structure toward some target/optimal level while allowing for costly adjustments.

assumption of this stream is that there is a firm value that can be readily observed. Both the first and second research streams for nonfinancial firms use market values for leverage (or capital). On the other hand, of the more than 1,000 individual US life insurers who submitted annual reports to the National Association of Insurance Commissioners (NAIC) in 2001, only two were publicly traded as stand-alone entities.¹¹ Approximately one-quarter were members of publicly traded conglomerates or holding companies. The remaining three-quarters were private stock or mutual companies.¹² Insurers report extensive annual individual accounting data to the NAIC. But they report according to the SAP (statutory accounting principles) system rather than according to GAAP.¹³ They are not required to mark all of their assets or liabilities to market. Many of the reported values are modified book values.¹⁴ The paucity of market values and the limitations resulting therefrom have been noted extensively in the literature on financial institutions.

Therefore, some capital structure studies use the subset of insurers who are publicly traded. The disadvantages are that the small sample size may limit statistical power and the traded subset may be

¹¹Zhao et al. (2008), "Marking Capital to Market for Non-Publicly Traded Companies: A Life Insurance Industry Case Study" (at SSRN)

¹²About 9% of life insurers are mutual companies by numbers, not dollar amount of assets or premium.

¹³SAP is used to report financial results to insurance regulators, while GAAP is used to report financial results to investors, creditors, and financial regulators such as the Securities and Exchange Commission (SEC). All insurance companies are required to report statutory financial statements, using the prescribed format of the NAIC annual statement, to the regulators in states in which they are licensed. In addition, public stock insurance companies are required to prepare GAAP financial statements and file copies with stock exchanges and the SEC. GAAP accounting applies to most businesses. Many sources discuss the differences between SAP and GAAP for life insurers. Asset valuation and expense recognition are the most significant differences (Gaver and Pottier 2005). In comparison with the going-concern basis of GAAP accounting that recognizes all assets, SAP identifies only high-quality assets (i.e., admitted assets) that can pay claims and does not allow illiquid and other assets (i.e., non-admitted assets) that may not be considered to be available to pay claims. For expenses, SAP accounting tends to emphasize cash flows, whereas GAAP accounting takes an accrual approach. For instance, under SAP, acquisition expenses, a significant component of expenses for most insurers, are recorded at the time a policy is written, while related premium revenues are recorded in proportion over the policy term. By contrast, under GAAP accounting, a portion of the expenses is deferred until coverage is provided in tandem with premium revenues. The mismatching of premium revenue and acquisition expenses under SAP also implies that net income under SAP differs substantially from that under GAAP. Furthermore, under GAAP, all companies in which a parent has a controlling interest (greater than 50%) through either direct or indirect ownership of a majority voting interest are to be consolidated when the parent prepares financial statements.

¹⁴The few insurance studies that use market values focus on the publicly traded group as the observational unit. For example, Staking and Babbel (1995) investigate the relationship between capital structure, interest rate sensitivity, and market value in the property/casualty (P&C) sector of the insurance industry by considering 25 publicly traded P&C insurers over 1981–1987. Cummins and Harrington (1988) analyze the relationship between stock returns, risk, and co-skewness for substantially all actively traded P&C insurers for the period 1970–1982. The number of public P&C stocks ranged from 26 to 41 by year. Shelor et al. (2002) find that the announcement of the life risk-based capital regulation had a significant effect on the market values of 21 publicly traded life and health insurers over 1989–1992. However, the conclusions of the above and other similar studies are made with extreme caution because the samples account for only a small portion of the entire industry and may not be representative, even at the group level. As Staking and Babbel (1995) point out, their small sample size also limits their findings. As a consequence of the dearth of market value data, statutory book value data have been extensively used in previous empirical research on insurers. Nevertheless, researchers acknowledge that lack of market values is a limitation and note that the use of book value data is not ideal. Among the contributions that have mentioned the disadvantage of accounting book value data, Cummins and Sommer (1996) state that "The use of book value in insurance research is the standard approach because of the limited number of insurers with publicly traded equity." The authors acknowledge that this is a limitation of the research. Kielholz (2000) argues that "An alternative to using market data would be to use accounting data. These procedures are generally considered seriously flawed since they are not prospective and do not necessarily reflect the current and future possible returns that can be earned in the market." Besides the insurance industry, the banking industry also suffers from lack of a large sample of market values of banks, especially independent banks (Shrieves and Dahl 1992). A number of authors have proposed alternatives to book value (e.g., Cummins and Sommer 1996; Baranoff and Sager 2002, 2003). But these proposals do not differ substantially from book value.

unrepresentative of the industry. Other studies use book values with caveats. A unique approach to the problem was offered by Zhao et al. (2008). Market values for traded affiliated groups were apportioned to affiliates after labor-intensive study of 10-K filings, and this set was extended to the industry by multiple imputation. Cross-validation showed that imputed market values were adequate to infer properties for populations, although accurate market values for individual insurers could not be assured.

Another key attribute is the nature of financing for life and health insurers. To finance its operations, a nonfinancial firm can choose among earnings, debt, or equity as main sources.¹⁵ But a life and health insurer's financing choices are different. After start-up capitalization, by far the largest source of funds for financing is premium revenue. US life and health insurers operate under the various states' insurance regulations, which require a minimum amount of initial capital to begin the business. Subsequently, insurers are required to maintain risk-based capital minima and meet other early warning elements in order to be considered financially stable and escape intrusive scrutiny by regulators.¹⁶

Life and health insurers can actually use conventional debt instruments for financing. However, as an empirical fact, they do not.¹⁷ The most significant remaining source of funds for financing is premium revenue.¹⁸ Insurers' liabilities are the reserves for future claims and as such an insurance policy can be viewed in a financing sense as a *contingent* loan or debt. This contingent loan has periodic premium revenue representing loans collected by the insurer to be paid back only when a loss event occurs within the coverage period. The contingent look-alike debt instrument is an insurance contract rather than a debenture.¹⁹ But this is a "strange" loan. Because of risk pooling, most insureds are repaid much less than their premium payments; some few are repaid much more. Because the "loan" received by the insurer is contingent, the repayment obligation amount is stochastic rather than deterministic.

For a nonfinancial firm, proceeds from a debenture might be used to buy machines for production and create cash flow, part of which can be used for interest payments and retirement of the debt. The machinery may provide collateral for the debenture. Also, the amount of the debt is determinate. Wealth is produced for the manufacturer largely on the asset side of the ledger, by the ability of the machinery to earn a return in excess of debt service and other costs. An insurer invests premium revenue in income-producing assets, such as bonds, stocks, real estate, mortgages, and policy loans. The assets are used for generating returns and for paying indeterminate future policyholder claims.

¹⁵This is the sequence of sources provided by the pecking order theory.

¹⁶There are other indicators that can prompt an examination of an insurer or supervision such as complaints data and various financial ratios. For more details see financial regulation at www.NAIC.org. Regulation is designed to assure solvency and thereby the insurer's ability to pay policyholder claims. However, empirical analyses show that most insurers operate well above their risk-based capital minima and thus do not strongly feel the lash of regulatory pressure in the ordinary financing decisions.

¹⁷In 2003, the liabilities of the life insurance industry totaled approximately \$3.85 trillion, of which less than 1% (only \$36 billion) constituted borrowings. Life insurer liabilities consist mostly of loss reserves, which are actuarial estimates of future claims payments.

¹⁸An additional source is investment income. Life insurers manage large portfolios of financial assets, on which they earn significant amounts. However, premium revenue dwarfs investment income. For example, in 2003, total premiums for the life insurance industry were \$606 billion; net investment income was \$146 billion—only one-quarter of premiums. Moreover, most investment income derives indirectly from premiums, as investments largely represent unspent pooled premiums for the purpose of paying claims as they occur.

¹⁹Other authors recognize, at least implicitly, that premiums are a kind of financing. For example, Froot (2007): "... if the firm allows internal funds to run down, it will increasingly have to choose between cutting highly rewarding investments or incurring the high costs of external finance. In the insurance and reinsurance industries, adjustment costs of capital appear most clearly in the aftermath of catastrophic events, when depleted industry capital results in high prices and reduced availability of insurance and reinsurance." Also, see Staking and Babel (1995) as another example.

The premium payment thus has a dual role: (1) it is a payment for the product of risk transfer from insured to insurer and purchases the ability to “sleep well at night” and (2) it provides financing for insurer operations analogous to debt. Correspondingly, the policyholder is both customer and financier—roles that are ordinarily distinct for nonfinancial firms.²⁰ The insurance customer thus has a stake in the success of the insurer—analogue to the financier’s stake in the success of a debtor firm. Customers of nonfinancial firms do not ordinarily have a similar stake in the vendor. Moreover, the assets and debt repayments (claims) of an insurer are temporally linked. The assets must be managed so that sufficient assets are available to convert conveniently to cash when needed to repay debt (pay claims). Otherwise, the insurer may face a liquidity crunch. This management of liquidity is of great importance to insurers and is called asset–liability matching. Generally, the debt repayments of a manufacturer are not temporally linked in a similar manner or to such a degree with asset-to-cash conversions, and the manufacturer looks to earnings or to refinance to repay debt. For an insurer, “refinance” means to sell more policies to other customers. Wealth is produced for the insurer largely on the liability side of the ledger, by the ability of the insurer to create more “debt” in the form of insurance contracts on which its returns (premiums and investment earnings) exceed its claims and other costs.

From the preceding discussion, it should be clear that the debt–equity focus that dominates capital structure studies for nonfinancial firms must be modified for insurers. The literature entertains two major modifications.

The first is to find an insurance parallel for the debt–equity dimension used in capital structure studies of nonfinancial firms. If we view insurer debt as more closely corresponding to policy claims than to conventional debt, then insurer debt is both contingent and indeterminate. The indefiniteness of insurer debt leads the literature to measure insurer leverage by the ratio of capital to total assets. Both capital and total assets are more definite than debt. The higher the ratio, the less levered the insurer. An alternative measure that superficially corresponds more closely to the debt–equity measure for nonfinancial firms is the ratio of loss reserves to total liabilities. However, loss reserves are actuarial estimates of future claims and so are less definite than capital. Furthermore, it is important to note that true market values may not be available for either the assets or the capital. This is because life and health insurers do not mark all of their assets to market in the statutory annual financial statements that insurers file with their regulators. This is a caveat that is provided in all the life and health research described in this chapter.

The second modification is to elevate the role of asset risk for insurers, especially for life insurers with large asset portfolios. The literature described in this chapter maintains that the choice of the degree of leveraging and the choice of asset risk for a life insurer should be viewed as interconnected and simultaneous decisions.²¹ This view is justified by the great importance of asset risk for an insurer. The asset portfolio represents accumulated premiums and earnings thereon, which are held to pay future customer claims. Therefore, insurance customers may worry about the ability of insurers to pay claims, in a similar way that lenders worry about the ability of nonfinancial firms to repay debt. The quality of the asset portfolio is thus of interest not only to management but also to the customers and to the regulators and rating agencies that act on behalf of customers. Capital may be used as a buffer against the risks of the asset portfolio. Either the capital or the portfolio composition may be adjusted to fine-tune their interrelationship.

²⁰For a mutual insurer, the policyholder is also owner, as well as customer and financier.

²¹Others have also argued for treating capital and asset risk as joint decisions, e.g., [Froot \(2007\)](#) and [Leland \(1998\)](#). Also see [Cummins and Sommer \(1996\)](#) for the property/casualty insurance industry.

30.2.3 *Asset Risks*

If asset risk is to be of equal importance to capital, then satisfactory measures of asset risk are required. The literature presents two perspectives on the nature of asset risk, with numerical measures for asset risk taking their cue from one or the other perspective.

The first perspective emphasizes *desiderata* of insurance customers, who want high probability of claims payments and low risk of insolvency. Will the quality of the asset portfolio persuade them to purchase policies? Insurance regulators focus on the insolvency aspect of asset risk with risk-based capital formulae and many other criteria. This view of asset risk historically was developed first to emphasize the minimization of insolvency risk. This is termed the actuarial point of view ([Babbel and Santomero 1999](#); [Santomero and Babbel 1997](#)).

The second perspective emphasizes the traditional risk-return trade-off of financial theory. Since life and health insurers manage their asset portfolios for return, insurer assets may be evaluated by their financial risk, as well as by their insolvency risk. Asset risk measures based on this perspective assess volatility of returns in some manner. Generally, actual returns on the portfolio are not available, so proxies are employed based upon publicly available yield rates for asset classes similar to the insurer's reported portfolio mix. The literature has not considered the question whether volatility measures alone are sufficient for assessing the financial risk of insurers who successfully practice asset–liability matching. If the up and down movements of assets correlate highly with the up and down movements of liabilities, then the negative consequences of high volatility may be neutralized by offsetting changes in matching liabilities.

The comparison between these two perspectives is the focus of the work by [Baranoff et al. \(2007\)](#). Regulatory-based measures of asset risk were used by [Baranoff and Sager \(2002, 2003\)](#) for life insurance and by [Shrieves and Dahl \(1992\)](#), [Jacques and Nigro \(1997\)](#), and [Berger \(1995\)](#) for banking. The theories underlying the asset risks are included in Tables 30.2, 30.3, and 30.6 below.

30.2.4 *Product Risks*

Insurers differ fundamentally from manufacturers by virtue of the nature of their products. Within the heterogeneous life insurance industry, one can see substantial differences among firms that are driven by differences in the mix of insurance products sold. Annuities, life insurance, health insurance, and reinsurance all bear different risk attributes. The risk of the product mix may be expected to have some impact upon major insurer decisions. Following the work of [Baranoff and Sager \(2002, 2003\)](#), [Regan and Tzeng, \(1999\)](#), and [Williamson \(1985, 1988\)](#), we summarize here the theories that regard major firm decisions as generated from the fundamental decision of the type of business to be in. Among those generated decisions are choices of capital structure and asset risks. [Baranoff and Sager \(2003\)](#) call this view the *business strategy hypothesis*. In this regard, the choice of business entails a choice of product (or product mix). The risk of that product(s) underlies capital structure and asset risk. Thus, in capital structure studies, product risk may be considered predetermined if interest lies in seeing the effects of a given choice of product and its risks.²² Product risk may also be considered endogenous if interest lies in judging how insurers balance capital against all risks simultaneously.²³

²²A natural context for predetermined treatment would be a study of an industry that provides similar products, e.g., [Baranoff et al. \(2010\)](#) study of capital structure in the health insurance industry.

²³A natural context for endogenous treatment would be a study of the product-heterogeneous life insurance industry, e.g., [Baranoff and Sager \(2002\)](#). Some other studies regard the risk devolving from product choice as endogenous. For example, in the nonfinancial literature, [Miao \(2005\)](#) summarizes the impact of products on capital structure and provides

Transaction-cost economics (TCE) provides an especially natural explanation to determine the product risks of the life and health insurance industries, as described by Baranoff et al. (1999). TCE theory was first introduced by Coase (1937) and further expanded by Williamson (1975, 1985, 1988, 1990) and Klein et al. (1978), among others.²⁴ TCE focuses on the transaction costs generated by the contracts that are associated with the products. The more complex, unique, and idiosyncratic the product, the more complex is the contract and the decisions surrounding capital and organization structures such as the degree of vertical integration (Williamson 1985) and the form of capital structure (Williamson 1988). Products that involve large contractual risks and uncertainties may lead to opportunistic behavior. These could generate conflicts among the stakeholders and increases in the transaction costs. And those higher transaction costs may trigger financing with more equity as stated by Kochhar (1996) “information asymmetry cannot be reduced in the transaction cost logic, the result is failure of the market form of exchange (debt) for firms with assets of high specificity level.”

For explaining the resolution of conflicts among stakeholders, agency theory complements TCE. When contracts create conflicts among the stakeholders, owners develop monitoring techniques to control management (Mayers and Smith 1981, 1986, 1988, 1994). Based on the mix of TCE and agency theory, Baranoff and Sager (2002) view health products as the riskiest line for life insurers since the health insurance contract can be regarded as a relational contract due to innovation in medical technology and the longer longevity of the population. Carr et al. (1999) consider annuities the least risky as do Baranoff and Sager (2002, 2003) since the risks embedded in the annuity contract are regarded more certain in terms of longevity risk. Carr et al. (1999) also view group insurance as less risky than individual contracts. Group business is the commercial line of the life industry. As in the property/casualty industry, commercial business is more complex and less uniform. Group contracts are customized, less standardized, and more incomplete in that it is subject to opportunistic behavior.

30.2.5 *The Management of Capital and Risks for Life and Health Insurers*

The literature entertains two opposing hypotheses about the relationship between capital and risk for insurers. One set of theories predicts that the relationship is positive. It is called the *finite risk* hypothesis. The second set of theories is combined to create the *excessive risk* hypothesis, which predicts negative interrelations between capital and risks. If an insurer acts to limit its overall risk, then maintaining a low level of capital would constrain it to pursue a conservative investment policy or low asset risk and vice versa. In this scenario, we would expect a positive correlation between capital and asset risk. The finite risk hypothesis is derived from the theories that imply that firms balance greater risk in one activity with lower risk in another. The theories include agency theory (starting with Jensen and Meckling 1976), transaction-cost economics (Williamson 1985, 1988), bankruptcy and regulatory cost, and complete markets (e.g., see Cummins and Sommer (1996), for the property/casualty industry and Berger (1995), for the banking industry.)

On the other hand, if an insurer does not act to limit its overall risk, then maintaining a low level of capital might lead it to pursue an aggressive investment policy with high asset risk and vice versa. This excessive risk hypothesis implies that greater risk in one activity may lead to greater risk in another. The theories leading to the excessive risk hypothesis are the risk subsidy hypothesis because of the

an equilibrium model in which capital structure and production decisions are simultaneously influenced by the same exogenous factors.

²⁴Monteverdi and Teece (1982), Grossman and Hart (1986), Joskow (1985, 1987), and Milgrom and Roberts (1992), among others. Shelanski and Klein (1995) provide a broad overview of research in TCE, which led to acceptance of the theory in the study of a variety of economic relations, including corporate finance.

Table 30.1 Summary of the expected relations per business strategy hypothesis (Source: [Baranoff and Sager 2003](#))

| | Group health | Group life | Group annuities | Individual annuities and pensions | Non-group health | Theory/hypothesis |
|--------------------------------|--------------|------------|-----------------|-----------------------------------|------------------|---|
| Capital | + | + | - | - | + | TCE—finite risk |
| Asset risk | - | - | + | + | - | Regulatory and bankruptcy cost—finite risk |
| Organization form: stock | + | + | - | - | + | Agency theory—finite risk |
| Distribution structure: broker | + | + | + | + | - | Complex group products monitoring by insureds—finite risk |

Table 30.2 Signs of expected relationships among capital structure, asset risk, organizational structure, and distribution system (endogenous variables) (Source: [Baranoff and Sager 2003](#))

| | Capital | Asset risk | Organization form: stock | Distribution structure: broker | Theory/hypothesis |
|--------------------------------|---------|------------|--------------------------|--------------------------------|--|
| Capital | | + | - | + | TCE, agency theory, and monitoring of stakeholders—finite risk. Owners prefer that managers take more risk while insureds prefer less risky insurers |
| Asset risk | + | | + | - | Regulatory and bankruptcy cost theory—finite risk |
| Organization form: stock | - | + | | + | Monitoring by owners—finite risk |
| Distribution structure: broker | + | - | + | | Monitoring by insureds—finite risk |

existence of guaranty funds, moral hazard, asymmetric information, signaling, and adverse selection (see [Cummins 1988](#); [Berger et al. 1995](#); [Downs and Sommer 1999](#)). [Babbel and Merrill \(2005\)](#) also provide a model that explains when insurers have been observed to seek excessive risk. The signs of the theoretically expected relations among capital, asset risk and selected other risks, and exposures to different product risks are summarized in [Tables 30.1](#) and [30.2](#). The tables also identify the theories that support the predicted signs.

30.2.6 Crisis Period Expectations

During the financial crisis in 2008, [Baranoff and Sager \(2011\)](#) expect finite risk to be under pressure, as asset portfolio volatility increased and sources of capital dried up. They predicted lower asset risk coefficients—possibly even negative coefficients if the life and health segments switch from finite risk to excessive risk. They also expected that the deterioration in the coefficients would be more pronounced in the segments that had relatively larger asset portfolios with more asset risk before the crisis, since those segments would have been hit harder by the crisis. Compared with the health

industry, the annuities segment with the largest asset portfolio was expected to move from finite risk toward excessive risk. Health insurers, on the other hand, despite being in riskier products, were not expected to be as affected by the markets as they have been regarded as countercyclical specialists.

For both specialist insurer segments, it would be expected, nevertheless, that the financial crisis would impair the ability of these insurers to maintain their precrisis relationship between capital and asset risks, with greater impact on the annuity specialists.

30.3 Profile of US Life and Health Insurers

In the USA, each insurer files an annual statement of detailed financial data with the NAIC in one and only one category. Among these categories are “Life” and “Health.” Data for most of the contributions discussed in this chapter are taken from these annual filings. Each category is large. In 2008, there were 838 Life filers with total assets of \$4.5 trillion, capital of \$337 billion, total premiums of \$728 billion, and net income loss of \$47 billion (compared with a net income gain of \$36 billion in 2007). The number of Life filers has declined by about 250 since 2001, all the while assets, capital, premiums, and income generally increased (except for the financial crisis year of 2008). The corresponding figures for the 878 Health filers in 2008 were \$152 billion in assets, \$76 billion in capital, \$346 billion in premiums, and net income of \$9 billion (down from \$13 billion in 2007). These figures have at least doubled since 2001, aided by an increase of about 150 in the number of Health filers.²⁵ These basic statistics point to major differences between Life and Health insurance filers. First, the mean Life filer has about 30 times the assets of the mean Health filer, although only about twice the capital. Second, premiums for Life filers are less than 1/6 of total assets, whereas premiums for Health filers are about twice total assets. Evidently, capital is relatively much more important for Health filers than for Life filers. One can infer a much more rapid pass-through from premium collections until claims payouts for Health filers than for Life filers. The literature that we discuss ties these differences to theory that gives primacy of effect to products.

30.3.1 Life Insurer Heterogeneity

Life filers are more heterogeneous than Health filers. Life insurers provide a mix of products for protection of dependents (life insurance), retirement (annuities), health (accident and health insurance—including disability), and risk mitigation/diversification (reinsurance). A large number of Life filers obtain substantial premium income from annuities, accident and health, and reinsurance lines, as well as from life insurance products. Although many Life filers offer a full range of these products, many others specialize in one product, with more than 70% of premiums from a single line. Specialist roles may put life insurers in mind-sets similar to those of other financial sectors. For example, life insurance and annuities specialists have some of the long-term financial intermediation character of banks; health and accident specialists have some of the short-term cash-basis intermediation character of property and casualty insurers. Henceforth, we refer to Life filers as the “life industry.”

²⁵Over time, many insurers have switched from filing under Life to filing under Health. Most of the insurers who have switched already had a substantial specialization in health insurance before the transition. The Life filers are heterogeneous in product orientation (see next subsection of this chapter).

Table 30.3 Life insurer specialty statistics for 2008

| Specialty | # of insurers | Total premiums written | Total assets | Capital | Net income |
|----------------|---------------|------------------------|---------------------|-------------------|--------------------|
| Life | 210 | \$39,295,418,209 | \$387,532,637,988 | \$42,127,607,284 | \$1,369,293,408 |
| Annuities | 94 | \$249,628,392,641 | \$1,813,688,600,000 | \$94,716,990,598 | (\$36,024,365,979) |
| Acc and Health | 169 | \$134,056,630,680 | \$194,805,402,443 | \$30,816,855,818 | \$6,170,838,751 |
| Reinsurance | 90 | \$34,552,672,929 | \$101,525,942,815 | \$18,373,554,999 | (\$1,138,558,342) |
| Combination | 225 | \$270,913,914,136 | \$2,017,271,000,000 | \$150,526,688,900 | (\$17,155,956,104) |

30.3.2 Health Insurer Homogeneity

Health filers have a more uniform product than the life industry. The predominant form of health insurance by premiums is comprehensive coverage, although there is also considerable involvement in the Medicare and Medicaid government programs, as well as in dental and vision lines, which are far less consequential in terms of premiums and risk to insurers as they are low level of exposure and not catastrophic in nature.²⁶ Health insurers occupy a central role in the US health-care system as intermediaries between consumers (patients), employers, government, and medical providers. In the literature that we discuss, sometimes the “health industry” means Health filers; occasionally it means Health filers plus specialist health and accident insurers that file in the Life category; sometimes Health filers and the health and accident Life filers are analyzed separately.

30.3.3 Life and Health Insurer Segmentation

Insurers in both the life and health industries pool premiums from policyholders, which they invest until needed to pay claims. The immediacy of the need for cash to pay claims determines the appropriateness of different investment vehicles. This observation underlies the need for asset/liability matching in insurance, a risk management technique by which insurers attempt to match duration of investments with forecasts of claims. The more immediate the need for cash, the more the investment must emphasize short maturity and liquid assets (health insurers hold relatively large amounts of both stocks and cash.)

The differential impact of product focus is seen most clearly within the life industry and between life and health. Some of the literature surveyed here separates the heterogeneous life industry into segments on the basis of premiums from different product lines as done initially by [Baranoff et al. \(1999\)](#). A reporting insurer is classified as an annuity specialist if 70% or more of its premiums derive from annuities, as an accident and health specialist if 70% or more of its premiums derive from accident and health lines, as a life specialist if 70% or more of its premiums derive from life lines, as a reinsurance specialist if 70% or more of its premiums derive from reinsurance, and otherwise as a combination insurer. Basic statistics for this product-based industry segmentation are shown in [Table 30.3](#) and clearly illuminate the importance of product focus for insurers.

In relation to assets, annuity specialists collectively have far less capital (2008 capital ratio = 0.05) than life specialists (0.11), accident and health specialists (0.16), or reinsurance specialists (0.18). All of these life industry ratios are much less than the collective capital ratio (0.50) of the insurers who report to the NAIC in the self-identified health category.

²⁶This includes Medicare supplement products.

30.4 Asset, Product, and Other Risk Measures

The simple statistics shown in Table 30.3 suggest that a measure of product risk for life insurers could be based upon the exposure an insurer has to products in different lines. This chapter discusses the work of Baranoff and Sager (2002, 2003, 2011) and Baranoff et al. (2007), who use the proportion of premium income that an insurer derives from its annuities lines, its lifelines, its accident and health lines, and its reinsurance lines to measure product risk. An advantage of such exposure-based product metrics is that they implicitly encompass all associated risks. (This comment also applies to exposure-based asset risk metrics.) A disadvantage is that they fail to disaggregate individual components of the risk. As noted in Sect. 30.2, a natural and obvious hypothesis is that the different capital ratios of the life industry segments could be related to the different risk characteristics of annuity, life, accident and health, and reinsurance products.

For the self-identifying health insurers who file with the NAIC under the Health category, their focus on health lines already strongly differentiates them from most of the life industry. However, some variations in risk within the health insurance industry may be discerned by examining the range of health insurance products of different risk characteristics. Table 30.4 shows the breakdown of the \$346 billion in premiums collected for Health filers in 2008.

As the name implies, *comprehensive* lines cover most medical conditions without limits. Under the Patient Protection and Affordable Care Act of 2010, there are no lifetime benefit caps, universal coverage is mandated, loss ratio minima are implemented, and preexisting conditions cannot be excluded. The federal employees lines are private *comprehensive* health plans for federal employees, although reported separately. The federal lines may be combined with other comprehensive lines, as in Baranoff et al. (2010). Comprehensive lines confer substantial risk to insurers. Although Medicare and Medicaid are government health programs, private insurers have substantial involvement and are at risk; they are not simply third-party administrators. However, various practices and procedures of the programs limit the extent of the risk for participating insurers. Dental and vision plans typically limit insurer risk through low annual benefit caps. So there is a gradation of risk among health lines as there is for the products sold by Life filers. However, the bulk of Health filers' business is the much riskier comprehensive lines. As is the case for the life industry, product risk measures for health insurers have been based on premiums collected in different lines, scaled by insurer size (e.g., total insurer assets.)

30.4.1 Exposure-Based Product Risk

Thus, an exposure product risk metric may be defined as a measure proportional to the level of insurer involvement with a given product. A common implementation of this definition is total insurer premiums collected in a given product line, divided by total insurer premiums from all lines, or some other measure of insurer size. Loss ratios also assess exposures to different products and have been proposed as product risk metrics.

Table 30.4 Premium written by health insurance filers—2008

| Comprehensive | Federal employees | Medicare | Medigap |
|-------------------|-------------------|------------------|-----------------|
| \$186,455,753,365 | \$26,691,623,131 | \$65,961,900,823 | \$7,546,285,051 |
| Medicaid | Dental | Vision | Other |
| \$42,265,127,923 | \$7,624,265,723 | \$1,336,723,111 | \$8,243,480,334 |

Table 30.5 Asset portfolio for life and health insurers by main asset classes for 2008

| 2008 | Corporate bonds | Other bonds | Stocks |
|---------------|---------------------|-------------------|-------------------|
| Life filers | \$1,566,154,388,215 | \$650,944,338,523 | \$164,623,983,448 |
| Health filers | \$34,558,903,391 | \$51,314,623,398 | \$22,318,484,614 |
| | Mortgages | Real estate | Cash |
| Life filers | \$326,367,529,585 | \$13,975,838,136 | \$54,385,205,523 |
| Health filers | \$50,474,182 | \$4,431,684,315 | \$4,944,019,974 |

30.4.1.1 Other Product Risk

Not all product metrics are exposure-based. For example, a number of life insurers now offer variable annuities with riders that assure annuitants against loss of principal and/or annuitant income, or assure withdrawals of principal or provide beneficiary death benefits. Under the traditional variable annuity, the insurer bears no risk in case of poor performance of equity markets. With riders attached, the variable annuity becomes a variable annuity with guaranteed benefits (VAGB), in which some of the market risk has been assumed by the life insurer. The insurer becomes liable to the extent that the annuitant's portfolio cannot generate the guaranteed benefit. To measure the risk of guarantees, [Baranoff et al. \(2010\)](#) proposed a Value-At-Risk-like metric based upon actuarial simulations of future market performance. These authors focused on VAGB with living benefits (accumulation, income, and withdrawals) but not death benefits (VAGLB). The guarantee risk of a VAGLB is defined as the mean of the 3,000 worst deficiencies among 10,000 simulations of the next 30 years, where a deficiency means a gap between guaranteed performance and simulated achievement.

30.4.1.2 Outcome-Based Product Risk

An exposure-based product risk metric is *ex ante* and implicitly encompasses all potential risks associated with the measured product line. Other metrics may be based upon outcomes, like the loss ratio associated with a product line. Outcome-based metrics are *ex post* and encompass only the achieved risk of the specific outcomes that are measured. This is implied in the combined risk measure created by [Cummins and Sommer \(1996\)](#) for the property/casualty insurance industry.

30.4.2 Asset/Investment Risks

30.4.2.1 Exposure-Based

Since insurers' asset portfolios include asset classes of different risks, the literature has developed exposure-based metrics for investment or asset risk. As shown in [Table 30.5](#), most of the asset portfolio of life insurers consists of corporate bonds (which include mortgage-backed securities) and other bonds with lower risk (government, municipal, and utility bonds). Health insurers hold relatively much lower amounts of corporate bonds and more of all other asset types, including cash and stocks, which is needed for day-to-day payment of health claims.

The literature has used weighted investment risk measures modeled on the C-1 component of the risk-based capital law (RBC). Such measures assign "penalty" weights to holdings in various asset classes based on the presumed riskiness of those classes. The "regulatory asset risk" measure used

in several of the contributions surveyed in Sect. 30.5 is of this type. So are the metrics developed in Born et al. (2009) and Cheng and Weiss (2011). However, the latter two studies are for property and liability insurers. The banking literature commonly employs the corresponding ratio of risk-weighted assets to total assets to assess the asset risk of banks (see Shrieves and Dahl 1992; Jacques and Nigro 1997; Aggarwal and Jacques 2001).

30.4.2.2 Volatility-Based

Market risk can be measured by volatility-of-returns measures like beta in portfolio theory or standard deviation. For the asset portfolios held by insurers, Baranoff et al. (2007) and Baranoff and Sager (2011) used a volatility-of-returns measure called “opportunity asset risk.” This measure estimates the monthly returns of an insurer’s invested portfolio by applying a number of market indices to corresponding components of the insurer’s portfolio (stock returns to stock holdings, bond returns to bond holdings, etc.) and then calculates the temporal volatility of resulting total returns. These returns are not the actual portfolio returns, but returns *potentially* earnable on asset classes of various durations, based on macro-level yields in the economy. Therefore, the opportunity asset risk measure encompasses the interest rate sensitivity noted by numerous authors as important in capital structure studies. The notion of estimating volatility of returns to assess asset risk is also employed in a related manner by Cummins and Sommer (1996) and Shim (2010) for the property and liability industries.

Table 30.6 compares the weighted exposure type of measure (regulatory asset risk) with the estimated volatility-of-returns measure (opportunity asset risk).

30.4.3 Other Risks

Organizational and operational risks include a host of factors that are often used as controls or predictors in capital structure studies. We will mention a few of them and common methods for measuring them. Although most insurers are not publicly traded, most are organized as stock companies. A less common alternative is the mutual company. There are numerous other low-frequency forms as well. In 2008, 636 of 838 reporting Life filers were stock companies as were 646 of 878 reporting Health filers. Many filers are affiliated with larger groups of related insurance companies. In 2008, 636 of 838 reporting Life filers were affiliated with a group as were 619 of 878 reporting Health filers. Both organizational form and group membership are commonly treated as 0–1 indicator variables, although some studies attempt to perform analyses on a group level because of the strength of the interrelationship among affiliates and the greater availability of market values and GAAP data for groups. Insurer size is an important characteristic for capital structure studies, since large firms typically hold less capital than small firms, relative to size. Size may be considered an operational factor, since the insurer’s business is conducted in an environment that may be affected by the scope of operations. Size is often represented by total assets, total premiums, total liabilities, or some combination of these three. The work surveyed includes alternatives to capital as means of balancing risk, such as derivative use, diversification, and reinsurance. However, these are used as controls rather than as interacting agents. Often they do not prove to be statistically significant in the models. A few findings that appear to support the excessive risk hypothesis may be in fact explainable by insurer activity in derivatives, as noted in the contributions. Further research is needed.

Table 30.6 Side-by-side summary comparison of two types of asset risk measures (Source: [Baranoff et al. 2007](#))

| | Regulatory asset risk | Opportunity asset risk |
|-----------------------|---|---|
| Computational process | Calculate raw regulatory asset risk measure based on C-1 component of risk-based capital: bond quality classes 1–6* (0.003,0.01,0.04,0.09,0.20,0.30, respectively) + common stocks*0.30 + preferred stocks*0.023 + total mortgages*0.03 (an average between 0.001 and 0.06) + real estate occupied, acquired, and invested* (0.1, 15,0.1, respectively) + (total short-term investments and cash)*0.003. Since this penalty driven portfolio measure depends on the size of the insurer, it is normalized by dividing by firm invested assets Regulatory asset risk measure = log(C-1 measure of risk-based capital/total invested assets) | Prevailing monthly exogenous indices returns (from T-bills, S&P 500 stocks, bonds of various credit and duration classes, real estate, mortgages, etc.) are applied to the firm’s specific asset portfolio values in 14 asset classes to yield constructed portfolio earnings for each month based on the proxy returns. The standard deviation of the twelve constructed monthly earnings is calculated for each year for each insurer—this is the raw <i>opportunity asset risk</i> Since this standard deviation depends on the size of the insurer, it is normalized by dividing by firm invested assets Opportunity asset risk measure = log(standard deviation of insurer’s constructed monthly returns/total invested assets) |
| Similarities | Broad asset mix of insurers Based on weighted average of asset portfolio Portfolio changes annually | Broad asset mix of insurers Based on weighted average of asset portfolio Portfolio changes annually |
| Differences | Oriented toward the objective of minimizing insolvency—assets with lower credit rating have higher “penalty” weights Weights are static throughout the years Risk measure is the weighted average of estimated (potential) losses of the portfolio | Oriented toward the objective of maximizing the value of the firm—volatility risk showing both gain and loss variability—depends on exogenous returns in the market Weights are dynamic from year to year Risk measure is the variability in the weighted average of potential earnings/losses of the portfolio |

30.4.4 Comparative Summary of Determinants for Capital Structure Studies of Nonfinancial Firms and Insurers

Using [Baranoff and Sager \(2011\)](#), we provide here a comparison between the general capital structure determinants and those that are used for insurers. The comparison is provided in [Table 30.7](#) which is based upon [Hovakimian et al. \(2004\)](#) and [Flannery and Rangan \(2006\)](#) for the nonfinancial forms and upon [Cummins and Sommer \(1996\)](#) and [Baranoff and Sager \(2002, 2003\)](#) for insurers.

30.5 Capital and Risk Interrelationship in the Past Two Decades in the USA

There has been limited empirical study of capital structure for the life and health insurance sector of the economy. Most of the work falls into the third stream of the capital structure literature that we noted in the introduction. This stream is specifically for the insurance industry and addresses the determinants of capital structure and/or the interrelationship of capital with

Table 30.7 Relevant determinants of capital structure for nonfinancial firms and for insurers (Source: Baranof and Sager (2011))

| Nonfinancial firms dependent variable: debt ratio | Insurance firms dependent variables (endogenous vars): capital ratio and asset risk |
|---|---|
| <i>Market to book ratio of assets</i> Idea: future growth => limiting leverage (pecking order, agency theory for nonfinancial firms) | <i>No exact analogue in insurance data</i> Most insurers are not publicly traded. Available asset values are a mix between book, amortized, and market values depending on the particular asset. Insurer capital is book capital; liabilities are mostly computed reserves |
| <i>Marginal tax rate</i> | <i>N/A</i> Insurance liabilities contain very little conventional debt. The favorable tax treatment of debt is not as applicable to capital structure of insurers |
| <i>Depreciation</i> | <i>N/A</i> Depreciation is mostly not applicable to insurance since the assets are mostly not machines for production |
| <i>Stock return</i> (traditional volatility-of-market-returns risk measure) | <i>Opportunity asset risk</i> Volatility-of-returns risk measure. In insurance, increased holdings of risky assets => adjustments in capital, with the effect depending upon whether the insurer operates under the finite risk paradigm (increased capital) or excessive risk paradigm (decreased capital) |
| <i>Asset tangibility-fixed asset proportions</i> In nonfinancial firms: more tangibility => more debt capacity | |
| <i>Size: total assets or revenues</i> | <i>Size: total assets</i> Economies of scope and scale <i>Size: total writings (premiums)</i> Economies of scope and scale <i>Size: total liabilities</i> Insurance liabilities consist of reserves to pay claims. Liabilities and assets need to match to meet the liquidity needs of claims |
| <i>R&D intensity</i> => more product risk Uniqueness of product/input | <i>Health writings/total writings</i> Increase in health ratio => more product risk <i>Annuity writings/total writings</i> Increase in annuity ratio => less product risk <i>Life writings/total writings</i> Increase in life ratio => less product risk Life insurers sell a mix of health, life, and annuity products. These products present very different risk characteristics. Their effects on capital depend upon whether the insurer operates under the finite risk paradigm or excessive risk paradigm. It has been argued that the riskiest specialty line is health insurance |
| <No match> | <i>Risk-based capital ratio:</i> $100 * \text{book capital} / (2 * \text{authorized capital})$ Applicable to regulated industries. This is a proxy for regulatory forbearance. It can also proxy franchise value |
| <i>Profitability</i> Retained earnings can be added to capital. The pecking order theory considers earnings to be the preferred type of financing | <i>Return on capital (income/capital)</i> Retained earnings can be added to capital. The pecking order theory considers earnings to be the preferred type of financing |
| <No match> | <i>Organizational type</i> ($1 = \text{stock}, 0 = \text{nonstock}$) Organization structure: agency theory |
| <No match> | <i>Indicator for member of group</i> ($1 = \text{yes}$) Organization structure: agency theory |
| <No match> | <i>Indicator for use of derivatives</i> ($1 = \text{yes}$) Proxy for sophistication and/or hedging |
| <i>Indicator for R&D</i> | <No match> |

insurer risks. There have been few insurance contributions in the first stream of the literature—in which the effects of different capital structures on firm value are assessed. Among those contributions that do address firm value of insurers we mention the earliest and most recent contributions known to us—[Staking and Babbel \(1995\)](#) and [D’Arcy and Lwin \(2012\)](#), both for the property/casualty industry. In this section of the contributions, we summarize the findings of several pertinent contributions in the third stream, for life and health insurer capital and risks.

We begin our survey with the [Baranoff and Sager \(2002\)](#) study of the interrelationships among capital, asset risk, and product risk for the life insurance industry for 1993–1997. The study finds support for finite risk in the positive interrelationship between capital and asset risk: Life insurers with large asset risk also have large capital ratios. However, support is also found for excessive risk in the negative interrelationship between capital and product risk: The difference in character between asset risk and product risk in their relationship to capital emphasizes the importance of separating product risk from asset risk instead of clumping all insurers’ risks together in a single firm-wide measure of risk as is done in [Cummins and Sommer \(1996\)](#) in their property and casualty industry study.

In this article, there is no segmentation of the industry along product lines. The unit of observation is the insurance company that reports to the NAIC, rather than the affiliated group to which it may belong. Capital, asset risk, and product risk are treated as endogenous. Capital is the ratio of book capital to total assets (some book and some market values). Product risk is level of exposure to health insurance (proportion of premiums from health lines) as explained in Sect. 30.4. Asset risk is a “regulatory” measure—the weighted average of asset portfolio with weights corresponding to risk, with weights as in RBC law (where higher risks receive higher weights), also explained in Sect. 30.4. The main variables have been converted to ratios to correct for firm size. The model accounts for dependence over time among the panel of life insurers.

The next article discussed here is the [Baranoff and Sager \(2003\)](#) study, which expands the interrelationships among capital and asset risk to organizational form (stock or mutual) and distribution system (broker or agent) in the life insurance industry for 1993–1999. The study explains and advances the business strategy hypothesis, in which the choice of business product is viewed as driver of other major business decisions—a view also championed by [Regan and Tzeng \(1999\)](#). Thus, the analysis of capital, asset risk, organizational form, and distribution form is conditional upon the choice of business product and product risk is treated as predetermined. In its treatment of the four endogenous factors, the contribution unites two strands of research, represented by [Regan and Tzeng \(1999\)](#) and [Cummins and Sommer \(1996\)](#) and [Baranoff and Sager \(2002\)](#). Tables 30.1 and 30.2 in Sect. 30.2 are from this chapter.

The authors find that the business strategy hypothesis is generally supported by the pattern of signs of coefficients of product risk variables in the four structural equations. The product risk variables are most strongly determinative of capital and distributional form, less determinative of asset risk, and not at all determinative of organizational form. The pattern of coefficient signs also tends to support the finite risk hypothesis. For the interrelationships among the four main variables, most coefficients are statistically significant, and all statistically significant signs comport with the predictions of finite risk. High asset risk is associated with high capital ratio. Insurers with shareholders have lower capital and higher asset risk than insurers without shareholders, as shareholder monitoring presumably drives management to seek the higher returns promised by aggressive value maximization. The higher capital ratios associated with broker distribution may represent insured monitoring of insurers for financially prudent vendors. Other operational risk determinants were not used in this study.

Again, there is no segmentation of the life industry by product line or by size. Capital is ratio of book capital to total (book) assets. Asset risk is the “regulatory” measure, organizational form is a 0–1 dummy indicator (1 = stock, 0 = not stock), and the distribution system is a 0–1 dummy indicator (1 = broker, 0 = agent). The legal difference between broker and agent is that a broker represents the insured, whereas an agent represents the insurer. This distinction is complicated by the state-to-state

vagaries of regulation (see [Baranoff et al. 2000](#)). Product risks are exposures to five lines—group annuities, life, group health, individual annuities, and individual health—with health representing high risk and annuities low risk as explained in Sect. 30.2.

A methodology novelty is the mixture of continuous endogenous variables (capital, asset risk) with limited dependent endogenous variables (organizational form, distribution form) in the four simultaneous structural equations, with probit models as structural equations for the latter two.

The next work is of [Baranoff et al. \(2007\)](#) which proposes simultaneous structural equation modeling for the life industry for 1994–2000 as a way to deal with unobserved underlying factors in multiple structural equations for an autocorrelated panel data set. The contribution seeks to determine the extent to which a volatility-of-returns investment/asset risk measure of the opportunity asset risk introduced in Sect. 30.4 may substitute for a “regulatory” investment (asset) risk measure. Both are compared in Table 30.6 above.

The contribution finds that the exposure and volatility measures of the asset risks that are explained in Sect. 30.4 are not equivalent proxies. Capital does not respond at all to the exposure investment risk measure (regulatory asset risk) for small firms, although capital does respond to the volatility-of-returns investment risk measure (opportunity asset risk). Since small insurers have substantially higher capital ratios and hold more low-risk assets (high-grade bonds, cash, etc.) than do large insurers, small insurers may not place much weight in their capital structure decisions on the insolvency risk due to their assets. On the other hand, the volatility-of-returns measure, opportunity asset risk of Table 30.6, does affect small firms positively: Increasing risk is associated with more capital. Both investment risk measures significantly affect capital in large firms in ways that comport with the finite risk hypothesis. The study also partitions the time period. During the bull market of 1998–2000, the effect on capital of both asset risk proxies increased for large insurers and substantially so for the opportunity asset risk. That is, large life insurers allocated proportionately more capital for given investment risk during the bull market than before it. On the other hand, the effect of the opportunity asset risk declined substantially for small insurers during the bull market—although the sign of the effect remained positive and significant. That is, small life insurers allocated proportionately less capital for given investment risk during the bull market than before it.

Since life insurer portfolio allocations did not change substantially during the bull market, a possible explanation is a realignment of perceived capital needs, with large insurers perceiving more need as the market boomed and small insurers perceiving less need. This model bifurcates product risk into two factors. The relatively risky health exposure factor is always positively associated with capital and the relatively less risky annuity exposure factor is always negatively related. The findings generally comport with the expectations of the finite risk hypothesis. Further tests confirm the conclusion that each of the investment risk measures adds a risk dimension to capital structure not covered by the other investment risk measures.

A simultaneous equation model with four structural equations is used. The class of life insurers’ investment risks is proxied by a single factor in the model; the class of product risks is proxied by two factors, one for relatively safe products and one for relatively risky products. These factors are presumed to be the unobserved “pure” risks that interact to yield the observable manifest variables. There is one structural equation for each of capital, investment risk, and the two product risks. In successive runs, the model swaps the exposure (regulatory) asset risk factor for the volatility-of-returns factor (opportunity asset risk) to assess the differential effects of the two measures. There is segmentation by size of insurer and time period (before and during the bull market of the late 1990s).

[Baranoff and Sager \(2009\)](#) study the effect that lowered ratings of mortgage-backed securities (MBS) would have on life insurer capital needs. The hypothesized mechanism for the effect is that lower MBS ratings result in more investment risk, which results in greater need for capital if the finite risk hypothesis prevails. The risks of MBS were not generally recognized in the study period of 2003 and 2006, prior to the financial crisis. One reason for this lack of recognition is that MBS are

mortgages bundled as bonds. When bundled as bonds, MBS received generally higher ratings than unbundled mortgages did. As bonds, MBS also received lower “penalty” weights than mortgages in the life RBC law. Life insurers held \$466 billion in MBS in 2006, the peak year of the real estate frenzy. Median life insurer exposure was 11% of total invested assets, with the top 10% of life insurers all exceeding 25% of total invested assets. Five scenarios of increasing proportion of MBS reclassification are used in the study. To estimate the effects, capital structure-like models are used, with capital as a function of investment risk and controls.

The authors find that life insurers reduced capital as they accumulated MBS before the crisis, as though they thought that acquiring MBS should raise the overall quality of the investment portfolio. Life insurers were unprepared for the need for MBS downgrades. Moreover, all five downgrade scenarios are shown to lead to large increases in investment risk, which would lead to significant estimated increases in capital. For example, under a moderate recategorization of residential MBS debt (downgrade 50% of insurer-held MBS from quality category 1 (highest) and 25% of quality category 2 to categories 5 and 6 (lowest)), a life insurer with median residential MBS exposure might be expected to increase its capital by 10% or more to maintain a historical relationship between capital and risk factors. The adjustments are even greater when both residential and commercial MBS are downgraded.

Another capital structure contribution relating the financial crisis is that of [Baranoff and Sager \(2011\)](#) which explores the impact of the financial crisis on the capital structure of both life and health insurers in both categories of Life filers and Health filers. The study compares the elasticity of capital with respect to investment risk in 2006 (just before the crisis) with the elasticity in 2008 (during the crisis). The elasticity of capital ratio reflects the ability (or willingness) of insurers to buffer their investment risks. Particular attention is paid to variation in the elasticity of capital across industry subsector segments, as the crisis was expected to affect some specialty segments more than others as described in the theory part in Sect. 30.2. The industry is segmented by business product focus (annuity, life, health, reinsurance, non-specialized), by size (large and small), and by organizational form (stock, mutual) based on the 70% rule described in Sect. 30.3.

The results show that during the crisis, all segments moved uniformly toward lower capital elasticities with respect to asset risk. Elasticities remained positive but were lower by factors of 3–5. Asset/investment risk was high during the crisis. Insurers may have lost the ability to buffer their investment risks, perhaps because of a partial shutdown of capital markets. In addition, since negative elasticity indicates excessive risk behavior, insurers moved closer to the dividing point between finite risk and excessive risk—a concern of interest to regulators. Insurers with an annuity focus had the greatest movement toward the excessive risk paradigm, but the finite risk paradigm persisted, nevertheless. Annuity insurers held the largest investment portfolios and thus bore the largest impact of the market crisis.

In a recent completed work that has been presented in various forums, [Baranoff et al. \(2010\)](#) study how life insurers managed their capital in respect of the risks of variable annuities with guaranteed benefits (VAGB) just before and in the beginning of the financial crisis. Only a relatively small subset of life insurers (70–80) were writing VAGB. Guarantees protect annuitants against some of the market risks of ordinary variable annuities. With over \$500 billion in annuitants account value, VAGB have been the most popular form of variable annuities since 2000. Four common types of guarantees assure annuitants of increasing annuitization income, increasing accumulation value, availability of withdrawals against principal, and beneficiary death benefit. By issuing the guarantees, insurers assume risk in return for extra fees. In a good market, these guarantees pose no threat to insurers. However, the collapse in equity markets of 2008–2009 exposed the risk of these guarantees. The contribution deals with living benefits guarantees (VAGLB), excluding death benefits. In addition to the straightforward measure of these risks by exposure metrics, the contribution introduces a new measure of *guarantee risk* that is based on actuarial simulations of future calls on the insurer to make

good on the guarantees. The model is standard capital structure regression with capital as a function of guarantee risk, investment risk, product risk, and other factors including derivatives for hedging the guarantee risks.

The research shows that life insurers who write VAGLB were in the finite risk paradigm with respect to investment and product risk. However, insurers with more guarantee risk for living benefits were shown to have lower capital ratios than insurers with less guarantee risk, *ceteris paribus*. The latter finding is consistent with excessive risk. A possible explanation may be found in the widespread use of derivatives among the panel of VAGLB writing insurers. Insurers may believe that the use of derivatives to hedge the additional asset-related risks of the guarantees provides a sufficient offset to these new risks and therefore that further capital need not be accumulated for that purpose.

Relevant to the point about derivative use is [Lin et al. \(2008\)](#), which examines hedging, investment, and financing simultaneously for 1992–1996 for nonfinancial firms. Theoretically and empirically, they find that firms with greater growth opportunity hedge more to reduce the likelihood of financial distress. They also find that for a given amount of risk management, there is a negative relationship between the level of risky investment and the level of debt. The contribution also provides a comprehensive literature review in the relationship between hedging, investment, and financing decisions (p.4).

Similarly, [Shiu \(2011\)](#) examines the role of reinsurance with leverage (inverse of capital). Using UK nonlife insurers, he finds that insurers with higher leverage tend to purchase more reinsurance and insurers with higher reinsurance tend to have higher levels of liabilities. This contribution tries to address the reverse causality of reinsurance on leverage. The result is consistent with the finite risk hypothesis.

In another very recent completed work that was presented in various forms, [Baranoff et al. \(2010\)](#) apply capital structure models to health insurance industry for 2001–2008 to learn how health insurers manage their capital. This is of particular interest because of provisions in US health-care reform legislation of 2010 that mandates universal coverage, no limitation on benefits, and loss ratio minima—all of which increase product risks for health insurers. As noted above, the theory suggests that the capital management of health insurers should differ from that of life insurers because of the needs driven by the different product foci.

The authors find that health insurers manage their capital in conformance with the predictions of finite risk. High product and/or investment risks are shown to be associated with high capital ratio. However, the elasticity of capital with respect to investment risk is low. The study reveals evidence that product risk is more important than investment risk for health insurers; the opposite is true for life insurers. For health insurers, product risks account for eight times as much of the explanatory power of the model for capital as investment risk does. Capital ratio is linked positively with loss ratios. Annual health insurer premiums far exceed total invested assets; the reverse is true for life insurers. The model suggests that health insurers will attempt to adapt to legislated increases in their risks by means that may act to undermine the cost-saving intentions of the legislation.

In the analysis, product risks are divided into three groups: comprehensive health care, limited coverage (dental, vision), and government programs (Medicare, Medicaid). Nevertheless, the authors do not segment the health insurance industry since insurers offering comprehensive coverage constitute the large majority of the industry. In the model, capital and volatility-of-returns investment risk (opportunity asset risk) are mutually interacting, driven by product risks and other controls, including loss ratios and utilization.

In the work of [Baranoff et al. \(2004, 2007\)](#) “Managing Capital Structure: The Case of Life Insurers—A Semiparametric Simultaneous Equations Approach” and “Rebalancing Target Capital in the Financial Sector: The Case of Life Insurance,” the authors investigate the capital-investment risk interrelationship as a means to estimate target capital and target asset/investment risk along with the speed of reversion toward target levels for life insurers in 1994, 1997, 2000, and 2002. Target capital is an unobservable variable that represents the putative level of capital ratio that a life insurer

strives to achieve. Since the actual capital for a given year is likely to differ from the target value, it is of interest to know if there is any evidence that insurers manage their capital so as to close the gap between actual capital and target capital and how fast the gap may be expected to close. These issues have been studied for firms in nonfinancial sectors as explained in Sect. 30.2, e.g., [Hovakimian et al. \(2004\)](#) and [Flannery and Rangan \(2006\)](#). [Baranoff et al. \(2004, 2007\)](#) are the only contributions known to us that study target capital (the trade-off hypothesis) for insurers. They find that the rate of gap closure between actual and target capital is essentially instantaneous—100% in 1 year. This could be explained by the high level of US regulation of insurer risk-based capital.

An important and novel feature of the authors' approach is the use of a nonlinear semiparametric model to estimate target capital. Since target capital is not observed, it must be estimated—typically by some kind of regression model. The estimates are then used in a partial adjustment model to estimate the rate of gap closure, if any. Because of the importance of investment risk to life insurers and its interrelationship with capital ratio, a further novel feature of the work is the joint estimation of both capital ratio and investment risk targets with the nonlinear model. The gap between target investment risk and actual investment risk is also found to close within essentially 1 year.²⁷

Finally, the research using the nonlinear model reveals that some of the relationships between capital and risks that have been modeled as monotonic and linear in the literature are actually non-monotonic and nonlinear. The significance of this finding is that there are subsets of the life industry in which insurers' capital ratio relationship with investment or asset risk follows the finite risk hypothesis and other subsets in which this relationship follows excessive risk. For example, at high levels of investment risk, the slope of target capital may switch from positive (finite risk) to negative (excessive risk). Use of linear models would wipe out this distinction.

30.6 Conclusion

In this chapter, we have reviewed the theory and empirics of capital structure for US life and health insurers over the last 20 years, and especially since 2000. As noted above, we organized the capital structure literature for this chapter into three streams based on the role of the key capital structure variable and application to insurers. The initial stream examines capital structure as a potential determinant of firm value. The second stream examines the determinants of capital structure, including the setting of targets for capital. Most of the first two streams exclude insurers. In the third stream, we explore the development and adaptation of capital structure theory for insurers. The bulk of this chapter is devoted to the work for life and health insurers within the third stream. We discuss the significant adaptations required to apply of the theory of capital structure for nonfinancial firms to life and health insurers. One of the most important adaptations is a refocusing from determinants of the leverage to capital/risk interrelationships. Most of the financing of life and health insurers come from customer premiums, which may be viewed as loans that insurers must repay only contingently in amounts and at times that are uncertain and must be actuarially estimated. Insurers invest the premiums until needed to pay claims. So the true claims of life and health insurers are estimates and subject to risk. The risk arises from uncertainty about the size of future claims (product risk) and uncertainty about the performance of invested premiums (asset/investment risk). The uncertainties are driven by the nature of the insurance products that are marketed. Some products generate frequent, near-term claims of great variability (health insurance). Other products generate occasional

²⁷This closure also fits in within the asset/liability matching of insurers which would lead to closures of gap to ensure that the claims will be covered in time. The existence of the trade-off hypothesis in insurance is a by-product of both asset/liability matching as well as the regulatory forbearance.

or long-term claims of predictable magnitude (life insurance, annuities). Capital is a buffer against unforeseen spikes in the realization of product or investment risks. The theories discussed in this chapter lay the foundation for understanding and interpreting and extending this framework.

From the empirical studies reviewed in Sect. 30.5, a few generalizations emerge and adumbrate future work:

1. For the most part, life and health insurers manage their capital in keeping with the predictions of the finite risk hypothesis. That is, insurers tend to balance an increase of risk in one area with a reduction of risk in another area, *ceteris paribus*. There is only limited support for the excessive risk hypothesis. Excessive risk predicts that insurers may not offset an increase of risk in one area by a reduction of risk in another. Excessive risk comes into play only under unusual circumstances and in using nonlinear models for some levels of capital. Circumstances that may lead to excessive risk are illustrated by the life industry's situation in the run-up to the financial crisis of 2007–2009. Many insurers held mortgage-backed securities (MBS) and sold variable annuities with guaranteed benefits (VAGB). Arguably, the precrisis circumstances resulted from failures to assess risk properly. For example, credit rating agencies failed to account for the true underlying risks of MBS. Also, regulatory standards counted MBS the same as the highest quality bonds with correspondingly low penalty weights in the life risk-based capital law. These circumstances incentivized life insurers to hold more MBS than they should have. VAGB were new products with which the industry had little prior experience despite risk management techniques with hedging instruments.
2. To maintain that insurers did provide for these risks, one would need to argue that the statistical models fail to capture the means by which insurers offset the risks. For example, it could be argued that insurers may have been attempting to offset risks of MBS and/or VAGB through derivative arrangements. Since reporting requirements for these derivatives have been weak, it is difficult to obtain data to adjust for them adequately in the statistical models, especially as such instruments are not connected directly to each product and explicitly explained in the data. However, even if insurers realized and provided for the risks of MBS and/or VAGB, there is no evidence of realization of the risks as related to derivative arrangements.
3. There is support for the notion that life and health insurers manage capital and risk jointly. Most of the contributions discussed in this chapter model capital and risks as simultaneously interacting variables. The analysis supports the endogenous nature of capital and risks.
4. However, the analysis also finds support for the primacy of product risk as a fundamental driver of other insurer decisions, in accord with the predictions of the business strategy hypothesis described in Sect. 30.3. Conceptually, an insurer first decides its business focus (line of specialty or combination of lines). Then the capital structure, investment risk, and other major decisions are informed by the choice of product.
5. As a consequence, capital structure varies among groups of insurers who focus on different insurance lines. Health insurers maintain relatively higher capital ratios than life insurers. The nature of the health insurance product requires that large amounts of cash be available for payment of health claims, which occur within a short time span of the collection of premiums. In addition, health claims may be expected to vary considerably among insureds. On the other hand, there is usually a long time between collection of life insurance and annuity premiums and their ultimate payout. In addition, the amounts of life and annuity payments are more nearly known and specified by contract. These product differences encourage larger long-term investment portfolios for life and annuity insurers than for health insurers and relatively larger capital buffers for health insurers than for life and annuity insurers.
6. Large insurers tend to maintain smaller capital ratios than small insurers. This is a predictable consequence of the statistical law of large numbers. The large insurer does not need the same amount of capital in relation to its size in order to buffer variable results as a small insurer does.

7. Mutual insurers tend to have higher capital ratios than stock insurers. Agency theory predicts this result, since the management of a mutual insurer is less closely monitored by stakeholders than the management of a stock insurer, and so takes less risk.
8. The financial crisis of 2007–2009 affected life and health insurers as predicted by finite risk and the business strategy hypotheses. All segments were driven toward excessive risk but remained within the realm of finite risk. Product specializations predict the manner by which the crisis affected insurers differentially. With their huge portfolios of invested assets, life insurers specializing in annuities were most impacted by the crisis. These life insurers hold large amounts of mortgage-backed securities (MBS) in their portfolios. Were it to be required that the capital structures of life insurers be adjusted to reflect the true risks of MBS, life insurers would need to add substantially to their capital.
9. The life insurance industry appears to set targets for capital and investment risk and to close the gap between achieved and targeted capital and investment risk more rapidly (in about 1 year) than any reported nonfinancial sector.
10. Relationships between capital and risk are not linear. Use of linear models may obscure the interpretation of theoretical relationships between capital and risks. For example, capital may increase for low and moderate levels of investment risk but decrease for high levels of investment risk. Most research papers use linear statistical models, and few report diagnostic tests of the applicability of linear models. The extent to which the use of conventional linear statistical models has distorted reported results in the literature remains an open question.
11. Relatively few contributions have investigated the impact of different capital structures on the firm values of insurers (the first stream of the literature that we identified). There are a few published contributions for the property/casualty industry but none for life or health. Empirically, the major roadblock is the lack of market values for insurers that results from the paucity of publicly traded companies. One avenue for attack may be to adapt the techniques suggested in the property and casualty studies along with the mark-to-market matching and imputation methodologies. However, the attempts made so far have been dishearteningly time-consuming.
12. In general, the widespread use of proxies in the insurance literature awaits empirical confirmation. A proxy is adopted when the variable that researchers would like to have is not available. So there is some uncertainty whether the reported results would remain the same if the unavailable variables were somehow available. The reply that they are unavailable, so we cannot use them anyway, is not really reassuring. Sometimes they are available in fact, but substantial time and resources would be required to measure them. Perhaps a combination of dedicated work and clever statistical ideas might resolve our doubts. For example, one thinks of the statistical technique of multiple imputation, in which available true values for a small subset of a population are projected to the rest of the population as if by magic. Values for the projected population are not accurate, except on average, but that is sufficient to produce accurate estimates of population parameters. Most capital structure questions are not really questions about individual insurers but questions about the population of insurers.

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Chapter 31

Insurance Market Regulation: Catastrophe Risk, Competition, and Systemic Risk

Robert W. Klein

Abstract Insurance regulation has long been a subject of considerable interest to academics, policymakers, and other stakeholders in the insurance industry. Among the areas explored by academics over the years, there are three topics of particular importance that have significant implications for the regulation of insurance companies and markets: (1) catastrophe risk, (2) competition, and (3) systemic risk. This chapter provides an overview of insurance regulation and discusses key issues that it faces and how it has responded to these issues including the role of competition, increasing catastrophe risk, and the reemergence of systemic risk in financial markets and its implications for insurance regulation.

31.1 Introduction

Insurance regulation has long been a subject of prominent interest to academics, policymakers, and other stakeholders in the insurance industry. The recent financial crisis and its cascading effects on the global economy have drawn increased attention to the regulation of financial institutions including insurance companies. Other issues, such as the rising number and cost of natural and man-made catastrophes, have significant regulatory implications. In general, as the nature and types of risks that households and businesses face have changed, the insurance industry has evolved to meet the need for efficient risk management solutions. This evolution has been marked by intense competition, the globalization of insurance markets, convergence in the financial services industry, new products and methods for financing and managing risk, changing technology, broader access to information and other important developments that have affected the role, and provision of insurance. As the insurance industry has evolved, so has its regulation. Regulators have been compelled to respond to the transformation of the insurance industry and the shifting environment in which it resides.

Three topics are particularly significant in terms of their implications for insurance regulation: (1) catastrophe risk, (2) competition, and (3) systemic risk. Concerns about catastrophe risk have greatly increased over the last two decades with the rising frequency and severity of natural disasters in the USA and worldwide as well as the heightened threat of terrorist events marked by the 9/11 attacks and other incidents. Governments and the insurance industry have been challenged in responding to this increase in catastrophe risk. Insurance companies have sought to enhance their

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assessment, pricing, and financing of catastrophe risk as well as adjust their contract provisions and exposures. In turn, insurance regulators have been confronted with the measures taken by insurers and compelled to react in terms of what changes they will allow and where they may seek to constrain insurers' actions, conscious of the need to maintain an adequate supply of catastrophe risk coverage. Governments also have explored and created mechanisms to fill in gaps and/or lower the cost of private catastrophe coverage.

Competition in the insurance industry has been a long-standing area of attention. Insurance markets that are relatively mature and that have low entry/exit barriers are generally populated by a large number of suppliers that compete aggressively to sell their products and services to various buyers. Insurance markets that are relatively immature may be subject to too much or too little competition depending upon the sophistication of their sellers and buyers. In such markets, regulators may be compelled to intervene to establish a reasonable level of stability or counter suppliers' market power depending upon the structure and performance of these markets. Even in mature insurance markets that are structurally competitive, public mistrust of insurance companies and political pressure may induce insurance regulators to impose constraints on insurers' prices and products. Hence, issues concerning competition and how insurance markets should be regulated are prominent in many countries.

Systemic risk and its implications for the regulation of insurance companies have been the subjects of considerable discussion in light of the financial crisis and the problems experienced by the investment subsidiaries of the American International Group (AIG) and monoline insurers. There also have been concerns about the potential effects of systemic risk in financial markets on the financial condition of insurance companies. There has been a vigorous debate over whether insurance companies are significant contributors to systemic risk in the financial sector, with most insurance experts concluding this is not the case. Nonetheless, governments are exploring or have adopted new regulations that could increase the regulatory oversight of insurance institutions that are deemed to be systemically significant. Further, insurance regulators are enhancing their monitoring of insurance companies that belong to corporate groups which could be exposed to financial risks arising from the activities of noninsurance entities within their group structures.

In this context, this chapter provides an overview of insurance regulation and discusses key issues that it faces and how it has responded to these issues including the role of competition, increasing catastrophe risk, and the reemergence of systemic risk in financial markets and its implications for insurance. Most of the discussion in this chapter is focused on the USA with some references to regulatory policies in the European Union (EU) for comparative purposes. The chapter is organized as follows. Section 31.2 articulates a set of principles for government intervention in insurance markets and discusses the types of regulatory remedies that might be used to address market failures in insurance. Section 31.3 reviews the basic framework for insurance regulation and the objectives, policies, and practices employed in the principal areas of insurance regulation. Section 31.4 assesses the competitiveness of insurance markets based on their structure and performance. Section 31.5 tackles the issue of catastrophe risk and how regulation affects its financing and management. Section 31.6 examines the topic of systemic risk in insurance and its regulatory implications. Section 31.7 offers concluding remarks.

31.2 Principles for Insurance Regulation

A survey of insurance regulation naturally begins with a review of basic principles of insurance regulation. It is important to articulate a rationale for why insurance markets and companies are regulated to lay a foundation for the review of the regulation of the particular areas covered in this chapter. This section begins by applying the concepts of workable competition and market failures to

insurance which form the basis for arguments for beneficial regulatory intervention. This is followed by a discussion of the types of regulatory remedies for insurance market failures that may enhance social welfare if properly designed. The section ends with a review of other possible motivations for regulatory intervention in insurance markets which may lead to certain regulatory policies that do not conform to the economic principles articulated here.

31.2.1 Market Failures and Regulatory Intervention

The economic rationale for regulatory intervention in markets is based on the concept of market failures (see, e.g., [Spulber 1989](#); [Viscusi et al. 2000](#)). Market failures arise when one or more of the conditions for perfect competition are violated. A market is considered to be perfectly competitive when there are numerous buyers and sellers of a homogeneous product, there are no barriers to entry and exit, and both buyers and sellers have perfect information. When these conditions are satisfied, the joint surplus or gains from trade of firms and consumers are maximized. However, in reality, few if any markets satisfy these conditions. A more reasonable standard for judging the need for regulation is the standard of “workable competition.” A market is considered to be workably competitive when it reasonably approximates the conditions for perfect competition to the extent that government intervention cannot improve social welfare ([Scherer and Ross 1990](#)).

The kinds of market failures that are most commonly found in insurance markets are severe asymmetric information problems and principal-agent conflicts. These market failures could prompt some insurance companies to incur excessive financial risk and/or employ market practices that harm consumers ([Klein 2009](#)). Insurance buyers, particularly households and small businesses, are severely challenged in terms of being able to assess the financial risk of insurance companies and understand the terms of insurance contracts. Principal-agent conflicts also work to the detriment of insurance buyers if insurance companies can increase their financial risk after their policyholders have paid premiums to these companies. Additionally, it is possible that insurers could acquire sufficient market power under certain conditions to constrain competition and manipulate the supply and price of insurance in order to earn excess profits.

Government intervention may be justified when market failures occur if intervention can remedy these failures and increase the efficiency of a market. For example, an insurance company may incur excessive financial risk because its owners could avoid paying the full costs of its insolvency due to the limited liability of corporations. The fiduciary role played by financial institutions such as banks and insurance companies coupled with their complexity present special problems for their creditors.¹ One could argue that if it is difficult and costly for consumers to properly assess the financial condition of insurance companies and protect their interests after they have paid premiums then it may be more efficient for the government to monitor insurers’ financial risk and take other measures to protect consumers’ interests.

An optimal regulatory scheme would be based on a set of principles under which regulators would seek to recreate the conditions for workable competition or implement remedies to compensate for market failures and maximize social welfare. This implies that regulators would strive to remedy true market failures and not try to artificially alter “undesirable” market outcomes that are not caused by market failures per se. There is also the presumption that regulators possess all the information they need and can implement appropriate remedies which may not always be the case. Not all market

¹[Saunders and Cornett \(2003\)](#) discuss the rationale for the regulation of financial institutions. While their principal argument is based on externalities (discussed below), other arguments also contribute to the case for government oversight.

failures can necessarily be corrected by regulation and the efficiency of any particular regulatory intervention must be judged in terms of regulators' ability to remedy a particular market failure and any deadweight costs associated with regulatory intervention that may exceed the benefits from intervention. It is also presumed that regulators will employ "best practices" and the most efficient measures to address market failures.

31.2.1.1 Solvency Regulation

The economic rationale for regulating insurer solvency is based on the problems created by costly information and principal-agent problems (Munch and Smallwood 1981). Insurance companies' incentives to maintain a high level of safety are compromised to the extent that the personal assets of their owners are not at risk for unfunded obligations to policyholders that would arise from bankruptcy. As noted above, it is costly for consumers to correctly determine an insurer's financial risk in relation to its prices and quality of service.² Insurance companies also can alter their risk after they have received funds from their policyholders. This could be characterized as a "principal-agent" problem that may be very hard for policyholders to monitor and control. These conditions could hamper consumers' ability to differentiate between insurers with varying risk levels and expose them to excessive financial risk.

There are other reasons why regulators may seek to curb excessive insolvency risk. There is the potential problem of "contagion" whereby a spike in insurer insolvencies could induce a "crisis of confidence" that may have adverse effects on other insurers. Additionally, negative externalities could arise from excessive insurer insolvency risk if the costs of unpaid claims are shifted beyond policyholders to their creditors. Consequently, the regulation of financial institutions is often coupled with insolvency guaranty mechanisms (e.g., deposit insurance, insurance guaranty associations) that assume at least some part of the obligations of bankrupt firms to those that entrusted their funds with these firms. However, the existence of insolvency guarantees could lead to moral hazard and undermine market discipline. Insurance buyers have diminished incentives to buy insurance from financially strong insurers if they know or believe that their claims will be covered if their insurer becomes bankrupt (Cummins 1988). Hence, the existence of insolvency guarantees further increases the need for good financial regulation to compensate for any diminution of market discipline due to these guarantees.

It would not make economic sense for regulators to attempt to eliminate all insolvencies because this would likely be too costly relative to any benefits that would be obtained from such a policy. A more reasonable objective would be to reduce the social costs of insurer insolvencies within limits that would be socially acceptable. It should be noted that the social cost of an insurer insolvency exceeds the lost equity of the insurer because it includes the costs imposed on policyholders and other creditors of the insurer. Regulators can reduce insolvency risk by compelling insurers to meet certain financial standards and intervening if an insurer assumes too much risk or gets into financial difficulty (Cummins et al. 1995).

²The costs of determining financial soundness are much lower today than they were in the past as anyone with knowledge and access to the Internet can check an insurer's claims paying ability provided by rating agencies. However, rating agencies cannot engage in enforcement actions (although they may pressure insurers to correct problems) and most countries do not accept the notion that they are an adequate substitute for government regulation.

31.2.1.2 Price Regulation

Different arguments have been offered for the regulation of insurance prices. One view is that insurers have an incentive to underprice the coverage they offer in an attempt to obtain more business and increase their profits, effectively betting on the possibility that their claims will be lower than expected (Joskow 1973; Hanson et al. 1974). If they “win” the bet, then they will collect the winnings in terms of additional profits. If they “lose” the bet, their losses are confined to the equity they hold and any further losses are passed on to policyholders and other creditors. This could induce other insurers to cut their prices in order to retain their business which would lead to a further weakening of the financial condition of the industry.³ The regulatory answer to this kind of problem has been the enforcement of uniform prices or price floors to prevent insurers from charging inadequate prices.

Alternatively, consumers and some regulators may believe that insurers will seek to overprice insurance in the absence of regulation. According to this view, it is necessary for regulators to impose price ceilings to prevent insurers from charging prices that exceed the cost of providing coverage. To rationalize such a policy, one might argue that consumer search costs impede competition resulting in excessive prices and profits.⁴ Another argument might be that insurers already entrenched in a market have an informational advantage over potential entrants that would effectively create an entry barrier that would diminish competition.

Many insurance economists question the need for price regulation of insurance products. If one looks at the empirical evidence on competition and the effects of insurance price regulation, most researchers conclude that price regulation is unnecessary and potentially harmful (Cummins 2002; Harrington 2002). Studies of insurance markets in the USA conclude that they are structurally competitive and their performance is consistent with what one would expect in a competitive market (Cummins and Weiss 1991; Klein 2005; Grace and Klein 2007). Entry and exit barriers tend to be low and concentration levels rarely approach a point that would raise concerns about insurers’ market power. Hence, under these conditions, one would expect insurance markets to be efficient and that prices will not exceed competitive levels.

31.2.1.3 Market Conduct Regulation

There appears to be greater justification for some level of regulation of insurers’ products and market practices, e.g., marketing and claim adjustment. Because of consumers’ difficulty in understanding the terms of insurance contracts and disparities in their bargaining power relative to insurers, they are potentially vulnerable to unfair marketing and claim practices.⁵ One example of this was the misrepresentation of life insurance products in the USA in the late 1980s and early 1990s (Klein 2012). Although several prominent insurers were involved in these practices, one would normally expect that most insurers would try to avoid abusive trade practices in order to maintain a good reputation for their treatment of their customers. There is a greater problem with insurance companies and intermediaries that lack sufficient incentives to maintain a good reputation or seek to prey on vulnerable consumers and that value the gains from such behavior more than any costs they would incur from obtaining

³This view likely stems from the periodic price wars (and subsequent insurer failures) that afflicted property-casualty insurance markets in the USA during the 1800s and early 1900s.

⁴Harrington (1992) explains but does not advocate this view. Further, the cost of shopping for insurance has dropped dramatically for personal lines of coverage (see Brown and Goolsbee 2002).

⁵It is true that consumers subject to unfair treatment might seek remedies through the courts and sometimes do so. However, legal remedies may not be feasible for consumers with limited resources and bills to pay. Also, it may be difficult to secure financial damages from some fraudulent insurers.

a bad reputation. Regulators need to pay particular attention to these kinds of firms who are not otherwise motivated to treat consumers fairly. Appropriate regulatory remedies could take the form of approving insurance products purchased by individuals and small businesses, monitoring insurers' market practices and consumer complaints, encouraging self-compliance measures by insurers, and sanctioning insurers who mistreat consumers.

31.2.2 *Other Motivations for Regulatory Intervention*

In contrast to market failures, there are situations where market conditions could lead to market outcomes that consumers and regulators may view as problematic (Klein 2009). These outcomes are not the result of market failures but rather are caused by factors affecting the cost of and/or the insurability of certain risks. For example, in some markets insurance may be expensive because claim costs are high. There may be other situations where insurers may be reluctant to supply insurance voluntarily because of severe adverse selection or moral hazard problems or correlated risk exposures, e.g., natural and man-made catastrophes. Although these kinds of outcomes can create consternation among consumers, they can be the natural result of properly functioning market forces and not something that can be remedied by regulation per se.

Nonetheless, consumer concerns and societal preferences may prompt governments to impose artificial regulatory constraints on insurance prices and other regulations intended to increase the availability of insurance or “engineer” the coverages provided in insurance contracts. One example of this (which is discussed in greater detail in Sect. 31.5) is Florida’s resistance to sharp hikes in the price of residential property insurance after the 2004/2005 hurricane seasons. Regulators may argue that such restrictions are needed to prevent large swings in the cost of insurance.⁶ There are other aspects of the political environment for certain insurance markets and their regulation that can lead to policies that are not in the best interest of consumers despite what they may believe. The political economy of regulation could be described as a setting in which different interest groups seek to influence regulators and legislators to adopt policies that are most beneficial to them.⁷ There may be some groups that have few members but have relatively substantial and concentrated economic interests. These groups are more likely to succeed on issues that are not transparent and or important to most consumers (Meier 1988). There are other issues, such as the price and availability of auto and homeowners insurance, that may be highly salient to many consumers, and this could result in substantial political pressure on regulators to compel insurers to lower the cost and/or increase the supply of insurance. Hence, a number of factors can affect regulatory policies and who benefits from such policies.⁸

These types of policies may be applauded by voters and interest groups who seek special treatment, but they can also result in significant market distortions that can ultimately worsen the problems that regulators are seeking to fix. For example, severe constraints on insurance prices can amplify moral hazard by decreasing insureds’ incentives to control their risk which can further escalate claim

⁶If regulators believe that rate increases are warranted, they tend to prefer to see these increases phased in gradually over time rather than implemented in 1 year.

⁷Insights from Becker (1983) and related literature are helpful in understanding how interest group politics may play in government policies regarding insurance. Stigler (1971) and Peltzman (1976) also laid the foundation for an economic theory of regulatory behavior that considers the potential influence of the concentrated economic interests of regulated firms and other groups. Political scientists such as Meier (1988) have broadened this framework to include other factors that might influence regulatory behavior, such as ideology, bureaucracy, the role of political elites, and the complexity and saliency of regulatory issues.

⁸See Meier (1988) and Klein (1995) for discussions of theories of regulatory behavior and how they apply to insurance.

costs and prevent insurers from earning a fair profit. Regulators may also impose mandatory service requirements which require insurers to accept all applicants or impose other constraints on their underwriting practices. These kinds of policies can prompt insurers to exit the market and severely reduce the supply of insurance.

31.3 Competition in the Insurance Industry

To develop a good understanding of insurance regulatory policies and assess their relative merits, it is helpful to review the evidence on the competitiveness of insurance markets. This section examines the empirical evidence on the structure and performance of key insurance sectors and markets. This examination utilizes the structure-conduct-performance framework (SCP) for analyzing the competitiveness and efficiency of insurance markets.⁹ According to this framework, a competitive market structure which elicits independent and competitive behavior by firms leads to efficient market outcomes such as fair profits and prices no higher than necessary to produce goods and services that meet consumer demands.

31.3.1 Market Structure

Economists typically look at several aspects of a market's structure in determining how it might be expected to affect firm conduct and market performance. These aspects include seller and buyer concentration, product differentiation, barriers to entry and exit, cost structures, vertical integration, and diversification. One could argue that the cost and quality of information available to buyers and sellers also can affect competition.¹⁰ Of these characteristics, seller concentration and barriers to entry and exit are particularly significant. In a highly concentrated market, there is the potential for firms to acquire substantial market power (individually and/or collectively) that they can use to control output and ultimately prices. At the same time, the cost of entry and exit can influence not only seller concentration but the ability of incumbent firms to exercise market power. According to the theory of "contestable markets," even in a highly concentrated market with low entry/exit barriers, if incumbent firms attempt to raise their prices above a competitive level, this will attract new entrants to the market who will drive prices back down to competitive levels (Baumol et al. 1982). Hence, the threat of entry by new firms can have a disciplinary effect on the behavior of incumbent firms.

Most of the existing literature on the structure and performance of insurance markets are specific to particular markets, and the analysis performed is often tied to other issues such as the effect of regulation on market outcomes.¹¹ There are also several studies that have conducted a more comprehensive assessment of the structure and performance of major industry sectors in various countries.¹² These studies have generally found that the principal industry sectors and markets are

⁹See Scherer and Ross (1990) for a more detailed explanation of this framework and its application to various industries.

¹⁰Scherer and Ross (1990) list a set of basic conditions that determine market structure in their explanation of the SCP framework. One of the conditions they list is technology. One could reinterpret "technology" to include information pertinent to the production and sale of a good or service. Arguably, information is an especially valuable resource to buyers and seller of insurance and plays an important role in the functioning and regulation of insurance markets.

¹¹See, for example, Carroll (1993), Bajtelsmit and Bouzouita (1998), Helms (2001), and Grace and Klein (2009a).

¹²Cummins and Weiss (1991) analyze the structure and performance of the property-liability insurance industry in the USA, and Grace and Klein (2007) examine the structure and performance of the US life insurance industry. Several studies of the structure and performance of the insurance industries in other countries are provided in Cummins and Venard (2007).

Table 31.1 Property-casualty insurance market structure: 2010

| Line | Number of insurers | Pct. of sector DPW (%) | CR10 (%) | HHI | Since 2001 | |
|-----------------------|--------------------|------------------------|----------|-----|-------------|-----------|
| | | | | | Entries (%) | Exits (%) |
| Personal auto | 915 | 35.0 | 38.2 | 370 | 15.1 | 31.8 |
| Commercial auto | 927 | 4.9 | 17.6 | 66 | 22.2 | 30.0 |
| Homeowners | 865 | 14.8 | 36.7 | 342 | 23.1 | 31.2 |
| Fire and allied | 995 | 4.8 | 35.8 | 231 | 24.1 | 28.4 |
| Commercial MP | 743 | 7.0 | 22.4 | 94 | 26.4 | 30.9 |
| General liability | 1,283 | 9.6 | 28.6 | 130 | 31.2 | 25.6 |
| Medical malpractice | 315 | 2.2 | 35.6 | 200 | 94.7 | 42.5 |
| Workers' compensation | 653 | 7.7 | 21.4 | 85 | 21.4 | 33.8 |
| Other | 1,337 | 14.0 | 23.1 | 99 | 20.6 | 26.5 |
| All lines combined | 2,488 | 100.0 | 20.2 | 86 | 18.1 | 27.9 |

Source: National Association of Insurance Commissioners (NAIC) and author's calculations

structurally competitive and profits do not exceed what would be considered a fair rate of return when these sectors and markets are relatively mature in terms of their development. However, some of these studies have also found high levels of technical and cost inefficiency in key insurance sectors. Further, developing markets may be plagued by high entry barriers and levels of market concentration which can have an adverse effect on competition.

Rather than reviewing the findings of each of these studies in detail which vary in terms of their focus and when they were conducted, I examine recent data on the basic structure and performance of the major industry sectors and markets supplemented by references to certain studies which provide additional insights. To make this exercise manageable, my data are confined to the USA. Figures reflecting the structure of property-casualty insurance lines on a countrywide basis are shown in Table 31.1. There were 2,488 insurance companies that sold property-casualty insurance in 2010, with several hundred companies competing in each major line. The principal measures of market concentration, the 10-firm concentration ratio (CR10)—the market share of the top ten insurers—and the Herfindahl-Hirschman Index (HHI)—the sum of the squared market shares of all insurers—also indicate competitive market structures in these lines. The top ten insurers accounted for no more than 38% of the premiums in any given line and 20–35% in many lines. Similarly, HHI values ranged from 66 to 370, with most lines falling between 100 and 200. These levels of concentration are considerably below levels that most economists consider necessary for firms to begin acquiring market power.¹³

Entry and exit barriers also appear to be low. Regulatory capital requirements are relatively modest compared to the standards set by rating agencies and the amount of capital insurers actually hold (Klein 2012). Information and the cost of establishing distribution systems likely have a greater impact on entry and exit, but these factors do not appear to impose significant barriers to many insurers.¹⁴ The ease of entry and exit is revealed by the high percentage of entries and exits in and out of these lines since 2001. These figures do reflect some industry and market restructuring as exits have exceeded entries in all lines shown except general liability and medical malpractice. This is consistent with the general consolidation of the industry and insurers' increased focus on markets where they believe they can be most successful. It also should be noted that these figures only reflect licensed insurers

¹³The Department of Justice (DOJ) has established merger guidelines, which consider markets with HHIs in excess of 2,000 to be highly concentrated. Mergers in such markets are subject to closer scrutiny by the DOJ.

¹⁴Information and expertise are arguably the most important resource to insurance companies as discussed above. To be successful in penetrating any market, insurers must have a good understanding of the risks they will underwrite and price.

Table 31.2 Life-health insurance market structure (2010)

| Line | Pct. of sector reserves (%) | Number of insurers | CR10 | HHI | Since 2001 | |
|---------------------|-----------------------------|--------------------|--------|--------|-------------|-----------|
| | | | | | Entries (%) | Exits (%) |
| Life | | | | | | |
| Industrial | 0.2 | 48 | 91.3% | 2,315 | 19.1 | 61.9 |
| Ordinary | 20.5 | 559 | 44.8% | 306 | 9.8 | 35.3 |
| Credit | 1.6 | 103 | 73.2% | 1,014 | 7.4 | 56.9 |
| Group | 5.9 | 333 | 62.9% | 765 | 9.6 | 38.5 |
| Annuities | | | | | | |
| Individual | 39.1 | 365 | 50.1% | 335 | 9.7 | 35.8 |
| Group | 27.5 | 144 | 58.4% | 501 | 13.3 | 44.5 |
| Supp contracts | 0.3 | 1 | 100.0% | 10,000 | 33.3 | 100.0 |
| Accident and health | | | | | | |
| Group | 2.3 | 349 | 68.9% | 1,128 | 14.1 | 43.6 |
| Credit | 2.5 | 82 | 80.6% | 2,023 | 5.9 | 57.6 |
| Individual | 0.1 | 355 | 69.3% | 895 | 13.9 | 37.6 |
| Other | 0.0 | 1 | 100.0 | 10,000 | 100.0 | 100.0 |
| All lines combined | 100.0 | 720 | 34.6% | 198 | 6.8 | 39.9 |

Source: NAIC data and author's calculations

domiciled in the USA and do not include international insurers, captives, and surplus lines companies which provide additional competition to licensed domestic insurers in some lines.

Table 31.2 presents 2010 data on the structure of different segments of the life and annuity sectors. As in the property-casualty sector, there are numerous insurers selling various life and annuity products. A total of 720 life-health companies reported data in 2010, and 100–560 insurers offer products in each of the major lines.¹⁵ In general, market concentration is relatively low in these broad lines and entry and exit activity is relatively high. Exits have exceeded entries, consistent with industry consolidation and the decline in the number of life-health insurance companies.¹⁶ Life insurers in the USA are also subject to competition from international companies and other financial institutions that offer products that compete with life insurance and annuity contracts with an investment component.

31.3.2 Market Conduct and Performance

Market conduct can encompass a number of different aspects of firm behavior including pricing, advertising, research and innovation, mergers, capital investments, and legal tactics. Particularly important questions are whether firms act independently in making their pricing and product decisions, continue to innovate in terms of developing new products to meet consumers' needs, and strive to maximize their efficiency in conducting their operations. Unfortunately, it is difficult to come up with good quantitative measures of firm conduct in insurance markets that one can compare with standard benchmarks for other industries. Hence, for the purposes of this chapter, it is more feasible to offer some qualitative observations on industry practices and then move on to a discussion of market performance.

¹⁵The number of insurance companies selling industrial life and health credit insurance is smaller, but these are small and declining markets.

¹⁶Many exits may represent mergers and acquisitions of life insurers into large holding companies.

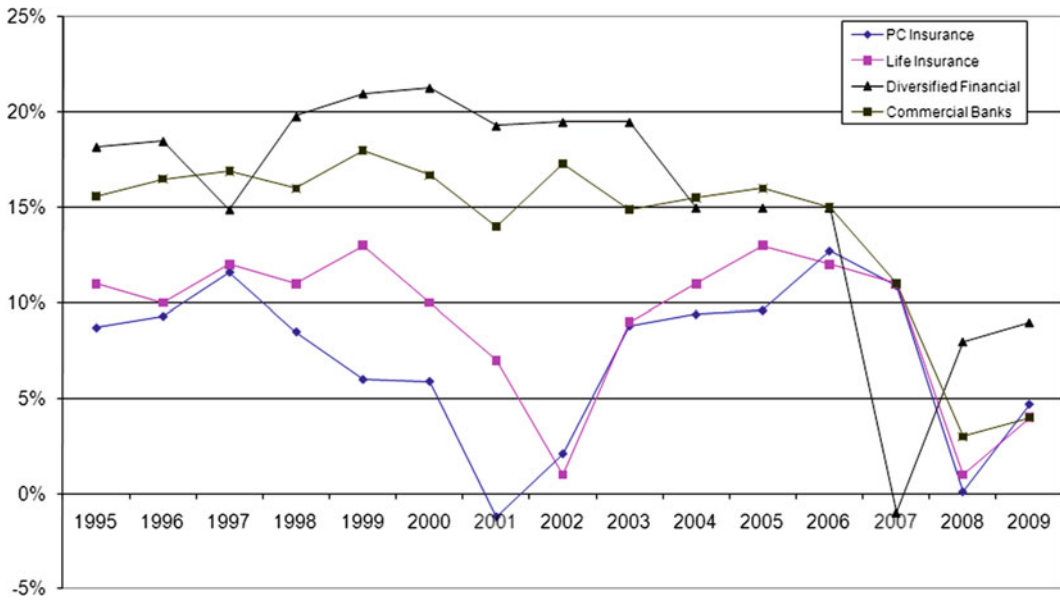


Fig. 31.1 Annual rate of return net income as % of equity: 1995–2009 (Source: Insurance Information Institute)

Since the 1950s, property-casualty insurers in the USA have taken a number of steps to increase the independence of their pricing decisions. With the passage of the McCarran-Ferguson Act in 1945, the industry formed rate cartels to stabilize their pricing subject to state regulatory oversight. However, over time, the institutions that promulgated uniform industry rates transformed themselves into “advisory organizations” that file only advisory loss costs with regulators. Insurers must develop their own loadings for expenses and profits and choose to adopt the advisory loss costs or modify them for their own purposes. Insurers may also file their own full rates without any reference to the loss costs filed by advisory organizations. With one exception, there is no evidence or studies that indicate that property-casualty insurers engage in explicit or tacit collusion to fix prices.¹⁷

There are no advisory organizations for life, annuity, and health insurance markets although companies selling products in these markets may use published mortality and morbidity tables as a starting point in their pricing. As in the property-casualty sector, I cannot find any evidence or studies that would indicate that life and health insurers collude to fix prices. A study by [Brown and Goolsbee \(2002\)](#) did find that the price of term life insurance fell dramatically over the period 1990–1997. Their analysis attributes much of this decline to the increasing use of the Internet by consumers shopping for term life insurance. This suggests that as consumers are able to obtain more information at a lower cost, it can spur even greater price competition among insurance companies, especially for products with more common features among different companies for which price comparisons are more feasible.

When economists assess the performance of insurance markets they focus their greatest attention on profitability and cost efficiency. There are various measures of profitability, but one commonly used is the rate of return on net worth or equity. Figure 31.1 compares the annual rates of return for the property-casualty and life insurance sectors in the USA against the rates of return for diversified

¹⁷In 2004, New York Attorney General Eliot Spitzer filed a suit against the insurance broker Marsh-McLennan for steering its commercial clients to insurers which with which it had contingent commission arrangements. Several prominent insurers also were implicated in the suit.

financial firms and commercial banks over the period 1995–2009. As can be seen from this chart, profits in both insurance sectors have been much lower than the profits earned in the other industries. The rate of return earned by property-casualty insurers in the USA based on these figures also falls below estimates of their cost of capital developed by [Cummins and Phillips \(2005\)](#). Hence, these data indicate that insurance companies in the USA are not earning excessive profits.

Measuring the efficiency of insurance companies is a more difficult task than measuring their profitability. Prior to the 1990s, industry analysts relied primarily on expense ratios as a measure of efficiency. However, there are problems with using expense ratios to gauge insurers' efficiency. A high expense ratio could indicate low efficiency, but it could also reflect greater expenditures on services to policyholders. Consequently, over the last two decades, economists have increasingly used frontier efficiency and productivity methods to analyze firm performance in insurance and other industries (see Chap. 25). These methods measure the performance of each firm against "best practice" cost, revenue, or profit frontiers derived from the dominant firms in the industry. A number of studies of the insurance industries in the USA and other countries using these methods have found evidence of the presence of scale economies and that smaller insurers have not achieved an efficient scale of operation (see, e.g., [Cummins and Weiss 2000](#); [Eling and Luhn 2010](#)).

This begs the question of how inefficient insurers could remain viable in a competitive market. A thorough response to this question is beyond the scope of this chapter, but it is possible to offer several observations. One is that there may be a certain amount of inertia among buyers that cause some to stay with less efficient insurers. This inertia may be eroding over time as new buyers enter insurance markets and existing buyers shop more intensively for "better deals." Indeed, there has been significant consolidation in the insurance industry as smaller insurers have been acquired by larger firms and some companies have narrowed their focus to product lines in which they are more competitive. A more realistic expectation for a competitive market might be a strong trend towards increasing efficiency. If one accepts such a proposition, then pertinent issues for both researchers and policymakers are whether the efficiency of an insurance market is progressing at a "reasonable" pace and if there are impediments to efficiency gains that need to be addressed.

31.4 Principal Areas of Insurance Regulation

In the USA, insurance is regulated principally at the state level, although the Congress can supersede state regulation where it chooses to do so. Each state (as well as the District of Columbia and the five US territories) has a chief regulatory official who is responsible for supervising insurance companies and markets within the state. In most states, the position of insurance commissioner is an appointed position, but in 12 states/territories insurance commissioners are elected officials. As discussed further below, the financial regulation of insurance companies is relatively uniform among the states, but the regulation of insurance prices, products, and market conduct is much less uniform. The state-based system of regulation in the USA contrasts with other countries which in most cases are regulated at a national level and in a few cases regulatory responsibilities are shared by state and national governments.

31.4.1 Financial Regulation

A primary objective of insurance regulation is to protect policyholders and others from excessive insurer insolvency risk. Regulators can seek to accomplish this objective by establishing and enforcing financial standards and acting against insurers who take on too much risk. Insurance regulators

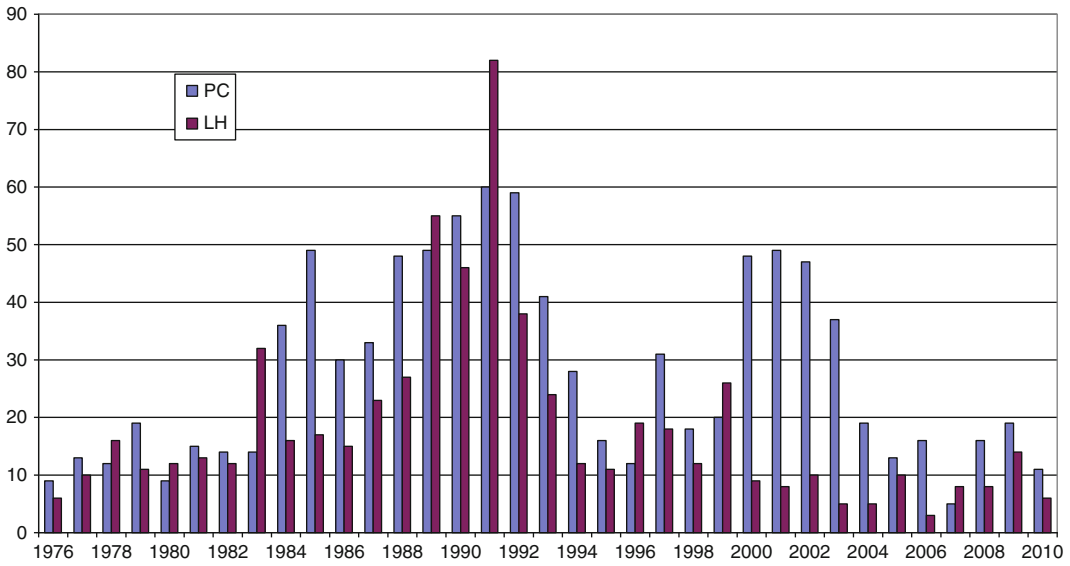


Fig. 31.2 Insurance company impairments property-casualty and life-health insurers (Source: A.M. Best)

can impose financial requirements due to their authority over insurance companies’ ability to incorporate and/or conduct business in their jurisdictions. Financial regulation includes a number of aspects of insurers’ operations, including (1) capitalization, (2) pricing and products, (3) investments, (4) reinsurance, (5) reserves, (6) asset-liability matching, (7) transactions with affiliates, and (8) management. Regulators also have the authority to step in and take remedial actions when insurers encounter financial distress or fail to comply with financial regulations, administer insurer receiverships (bankruptcies), and utilize insolvency guaranty mechanisms that cover a portion of the claims of insolvent insurers.

Figure 31.2 shows the number of property-casualty and life-health insurer insolvencies for the period 1976–2010. The frequency of life-health insolvencies is principally affected by asset problems and policy lapses and terminations due to an increase in interest rates. The number of property-casualty insolvencies is largely driven by the underwriting cycle and particularly significant events such as Hurricane Andrew in 1992. Some readers might wonder why the 2004/2005 storms seasons in the Southeast did not result in a large number of insolvencies. The most compelling explanation for this is that many insurance companies by that time had significantly improved their assessment and diversification of catastrophe risk as well as reduced their exposures in hurricane-prone areas to levels they could reasonably manage.¹⁸ More generally, it is possible that regulatory changes implemented in the late 1980s and early 1990s have led to fewer insolvencies, but it is difficult to disentangle the effect of improved regulation from the effects of tighter rating agency standards and better financial risk management by insurance companies.

A detailed review of each of these aspects of financial regulation is beyond the scope of this chapter, but capital requirements warrant some discussion. Capital requirements have long been a critical element of financial regulation of insurance companies, but they have received special attention in

¹⁸There were five insurance company insolvencies in Florida that could be attributed to the 2004/2005 storm seasons (three of these companies belonged to the Poe Group). The companies that became insolvent were “small” single-state companies that Florida regulators had allowed to take on too many exposures relative to their capacity to absorb the associated losses that would occur if severe hurricanes struck the state (Grace and Klein 2009b).

recent year in light of the Basel II accords and associated developments in the USA, the EU, and other countries.¹⁹ Prior to the 1990s, fixed capital requirements were common. Over the past 15 years, most of the major developed economies have moved towards some form of risk-based approach to determining insurers' capital requirements (ChandraShekar and Warriier 2007; Eling et al. 2009). Under a risk-based approach, regulatory capital requirements may be calculated by using simple or complex formulas or standard or internal capital models.

In the USA, regulators employ both fixed capital requirements determined by each state and uniform risk-based capital (RBC) standards based on complex formulas developed by the NAIC that have been adopted by every state.²⁰ Different formulas apply to property-casualty, health and life insurance companies. In these formulas, selected factors are multiplied times various accounting values (e.g., assets, liabilities, or premiums) to produce RBC charges or amounts for each item. These charges are aggregated into several "baskets" and then a covariance adjustment is applied to reflect the assumed independence of certain risks. An insurer's calculated RBC amount is matched against its actual total adjusted capital (TAC) to assess the adequacy of its capital from a regulatory perspective. If a company's TAC falls below its RBC requirement, certain company and regulatory actions are required that depend on the severity of the company's capital deficiency.

When the US system was first adopted in the early 1990s, it was considered to be more sophisticated than the regulatory capital requirements used in other countries and a significant advancement over fixed capital requirements. However, over time, its reliance on static formulas to determine how much capital an insurer should hold has come under increasing criticism by economists in light of the developments that have occurred in dynamic financial analysis (DFA) and the use of models to assess and manage insurers' financial risk (Cummins and Phillips 2009; Holzmuller 2009). Also, the US RBC formulas omit some significant areas such as operational risk and catastrophe risk. US regulators have indicated a willingness to address these omissions and consider greater use of modeling to determine risk charges in certain areas but appear to strongly resist moving to a more comprehensive model-based approach such as that being developed in the EU (Vaughn 2009).

The development of new capital standards in the EU is being guided by its Solvency II initiative. Solvency II consists of three pillars: (1) quantitative requirements, (2) qualitative requirements and supervision, and (3) supervisory reporting and public disclosure. A primary goal of the EU's Solvency II initiative is to develop and implement harmonized RBC standards across the EU based on standard or internal company models. The intent is to take an enterprise risk management (ERM) approach towards capital standards that will provide an integrated solvency framework that covers all significant risk categories and their interdependencies.

Based on the Solvency II directives that have been adopted to date, there will be two levels of regulatory capital requirements. The first level is the minimum capital requirement (MCR) which is the minimum amount of capital that an insurer would be required to hold below which policyholders would be subject to an "unacceptable" level of risk (in the view of regulators). An insurer that fails to meet its MCR would be subject to immediate regulatory intervention. The second level is the solvency capital requirement (SCR), also known as "target capital," that is intended to represent the economic capital an insurer needs to hold that will allow it meet its claim obligations within a prescribed safety level. The economic capital for a given insurer will be derived by using a Value-at-Risk (VaR) calibration at a 99.5% confidence level over a 1-year time horizon.²¹ The SCR will encompass all

¹⁹Basel II is the second of the Basel accords which are recommendations on banking laws and regulations issued by the Basel Committee on Banking Supervision. Basel II has been extended and superseded by Basel III which sets global regulatory standards on bank capital adequacy, stress testing, and market liquidity risk developed in response to perceived deficiencies in financial regulation revealed by the 2007–2009 financial crisis.

²⁰An insurer is required to have capital that meets or exceeds the higher of the two standards.

²¹This is essentially equivalent to limiting an insurer's probability of default to 0.5%.

risk categories that are viewed as significant by regulators, including insurance, market, credit, and operational risk as well as risk mitigation techniques employed by insurers (e.g., reinsurance and securitization). An insurer that falls between its MCR and SCR *may be* subject to regulatory action based on regulators' determination of whether corrective steps are warranted. The MCR would be calculated using a simplified modular approach calibrated at an 85% (VaR) confidence level subject to a corridor of 25–45% of an insurer's SCR and a monetary minimum floor.

Regulators in the EU are looking at both the use of both standard and internal models to calculate the MCR and SCR. A standard model has the advantage of being more uniform among insurers (companies would be allowed to make certain adjustment to customize a standard model to fit with their particular circumstances) and the companies that use them presumably would not want to expend the additional resources needed to develop an internal model. An insurer may prefer to use an internal model to better correspond to its particular circumstances and needs subject to certain standards established by regulators. Insurers with more resources or that are already performing internal capital modeling will probably be more likely to opt for an internal model, while small- and medium-sized insurers may be more likely to adopt a standard model because of resource considerations. An insurance company will need to obtain regulatory approval to be allowed to use an internal model to determine its capital requirements.

31.4.2 Market Regulation

Insurers' prices, products, and conduct are the principal areas of focus in market regulation. In the USA, the extent and stringency of price regulation vary significantly by line and by state. The lines subject to the greatest rate regulation are personal auto, homeowners, workers' compensation, and health insurance. The reality is that in most states and markets, at a given point in time, regulators do not attempt to impose severe price constraints. However, as discussed above, the problem arises when strong cost pressures compel insurers to raise their prices and regulators resist market forces in an ill-fated attempt to ease the impact on consumers.²² Inevitably, severe market distortions occur. Ultimately, insurance markets can be sucked into a "downward spiral" as the supply of private insurance evaporates and state mechanisms are forced to cover the gap.

Insurance pricing was essentially deregulated in the EU in 1994 with the introduction of the Third Generation Insurance Directive. However, certain factors used in insurance pricing are still subject to regulation in some member countries. One example of this is the automobile insurance bonus-malus system in France (Dionne 2001). Although auto insurance rate levels are not subject to explicit constraints, the premiums are adjusted by a bonus-malus coefficient (set by law) that considers a driver's past experience. Also, in March 2011, the European Court of Justice banned gender-based pricing insurance. Hence, while insurance pricing in the EU has largely been deregulated, some constraints still exist which affect insurers' ability to implement full risk-based rates.

Insurance products are effectively regulated in the USA through requirements that policy forms must receive prior approval before they are implemented. Regulators focus primarily on insurance policies purchased by individuals (e.g., auto, home, life, and health) and small businesses. The intent expressed by regulators is to ensure that there are no major gaps in the coverages that one would normally expect to find in a given insurance product or policy provisions that would be highly detrimental to consumers. Their concern is that unsophisticated insurance buyers do not have the capacity to identify such gaps or provisions. Regulators typically refer to standardized policy forms

²²Regulators may seek to suppress overall rate levels and/or compress rate differentials between low- and high-risk insureds.

developed by industry advisory organizations, such as the Insurance Services Office (ISO), to evaluate the specific policies filed by insurers. However, in some instances, states may require insurance policies to conform to idiosyncratic regulatory preferences that go beyond generally accepted industry standards. Further, some policy provisions can be contentious such as the use of special wind deductibles in homeowners insurance policies or the exclusion of coverage for certain perils such as sinkholes or mold contamination.

Market conduct regulation takes various forms in the USA. Regulators stated objective is to deter and sanction abusive trade practices that take undue advantages of consumers, such as the failure to pay legitimate claims or misleading sales practices. Historically, US regulators have relied on market conduct exams and the monitoring of consumer complaints to uncover compliance violations or “unfair” treatment of consumers. More recently, US regulators have required insurers to file “market conduct statements” to assist their monitoring activities. The industry has expressed concerns about the efficiency of the methods used to regulate market conduct. Market conduct exams have been criticized for being too extensive, duplicative, and costly and placing more emphasis on minor errors than major patterns of abuse. The evidence also suggests that regulators fail to recognize and encourage insurer self-compliance efforts which could enable a more efficient allocation of regulatory resources (Klein and Schacht 2001).

31.5 Catastrophe Risk

The risk of “natural” and “man-made” disasters has increased dramatically in many parts of the world due to a combination of factors, including population growth and economic development, climatic changes and weather cycles, geologic activity, and political unrest. The rising cost of catastrophes is evident in Fig. 31.3 which plots annual insured losses from catastrophes in the USA from 1985 to 2011 and Fig. 31.4 which plots annual insured losses from catastrophes worldwide for the period 1970–2011.²³ Insurance regulation and other government policies play a key role in the management and financing of catastrophe risk. Various stakeholders bear the risk and costs of catastrophes in different ways through the interaction of the public and private sectors that affect their incentives and the efficiency of catastrophe risk management. This section examines several key aspects of regulatory and other government policies associated with catastrophe risk including regulatory requirements for insurers’ management of their catastrophe risk, catastrophe risk financing, price and market conduct regulation, and government financing of catastrophe risk.

31.5.1 Regulatory Requirements for Catastrophe Risk Management

The management of catastrophe risk in an insurance company would be expected to encompass several elements including risk assessment, underwriting, pricing, policy design, and financing. Risk assessment involves the use of catastrophe models to evaluate an insurer’s potential losses from a given catastrophic peril based on the nature and location of its exposures. An insurer’s underwriting policies and decisions determine its exposure to catastrophe losses and where and how much risk it will assume. Its pricing determines the amount of premiums it will collect to finance potential losses as well as the incentives of insureds to take steps to mitigate their vulnerability to catastrophe losses.

²³It should be noted that these figures omit uninsured losses and that total economics losses from a catastrophic event can be much higher than insured losses.

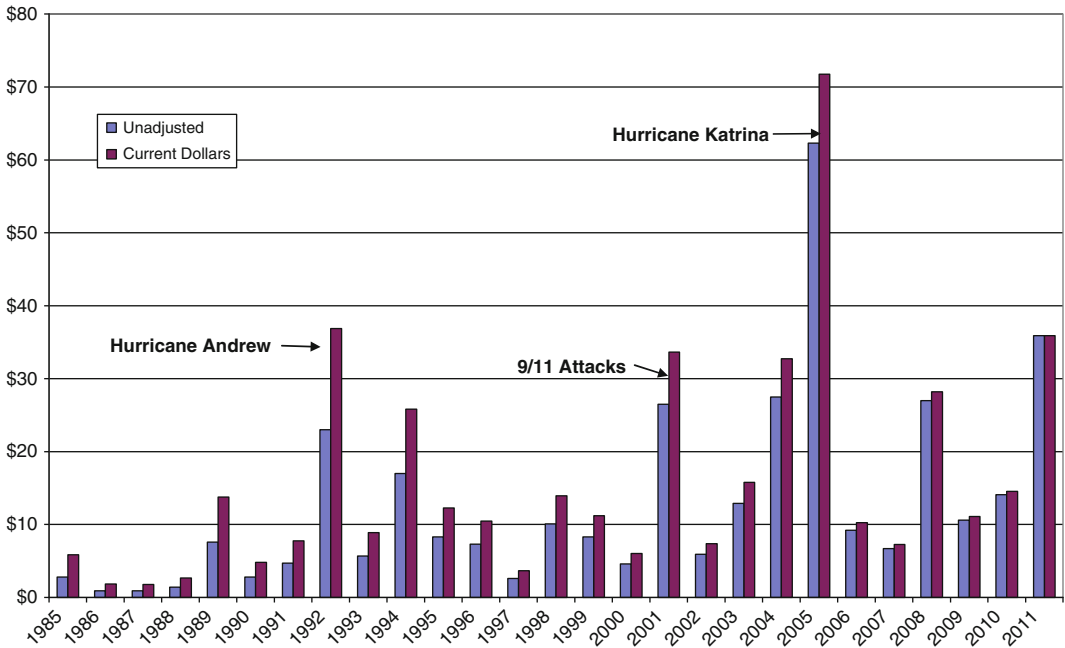


Fig. 31.3 Insured losses for US catastrophes (\$B) 1985–2011 (Source: Insurance Information Institute)

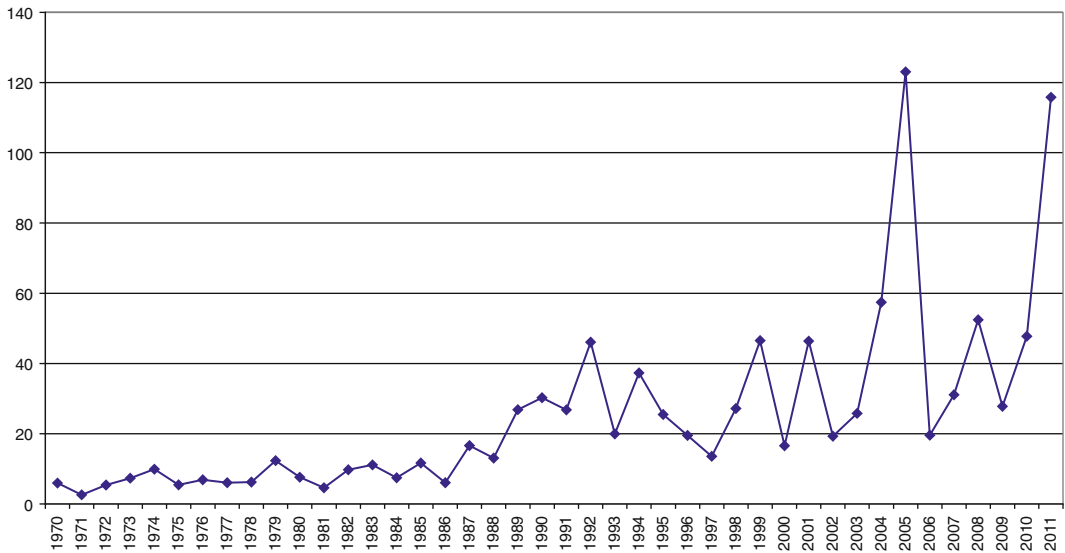


Fig. 31.4 Worldwide insured catastrophe losses (\$B) 1970–2011 (adjusted to \$2011) (Source: Swiss Re, sigma. No. 1/2011)

Policy design can also affect an insurer’s potential losses from catastrophic events in terms of the perils that are covered and cost sharing with insureds. Finally, an insurer must determine how it will fund its catastrophe losses utilizing its revenues, surplus, reinsurance, and potentially other catastrophe financing mechanisms including derivative instruments such as cat bonds and options. Ultimately, a principal objective of an insurer’s catastrophe risk management program should be to ensure that it

will be able to absorb the losses from major catastrophic events and remain solvent and viable (Klein and Wang 2009).²⁴

Regulators “supervise” insurers’ catastrophe risk management programs through two principal ways: (1) reviewing and approving insurers’ cat risk management programs and (2) capital requirements. In the USA, financial examiners are instructed to review insurance companies’ catastrophe risk management with some guidelines on how such a review should be performed.²⁵ Beyond the guidelines provided, the scope and sophistications of these reviews likely vary among states. States such as Florida, where hurricane risk is a significant concern, appear to have developed special questionnaires and reports that are used by financial analysts and examiners to assess how well an insurer is managing its catastrophe risk. In states where catastrophe risk is less of a concern, regulatory reviews of insurers’ catastrophe risk management may be less prescribed and examiners may exercise greater judgment in how they conduct these reviews. In theory, the objectives of these reviews should be to ensure that an insurer understands its catastrophe exposure and has adequate surplus and reinsurance in place to maintain its catastrophe risk within acceptable parameters.

Catastrophe risk also can be incorporated into regulatory capital requirements which would be expected to increase insurers’ incentives to properly manage their catastrophe risk. Capital charges for catastrophe risk can be derived using standard formulas or modeled scenarios. Of the two approaches, the latter is more sophisticated and potentially more desirable (from a regulatory perspective) for insurers with significant catastrophe exposures. Currently, neither US RBC requirements nor EU capital requirements explicitly consider an insurer’s catastrophe risk, but this omission is being rectified in both jurisdictions in the development of revised capital standards.²⁶ For several years, the NAIC has been working on adding a catastrophe risk component to its RBC formula for property-casualty insurers. Based on the latest draft proposal, the RBC charge for catastrophe risk will be based on modeled property catastrophe losses (see NAIC 2010). Separate risk charges would be determined for the hurricane peril and the earthquake peril and would not be subject to a covariance adjustment based on the premise that the risks from these perils are independent of each other and other risks included in the RBC formula. Each charge would be calculated on gross of reinsurance basis and a negative charge or credit would be determined based on a company’s modeled anticipated ceded reinsurance. The actual charge applied would be on a net basis and calculated by subtracting the reinsurance credit from the gross of reinsurance charge.

In the EU, the capital requirements being developed under Solvency II will also have a catastrophe risk sub-module (EIOPA 2011).²⁷ Under the current proposal and technical provisions being tested, the cat risk charge could be calculated using two alternative approaches. If no regional scenarios are provided by a regulator, a standard formula would be used to calculate the capital charge for nonlife catastrophe risk. The formula would apply different factors to an insurer’s net written premiums broken down by lines of business. The charges for each line of business would be subject to a covariance adjustment based on assumptions about the independence of cat risk associated with each line of business. The second approach would utilize modeled scenarios to determine the nonlife cat

²⁴Insurers calculate various risk metrics of their potential losses from different catastrophic perils based on their exposures, reinsurance, and other financing arrangements. One of these metrics is an insurer’s Probable Maximum Loss (PML) which is similar in concept to Value-at-Risk (VaR) measurements. Typically, an insurer will structure its cat risk management program to ensure that it can meet specified PML targets and remain solvent.

²⁵The NAIC publishes the Financial Condition Examiners Handbook as a basic reference tool to guide regulators in how to conduct financial examinations.

²⁶When the US RBC system was first developed, regulators considered adding a capital charge for catastrophe risk but decided it would be too complicated and controversial at that time. As for the EU, the current approach for determining insurers’ capital standards is very simple and does not explicitly create capital charges for a number of specific risks so the inclusion of capital charge for catastrophe risk would not be consistent with this simplified approach.

²⁷Under current projections, Solvency II is scheduled for full implementation beginning in 2014.

risk charge for an insurance company. A regulator could provide regional scenarios that could be used by insurers to determine their cat risk charge or a company could be given the option of using its own customized catastrophe scenarios based on the classes of business that it writes and their geographic concentration.

31.5.2 Regulation of Catastrophe Risk Financing

Regulators can affect the use of catastrophe risk financing mechanisms in several ways (Klein and Wang 2009). One way they do this is by imposing constraints on or barring insurers from using certain instruments or creating other impediments. Second, regulation can either facilitate or inhibit catastrophe risk financing in terms of the rules governing accounting for and financial reporting of catastrophe risk transactions. Thirdly, there is the issue of whether an insurer's use of catastrophe risk financing is considered in regulatory assessments of its capital adequacy and financial risk which could affect insurers' motivation to use efficient risk financing devices. Finally, other regulatory and government policies, such as the regulation of insurers' rates and market practices, the creation of government insurers/reinsurers, and tax rules, also influence the economic viability of catastrophe financing instruments.

31.5.2.1 Surplus and Catastrophe Reserves

Retaining additional surplus to absorb catastrophe losses has been used as a conventional catastrophe risk financing mechanism and serves as an insurer's first layer of protection. Any catastrophe losses it retains are funded by its surplus and designated catastrophe reserves if allowed. In the USA, regulatory and tax policies do not discourage this "self-funding" of catastrophe losses by insurers but make it more costly than it needs to be. First, insurers are generally required to keep catastrophe funds in their general surplus accounts which makes these funds vulnerable to being drawn down for other uses. Another problem is regulators may view higher amounts of surplus held to fund catastrophes as a justification for imposing tighter constraints on an insurer's rates. A third problem is that additions to surplus are taxed as income and the investment earnings on this surplus are also taxed which slows its accumulation.²⁸ US regulatory and GAAP accounting rules do not permit insurers to establish catastrophe reserves, i.e., reserves for losses arising from events that have not yet occurred.

Insurers and US regulators support the idea of allowing insurers to set up tax-favored catastrophe reserves, but the necessary accounting and tax provisions to facilitate such reserves have not been enacted (Davidson 1996; Harrington and Niehaus 2001). In concept, an insurer would be allowed to contribute up to a certain amount of its income every year to a reserve intended to fund future catastrophe losses and the reserve would be reported as a liability in an insurer's financial statement. Contributions to the reserve and investment earnings associated with the reserve would not be taxed. However, the federal government (Congress and the Internal Revenue Service) have not been enthusiastic about providing favorable tax treatment for catastrophe reserves because of the concern that they would be manipulated to reduce insurers' taxes. This contrasts with tax policies in EU countries which typically allow insurers to deduct contributions to and investment earnings on catastrophe reserves from their income in determining their tax liability (US General Accountability Office 2005).

²⁸Harrington and Niehaus (2003) estimated that the tax cost of holding additional capital to cover catastrophe losses could exceed 100% of the "expected cost of claims" at higher layers of an insurer's catastrophe risk exposure.

31.5.2.2 Reinsurance

Reinsurance continues to be the primary mechanism used by insurers to diversify their catastrophe risk. Approximately 40–50% of catastrophe losses in the USA are covered by reinsurance. The primary issue in the USA has been the different treatment of reinsurance transactions with domestic versus foreign reinsurers. Under the current rules in most states, insurers are allowed “full credit” for contracts placed with reinsurers domiciled and regulated in the USA and some “approved” foreign insurers who deposit funds in US financial institutions according to regulatory collateral requirements.²⁹ These rules require foreign reinsurers to provide collateral equal to their gross liabilities plus \$20 million to ceding US insurers. This is a significant issue as foreign reinsurers had a 59.9% share of “unaffiliated” premiums ceded by US insurers in 2010, according to the Reinsurance Association of America (RAA), up from 57.8% in 2009.³⁰ The different treatments of domestic and foreign reinsurers affect US insurers in several ways. First, insurers are not allowed to subtract premiums ceded to unauthorized insurers in calculating their net premiums which is used as a proxy measure of their potential future liabilities and risk. Second, insurers are not allowed to count recoverables from unauthorized reinsurers as an asset except to the extent that ceding insurers hold or have access to collateral deposited by the reinsurers. Ultimately, collateral requirements effectively increase the cost of foreign reinsurance and penalize US insurers that buy reinsurance from foreign reinsurers that do not meet regulatory collateral requirements. *Cummins (2007)* observes that the US requirements are inconsistent with global insurance/reinsurance markets and are directly opposed to the EU Reinsurance Directive that effectively abolishes collateralization.³¹

This approach to the differential treatment of reinsurance transactions has been strongly criticized by US insurers and foreign reinsurers as being inefficient and unfair. In response to this criticism, the NAIC has adopted changes to its model law and regulation that govern credit for reinsurance. Under the new provisions, domestic and foreign reinsurers can elect either to be subject to the same collateral requirements imposed in the prior model law or qualify as an “eligible insurer” that would be subject to reduced collateral requirements if they comply with number of criteria. The collateral requirements for certified reinsurers that meet these criteria would be scaled according to the ratings assigned to them by regulators. The ratings assigned by regulators are based on the ratings of reinsurers assigned by major rating agencies. Under this system, reinsurers with the highest ratings are not required to post any collateral. Reinsurers with lower ratings are required to post collateral based on a scale developed by the NAIC that progressively requires more collateral to be posted the lower a reinsurer’s rating is.³² Regulators in several states including Florida, Indiana, New Jersey, and New York have already changed their laws to reduce collateral requirements for foreign reinsurers (consistent with

²⁹The discrimination against foreign reinsurers stems from US regulators’ concerns about their ability to access funds from a foreign reinsurer outside their regulatory jurisdiction. The laws in most states generally conform with the NAIC’s Credit for Reinsurance Model Law. Most recently, several states have modified their laws to provide more favorable treatment for reinsurance ceded to foreign reinsurers consistent with a reform proposal that was adopted but not implemented by the NAIC, as discussed further below.

³⁰The term “unaffiliated” refers to the relationship between the primary insurer (i.e., ceding insurer) and the reinsurer (i.e., assuming insurer). A primary insurer may cede business to a reinsurer with which it is affiliated (i.e., they are owned by the same parent company) and/or reinsurers with which they are not affiliated.

³¹See *Evans (2007)*.

³²For example, a reinsurer that has an A rating from A.M. Best (and/or equivalent ratings from other rating agencies) would be required to post collateral equal to 20% of its obligations to US insurers. A reinsurer with an A rating from A.M. Best would be required to post collateral equal to 50% of its obligation to US insurers. Under the NAIC regulations, regulators are required to use the lowest financial strength rating received from an approved rating agency in determining the highest possible rating of a certified reinsurer.

the NAIC's proposed rating scale) to help lower the cost of catastrophe reinsurance for insurers based in their jurisdictions.

It should be noted that reinsurers are not subject to price regulation in contrast with primary insurers. Hence, when the cost of reinsurance increases, this can create a problem for primary insurers if regulators do not allow them to raise their rates to compensate for the higher cost of reinsurance. This is not a problem that regulators can directly control as they have no authority to force reinsurers to lower their prices. This has led regulators to explore other measures such as the creation of a state catastrophe reinsurance funds (discussed further below) or lowering collateral requirements for foreign reinsurers as discussed above.

31.5.2.3 Derivative Instruments

As discussed in [Klein and Wang \(2009\)](#), attempts to establish markets for catastrophe put options for natural disasters have not proved to be successful in the past, but there are recent efforts to reestablish viable options markets. The New York Mercantile Exchange (NYMEX) and the Chicago Mercantile Exchange (CME) have created mechanisms for the trading of cat futures and options. US regulators allow insurers to use options for risk hedging purposes, but there are no provisions for valuing such transactions in financial reporting prior to their triggering. Presumably, if a catastrophe option was triggered, an insurer could report its expected payoff as an asset pending the receipt of a cash payment. To date, the volume of trades in cat options and futures has been relatively small, so they have not yet become a significant source of risk transfer for US insurers. Regulators also have allowed insurers to engage in catastrophe swaps, albeit without associated financial accounting provisions or recognition of its favorable impact on their financial risk. There is no publicly available data on the level of swap activity in insurance markets, but there are anecdotal reports that they play a significant role for international reinsurers. More favorable regulatory treatment in the USA would increase US insurers' incentives to use cat options, futures, and swaps when their underlying attributes would make them economically desirable.

Catastrophe bonds have been the most popular derivative instrument used by US insurers to diversify their catastrophe risk. In 1999 and 2001, the NAIC adopted model acts to make "onshore" issuances of cat bonds more feasible, but almost all cat bonds issued by US insurers have been done "offshore."³³ There are several reasons for this as discussed by [Klein and Wang \(2009\)](#). Many US insurers issuing cat bonds through offshore Special Purpose Reinsurance Vehicles (SPRVs) have the trust funds associated with these instruments hold their deposits in US-certified institutions. This effectively provides the collateral required for the "reinsurer" (i.e., the SPRV) to be treated as authorized under US regulations without the SPRV actually being located and regulated in the USA. Consequently, regulatory accounting rules have not been an issue for US insurers that have issued cat bonds through offshore vehicles.

Consequently, the principal obstacles to onshore SPRVs appear to be their tax and regulatory treatment.³⁴ These factors may help to explain why no onshore securitizations have occurred. Currently, profits earned by offshore reinsurer affiliates of US insurers are not taxed in the calculation of the consolidated profits of US insurers. However, premiums paid to an offshore reinsurer (affiliated or not) are subject to an excise tax based on the gross premiums paid "regardless of the eventual

³³"Onshore" securitization refers to transactions that would be accomplished through a US-regulated entity or mechanism. "Offshore" securitizations refer to transactions that are conducted using non-US entities or mechanisms.

³⁴[Klein and Wang \(2009\)](#) provide an illustration of the tax advantages of an offshore securitization over an onshore securitization. [Cummins \(2008\)](#) observes that the NAIC model act still imposes a number of regulatory hurdles in forming and using onshore SPRVs.

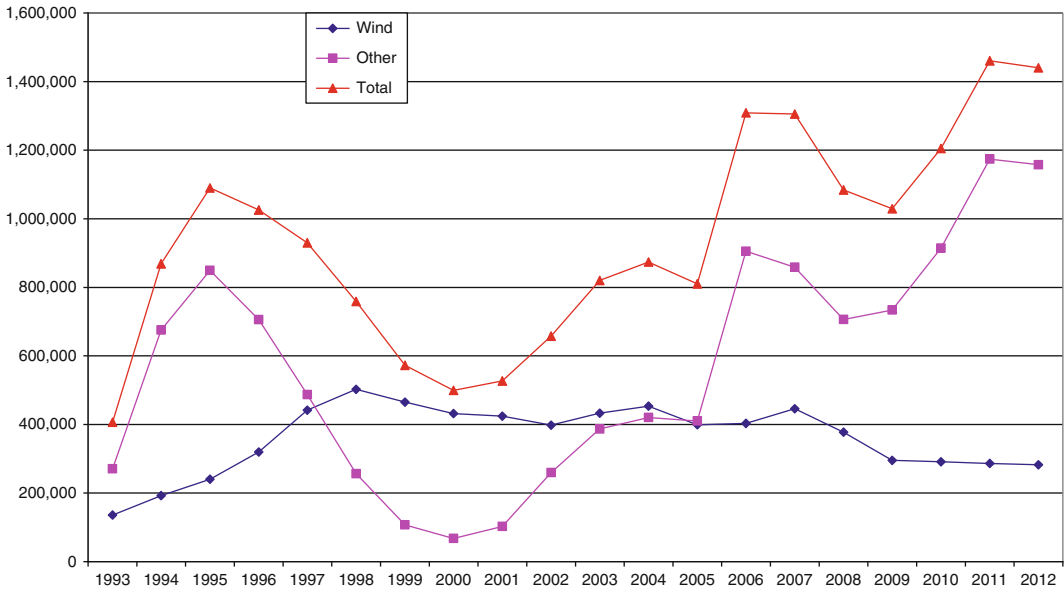


Fig. 31.5 Florida property insurance residual market number of policies: 1993–2012 (Source: Citizens Property Insurance Corporation)

outcome of the coverage.” Offshore SPRVs also have much lighter regulatory burdens and the transactions can be completed more quickly. The boom of SPRV facilities in Bermuda and the Cayman Islands has promoted the establishment of specialized law firms and professional services for such facilities.

31.5.3 Price and Market Conduct Regulation

The price of private insurance that covers catastrophe perils has risen substantially in some geographic areas where catastrophe risk is especially high. For example, homeowners insurance in coastal areas subject to hurricane risk have seen their premiums escalate over the last 2 decades (Klein 2008). This has created tension between insurers and regulators over the price of homeowners insurance in the areas that have experienced the greatest rate increases. Some states, such as Florida, have attempted to place tight constraints on homeowners’ insurance rates in coastal areas. These constraints have contributed to the retrenchment of major insurers from these areas. This, in turn, has driven a large number of homeowners into Florida’s residual market mechanism, the Citizens Property Insurance Corporation (FCPIC). The dramatic growth in the number of policies insured by the FCPIC is evident in Fig. 31.5. As of March 31, 2012, Citizens had 1.4 million policies in force and over \$502 trillion in insured exposures.³⁵

This illustrates the kinds of problems than occur when regulators seek to constrain the price of insurance coverages that cover catastrophic perils. Suppression of overall rate levels or compression

³⁵Of the total policies in force, 96.6% were for personal residential properties. Personal residential properties accounted for 75.3% of the total exposures in force. Commercial residential and nonresidential properties accounted for the other policies and exposures in force.

of geographical rate structures can compel insurers to tighten the supply of insurance which decreases the availability of coverage. Also, these policies can reduce insureds' incentives to optimally manage their risk from natural disasters. However, regulators cannot force market long-term outcomes at odds with economic realities, e.g., low rates and widely available coverage in the face of very high risk, without the government replacing private insurers as the principal source of insurance coverage.

Regulators can constrain many other aspects of insurers' market activities beyond pricing, which can have further effects on the sustainability of their operations (Klein 2008). For example, regulation of underwriting and the policy terms that insurers can use have a significant impact on hurricane-prone insurance markets. The regulation of underwriting—e.g., the rules insurers use to select or reject applicants, insurer decisions to reduce the number of policies they renew or new policies they write—can be somewhat difficult to specify because of the complexity and opaque nature of this aspect of regulation. Some aspects of the regulation of policy terms, e.g., the maximum wind/hurricane deductibles that insurers are allowed to offer, are more readily discernable, but other aspects may be obscured in the policy form approval process. Generally, it appears that insurers have been allowed to substantially increase the maximum wind/hurricane deductibles they are allowed to offer, but there has been greater regulatory interference with their underwriting decisions.³⁶

As noted above, other aspects of insurers' activities are regulated such as marketing and distribution, the servicing of policies, and claim adjustment. The regulation of claim adjustment can be especially relevant in the context of catastrophe risk. Following a disaster, regulators may pressure insurers to make more generous claim payments and pay claims more quickly.³⁷ Disputes over “wind versus water” damages were particularly contentious following Hurricane Katrina in 2005 leading to a number of lawsuits (Kunreuther and Michel-Kerjan 2009). The potential for regulators to pressure insurers on claim payments and litigation increases the uncertainty that insurers face in assessing and pricing catastrophe risk. This greater uncertainty can prompt insurers to further boost their rates or reduce the supply of insurance which can have negative repercussions for many insureds.

31.5.4 Government Financing of Catastrophe Risk

Government financing of catastrophe risk can occur through various ways using different mechanisms. Countries vary in terms of their reliance on private versus government financing of different catastrophic perils. One approach is the direct provision of insurance through a government program

³⁶Klein (2008) discusses and documents the nature of this interference in greater detail. For example, some states limit or prohibit the use of certain underwriting criteria, such as the age of a home and/or its market value, a history of prior claims, and the insured's credit score. Also, some states issued moratoriums on policy cancellations/nonrenewals following major hurricanes. Further, some states have increased prior notice requirements for insurers electing to nonrenew policies in a specified area due to concerns about hurricane risk. Also, some states may limit the size of the wind deductible that an insurer can require as a condition for writing a new policy or renewing an existing policy.

³⁷For example, Florida requires insurers to report data on their handling of hurricane claims and subjects insurers to claim audits. While these measures may not explicitly require insurers to pay claims more quickly or offer higher settlements, they can be used to apply implicit pressure. These requirements are specified in Rule 69O-142.015 Standardized Requirements Applicable to Insurers After Hurricanes or Natural Disasters issued on June 12, 2007. The Florida Office of Insurance Regulation (FLOIR) also performs targeted market conduct examinations of insurers' handling of hurricane claims which can result in sanctions if regulators determine that an insurer has failed to adjust and settle claims in an appropriate manner. For example, the FLOIR accused Nationwide for underpaying 2004 hurricane claims and forced the company to review how it handled these claims. See “Nationwide Agrees to Review Hurricane Claims in Florida,” *Columbus Dispatch*, October 15, 2005. The Florida Governor also set deadlines for insurers' settlements of 2004 hurricane claims. See “Deadline is Set for Insurers to Settle Storm Claims,” *Palm Beach Post*, October 27, 2004.

or state-sponsored insurer. A good example of this is National Flood Insurance Program (NFIP) which was established in 1968 and is administered by the Federal Emergency Management Agency (FEMA).³⁸ The NFIP provides flood insurance to homeowners and businesses subject to specified maximum limits. As of January 2012, the NFIP had 5.6 million policies and approximately \$1.3 trillion in coverage in force, most of which were for residential properties.³⁹ The NFIP has suffered severe fiscal problems due to legal constraints on its ability to charge adequate premiums, claim payments for properties that have suffered repetitive losses, and large payouts following major disaster such as Hurricane Katrina. Federal law has prevented the NFIP from charging risk-based rates for certain properties which has been a significant contributor to its fiscal problems. In 2011, both the US Senate and the US House passed bills that would reform the NFIP which included provisions that would phase in risk-based premiums, but they failed to come to agreement on final legislation that could be enacted.⁴⁰

The California Earthquake Authority (CEA) is a good example of a state-sponsored insurer.⁴¹ It was established in 1996 to head off an impending crisis in the supply of homeowners insurance in the state of California following the Northridge earthquake in 1994. Under California law, insurers that write homeowners insurance must also offer earthquake coverage to consumers who purchase a homeowners insurance policy (the purchase of earthquake coverage is optional to the consumer). Because of this mandate and their concern about the increasing risk of earthquakes, insurers were threatening to withdraw from the homeowners' insurance market. This led to the creation of the CEA which provides earthquake insurance policies on residential properties which insurers can issue to homeowners in lieu of issuing their own earthquake policy or endorsement. The hope was that the CEA would bolster the supply of earthquake insurance and increase the number of homeowners that would purchase it. Unfortunately, the opposite has happened and the percentage of homeowners with earthquake coverage has steadily dropped from approximately 31% in 1996 to 14% by 2004 (Zanjani 2008). Many California homeowners believe that the cost of earthquake insurance is excessive relative to the amount of coverage provided. Hence, there is a concern about the large number of homeowners who lack earthquake insurance coverage which could result in a substantial amount of uninsured losses if a severe earthquake were to strike one of the major population centers in California.

There are also government mechanisms to provide reinsurance for certain catastrophic perils. One example of this is the federal government's Terrorism Risk Insurance Program (TRIP) which provides a backstop for insurance claims stemming from acts of terrorism.⁴² The program was initially established in 2002 through the enactment of the Terrorism Risk Insurance Act (TRIA) following the wake of 9/11 attacks. Prior to 9/11, most commercial insurance policies included terrorism coverage. However, after 9/11 reinsurers essentially vacated the terrorism reinsurance market and insurers were reluctant to continue to offer terrorism coverage without federal assistance which motivated Congress to enact TRIA. The program effectively allows eligible insurers to recoup a portion of their losses from a terrorist act from the Department of the Treasury for commercial lines only subject to industry and insurer triggers and retention levels. The total cap on federal coverage is \$100 billion. To be eligible for federal payments, an insurer is required to offer terrorism coverage to their commercial

³⁸For more information on the NFIP, see Michel-Kerjan (2010).

³⁹Obtained from FEMA's website on April 29, 2012 at <http://www.fema.gov/business/nfip/statistics/stats.shtm>

⁴⁰For further discussion of proposals to reform the NFIP see Michel-Kerjan and Kunreuther (2011).

⁴¹See Zanjani (2008) for an analysis of the private and public provision of earthquake insurance in California.

⁴²See Kunreuther and Michel-Kerjan (2004) for a discussion of the issues involved with terrorism risk insurance in the USA.

policyholders. Eligible insurers are not required to pay any upfront premiums to the government.⁴³ Instead, any losses paid by the Treasury would be recouped through an ex-post surcharge of up to 3% annually on premiums paid by policyholders. The program was initially set to expire at the end of 2005 but has been extended by subsequent legislation through the end of 2014. The Obama administration has stated that it does not believe that the program should be extended beyond 2014, but this position has been strongly opposed by insurers who argue that TRIP serves an important and useful role and should be continued.

Another example of a government catastrophe reinsurance program is the Florida Hurricane Catastrophe Fund (FHCF). Florida is the only state that has established such a facility. The FHCF provides catastrophe reinsurance to primary insurers underwriting property coverage in the state and was established following Hurricane Andrew. The establishment and growth of the FHCF has been a matter of some controversy. Proponents of the FHCF contend that it helps to fill a gap in private reinsurance capacity and also provides reinsurance at a lower cost. It should be noted that the FHCF can accumulate tax-favored reserves (an option not currently available to US insurers and reinsurers) and can also access credit supported by local bonding authority. Opponents of the FHCF question the need to augment private reinsurance, raise concerns about crowding out private reinsurance, and cite the potential for financial shortfalls that can lead to assessments on insurers/consumers in the state.

Residual markets mechanisms also could be viewed as a quasi-governmental form of government financing of catastrophe risk. The administration and regulation of residual market facilities can have significant effects on property insurance markets and vice versa. These mechanisms include Fair Access to Insurance Requirements (FAIR) plans, wind/beach pools, and special corporations that write both full and wind-only coverage.⁴⁴ The important aspects of residual market administration include rates, eligibility requirements, available coverages, and coverage provisions. Suppressing or compressing residual market rate structures, lenient eligibility requirements, and generous coverage terms can cause significant problems.⁴⁵ In turn, suppressing or compressing insurers' rates can tighten the supply of insurance in the voluntary market and force more properties into the residual market.

Finally, there is the provision of federal disaster assistance. As discussed by [Michel-Kerjan and Volkman-Wise \(2011\)](#) and [Michel-Kerjan and Kunreuther \(2011\)](#), there has been a substantial increase in the number of the presidential disaster declarations over time. There were 597 disaster declarations for the years 2001–2010 compared to 191 disaster declarations for the years 1961–1970. There were 98 disaster declarations in 2011 which exceeded the previous record of 87 declarations in 2010. A number of factors affect the number of disaster declarations and the amount of aid provided including the number and severity of disasters, the amount of uninsured losses, media coverage, public sympathy, and politics ([Michel-Kerjan and Kunreuther 2011](#)). Unfortunately, it is difficult to obtain comprehensive data on the total amount of assistance provided and the associated cost to taxpayers, but the number of declarations and the studies conducted on federal disaster assistance indicate that cost of assistance has also escalated over time.⁴⁶

The provision of federal disaster assistance raises two important issues in the context of catastrophe risk management. One issue is the failure of many homeowners to purchase insurance for certain

⁴³[Michel-Kerjan and Raschky \(2011\)](#) found that this approach to funding the program (no upfront premiums, post-event recoupment charges) had a negative impact on insurers' diversification when contrasted with wind and earthquake commercial insurance lines.

⁴⁴FAIR plans exist in 32 states and supply full property coverage to insureds who cannot obtain coverage in the voluntary market. Wind/Beach plans provide wind only coverage for properties in designated coastal areas in the states of Alabama, Mississippi, North Carolina, South Carolina, and Texas. There are two state-run insurance corporations—the Florida Citizens Property Insurance Corporation and the Louisiana Citizens Property Insurance Corporation.

⁴⁵This was demonstrated in the state case studies for auto insurance in [Cummins \(2002\)](#).

⁴⁶[Cummins et al. \(2010\)](#) provide a comprehensive analysis of the federal government's exposure to catastrophic risk.

catastrophic perils such floods and earthquakes. A second issue is how disaster assistance influences property owners' incentives to mitigate their exposure to catastrophe risks. What many people may not realize is the bulk of federal disaster assistance is provided to local governments to rebuild infrastructure; the assistance received by individuals consists mainly of small grants to cover immediate expenses and subsidized loans to help them rebuild or repair their homes. Nonetheless many property owners may operate under the misperception that the government will bail them out if they suffer significant uninsured losses from a catastrophe. This misperception could reduce property owners' motivation to mitigate their exposure to catastrophe perils and/or fail to purchase adequate insurance (Michel-Kerjan and Volkman-Wise 2011).

31.6 Systemic Risk

The problem of systemic risk has garnered significant attention since the financial crisis of 2007–2010. As noted by Cummins and Weiss (2010), because the crisis began in the financial sector and there was a federal bailout of the AIG, questions have been raised about whether the insurance industry is a major contributor to systemic risk (see also Schwarz 2008; Geneva Association 2010). As discussed further below, the empirical evidence indicates that the insurance is not a significant contributor to systemic risk in the economy. This raises the question of whether there is a need for increased regulation of insurance companies as systemically risky institutions. A second, and perhaps the most important, issue concerns insurance companies' exposure to systemic risk and how regulation should address this exposure.

31.6.1 Regulation of Systemic Risk

Several studies have examined the question of whether the US insurance industry poses significant systemic risk to the economy. There appears to some consensus that the core activities of insurance companies do not pose systemic risk to the economy. Grace (2010) concludes that insurance does not create significant systemic risk to the economy. Harrington (2011) also concludes that insurance companies have a much lower potential for systemic risk than other financial institutions. It should be noted that problems experienced by AIG and its role in the financial crisis is a special case. The AIG received prominent attention because of its losses on credit default swaps due to the activities of its investment subsidiaries and not its insurance operations. AIG also engaged in securities lending which added to its liquidity problems.

In 2007, AIG was the fifth largest global insurance companies based on total revenues. In 2008, it fell out of the top ten but then rebounded to become the sixth largest global insurance company by 2010. As noted above, AIG's problems stemmed primarily from the activities of its investment subsidiary AIG Financial Products Corporation (AIGFP), headquartered in Fairfield, Connecticut, with major operations in London. In the Spring of 2008, AIGFP suffered substantial losses on credit default swaps that it had issued and traded. When AIGFP had issued these instruments, it expected to pay few if any claims. However, as the real estate market began to implode in 2007 and the financial crisis worsened in 2008, many firms began to default on their debt forcing AIGFP to assume losses far greater than what was ever anticipated and what it was prepared to handle. AIGFP's losses prompted the credit rating agencies to downgrade the credit rating of the AIG group in September 2008. This forced the Federal Reserve Bank to issue an \$85 billion line of credit to AIG to avert a crisis that could have brought down other financial institutions (which had purchased credit default swaps from AIGFP) and the collapse of financial markets. Since then, AIG has been winding down its financial

products division and refocusing its attention on its insurance operations. In a similar manner, Swiss Re lost its number one position to Munich Re due to the losses it suffered on its asset management activities during the financial crisis.

Cummins and Weiss (2010) also analyze the potential for the insurance industry to cause systemic events that spillover to other segments of the financial sector and the general economy. Their primary conclusion is that the core activities of US insurance companies do not create systemic risk. However, they did find that the noncore activities of insurers do constitute a source of systemic risk. The noncore activities of insurance company holding groups include trading in derivatives (e.g., credit default swaps), asset lending, asset management, and providing financial guarantees. They note that although information on the noncore activities of insurance companies is difficult to obtain, their analysis indicates that the leading global insurance organizations have significant exposure to credit default swaps.

Despite the strong evidence that insurance companies are not major contributors to systemic risk, the Congress has included insurance in the enactment of new regulations aimed at identifying, monitoring, and controlling the activities of financial institutions deemed to be systemically important. Most importantly, in the context of this discussion, Title I of the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010 established the Financial Stability Oversight Council (FSOC) which has broad authority to constrain what it deems to be “excessive risk” in the financial system. The FSOC has 10 voting members and 5 nonvoting members. One of the voting members is a presidential appointee with insurance expertise. The nonvoting members include the Director of the Federal Insurance Office and a state insurance commissioner designated by the NAIC.

The FSOC is charged with three primary responsibilities:

1. To identify risks to the financial stability of the USA that could arise from the material financial distress, failure, or ongoing activities of large, interconnected bank holding companies or nonbank financial companies or that could arise outside the financial services marketplace
2. To promote market discipline by eliminating expectations on the part of shareholders, creditors, and counterparties of such companies that the government will protect them from losses if they fail
3. To respond to emerging threats to the stability of the US financial system

As discussed by Harrington (2011), Section 113 of the Dodd-Frank Act authorizes the FSOC to designate a nonbank financial company, including an insurance company, as systemically important that should be subject to enhanced regulation and supervision by the Federal Reserve. Section 113 further specifies the factors the FSOC should consider in making such a determination. These factors include:

1. The extent of its leverage
2. The extent and nature of its off-balance sheet exposures
3. The extent and nature of its transactions and relationships with other significant bank and nonbank holding companies
4. Its importance as a source of credit for households, businesses, state, and local governments and as a source of liquidity for the US financial system
5. Its importance as a source of credit for low-income, minority, or underserved communities and the impact of its failure on the availability of credit in these communities
6. The extent to which its assets are managed rather than owned by the company and the extent to which ownership of assets under management is diffuse
7. The nature, scope, size, scale, concentration, interconnectedness, and mix of its activities
8. The degree to which it is regulated by one or more primary financial regulatory agencies
9. The amount and nature of its assets and liabilities
10. Any other risk-related factors that the FSOC deems to be pertinent

After receiving comments on earlier proposed rules, on April 3, 2012, the FSOC issued a final rule and interpretive guidance on how it will implement its authority to require supervision and regulation of nonbank financial companies under Section 113. The rule outlines a framework for determining whether a nonbank financial company is a “systemically important financial institution” (SIFI). The framework is structured around six broad categories:

1. Size
2. Lack of substitutes for the financial services and products the company provides
3. Interconnectedness with other financial firms
4. Leverage
5. Liquidity risk and maturity mismatch
6. Existing regulatory scrutiny

Consistent with the views expressed by industry representatives and the conclusion of the studies cited above, [Harrington \(2011\)](#) argues that the core activities of property-casualty insurers do not pose systemic risk and that a reasonable application of the FSOC’s authority should not result in a determination that any property-casualty insurers are systemically important. He also expresses the opinion that although some large life insurers may pose greater systemic risk than property-casualty insurers, few if any life insurers should be deemed as systemically important. However, there is also the issue of the noncore activities of major insurance organizations. [Cummins and Weiss \(2010\)](#) observe that these noncore activities are beyond the traditional purview of insurance regulators and have not been rigorously supervised by bank regulators. Insurance regulators’ failure to look closely at the noncore activities of insurance organizations likely stemmed from their belief that this was the responsibility of other regulators of these organizations.⁴⁷ Consequently, they argue that regulators need to significantly improve their capabilities in group supervision on a worldwide scale. It will be interesting to see how the FSOC applies its final rule, interpretive guidance, and judgment in determining which, if any, insurance organizations are systemically important.

31.6.1.1 Regulation of Insurers’ Exposure to Systemic Risk

The second issue that warrants discussion is the insurance industry’s exposure to systemic risk and its implications for the financial regulation of insurance companies. [Cummins and Weiss \(2010\)](#) examined the primary indicators that determine whether financial institutions are systemically risky as well as contributing factors that would increase their vulnerability to systemic events. As noted above, they concluded that core activities of insurance companies do not pose systemic risk to the economy. However, they also found that life insurers are subject to intra-sector crises because of their leverage and liquidity risk and that both life and property-casualty insurers are vulnerable to “reinsurance crises” arising from counterparty credit exposure.

[Wang et al. \(2009\)](#) also conducted a study of the financial crisis and its impact on the life insurance industry. They note that a number of life insurers were stressed by the crisis, initially due to losses on their credit-backed securities, followed by a subsequent decline in the value of other assets they held as the crisis spread through the financial sector and the general economy. As a consequence, several large insurers sought financial assistance from within their holding companies and/or the federal government. There were also a number of rating downgrades of life insurers as a result of their asset

⁴⁷Historically, insurance regulators have viewed their role to supervise the insurance companies within holding company organizations, trusting other financial regulators to supervise the noninsurance activities of these groups. This is changing somewhat as insurance regulators are increasing their emphasis on group-wide supervision in which they will communicate with other financial regulators on the activities of noninsurance entities within a group.

problems. In contrast, property-casualty insurers were much less affected by the crisis (Grace 2010; Cummins and Weiss 2010). Further, no major insurer insolvencies can be directly attributed to the financial crisis.

The experience of insurance companies during the crisis is consistent with assessments of their vulnerability to systemic events and turmoil in financial markets and economic recessions. Life insurers are more vulnerable to systemic risks generated in other parts of the financial sector than property-casualty insurers for several reasons. As discussed by Cummins and Weiss (2010), life insurance companies are more highly leveraged than property-casualty insurers and are exposed to severe liquidity risk due to their holdings of mortgage-backed securities and privately placed bonds. Life insurers also sell products with embedded options such as minimum interest guarantees.

This assessment of insurance companies' exposure to systemic risk has several implications for their regulation. First, a robust and properly focused regulatory system should encourage and compel insurers to properly manage all of the significant risks that they face, including the potential adverse effects of problems in the financial sector and the general economy. Second, regulators can increase their attention to insurers' exposure to systemic events in their financial monitoring and assessment of companies' risk management programs. Third, regulators can place limits on certain activities or practices that increase insurers' exposure to problems in the financial sector. Examples of this approach include statutory limitations on investments in mortgage-backed securities and actions aimed at curbing securities lending. However, this approach requires an appropriate balance of risk and cost, i.e., regulators need to consider how limitations on insurers' investment practices might affect their ability to offer appropriate products at a reasonable price. Ensuring that insurance companies are properly managing their financial risk is preferable to regulatory micromanagement of their operations.

31.7 Concluding Remarks

There is no doubt that regulation plays a prominent role in insurance and perhaps little disagreement with the proposition that it should. However, there can be significant differences of opinion over what aspects of insurance should be regulated and specific regulatory policies in many areas. A strong case can be made that because of the inefficiencies created by high information costs and principal-agent conflicts, there should be some form of solvency regulation of insurance companies. A similar argument can be made for regulating certain aspects of insurers' market conduct. At the same time, there appears to be little economic justification for regulating insurance prices in well-developed insurance markets where competition should ensure risk-based rates that are no higher than necessary to provide insurers with a fair rate of return.

But even in the areas of solvency and market conduct, there can be a wide divergence of opinion with respect to specific regulatory policies and practices. As countries seek to modernize their systems for solvency regulation, there are strong debates over what policies are necessary and appropriate as well as the methods employed by regulators to ensure that insurers do not assume excessive financial risk. Insurers (and some academics) are concerned that some of the measures being considered are excessive and overly intrusive and will impose unnecessary costs on insurance companies. Some of the methods used to regulate market conduct, at least in the USA, also have been criticized for being excess and inefficient. Additionally, there are concerns regarding other aspects of market regulation such as prohibitions on certain underwriting criteria, mandatory offer requirements, and mandated benefits.

Tensions between insurers and regulators can be especially high in lines of insurance subject to high-risk and escalating claim costs. The pricing, financing, and management of catastrophe risk have been very contentious in the USA. In some states, regulators have sought to constrain the

price of homeowners insurance in coastal areas and resist insurers' efforts to reduce their exposure to catastrophe losses. Government financing of catastrophe risk raises concerns with respect to cross-subsidies and negative effects on property owners' incentives to buy adequate insurance and take steps to mitigate their exposure to catastrophe losses.

The issue of systemic risk has garnered considerable attention due the recent financial crisis and the problems encountered by AIG. While there is a general consensus among academics that the core activities of insurance companies are not a significant contributor to systemic risk, the federal government has adopted regulations that could potentially deem certain insurance companies to systemically important and make them subject to increased regulation by the Federal Reserve. Industry representatives remained concerned about how these regulations will be implemented and the potential for some insurance companies to be deemed systemically significant. There is less disagreement over whether insurance companies have some exposure to systemic risk generated in other parts of the financial sector and reasons to be concerned that certain noncore activities of insurance holding companies contribute to systemic risk. These issues have attracted regulators' attention and the measures that they propose to address these issues will likely generate a healthy debate.

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Chapter 32

Insurance Markets in Developing Countries: Economic Importance and Retention Capacity

Jean-François Outreville

Abstract In the past, developing and emerging countries have considered financial institutions locally incorporated or even state-owned monopolies, an essential element of their economic and political independence. At the same time, structural, financial, and technical constraints such as the small size of the markets and the lack of sufficient experience have limited the retention capacity of these markets. Reliance on foreign insurance and reinsurance has remained an important policy issue. The purpose of this study is to present two important features of insurance markets in developing and emerging economies. The first issue is the relationship between insurance development and economic development which has been assessed in many empirical studies. The second issue is to present some empirical tests of the relationship between the market structure and the retention capacity for some of these countries.

Keywords Retention capacity • Developing countries • Insurance markets

“Indeed, if it is agreed that differences in government policies are responsible for much of the variation in economic performance among nations, it must be a research topic of the uppermost priority to try to establish which institutional circumstances are conducive to various types of policies”

J.E. Stiglitz, “Economics of Information and the Theory of Economic Development,” NBER, 1985, Working-paper no 1, p. 566.

32.1 Introduction

The developing countries are not only consumers but also suppliers of insurance services. In domestic markets, the supply of insurance services generally consists of services provided by national companies, with local and/or foreign capital, as well as by foreign companies and agencies or branches. It may therefore be said that domestic and imported insurance and reinsurance services are the two components of the total supply of insurance services.

Insurance, like other financial services, has grown in quantitative importance as part of the general development of financial institutions and markets. Several empirical studies have demonstrated the

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high-income elasticity of the demand for insurance in developing countries (Beenstock et al. 1988; Outreville 1990; Beck and Webb 2003). However, the demand remains insufficient in many developing countries and mainly focuses on low expense coverages such as automobile insurance or on high risk coverage such as transport insurance or insurance for large plants, leaving the insurance companies with an unbalanced portfolio of risks. As a result, insurers in most developing countries have to rely heavily on international insurance and reinsurance services.

The protectionism which has developed in most countries should be viewed as a decision to produce internal insurance services, as opposed to importing these services. Public enterprises were considered a macroeconomic tool and as such used by governments to produce not only insurance services but also social and macro-economic outputs. Today, almost all developing countries have a local insurance industry providing coverage for the domestic risks. However, if their reliance on foreign insurers has decreased markedly for some lines of business during the last 20 years, reliance on foreign reinsurance services has increased (UNCTAD 1994, 2005). Structural, financial, and technical constraints such as undercapitalization, the small size of markets, and the lack of sufficient experience and know-how limit the reinsurance capacity of these markets. In principle, and all other things being equal, as the volume of business increases in line with economic growth in these countries, it might be expected that the capacity will automatically be enhanced and the present dependence on reinsurance will decrease.

The decision to produce internal insurance as opposed to importing external insurance and reinsurance services was also viewed against the background of the critical shortage of foreign exchange affecting most developing countries. It is, however, almost impossible to assess the volume of trade in insurance services. Systematic analysis of the balance of payments is virtually useless unless it takes into account the net present value of inflows and outflows over a full business cycle.

Empirical evidence in the literature suggests that the developing countries rather have a supply-leading causality pattern of development than a demand-following pattern.¹ Many governments have indeed established new financial institutions under what has been termed a “supply-leading approach” to financial development and have considered locally incorporated insurance institutions or even state-owned monopolies an essential element of their economic and political independence. Another view supports the bidirectional relationship between financial development and economic growth (Demetriades and Hussein 1996; Greenwood and Smith 1997). Recently, some papers have focused on the relationship between financial development, insurance development, and economic growth.² The role of the insurance sector and its contribution to development is now at the agenda of international organizations such as UNCTAD, the World Bank, and the IMF (UNCTAD 2005).

The purpose of this chapter is to review two features that characterize the insurance markets in developing and emerging economies, i.e., the causality links between insurance growth and economic development and the factors that may affect the aggregate retention capacity of these markets. The cross-sectional analysis in the first part is based on recent available data published by SwissRe, and in the second part, the regression analysis is based on data published by the United Nations Conference on Trade and Development (UNCTAD 1994) in a survey of insurance and reinsurance operations in developing countries. The database for the analysis is limited to countries for which the overall retention ratio is available for years 1988–1989. It remains, as of today, the only set of data available for most of the developing countries and providing detailed information by line of business, loss ratios, retention ratios, and information on market structure.

The next section examines the economic importance of insurance markets in developing countries and the causality links between insurance growth and economic development. In the following section, the retention capacity is defined as the total premium volume of business retained at the country

¹See Jung (1986) and Dee (1986) and subsequent work by Levine and Zervos (1998) and Levine et al. (2000).

²See Outreville (2011) for a survey of the literature.

Table 32.1 Market share of the World insurance premiums

| Market | 2010 | 2000 | 1990 |
|-------------------------|---------|---------|---------|
| North America | 29.54 | 37.03 | 37.91 |
| Europe | 37.35 | 32.15 | 33.93 |
| Asia | 26.76 | 26.48 | 24.63 |
| (Japan and South Korea) | (18.24) | (20.60) | (22.55) |
| (Other Asia) | (8.52) | (5.88) | (2.08) |
| Latin America | 2.95 | 1.64 | 0.70 |
| Oceania | 1.87 | 1.59 | 1.77 |
| Africa | 1.53 | 1.11 | 1.06 |
| Total | 100.00 | 100.00 | 100.00 |

Source: Sigma, World insurance (several years), Swiss Re publications

level by the market for its own net account. Two approaches which have been suggested in the literature are examined: (1) the structure of providers in a market determines the capacity and there is a justification for political intervention and (2) resources' endowment in a country influences the capacity and more attention shall be paid to development factors. Because of the shortcoming of these two approaches and rather than assess which model determines the most the behavior of the retention ratio, an alternative proposal combining all factors is developed and tested empirically in the last section.

32.2 The Economic Importance of Insurance Markets in Developing Countries

Insurance is of primordial importance in domestic economies and internationally. The role of insurance in the development process is difficult to assess, but there is some evidence that the promotion of insurance programs might have a particularly significant impact on the level of personal saving in many developing countries (UNCTAD 1982). However, the insurance industry remains small in developing countries as measured by the market share of world insurance premiums (Table 32.1).

In 2010, insurance companies worldwide wrote US\$ 4,340 billion in direct premiums; in other words, the equivalent of about 7.0% of global GDP was used to purchase insurance products. During the same year, insurance companies in developing and emerging economies generated premiums worth US\$ 650 billion representing about 15% of the world insurance premiums.³

Following previous empirical research, the relationship between insurance premium volume and GDP is hypothesized to be a log-linear relationship. Graphic analysis makes it possible to verify that the adjustment appears to be relatively satisfactory bearing in mind the diversity of the countries considered, the disturbing influence of exchange rates, and the probable imperfections in the statistical data (Fig. 32.1). The relationship is based on 55 developing and emerging countries and for average values of premiums and GDP over the period 2007–2009 to smooth the effects of the financial crisis over this period of time. Average premiums over the period range from 0.47 b\$ (Mauritius) to 152 b\$ (China). This relationship is very similar to previous results found by Beenstock et al. (1988) for a sample of 45 developed and developing countries in 1981, by Outreville (1990) for 55 developing countries in 1983–1984, by Beck and Webb (2003) for 68 countries over the period 1961–2000, and more recently, by Outreville (2011) for a sample of 80 countries.

³Sigma, World Insurance in 2010, No2/2011, Swiss Re publication.

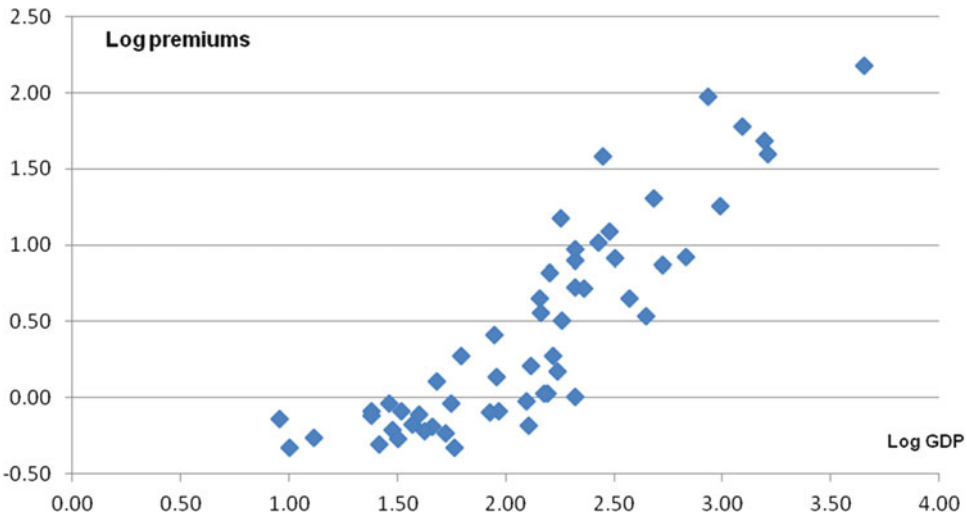


Fig. 32.1 Relationship between insurance premiums (in log) and GDP. Average values 2007–2009, 55 countries

Income elasticity has been calculated in several studies and the results are very close to each other. [Beenstock et al. \(1988\)](#) find an income elasticity of 1.37 and [Outreville \(1990\)](#) finds an elasticity of 1.34 for a cross section of developing countries. [Outreville \(1996\)](#) finds an elasticity of 1.31 for Latin and Central American countries alone. [Beck and Webb \(2003\)](#) report an elasticity of 1.47 and more recently [Li et al. \(2007\)](#) report values between 1.09 and 1.28 and the most recent study by [Outreville \(2011\)](#) finds an income elasticity of 1.22 for a sample of 80 countries.

In fact, individual country experiences are too heterogeneous to accord neatly with any very simple generalization and very little is known about the demand and supply relationship in these countries. Some societies have achieved high levels of human development at modest levels of per capita income. Other societies have failed to translate their comparatively high-income levels and rapid economic growth into commensurate levels of human development. Some authors argue that other factors are linked to the culture of the nations ([Chui and Kwok 2008, 2009](#)) or are becoming more important at higher levels of education and GDP ([Park and Lemaire 2011](#)).

Human development is a process of enlarging people's choice. The most critical ones are to lead to a long and healthy life, to be educated, and to enjoy a decent standard of living. Human development is measured by UNDP as a comprehensive index—called the human development index (HDI)—reflecting life expectancy, literacy, and command over the resources to enjoy a decent standard of living.

Two measures are used traditionally to show the relative importance of insurance within national economies. Insurance penetration is the ratio of direct premiums written to gross domestic product (GDP) and insurance density indicates the average annual per capita premium within a country expressed in US dollars. It indicates how much each inhabitant of the country spends on average on insurance, but currency fluctuations affect comparisons. The measure of insurance density is preferred when comparing data with the level of human development. Average densities range from 4.6 in Bangladesh and 6.2 in Nigeria to 2079 in South Korea and 2566 in Singapore. Figure 32.2 shows the relationship between the level of insurance density and the HDI for the countries considered.

Considering the size of insurance activities and the economic functions of insurance it should also play a major role in economic growth. Compared to the vast literature focusing on bank, stock, and bond markets and their respective environment, it is surprising that no empirical work on the causality links between insurance and economic growth was published before [Ward and Zurbrugg \(2000\)](#)

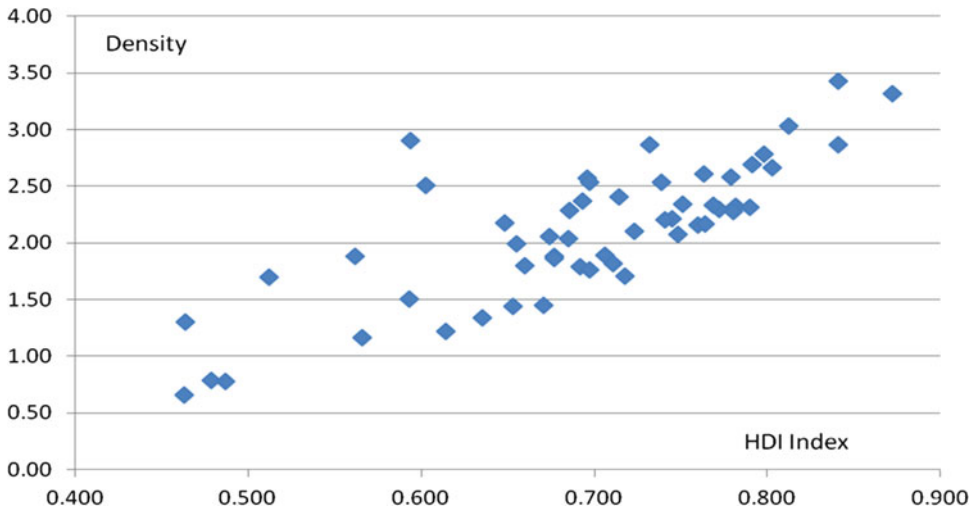


Fig. 32.2 Relationship between density (in log) and the HDI index. Average values 2007–2009, 55 countries

who are the first to show some evidence of a supply-leading pattern.⁴ More recent studies tend to demonstrate that life insurance is more important for high-income countries and that on the opposite, nonlife insurance is more important for emerging and developing countries. The life insurance sector is often of relatively less importance in developing countries.⁵

32.3 The Retention Capacity of Developing Countries' Markets

The aggregate retention capacity of developing countries' markets is low. Retention capacity is defined as the ratio of net premiums written (i.e., premiums written in the country plus reinsurance assumed minus premiums ceded outside the country) to gross premiums written at the aggregate level of the country. The retention capacity is therefore the net result of all insurance and reinsurance transactions. Unfortunately statistical information is not readily available for developing countries, and data published by the United Nations Conference on Trade and Development (UNCTAD 1994) in a survey of insurance and reinsurance operations in developing countries remains, as of today, the only set of data available for most of the developing countries and providing detailed information by line of business, loss ratios, retention ratios, and information on market structure. The data presented in this survey are available for years 1988 and 1989. The average retention is close to 66%, but there is a large dispersion among countries (see Table 32.2 and Appendix Table 32.6). A sizeable number of countries have a retention capacity lower than 50% of the total volume of business transacted by insurers.

⁴Despite the apparent lack of literature on the role of insurance, the work by [Outreville \(1990, 1996\)](#) identifies links between an economy's financial development and insurance market development. The work of [Soo \(1996\)](#) is also mentioned in the literature. This dissertation provides evidence that the growth in the life insurance industry in the USA has contributed to productivity and economic growth. See [Outreville \(2011\)](#) for a survey of the literature.

⁵[Haiss and Sumegi \(2008\)](#), [Arena \(2008\)](#), and [Han et al. \(2010\)](#) observed a significant relationship between nonlife insurance and economic growth in developing countries. In more developed markets, life insurance activity contributes to economic growth through complementarities with the banking sector and the stock market. Support for this idea can be found in the work of [Catalan et al. \(2000\)](#).

Table 32.2 Retention capacity in selected developing countries

| Year | Sample size | Average retention | Number of countries with retention <50% |
|------|--------------|-------------------|---|
| 1988 | 62 countries | 66.4 | 16 |
| 1989 | 50 countries | 66.5 | 10 |

Source: UNCTAD (1994)

Countries having a reinsurance company operating locally (see Appendix Table 32.6) may be assuming local insurance business as well as business from abroad. One of the important reasons why reinsurance is taken out abroad is obviously to make up the shortage of capacity of the internal market. The problem of reinsurance planning at the level of a company is solved essentially according to the individual requirements of the company, the nature of the business, its volume, and its territorial distribution in each class of business, the type and size of the risks to be covered, the capacity of the aggregate insurance portfolio, the financial strength of the company, and the possibilities of placing its business and its past experience, know-how, and future expectations. However, it is worth knowing that the protectionism which has developed in almost all countries has rarely been dictated by these technical considerations (UNCTAD 1973).

The sizes and quantities of risks normally vary from one company to another and also from one country to another. The portfolio of a company operating in a small and highly fragmented market will inevitably be very different from that of a company enjoying a complete monopoly, and their respective retention capacities and reinsurance needs will also differ.

The problem of optimal reinsurance has received limited attention in financial economics or insurance literature (Doherty and Tinic 1981; Mayers and Smith 1982; Blazenco 1986; Garven 1987; Garven and Loubergé 1996, Garven and Lamm-Tennant 2003, Powell and Sommer 2007, Adams et al. 2008). Empirical research by Mayers and Smith (1990) documents that factors such as ownership structure, firm size, geographic concentration, and line-of-business concentration influence the demand for reinsurance.⁶

32.4 Market Structure and the Retention Capacity

Structural characteristics of the market for financial institutions play a major role in determining the allocational efficiency of the demand and supply of financial services. If the objective is to retain in the country as much insurance business as is technically possible—with due regard to the stability of the insurance concerns—market structure is the first aspect to be considered. The problem of reinsurance in many developing countries is that these structures have rarely been established according to given retention requirements.

As shown in Outreville (1990, 1991) and more recently in Ward and Zurbrugg (2002) and Li et al. (2007), the size of the insurance sector is significantly related to the level of development and size of the financial sector of the economy. The purpose of this section is to verify if the retention capacity of a market is affected by the size and the ownership structure or nature of the market, i.e., type of competition, restriction to competition. The following general equation is proposed:

$$\text{Retention Capacity} = f\{\text{Size of the market, Financial development, Market structure, Local reinsurance}\}.$$

⁶Only a few contributions have verified empirically the importance of some of these variables. Cole and McCullough (2006) examine the effect of the state of the international reinsurance market on the demand for reinsurance by US insurers. Outreville (1995) provides a cross-sectional analysis of reinsurance demand by developing countries.

Table 32.3 Estimates of the relationship between the retention capacity and market structure variables

| Variables | (1) | (2) |
|-----------------------|-----------------------------|------------------------------|
| Intercept | 58.65 | 61.46 |
| Size (total premiums) | 0.07 (1.90) ^a | 0.07 (1.92) ^a |
| M2/GDP | 0.06 (0.57) | |
| MONOP | 17.4 ^b (2.97) | 17.35 ^b (2.99) |
| NATION | -5.98 (1.00) | -6.96 (1.23) |
| LOCALRE | 1.65 (0.37) | 1.46 (0.33) |
| R2 | 0.33 | 0.32 |
| F | 3.32 | 4.15 |

Note: In () are the *t*-statistics

^aSignificant at the 0.10 level, ^bSignificant at the 0.05 level The dependent variable is the retention capacity

The retention capacity of a market is measured as the ratio of net property–liability insurance premiums written to gross premiums written. It seems plausible to assume that the retention capacity of a market is directly related to its absolute size. The size of the market is calculated by the total amount of gross premiums written in a country.⁷ Financial development is proxied by the ratio of the broad definition of money to GDP (M2/GDP) and defined by [Feldman and Gang \(1990\)](#) as financial deepening.

Two dummy variables are used to evaluate the market structure; one variable indicates if the market is a monopolistic one or not (MONOP), and the other variable indicates if the market is competitive but restricted to national companies (NATION). The third alternative is a market fully open to international competitors. The appropriate variable to be tested in this context would be a measure of the concentration ratio. It is not available for most of the countries in our sample. Finally, a third dummy variable indicates the presence of a locally incorporated reinsurance company (LOCALRE) with the expectation that a local reinsurer would imply a higher retention capacity for the market.

The equation is estimated cross-sectionally with 40 developing countries of the sample (Appendix Table 32.6). The database for the analysis is limited to countries for which the overall average retention ratio is available for years 1988–1989. Economic and financial variables are taken from the International Financial Statistics published by the IMF (Appendix Table 32.7). Since the dependent variable is a ratio and the predetermined variables are assumed to be uncorrelated with the disturbance term, the OLS method is applied to estimate the impact coefficients of the equation. A correlation matrix of all variables is presented in Appendix Table 32.8.

The results are presented in Table 32.3. It is expected that the retention capacity of a market would increase with the size of the market and the level of financial development. However, only the estimated coefficient for the size variable is significant.

In markets restricted to foreign competition, the presence of many firms selling essentially identical products is not necessarily conducive to efficiency and profitability. In many developing countries, the insurance market is characterized by the existence of too large a number of small domestic companies with small retention limits. This is certainly the case when the market is restricted to

⁷Retention is a function of the financial capacity of a firm which itself relates to the amount of business written. At the aggregate level the retention capacity of a market shall be related to the size of the market.

national companies. The coefficient NATION in the equation has the expected negative sign but is not statistically significant. On the contrary, for monopolistic markets, the variable MONOP shows a positive and significant coefficient. This result could give support to the claim that a few developing countries with a high concentration of the insurance business in few companies have been more successful in expanding business and retaining premiums.

Some developing countries have instituted compulsory reinsurance cessions to local reinsurance organizations. The efficacy of compulsory internal reinsurance cessions is a highly contentious issue. Although the sign of the variable LOCALRE is positive as expected, it is not significant. As advocated by [Eden and Kahane \(1990\)](#), the large international reinsurers possess an advantage not available to local reinsurers: they are more diversified.

32.5 Comparative Advantage and the Retention Capacity

In recent years there has been a noticeable increase in attention paid to the factors responsible for the development and distribution of international financial services. [Kindleberger \(1974, 1985\)](#) listed a number of plausible factors and also pointed to the difficulties of reaching quantitative evaluations.

The analyses in quantitative studies are at a level of aggregation which deals with total financial activity. Indeed empirical work has frequently lumped together banking, insurance, real estate, and other financial services, and certainly no attempt has been made to explain different activities with the exception of banking activities ([Ball and Tschoegl 1982](#); [Hultman and McGee 1989](#)).

The comparative advantage of some of the financial institutions of developed countries has provided a strong global network for the supply of international financial services ([Moshirian 1993](#)). Historically connected with the pattern of international trade, insurance and reinsurance services are considered part of the financial services which are essential for adequate risk coverage. A number of researchers have argued that there should be a similarity in the patterns of trade in goods and services ([Arndt 1988](#)). In service industries including insurance the work of [Sapir and Lutz \(1981\)](#) confirms this similarity.

An approach to testing the Heckscher–Ohlin–Vanek (HOV) theory to explain the patterns of international trade in the context of intercountry differences in factor endowments is provided in [Leamer \(1974, 1984\)](#), [Leamer and Bowen \(1981\)](#), and [Balassa \(1979, 1986\)](#). The influence of scale economies on the volume of trade has also been recognized in the literature since Krugman's seminal contribution in 1979.⁸

Trade in insurance services in developing countries shall be viewed as a component of total supply of insurance services and often make up for the shortage of internal services. Factor endowments of a country may explain the need for international insurance services. The purpose of this section is to verify if the determinants of comparative advantage in financial services also explain the production of insurance services in developing countries as measured by the retention capacity of these markets.

⁸The monopolistic competition trade model is summarized in [Helpman and Krugman \(1985\)](#). Empirically the HOV theorem performs poorly and, by implication, so do increasing returns to scale and imperfect-competition models that yield the HOV theorem ([Trefler 1995](#)).

Table 32.4 Estimates of the relationship between the retention capacity and endowment factors

| Variables | (1) | (2) |
|-----------|-----------------------------|-----------------------------|
| Intercept | 57.17 | 60.29 |
| ES | 1.44 (0.51) | 0.11 (0.84) |
| CL | 2.01 ^a (1.97) | 2.86 ^b (2.16) |
| RE | 0.47 ^a (2.16) | 0.46 ^a (2.14) |
| R2 | 0.26 | 0.27 |
| F | 4.01 | 4.21 |

Note: In () are the *t*-statistics

^aSignificant at the 0.10 level, ^bSignificant at the 0.05 level

The dependent variable is the retention capacity. The size variable (ES) is the ratio premiums/GDP in (1) and M2/GDP in (2)

Following [Moshirian \(1994\)](#), a model of sources of comparative advantage of international financial services is proposed in the general following form:

$$\text{Retention capacity} = a_0 + a_1ES_i + a_2CL_i + a_3RE_i$$

- i = country subscript and the variables
- ES = scale variable
- CL = capital–labor ratio
- RE = resource endowment variable

The economy of scale factor (ES) is usually measured by the per capita GDP. The GDP variable used by [Sapir and Lutz \(1981\)](#) for insurance services is not statistically significant for all their estimations. As an alternative approach, the size of the market is approximated by the measure of financial development suggested by [Feldman and Gang \(1990\)](#).

Following [Leamer \(1974\)](#) and [Balassa \(1979\)](#), the capital stock of each country is calculated by the country's gross domestic investment and divided by the labor force figure to obtain an estimate of the capital–labor ratio (CL) for each country.

The human capital endowment (RE) is one of the sources of comparative advantage for financial services. A standard approach is to treat human capital, or the average years of schooling of the labor force, as an ordinary input in the production function. The work of [Mankiw et al. \(1992\)](#) is in the tradition. Following [Baldwin \(1971\)](#) the percentage of the labor force with tertiary level education is used as a proxy variable for human capital endowment.

Since the predetermined variables and stochastic disturbances appear on the right-hand side of the equation, and the predetermined variables are assumed to be uncorrelated with the disturbance term, the ordinary least squares method can be applied to estimate the impact coefficients of the equation. Several equations have been estimated to test for alternative proxies for the variables and the regression results for two equations using two different measures of ES are presented in [Table 32.4](#). The Park test has been used to verify the assumption of homoscedasticity by regressing the residuals obtained from the regression on the size variable ([Gujarati 1988](#)). There is no statistically significant relationship between the variables.

Premiums written in a country do not seem to provide an answer for economies of scale in reinsurance services. This was also the case in [Sapir and Lutz \(1981\)](#), and [Moshirian \(1994\)](#) found no significant relationship with the size variable. The alternative measure of financial development used in (2) is not significant either. This result surprisingly differs from the previous result and shall be attributed to the multicollinearity that appears to be present between the variables in the model.

On the other hand, the capital–labor ratio (CL) and the human capital endowment (RE) are the two variables that significantly explain the level of retention of a country.

32.6 A Consolidated Model Explaining the Retention Capacity

It may be argued that the level of financial development is determined endogenously and belongs to a general interdependent system of simultaneous equations. The application of the ordinary least squares method leads to inconsistent estimates. An alternative approach is to regress the measure of financial development on the GDP, the average inflation rate, the resource endowment variable, and the dummy variable associated with a monopolistic market, and use residuals of the estimation procedure as an adjusted measure of financial development (FD*). This variable also may be an appropriate measure of monetization in inflation prone countries.⁹

It has been argued by [Gupta \(1990\)](#) that the inclusion of sociopolitical variables in general and the factors of political violence in particular change the traditional model of economic growth. While investment in human capital is part of the income-increasing force, factors causing political instability, on the other hand, are part of the income-retarding force. The index (PI) published in [Romer \(1993\)](#) is used in this study. Following [Barro \(1991\)](#) it measures political instability as the mean number of revolutions and coups per year.¹⁰

The purpose of this section is to present a consolidated model explaining the retention capacity of a market based on competitive advantage, structural variables, and political instability. The following general equation is proposed:

$$\text{Retention Capacity} = f\{\text{Financial development (FD)}, \text{Capital – Labour ratio (CL)}, \\ \text{Human development (RE)}, \text{Political instability (PI)}, \text{Market structure (MONOP, LOCALRE)}\}.$$

The estimates are presented in Table 32.5. To verify the degree of multicollinearity, we regress each of the explanatory variables on all the remaining variables; the correlation coefficients R^2 of these auxiliary regressions (column 2) give a low measure of multicollinearity. All the variance inflation factors (VIF) are lower or close to 2.0 (column 3).

Similarly to previous results, the level of financial development, although positive as expected, does not affect significantly the level of retention. The comparative advantage variables CL and RE are significant variables. Political instability (PI index) affects negatively the reinsurance capacity of developing countries. Some developing countries have instituted compulsory reinsurance cessions to local reinsurance organizations (LOCALRE). For this variable, the coefficient was very low and never found significant in any validations of the model and therefore was dropped in the last version presented in Table 32.5.

[Garven and Lamm-Tennant \(2003\)](#) argue that not only the portfolio and financial leverage factors have an influence on reinsurance, but also the tax status of corporations, in an international framework, should be a relevant factor in determining the demand for reinsurance. [Garven and Loubergé \(1996\)](#) show that within an option-pricing framework, reinsurance is used to allocate tax shields to those firms that have the greatest capacity for utilizing them, in much the same manner as leasing companies share

⁹Studies suggest that changes due to disinflation and deregulation have had a smaller effect on M2 than on M1 growth and that the relationship between M2 growth and inflation has remained fairly stable ([Reichenstein and Elliott 1987](#); [Bernanke and Blinder 1988](#)).

¹⁰It is worth noting that this result suggests that political instability is strongly associated with inflation and monetary instability.

Table 32.5 Estimates of the consolidated model explaining the retention capacity

| Variables | (1) | (2) | (3) |
|-----------|-------------------------------|------|------|
| FD* | 0.14 (1.14) | 0.27 | 1.37 |
| CL | 2.49 ^a (2.03) | 0.36 | 1.56 |
| RE | 0.52 ^b (2.35) | 0.52 | 2.08 |
| PI index | -11.18 ^a (1.58) | 0.34 | 1.52 |
| MONOP | 14.91 ^b (2.71) | 0.09 | 1.10 |
| LOCALRE | N.S. | 0.31 | 1.45 |
| R2 | 0.44 | | |
| F | 5.22 | | |

Note: In () are the *t*-statistics

^aSignificant at the 0.10 level

^bSignificant at the 0.05 level

tax shield benefits with lessees in leasing markets. Insurers in low-tax countries will tend to provide reinsurance cover to insurers in high-tax countries. This may explain, at least partly, why captive reinsurance companies are located in low-tax domiciles.

Several tests were conducted to verify the effect of corporate tax rates, but the estimated coefficient is not significant in the multiple regression analysis. An alternative measure using taxes on international trade and transactions as measured by the International Monetary Fund is not significant either.

32.7 Discussion

Insurance, like other financial services, has grown in quantitative importance in developing and emerging economies as part of the general development of these economies. The first part of the chapter presents the relationships that exist between the level of development of the insurance sector and the level of development of the countries concerned.

The protectionism which has developed in many of these countries could be seen as the decision to established national insurance companies and markets to meet their own insurance needs. However, their reliance on foreign insurance and reinsurance markets has remained high. The small size of the markets, the imbalance nature of the insurance portfolios, and certainly the lack of sufficient experience and know-how are among the main reasons for this situation.

This chapter has also analyzed the relationship between the retention capacity and structural factors affecting these markets. The empirical results, based on a cross-sectional analysis of 40 developing countries, indicate that, the size of the market, the level of financial development and the competitive structure of the market are relevant factors explaining the retention capacity. Human capital endowment and the capital-labor ratio are also significant factors explaining the retention capacity of insurance markets in developing countries.

The importance attributed to the existence of a local market and to the building up of retention capacity has often been dictated by political considerations rather than by technical reasons. If it is true that the developing countries have a supply-leading causality pattern to development, then more attention should be paid to factors such as the level of financial development and the market structure of suppliers.

Much inefficiency may be less a function of ownership than of government regulation and market structure. Adequate regulation of an industry requires so much information that establishing effective regulation of privatized firms may prove more demanding of the state's administrative capabilities than operating a state-owned monopolistic institution. The proper sequencing of privatization and liberalization is a critical issue for policy-makers.

Acquiring a long-term competitive position in insurance services depends on the development of human capital, on the level of development in the rest of the economy and on improvements in the financial strength of the insurance carriers. It is unrealistic to presuppose that the developing countries will be able to gain access to developed countries' markets. The increased participation of companies from developing countries in sharing arrangements or pools with experienced and large companies from developed countries could help in transferring the necessary technological and human resources know-how which developing countries need for building competitive insurance firms.

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Appendix Table 32.6 List of countries used in the regression analysis; average values for 1988–1989

| Country | Insurance penetration (%GDP) | Retention ratio | Local reinsurance | Monopolistic market |
|-------------------|------------------------------|-----------------|-------------------|---------------------|
| Algeria | 1.48 | 93.1 | Yes | Yes |
| Argentina | 1.04 | 74.9 | Yes | No |
| Bahamas | 2.58 | 77.0 | Yes | No |
| Barbados | 3.42 | 61.1 | No | No |
| Chad | 0.35 | 57.6 | No | No |
| Chile | 1.14 | 50.5 | Yes | No |
| Costa Rica | 1.94 | 80.8 | Yes | Yes |
| Cote d'Ivoire | 1.55 | 70.6 | No | No |
| Cyprus | 1.41 | 80.8 | No | No |
| El Salvador | 0.84 | 44.5 | No | No |
| Ethiopia | 1.18 | 84.3 | No | Yes |
| Fiji | 1.20 | 60.3 | Yes | No |
| Gabon | 1.81 | 76.1 | Yes | No |
| Ghana | 0.28 | 68.7 | Yes | No |
| Guatemala | 0.67 | 62.6 | No | No |
| Honduras | 0.65 | 50.4 | No | No |
| Indonesia | 0.66 | 55.0 | Yes | No |
| Jamaica | 3.45 | 54.3 | No | No |
| Korea, | 1.43 | 93.4 | Yes | No |
| Rep. of Malawi | 1.52 | 78.6 | Yes | No |
| Malaysia | 2.02 | 58.5 | Yes | No |
| Mali | 0.50 | 71.0 | No | No |
| Malta | 2.10 | 86.3 | No | No |
| Mauritius | 1.60 | 51.5 | No | No |
| Mexico | 0.70 | 73.6 | Yes | No |
| Morocco | 1.21 | 65.4 | Yes | No |
| Nigeria | 0.55 | 49.9 | Yes | No |
| Oman | 0.86 | 59.8 | No | No |
| Paraguay | 0.74 | 50.4 | No | No |
| Philippines | 0.61 | 77.0 | Yes | No |
| Seychelles | 1.62 | 61.6 | No | Yes |
| Singapore | 1.37 | 77.4 | Yes | No |
| Solomon Islands | 1.30 | 41.0 | No | No |
| Sudan | 0.64 | 32.9 | Yes | No |
| Syria | 0.32 | 76.1 | No | Yes |
| Thailand | 0.66 | 63.4 | Yes | No |
| Togo | 1.07 | 61.7 | No | No |
| Trinidad & Tobago | 2.40 | 52.7 | Yes | No |
| Tunisia | 0.91 | 64.1 | Yes | No |
| Zambia | 2.01 | 83.9 | No | Yes |

Source: UNCTAD (1994)

Appendix Table 32.7 Data sources

| | |
|--|---|
| Insurance data | UNCTAD statistical survey on insurance in developing countries |
| GDP, inflation, population gross domestic investment | UNCTAD handbook of international trade and development statistics |
| Education, labor force | UNDP human development report |
| Currency exchange rates, M1, M2 | IMF international financial statistics |
| Corporate tax rates | IMF Government Finance statistics |

Appendix Table 32.8 Correlation matrix

| | CL | RE | M2/GDP | Inflation | GDP | Politics | LocalRE | Monopoly | Crop. taxes |
|-------------|-------|-------|--------|-----------|-------|----------|---------|----------|-------------|
| CL | 1 | | | | | | | | |
| RE | 0.25 | 1 | | | | | | | |
| M2/GDP | 0.62 | 0.15 | 1 | | | | | | |
| Inflation | -0.3 | -0.01 | -0.23 | 1 | | | | | |
| GDP | 0.16 | 0.57 | -0.05 | 0.003 | 1 | | | | |
| Politics | -0.27 | 0.41 | -0.21 | 0.12 | 0.2 | 1 | | | |
| LocalRE | 0.04 | 0.26 | -0.03 | -0.05 | 0.46 | 0.12 | 1 | | |
| Monopoly | -0.5 | 0.05 | 0.14 | 0.46 | -0.12 | -0.02 | -0.33 | 1 | |
| Crop. taxes | -0.1 | -0.33 | -0.02 | 0.19 | 0.11 | 0.18 | 0.33 | 0.04 | 1.0 |

Chapter 33

Health Insurance in the United States

Michael A. Morrisey

Abstract Health insurance in the United States continues to be a complex mix of private and public programs. The advent of health-care reform legislation, the Patient Protection and Accountable Care Act (PPACA), portends significant new challenges and research opportunities. This chapter provides a historical overview of the US system and a summary of the key features of the PPACA that affect health insurance. Attention is then directed to the key issues in health insurance and an update on the research undertaken in the last decade. Key topics include adverse selection and moral hazard where the new research examines multidimensional selection, forward-looking behavior, prescription drug coverage, and utilization management as a mechanism to control moral hazard. Managed care continues to be the dominate form of private coverage and the research on its comparative advantage in selective contracting is reviewed along with the evidence on managed care backlash and the efforts at provider consolidation. New research is beginning to examine the market structure, conduct, and performance of the health insurance sector and this is reviewed. Much of the chapter is devoted to new research on important aspects of employer-sponsored health insurance. This includes premium sensitivity, compensating wage differentials, and the tax treatment of employer-sponsored coverage. Significant new research has also examined the role of the employer as agent for his/her workers. Individual, non-group markets have historically played a minor role in the USA. Knowledge of these markets is reviewed as is the imming market in high-deductible health plans. Early research on state insurance regulation typically found only small effects. More recent research has tended to examine the effects of specific laws and to explore the effects among high- and low-risk individuals and firms. Finally, there has been substantial new research focusing in the Medicare program for older residents. This work examines the effects of risk adjustment in the Medicare Advantage program and the effects in the Medicare prescription drug program. Throughout the chapter attention is given to future avenues of research that are likely to emerge from the PPACA legislation.

33.1 Introduction

The purpose of this chapter is twofold. First, it presents a baseline of knowledge about health insurance markets in the United States as that country prepares to embark on an expansion of public and private insurance provision designed to cover all its citizens and legal residents beginning in 2014. Second,

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the chapter summarizes the empirical research on health insurance with an emphasis on that which has emerged in the last 10 years or so.

The chapter begins with a brief history of the development of health insurance in the USA and summarizes the nature and extent of coverage provided through employers, individual purchase, and government programs, particularly Medicare and Medicaid. It then summarizes the key features of the expanded coverage that are provided through the Patient Protection and Affordable Care Act, conventionally referred to as the PPACA.

This is followed by a discussion of the extent of adverse selection in health insurance and efforts to accommodate it in public and private markets. Moral hazard is then reviewed, summarizing the RAND Health Insurance Experiment and the new findings that have emerged since, largely in the area of prescription drugs. The discussion also reviews the literature on utilization management approaches to limiting moral hazard. This is followed by a discussion of the rise and fall of managed care, focusing on the extent of favorable selection it enjoyed, the effects of selective contracting on health-care prices, and the managed care backlash. The topic of employer-sponsored health insurance is presented with particular attention to compensating wage differentials and the tax treatment afforded employer-sponsored coverage. The research findings on the small group and individual markets are then briefly discussed. The role of government in regulating and funding the USA is discussed through sections on insurance regulation: the Medicare program, largely for seniors, and the Medicaid and Children's Health Insurance Plan (CHIP) for the indigent. Throughout the chapter the implications for the PPACA for future research are highlighted.

33.2 History, Coverage, and Reform of Health Insurance in the United States

33.2.1 Development of Private Health Insurance

The development of health insurance in the USA is usually dated from the Great Depression. Baylor University Hospital in Dallas, TX, began providing 21 days of hospital care for 50 cents per month in 1929. The American Hospital Association soon began approving these "hospital service plans," granting exclusive geographic territories to each plan, and requiring that all hospitals in the defined geographic area be included in the plans. These nonprofit "Blue Cross" plans operated with community rating. The American Medical Association began approving analogous "Blue Shield" plans in 1939. These plans were indemnity in nature; beneficiaries had free choice of physicians and received cash payments with which they could settle their physician bills. These insurance organizations remained creatures of their respective provider organizations until the 1960s (Numbers 1979; Starr 1982). The forerunners of health maintenance organizations (HMOs) also began during the Depression. The Ross–Loos Clinic in Los Angeles, CA, is generally credited as the first such plan, first offering coverage to employees of the Los Angeles Department of Water and Power in 1929. These "prepaid group practices" were established in many urban areas throughout the country during the 1930s. They faced substantial opposition from organized medicine. It is for this reason that these early plans owned their own hospitals; their physicians could not get admitting privileges at local hospitals (Kessel 1959). Commercial carriers initially considered "health" to be uninsurable for obvious adverse selection reasons. This concern was overcome by offering "hospital" and "surgical" coverage, each with schedules of indemnity payments. The first commercial hospital coverage was provided in 1934 with surgical coverage following in 1938.

There were antecedents to these plans. Fishback and Kantor (2000) have recently reexamined the 1910–1920s development of workers' compensation insurance. They conclude that its successful

enactment came about because it offered both protection to those who suffered workplace injury and because it offered employers protection from future liability with the costs of the program shifted to workers in the form of lower wages. They also argue that the reciprocal nature of these benefits explains why workers' compensation laws were enacted but the proposals for compulsory health insurance in the progressive era were not. In important new historical work, [Murray \(2007\)](#) argues that it was the success of industrial sickness funds that undercut the compulsory health insurance efforts of the progressive era. He exhaustively examined these funds. They were organized by employers or by fraternal organizations of workers themselves. They typically provided financial benefits if one were unable to work for reasons of sickness or injury. Adverse selection was dealt with primarily through waiting periods, age limits, and employment requirements; moral hazard was limited by a board of fellow workers that would certify when the beneficiary was sufficiently sick or injured to warrant benefits. Murray finds evidence of company-founded sickness funds as early as the Civil War era with the 1890 US Census reporting over 1,200 nonfraternal mutual assistance funds in operation. The sickness funds died out, he argues because of improved actuarial methods in the 1940s.

The prevalence of private health insurance expanded during World War II, in large part because employer-provided health benefits were not considered wages and thus could be used to recruit and compensate workers in a period in which wage and price controls were rigorously enforced. At the end of the war approximately 23% of the population had some form of private health insurance; by 1965, this had risen to 73 % and to 83 % by 1975 ([HIAA 1990](#)).

This growth was largely fueled by the tax treatment of employer-sponsored health insurance. The Internal Revenue Service issued a private ruling in 1943 holding that employer-provided health insurance benefits were not subject to federal income taxation; the Congress codified this ruling in 1954 ([Thomasson 2003](#)). The states have followed the federal model and also excluded employer-sponsored health insurance from state income taxation. The tax treatment provided strong incentives to shift compensation from taxed money income to untaxed health insurance. [Seldon and Gray \(2006\)](#) estimate that the tax revenues lost as a result of this action were some \$208.6 billion or roughly two-thirds of what the federal government spent on Medicare during the same time period.

The Blue Cross and Blue Shield plans employed community rating, setting a single premium for all subscribers. Experience rating was introduced by commercial insurers in the 1950s. As [Cunningham and Cunningham \(1997\)](#) observe, this was driven by efforts on the part of the commercials to attract more business by offering lower premiums based on lower expected claims experience. By 1954 they insured more covered lived than did the Blue plans. By the 1960s virtually all plans were experience rated.

In the 1974 the Congress passed the Employee Retirement Income Security Act (ERISA) in response to problems in the defined benefit pension market. This legislation allowed self-insured group health plans to be exempted from state insurance regulation and led to a substantial shift to such plans. Indeed, by 2009, some 57 % of insured workers were in self-insured plans ([KFF and HRET 2010](#)). Ironically, ERISA also spurred state level health insurance regulation by effectively removing large employers from state legislative debates over benefit provisions that were required to be included in plans. There were few such laws in the 1970s; however, by 2010, [Bunce and Wieske \(2010\)](#) report nearly 2,200 such laws covering benefits ranging from alcohol abuse treatment to opticians.

While prepaid group practice plans existed from the 1930s, managed care emerged as a major factor in most US health insurance markets only in the 1980s and is now the dominant form of private health insurance. In 1988 some 73 % of insured workers were in a conventional health plan; by 2010 only 1 % was in one ([Claxton et al. 2010](#)).

The two major forms of managed care are HMOs and preferred provider organizations (PPOs). As [Glied \(2000\)](#) observes, "There is no single broadly accepted definition of the term nor do any existing definitions persuasively distinguish managed care from other types of health insurance" (page 709). The principal distinguishing feature of a managed care plan used here is its limited network of providers. HMOs tend to have more limited panels of hospitals and physicians. They

also bear underwriting risk; they are insurers. In contrast, PPOs tend to effectively have much larger panels of providers. They also often do not bear risk. Instead, many of them negotiate contracts between self-insured (risk-bearing) employers and provider groups. A PPO essentially has two sets of providers. The first is its in-network providers. They may be accessed by subscribers who pay relatively small co-pays. The second, its out-of-network providers, may be accessed at any time as long as the subscriber is willing to pay substantially higher co-pays or deductibles. As noted below, the broader networks inhibit the PPOs ability to negotiate as favorable prices from providers as HMOs. The public and provider backlash against managed care plans since the turn of the twenty-first century has arguably led to broader networks, reduced ability to negotiate prices, and higher insurance premiums.

The most recent development in the private health insurance market has been the introduction of high-deductible health plans. Congress enacted legislation in 2003 which allowed individuals and employers to combine a catastrophic health insurance plan with a tax-sheltered “health savings account” (HSA). The intent was to encourage individuals to consider the value of the health services they purchased by facing the full price of routine services. The HSA component allows any unused funds to be “rolled over” and available for health spending in a subsequent year. By 2010 [Claxton et al. \(2010\)](#) report that 13 % of insured workers were in a high-deductible health plan.

33.2.2 *Medicare and Medicaid*

The key federal health insurance programs were enacted in 1965 and built on earlier Kerr-Mills legislation that provided federal support for state programs to provide medical care to the aged poor. Medicare provides health benefits to virtually all people over age 65 as well as to those who are disabled. It was modeled on the Blue Cross and Blue Shield plans of the 1960s. So, it has hospital coverage, “Part A,” and physician coverage, “Part B.” Beneficiaries are allowed to go to any participating provider who will be paid by Medicare according to a fee schedule. “Part C,” a set of managed care options, was introduced in the 1970s and expanded since. Part C plans are privately offered and are a substitute for traditional Medicare. Beneficiaries choosing a Part C plan may have to pay an additional premium, but they typically get a broader array of services. “Part D,” prescription drug coverage, was added in 2006. Here beneficiaries may only choose a private plan and pay a premium for the coverage. Part A is financed by payroll taxes on working persons. Parts B and D are heavily subsidized. Seventy-five percent of Part B and Part D costs are paid from general federal tax revenues; only twenty-five percent is by beneficiaries as premiums. All but 10 % of Medicare beneficiaries have some form of supplemental coverage. These include employer-sponsored retiree health benefits, individually purchased “Medigap” supplemental coverage, public Medicaid coverage, or the more extensive coverage available through Medicare Part C (i.e., Medicare Advantage) coverage ([KFF 2010a, b](#)).

Medicaid, also enacted in 1965, is a federal–state matching program for selected low-income populations. The state share of the costs is determined by the per capita income in a state relative to the national average. Poorer states have more of their Medicaid costs covered from federal sources. Medicaid has been expanded several times, and the states have considerable flexibility in establishing eligibility and the generosity of benefits. The federal legislation specifies categorical benefits and the state has discretion to cover other optional services and populations. This makes state Medicaid programs very heterogeneous. To oversimplify, there are four groups of people eligible for coverage. Children under age 19 are covered in households with income at least below 100 % of the federal poverty line. Expansions through the CHIP have raised this to at least 200 % and sometimes as high as 400 % in some states. Children make of the largest share of recipients (50 %); however, they are the least costly to cover. The disabled make up only 14 % of recipients but 42 % of expenditures

Table 33.1 Number and percentage of US population by source of insurance, 2010

| | Millions | Percent |
|----------------------------|----------|---------|
| Persons under age 65: | | |
| Employer sponsored | 156.1 | 48.3 |
| Non-group (individual) | 18.9 | 5.8 |
| Medicare | 7.9 | 2.4 |
| Medicaid | 45.0 | 13.9 |
| Military | 7.9 | 2.4 |
| Uninsured | 49.1 | 15.2 |
| Persons aged 65 and above: | | |
| Medicare | 38.5 | 11.9 |
| Total | 323.4 | 99.9 |

Notes: Computed from data in [Fronstin \(2011\)](#) and [KFF \(2010a, b\)](#). All values are for those under age 65 unless otherwise indicated. Virtually all of those aged 65 and older with Medicare coverage also have additional private or public coverage which is not reflected in this table

([KFF 2008](#)). The low-income elderly are the third group covered. Medicare does not provide much coverage for long-term care services; Medicaid covers this. Approximately 45% of nursing home expenditures in the USA are paid by the Medicaid program ([KFF 2008](#)). The final group is poor adults. This coverage is largely restricted to pregnant women with income at least below 133% of the poverty line. It is this group, poor adults, that will benefit from the Medicaid expansion that is included in the PPACA health-care reform legislation (see below).

33.2.3 Extent and Sources of Insurance Coverage

Residents of the USA receive health insurance coverage from a variety of private and public sources. These are summarized in [Table 33.1](#). Some 156 million residents have coverage through their employer. About half are active workers, and the other half are dependents. Among those employed in large firms (5,000 or more employees), over 70% have a choice of health plans. In contrast, only 10% have a choice of plans in firms with less than 200 employees. Most of those with employer-sponsored coverage are enrolled in a PPO (59%) and 19% in an HMO ([Claxton et al. 2010](#)). While only 1% is in a conventional plan, these are most likely to be employed by a small firm.

Less than 6% of residents purchase coverage in the non-group market. Middle-aged adults, aged 55–64, have the greatest probability of having this coverage. The non-group market is expected to grow dramatically with the PPACA. The insurance mandate in PPACA requires virtually everyone to have health insurance. It is expected that those citizens and legal residents who have incomes above 100% of the federal poverty line will purchase coverage in the individual market. [Buettgens and colleagues \(2011\)](#) estimate that the number of people with non-group coverage will increase by nearly 43% to approximately 23.8 million.

There are nearly 50 million uninsured people in the USA. Eighty percent of these are between the ages of 18 and 34. Over one-third are Hispanic and 20% are African-American ([Fronstin 2005](#)). The early estimates of health-care reform suggested that by 2016 when the legislation is largely implemented, this number will be reduced to approximately 21 million ([CBO 2010](#)). Approximately half of these remaining uninsured are thought to be undocumented aliens who are ineligible for coverage. The rest are people who do not acquire coverage in spite of the insurance mandate, penalties for non-purchase, and subsidies for those with incomes up to 400% of the poverty line. However, these early estimates now almost certainly overstate the number of people gaining health insurance due to the 2012 US Supreme Court ruling on the PPACA. See below.

33.2.4 Patient Protection and Affordable Care Act

The PPACA was enacted in March 2010; most of its provisions go into effect in 2014. This section briefly summarizes the key insurance provisions, the impact of the 2012 Supreme Court decision, and it highlights some of the early research. There are five essential elements of the Act: the individual mandate, the Medicaid expansion, the role of employers, the creation of health insurance exchanges, and the funding of these provisions. The Kaiser Family Foundation website provides a useful legislative summary, an update of regulatory and judicial actions, and a timeline for implementation at <http://www.kff.org/healthreform/8061.cfm>.

33.2.4.1 Individual Mandate

The individual mandate requires virtually all US citizens and legal residents to obtain health insurance. This provision obviously seeks to establish near universal insurance coverage. However, it has important features necessary to the functioning of the insurance market. The legislation eliminates the use of preexisting conditions as an underwriting feature. The illegality of a health status criterion for establishing premiums or excluding persons from coverage provides a strong incentive for individuals to forego coverage until such time as they seek health services. The mandate provides a legal basis to thwart this potentially dramatic adverse selection. The mandate is enforced by a penalty on those who fail to obtain coverage. When fully implemented in 2016 the penalty is \$695 per year or 2.5 % of income, whichever is higher. Thus, someone earning \$50,000 in taxable income would be subject to a penalty of \$1,250. The penalty is adjusted for inflation going forward. Many have argued that the penalty is insufficient to assure compliance. It is also the case that the regulations implementing the law will establish limited open enrollment periods that will also limit adverse selection.

The PPACA provides public Medicaid coverage for those with incomes below 138 % of the federal poverty line (see below). Subsidies will be provided for many above this threshold. The subsidies are reduced as income rises and are pegged to a benchmark health plan in each area. A single person household with an income above 138 % of the poverty line (annual income of \$15,028 in 2011) will have to pay no more than 2 % of their income on health insurance. Those with incomes between 300 and 400 % of the poverty line will pay no more than 9.5 % of their income for coverage. Those eligible for the subsidy will also face smaller co-payments than others, the levels again depending upon their income. [Buettgens et al. \(2011\)](#) estimate that 7.1 million additional people would be enrolled in non-group plans in 2011 if the legislation were fully implemented. At the time of implementation, the [CBO \(2010\)](#) estimated that the premium subsidies and lower co-payments would cost \$464 billion over the 2014–2019 period.

33.2.4.2 Medicaid Expansion

The PPACA provides for a substantial expansion of the Medicaid program. In essence, it expands eligibility for coverage to those adults between the ages of 19 and 64 who have household incomes below 138 % of the poverty level. Aside from the disabled and pregnant women, this is a group that generally has not had access to public coverage. At the time of enactment the Congressional Budget Office ([CBO 2010](#)) estimated that when fully implemented the expansion would cover an additional 16 million people, an expansion of the program by over 45 %. CBO estimated that the federal cost of the expansion would be \$434 billion over the initial 6 years of operation. The full cost is higher because while the federal treasury pays for all of the costs of the expansion in 2014, it only pays 90 % by 2019 with the states required to pay the remaining portion.

In June 2012 the US Supreme Court upheld the constitutionality of the law, finding justification of the individual mandate in the taxing powers of the Congress. As we noted above, the PPACA expanded eligibility for Medicaid. It did this by providing a substantial inducement to the individual states to expand their Medicaid programs. If a state failed to do so it would lose the federal matching share for its entire Medicaid program, both the new expansion and the existing program. The Court ruled that the Congress over stepped its authority; only the matching funds for the new expansion could be withheld. This had the effect of making the Medicaid expansion a state option. It is unclear how many states will ultimately decide not to expand their programs, but to the extent any do, the estimates of expanded coverage are overstated.

33.2.4.3 Employer Coverage Under the PPACA

Employer-sponsored coverage is also affected by the PPACA. Large employers, those with more than 50 employees, must provide coverage or pay a fine of \$2,000 per employee. This provision has been deferred until 2015. There has been some concern that employers will drop coverage entirely. However, given that insurance coverage is part of worker compensation, a reduction in benefits would require a compensating wage differential plus the fine; it is unlikely that this will happen to a significant degree. A bigger concern in the large group market is “grandfathering.” Large group plans are exempt from the provisions of the PPACA if their coverage doesn’t change “too much” from the coverage they offered at the time the PPACA was enacted with respect to out-of-pocket premiums, co-pays and deductibles, or other significant features the plan offerings. As a result, employer-sponsored plans are likely to become static in their design. A second important element of the PPACA affecting large employers is the “Cadillac Plan Tax.” Plans valued at \$10,200 for single coverage or \$27,500 for family in 2018 will be subject to a 40% tax on the amounts above these thresholds. While these thresholds are indexed for inflation beginning in 2020, [Herring and Lentz \(2011\)](#) argue that because health-care costs will rise faster than general inflation, the Cadillac Tax will initially cover approximately 16% of health plans in 2018 but approximately 75% of plans by 2029.

Those employers with fewer than 50 workers are not subject to the penalty for not offering health insurance. They are, however, eligible for short-term subsidies intended to encourage participation. The ongoing subsidy program begins in 2014; it provides small employers with a 50% tax credit for purchasing coverage through an exchange. However, individual small employers may only receive the credit for 2 years and they would lose the credit if the firm employs more than 50 full-time workers. Micro simulation estimates suggest that the employer provisions will have only a small impact on the decision to offer coverage ([Garrett and Buettgens 2011](#); [Eibner et al. 2010](#)). However, McKinsey, a human resources consulting firm, has released a survey which suggests that as many as one-third of employers will drop coverage and send their employees to an exchange ([Singhal et al. 2011](#)). The differences in the projections reflect estimates based on past but not totally similar experience in the case of the micro simulations and expectations about future events in the case of the survey.

33.2.4.4 Insurance Exchanges

The PPACA calls for the establishment of individual and small employer [Small Business Health Options Program (SHOP)] exchanges by 2014. An exchange is a state agency, quasi-governmental organization, or a nonprofit firm authorized by individual states to provide a marketplace for health insurance plans. The exchanges must certify health plans if they are to offer coverage in a state exchange. Among other things, the certification requires that the plans offered must provide “essential health benefits.” At this writing the states are to be allowed to define essential benefits based upon popular plans offered in their state. Each plan offered is to cover the essential benefits at “platinum,” “gold,” “silver,” or “bronze” levels. The levels refer to the share of expected claims

costs that the subscriber must pay out of pocket. A platinum plan only requires the subscriber to pay 10 % of expected claims; the bronze requires out-of-pocket payments of 40 %. Plans can meet these requirements in a variety of ways through deductibles, co-pays, or coinsurance provisions. However, there are out-of-pocket maximums that will also apply. These maximums have been deferred until 2015.

Insurers may set different premiums based upon age (within the highest premium being no more than three times the lowest), geographic location, family composition, and tobacco use (with tobacco users paying no more than 50 % more than nonusers). Even though the plans are not allowed to medically underwrite their offerings, it is still possible and perhaps likely that there will be substantial differences in the claims experience of different plans. The exchanges are responsible for implementing a risk adjustment mechanism whereby plans with more favorable claims experience will compensate that plans have unfavorable experience.

In addition, the plans must meet medical loss ratio minimums. For plans covering individuals, medical expenses must be at least 80 % of premiums; for small groups the claims expenses must be at least 85 % of premiums. [Abraham and Karaca-Mandic \(2011\)](#) estimated that, as of 2009, some 29 % of their insurer-state observations in the individual market would fail to meet the 80 % medical loss ratio.

The exchanges also will determine an individual's eligibility for Medicaid and subsidized premiums and a small group's eligibility for a tax credit. Thus, the exchanges will verify income and other eligibility data. Verification has also been deferred until 2015. They are also to provide outreach services and Internet, phone, and walk-in options for people to enroll and to change plans. The [CBO \(2010\)](#) estimated that by the end of the decade there would be some 24 million people enrolled in the exchanges. To put this in some context, in 2009, there were some 16–17 million residents in non-group products ([Fronstin 2010](#)).

33.2.4.5 Estimated Costs and Overall Evaluation

At the time of enactment, the [CBO \(2010\)](#) estimated the 10-year federal spending and revenues resulting from the PPACA. The exchanges were expected to cost approximately \$464 billion, largely as a result of the premium subsidies offered to individuals. The Medicaid expansion was nearly as costly, \$434 billion. The credit for small employers was expected to be modest, estimated to cost some \$40 billion. The legislation pays for these by reducing Medicare spending by some \$455 billion. This is accomplished largely by reducing payments of Medicare managed care plans and reducing physician fees. It also raises specific taxes and fees: Medicare taxes on higher-income individuals are raised and fees are imposed on drug and durable medical equipment manufactures and on insurers. The penalties for not purchasing coverage are estimated to only generate \$69 billion either because most will buy coverage or because the penalties are modest.

As yet, there has been little academic research examining the likely effects of the PPACA. [Newhouse \(2010\)](#) provides the most accessible review of the incentives inherent in the plan. [Holtz-Eakin \(2011\)](#) and [Gruber \(2011\)](#) provide alternative summaries of the effects of the Massachusetts health-care reform model that served as a model for many of the features in the Act.

33.3 Adverse Selection

Adverse selection exists when individuals or groups know more about their likely use of health services than does the insurer and the purchasers use this knowledge to their advantage. There has been considerable research seeking to determine the existence and extent of adverse selection among health insurance plans. [Cutler and Zeckhauser \(2000\)](#) provide a review of the adverse selection evidence relating to less healthy people disproportionately choosing higher option health plans.

Most of the adverse selection research, however, has focused on differences between fee-for-service (sometimes called indemnity) plans and managed care plans. The focus has typically been on HMOs. Miller and Luft (1994) reviewed much of this early literature and concluded that HMOs attract a healthier draw of the population. This favorable selection partially explains the lower premiums and lower health services utilization often observed in HMOs. More recently, Altman et al. (2003) have taken this analysis further by seeking to disentangle cost differences between managed care and fee-for-service insurers that were attributable to favorable selection vs. lower health services prices negotiated by HMOs. They used claims data from state and local government employees in Massachusetts in 1994 and 1995 and focused on eight health conditions ranging from acute myocardial infarction to diabetes to live birth. Overall, they concluded that of the \$107 difference in per person claims costs (in 1995 dollars) 51 % of the lower HMO claims costs were attributable to the healthier populations that enrolled in the HMOs, 5 % were due to a slightly less aggressive treatment intensity provided in the HMOs, and the remaining 45 % were due to lower prices negotiated by the managed care plans.

A second issue has revolved around the extent to which adverse selection is enduring in health insurance markets. If utilization quickly reverts to the mean, an insurer strategy of seeking low utilizers or avoiding high utilizers has limited value. Garber et al. (1999), Monheit (2003), Maciejewski et al. (2004), and Rettenmaier and Wang (2006) all examine Medicare claims data, one of the few sources with longitudinal insurance data. They conclude that while there is a very large transitional component, those with higher claims experience in a base year continue to have higher claims experience in as many as eight subsequent years. This finding holds even after accounting for the large number of deaths in the Medicare population.

The newest work on adverse selection has focused on the decision to take-up employer-sponsored coverage, multidimensional aspects of selection, and the effects of underwriting restrictions. Bundorf and colleagues (2010) examined the relationship between health status, income, and the take-up of health insurance offered through an employer. They used the Medical Expenditure Panel Survey (MEPS) from the 1996–2002 period and found that those with lower risk of poor health were less likely to have had coverage whether through a large, medium, or small employer group. This result was particularly large for those with low and medium incomes; those with the lowest risks of poor health in these income groups were 18 and 9 percentage points less likely, respectively, to be covered by insurance. They speculate that this may be because these individuals face high out-of-pocket premiums and/or low wages that limited the affordability of coverage.

33.3.1 *Multidimensional Aspects of Adverse Selection*

Most research on selection in insurance focuses on a single combined dimension: expected claims experience. More recent work has sought to disaggregate the reasons for the expected claims. Multidimensional aspects of selection in health insurance have been explored in long-term care insurance and private supplemental coverage for Medicare beneficiaries. Finkelstein and McGarry (2006) examined the demand for long-term care insurance. This form of private insurance provides coverage for such things as nursing homes and assisted living facilities. They used data from older respondents to the Health and Retirement Study (HRS). The data set provided information on ex ante subjective likelihoods of being in a nursing home in the ensuing 5 years as well as subsequent nursing home use. Thus, they are able to directly test the hypothesis of asymmetric information. In addition, however, the survey provided information on the respondent's use of seat belts and preventive health activities, with were used as proxies for risk aversion. Finkelstein and McGarry found that those with higher ex ante subjective likelihoods of using a nursing home were more likely to buy coverage, implying adverse selection. But this effect was offset by favorable selection into coverage by those who were arguably more risk averse.

Fang and colleagues (2008) used the HRS jointly with Medicare claims data and responses from the Medicare Current Beneficiaries Survey. They explored the extent of adverse selection and its sources in the purchase of Medicare private supplemental coverage called “Medigap.” Instead of a positive correlation between the purchase of a Medigap plan and claims experience, they found a negative correlation. This is inconsistent with classic asymmetric information. They then examined the determinants of individual’s private information that were consistent with both buying Medigap insurance and having lower claims experience risk. Unlike Finkelstein and McGarry, they do not find preferences for risk to explain the patterns of behavior. Instead, they concluded that higher cognitive ability was the key pathway that explained the purchase of coverage by lower utilizers.

33.3.2 *Adverse Selection and Underwriting Regulation*

LoSasso and Lurie (2009) provide empirical evidence on the effects of regulatory underwriting restrictions on the purchase of non-group health insurance. Most states in the USA allow insurers to employ medical underwriting in the non-group market. During the period 1993–1996 eight states prohibited medical underwriting. One mandated pure community rating, and the others limited underwriting to some combination of age, gender, geographic location, and family composition. The standard asymmetric information proposition would suggest that those with greater health risks would differentially buy coverage and those with lower risks would drop coverage. LoSasso and Lurie used data from the 1990 through 2000 Survey of Income and Program Participation to estimate the effect of the underwriting prohibition on the purchase of non-group coverage by “healthy” and “unhealthy” individuals. They found that the probability of having non-group coverage declined by 2.0% for healthy individuals and increased by 4.5% among unhealthy people. There was a 3.9% increase in the probability of healthy people being uninsured and a 7.4% reduction in the probability of being uninsured by the unhealthy. This is the best empirical evidence to date on the effects of combining dissimilar health risks in a common risk pool.

33.3.3 *Guaranteed Renewal Policies*

A related adverse selection problem is that of guaranteed renewable policies and the apparent inability to purchase a long-term health insurance contract. Typically people are able to purchase single-year insurance policies, but not multi-year ones. If one is in good health in period one, one pays a low premium. If one contracts a chronic condition, one’s premium is higher in period two. Guaranteed renewable policies provide one with the right to buy a policy in period two at the same price as period one. Obviously, the guaranteed renewable policy has a higher premium than a simple one-period policy to reflect the expected higher future claims experience. A risk adverse individual would be willing to purchase a guaranteed renewable policy. However, as Cochrane (1995) points out, such a front-loaded policy is not sustainable in a competitive insurance market. Those who learn they are healthier, on average, will begin to buy a series of single period policies leaving only those with health problems in the guaranteed renewable product. His solution to this problem is a series of severance payments conditioned on the health state of the insurance purchaser at the end of each period. If one is sicker, the insurer gives one the present value of the associated lifetime stream of health-care costs. If one is healthier than average, one gets a payment associated with this lower expected claims experience. In either case the purchaser is then free to buy coverage from any insurer at rates that reflect each buyer’s expected claims experience.

A key argument against this solution is that young individuals may be capital constrained in buying what may be very expensive front-loaded premiums. Herring and Pauly (2006) argued that the

Cochrane model rests on untested assumptions about actual claims costs over time. They use MEPS data to construct an age profile of what ideal guaranteed renewal premiums would look like and then compare these to actual premiums for age-specific individual coverage. They find that the pattern of guaranteed renewal premiums rises with age. This is because low-risk expected claims increase with age, the likelihood of becoming high-risk increases with age, and high-risk people tend to recover or die. They also find that the guaranteed renewal premium pattern tracks well with the actual age-specific premiums. The actual premium increases do not fully reflect increases in health spending but rather are consistent with some front-loading. As the authors say "...it does seem that existing premium schedules come reasonably close to the optimal incentive-compatible patterns of premiums we estimate" (page 416).

33.3.4 Future Research and the PPACA

With the implementation of the PPACA, research is likely to focus on the extent of and the mechanisms by which adverse selection occurs in the exchange plans and between the exchange plans and those offered outside the exchanges. An important question will be the ability of exchanges to risk adjust the claims consequences among the plans as required by the law.

33.4 Moral Hazard

33.4.1 Moral Hazard and Coinsurance

The enduring empirical evidence on moral hazard in health care is the RAND Health Insurance Experiment (Newhouse et al. 1993). This study randomly assigned some 8,500 people to one of several health insurance plans with differing degrees of cost sharing and followed them for 4 years, from 1974 to 1977. Overall, the study indicated that per capita spending was over 23 % higher for those with free care compared to those paying a 25 % coinsurance rate and over 54 % higher compared to those paying virtually the full price of services. Much of this was due to greater physician visits, which were 36 % higher. The estimated health services price elasticity was -0.2. Mental health services were much more price sensitive than medical services. The study continues to be regarded as the gold standard for examining the effects of price on the use of health services for three reasons. First, its methodology is extraordinarily strong in that it randomly assigned people to alternative insurance regimes, thus limiting the influence of adverse selection. Second, it examined virtually the entire spectrum of health services in a consistent framework. Finally, subsequent smaller-scale studies have tended to obtain results consistent with those obtained from the experiment. The results of the experiment continue to be the basis of any number of recent analyses; see, for example, CBO (2006).

This is not to say there have not been challenges to the RAND methodology and findings. There continues to be challenges to the study concerning the limited time period for follow-up of health effects and the advent of new health-care technologies that may undermine the utility of the study's findings today.

33.4.2 Moral Hazard: Forward-Looking Behavior and Supply Response

A different challenge recently has been mounted by Kowalski (2009), albeit still in manuscript form. She argues that the analysis in the RAND experiment employs myopic prices and that the true effects

are larger by an order of magnitude if one uses forward-looking prices. The key issue is when one faces a stop loss feature in an insurance plan. When one's spending exceeds the stop loss, the marginal price of care is zero. A myopic purchaser only considers the price at the point of service. The forward-looking purchaser incorporates their expectation of exceeding the stop loss. If they expect to do so, then they will make purchasing decisions, throughout the insurance contract period as though they have exceeded the stop loss. Taking forward-looking behavior into account, she finds an overall price elasticity of -2.3 over the middle range of expenditures. In another working paper [Aron-Dine and colleagues \(2012\)](#) investigated the myopia issue with data from Alcoa, Inc. and two anonymous firms over the 2004–2007 period. Their key test was to examine the differences in the use of health services between yearlong employees and new hires, who, because of the annual deductibles, face different year end out-of-pocket prices for health services. They found future price elasticities of -0.4 to -0.6 . These are substantially smaller (in absolute value) elasticity estimates than those implied by fully forward-looking behavior of Kowalski but much larger than those found in the RAND health insurance experiment.

A bigger picture examination of the effects of moral hazard with major implications for large-scale changes in health insurance coverage was presented by [Finkelstein \(2007\)](#). She examined the introduction of the Medicare program in 1965 on hospital spending. She argues that, on average, approximately one-half of the elderly population had Blue Cross-type hospital insurance in the early 1960s with another 30% having much more modest coverage. After Medicare's enactment in 1965 virtually all seniors had very good hospital coverage. There was substantial pre-Medicare geographic variation in coverage that she exploits. Essentially Finkelstein estimates a series of hospital-specific expenditure and utilization equations that include county and year fixed effects along with state-year and Medicaid (which was enacted at the same time) introduction measures. Medicare's impact was measured as the 1963 proportion of the elderly in the region without Blue Cross coverage interacted with the year fixed effects. She found that the introduction of Medicare increased hospital expenditures by 37% between 1965 and 1970. In contrast, extrapolating the results of the RAND Health Insurance Experiment to the Medicare population would suggest an increase in spending of only 5.6%. She argues that much of this difference is likely the result of changes in market-wide capacity. With the introduction of broad-based Medicare coverage, hospitals incurred the fixed costs to expand their capacity dramatically, particularly in areas where there was relatively low ex ante coverage. The implication is that RAND Health Insurance-based estimates of the cost implications of broad-based insurance expansion may be substantially understated.

33.4.2.1 Moral Hazard Research and the PPACA

Future research on moral hazard issues stemming from the PPACA will likely address two broad issues. The first, obviously, is whether utilization expansions are more in keeping with the RAND findings or the more systemic effects suggested by Finkelstein's work. A related question is the extent to which the existing clinical capacity can handle the expanded demand expected to arise from the expanded coverage and the dynamics by which the provider markets adjust. The second, more micro set of issues, deals with how the sometimes large co-pays and deductibles in the bronze through platinum benefit levels will affect health services utilization.

33.4.3 Moral Hazard and Prescription Drugs

Much of the recent empirical work on the extent of moral hazard in health care has focused on prescription drug coverage. This work has stemmed from the innovative insurance plan design for

prescription drugs, e.g., the use of co-pays, tiered coverage by drug class, formularies, and benefit caps. In addition, prescription drugs have become a major source of health-care spending and a significant source of improved health outcomes. [Goldman et al. \(2007\)](#) provide a remarkably detailed review of some 132 studies dealing with prescription drug cost sharing. They drew several conclusions. First, the own price elasticity of demand for prescription drugs ranged between -0.2 and -0.6 . The use of coinsurance rather than co-pays resulted in elasticities closer to the -0.2 , but these also tended to be limited by the presence of maximum out-of-pocket limits. Second, elasticities tended to be larger (in absolute value) when there are more substitutes in the therapeutic class. For example, the use of antidiabetic drugs, with few substitutes, was reduced much less than anti-inflammatory drugs that have more substitutes including some nonprescription options. Third, the introduction of benefit caps that limit the number of prescriptions per time period or the dollar value of the covered medications had effects analogous to other cost-sharing measures. Fourth, the evidence of the effects of cost-sharing provisions on health outcomes was mixed. Direct measures of health are limited; most studies have tended to focus on other areas of medical spending such as emergency department use or hospitalizations that may result from the health implications of prescription drug use. The studies focusing on chronic conditions found unambiguous increases in the use of nondrug health services suggesting meaningful deleterious effects on health status. However, studies focusing on broader populations did not find increases in the use of other services. Finally, their review found that there is remarkably little reliable evidence to suggest that low-income groups are more price sensitive than other groups.

The findings that cost sharing may harm the health status of those with chronic conditions have led to initiatives known as “value-based insurance design.” These efforts impose smaller or even zero co-payment levels on medications shown to confer large health benefits relative to their costs. As of yet, however, few studies have adequately evaluated the ability of these studies to improve health and/or reduce costs ([Choudhry et al. 2010](#)).

The introduction of the Medicare Part D prescription drug coverage, largely for those over age 65, has also generated a number of studies examining the effects of the expanded government coverage on take-up, utilization of drugs, and spending. [Yin and colleagues \(2008\)](#), for example, found that monthly drug utilization increased by 5.9 % after enrollment in Part D. [Levy and Weir \(2009\)](#) found that take-up was high among those Medicare beneficiaries without drug coverage in 2004. By 2006, 50–60 % had acquired coverage.

More innovative is work by [Duggan and Morton \(2010\)](#) which examined the effects of Medicare Part D on pharmaceutical prices and utilization. They characterize conventional wisdom as hypothesizing that the introduction of an insurance regime would lead to two results: (1) consumers would have smaller price elasticities for prescription drugs and (2) drug prices would be higher because drug manufacturers with market power conferred by patent would exploit the reduced consumer price sensitivity. They conceptualize the Part D program as offering consumers the opportunity to obtain both insurance coverage and a purchasing agent (the private Part D insurance plan) that is able to channel utilization within therapeutic drug classes to one manufacturer or another on the basis of negotiated price. Empirically they conclude that in 2006 the plans negotiated drug prices that were 20 % lower than they would have been. This result is consistent with the evidence on selective contracting by managed care plans that is reviewed below.

33.4.4 Utilization Management to Control Moral Hazard

A second generic approach to dealing with moral hazard in health care is to enlist expert review to approve or disapprove payment for health services based on clinical necessity. This is called utilization management. Much of the early evaluation work focused on the effects of hospital preadmission certification and concurrent review used in tandem. The former requires prior insurer approval before

a non-emergent hospital admission would be approved for payment; the latter requires ongoing approval for additional days of stay. Analysis using data from the 1980s found that these programs reduced hospital admissions or days by about 4 %. Inpatient expenses were reduced by as much as 8 % and inpatient expenses per member by 2.6 %. See [Morrisey \(2008\)](#) for a review. More recent work by [Lessler and Wickizer \(2000\)](#) found that all of the inpatient savings in their study of cardiovascular utilization management came from shorter lengths of stay and none from denials of admission requests. It is unclear whether the lack of effects for admissions stemmed from a lack of program effect, a decade of learning by clinicians and hospitals, or the special circumstances of cardiovascular care. They also found no increase in readmissions for medical diagnoses but an increase in surgical readmissions. However, the increase was only for those surgical patients who had been denied two or more days of additional care.

There have been even fewer rigorous studies of ambulatory utilization management. [Kapur and colleagues \(2003\)](#) examined the distribution of coverage requests by two large California medical groups. They found that 8–10 % of requests were denied. The denials typically related to emergency care, diagnostic testing, and durable medical equipment. However, fewer than 30 % of the denials were for medical necessity; most dealt with the insurer not being contractually liable for the service or the proposed provider was not a member of the insurer's panel of providers. Thus, much of what passed for utilization management appears to be standard claims adjudication. Prior authorization and formulary restrictions for prescription drugs have received much more scrutiny. [Goldman et al. \(2007\)](#) reviewed these studies and concluded that while there is some evidence that they reduced use within a restricted class of drugs, the programs tended to be uncorrelated with overall medical care utilization or spending.

“Gatekeeping” refers to a requirement that a patient may only get covered care from a specialist, if that care results from a referral by the patient's primary care provider. [Ferris et al. \(2001\)](#) have found that the elimination of a long-standing gatekeeping requirement had virtually no effect on the number of visits to either primary or specialty physicians. Other studies corroborate this finding; see [Morrisey \(2008\)](#).

Disease management and intensive case management are the newest forms of utilization management. They focus attention on patients with particular chronic or high-cost conditions. There is little evidence that such programs have been effective in reducing utilization ([CBO 2004](#)). More recently, [Peikes et al. \(2009\)](#) reviewed the effects of 15 randomized trials of care coordination for Medicare beneficiaries. They found that 13 of the 15 programs had no statistically significant effect on hospitalizations and none of the programs generated net savings.

Overall, there is substantial evidence that patient cost sharing is an effective method of reducing moral hazard in ambulatory care services. The evidence for its effectiveness for inpatient care is much more modest. In contrast, the empirical evidence on utilization management suggests that it is relatively more effective in reducing moral hazard in the inpatient setting but much less effective in ambulatory care.

33.5 Managed Care and Selective Contracting

Managed care refers to health insurance provided through HMOs, PPOs, and their derivative organizational forms. Traditionally a managed care plan offered care through a limited set or network of providers; consumers had to receive care from a network provider or forgo coverage from the insurer. In the 1980s organizational forms expanded with PPOs that allowed consumers to use nonnetwork providers if they paid higher co-pays or deductibles. The key feature of managed care, however, is selective contracting. In exchange for some assurance of patient volume from the managed care plan, providers agree to accept lower prices.

Traditionally health insurers established billed charges and allowable-cost payment mechanisms with physicians and hospitals that essentially meant that insurers paid whatever providers charged. As a consequence, competition took non-price forms. [Robinson and Luft \(1987\)](#) demonstrated that controlling for other factors, more hospitals in a geographically defined market area led to higher, not lower, costs as providers competed along quality, service, and amenity margins. Selective contracting potentially changed the underlying incentives by introducing price into the decision matrix.

33.5.1 Effects of Selective Contracting

The best of the work on the effects of selective contracting was by [Melnick et al. \(1992\)](#). They examined the relative prices negotiated for medical and surgical admissions by a statewide PPO owned by Blue Shield of California with 190 general hospitals. Controlling for a wealth of relevant factors, they were able to empirically demonstrate that the Blue Shield PPO was able to negotiate lower hospital prices when:

- There were more hospitals in the market area.
- The PPO had a larger share of the hospital's book of business.
- The hospital had a smaller share of the PPO's book of business.
- Hospital occupancy rates were lower at the negotiating hospital and/or at neighboring hospitals.

Thus, the presence of selective contracting led to pricing experience consistent with conventional predictions about the effects of competition in markets. There were a number of studies conducted throughout the 1980s and 1990s examining the effects of managed care on hospital prices, costs, and market share. While few were as elegant as the Melnick et al. analysis, virtually all found that managed care reduced at least the rate of increase in health-care spending, sometimes substantially. See [Morrisey \(2001\)](#) for a review. This result is attested to by private health insurance premium data. During the period 1989 through 1996 the percentage increase in employer-sponsored health insurance premiums declined from 18 to 0.5 % ([Morrisey 2008](#)) arguably because selective contracting led to lower provider prices. More recent research continues to find price-reducing effects of managed care, albeit with smaller price effects. [Wu \(2009\)](#), for example, uses 1994 through 2000 Massachusetts data and found that larger managed care plans obtained greater volume discounts from hospitals and that the effect was larger if the plan was able to channel patients to particular providers.

33.5.2 Managed Care Backlash and Provider Consolidation

In the late 1990s and well into the 2000s health insurance premiums began to escalate. This has been attributed to greater consolidation among providers and to a managed care "backlash." Both phenomena are consistent with predictions of reduced competition leading to higher prices. If hospitals or physicians in a market consolidate, then there are fewer competitors, potentially less idle capacity, and the (combined) providers will have a bigger share of the managed care plan's book of business. As a result, providers would be able to raise prices. The backlash is said to have arisen from consumers dissatisfied with narrow networks and a fear that they would be denied coverage for quality services. Faced with this perception, managed care plans have the incentive to expand their networks. However, this expansion would have the effect of diminishing the patient volume that plans were able to assure any one provider, resulting in higher provider prices.

The evidence supporting either of these scenarios is less than definitive. With respect to provider behavior, the Federal Trade Commission has successfully challenged a number of alleged physician

price-fixing schemes (see [Morrissey 2008](#)) and argued for increased competition in hospital markets ([FTC/DOJ 2004](#)). With respect to hospital consolidation, [Town and colleagues \(2007\)](#) reported that over the period 1990 through 2000 there were 100 or more hospital consolidations in 8 of the 11 years with a merger in 40 % of the market areas they studied. They found no relationship between HMO market share and subsequent hospital consolidation. Evidence of the effects of consolidation on hospital prices comes from studies conducted using late 1980s and early 1990s data. The studies predate the late 1990s rise in premiums and are controversial; see [Morrissey \(2001\)](#) for a review. However, the evidence from that period did not find large price increases as a result of consolidation. Less rigorous work by the [Government Accountability Office \(2005\)](#) did find that 2001 hospital prices paid by the Federal Employees Health Benefits Plans were 18 % higher in the quartile of metropolitan areas with the least hospital competition compared to the quartile with the most. It also found that metropolitan areas with the least HMO capitation had hospital and physician prices that were 10 % higher than in the areas with the most capitation. More recently, [Melnick et al. \(2011\)](#) used metropolitan hospital price data from 2001 and 2004 to examine the effects of hospital and managed care concentration on hospital prices. They found that greater hospital concentration was associated with higher hospital prices; if a hospital market moved from roughly three equal-sized hospitals to two, hospital prices were estimated to increase by about 8.3 %.

The research demonstrating the effects of a managed care backlash is still less definitive. Consumer surveys and media assessments from the late 1990s do support antagonism toward managed care ([Blendon et al. 1998](#); [Brodie et al. 1998](#)). One marker of the backlash could be the relative decline in HMO enrollment in favor of PPOs that typically offer greater access to providers. However, work by [Marquis et al. \(2004/2005\)](#) examined the decline in HMO (the plans with narrower provider networks) enrollments between 1998 and 2001 and found no association between declining enrollment and plausible measures of greater provider choice in insurance options. They “conjecture[ed] that backlash either represented the views and perceptions of physicians and the media while consumers were generally satisfied... or that consumers exercised ‘voice’ and health plans responded very quickly to avoid losing market share” (p.387). Consistent with this view, [Melnick and Ketcham \(2008\)](#) found that California HMO hospital networks were essentially unchanged over the 1999–2003 period, suggesting that HMOs did not expand their provider networks in response to the backlash. However, [Dranove and colleagues \(2008\)](#) examined hospital price/concentration data from California and Florida for selected years between 1990 and 2003. They found that less hospital concentration was associated with lower hospital prices early in the period, but the relationship weakened and may have reversed by 2003. They suggest that this effect is consistent with the presence of the managed care backlash.

33.6 Health Insurance Market Structure, Conduct, and Performance

With the exception of the analysis of the effects of managed care penetration, there has been remarkably little serious research on the extent of concentration in the private health insurance industry and its consequences on premiums. As [Scanlon et al. \(2006\)](#) note, even that literature is limited by its focus on HMOs, largely to the exclusion of PPOs and other forms of managed care. More generally, the private health insurance market in the USA is effectively segmented into three broad components. The first is the individual, non-group, market. This market is characterized by a very few insurers with large market shares in each state, augmented by a large number of other carriers with very small shares ([Chollet et al. 2000](#)). There is a growing Internet-based individual market, but it is unclear how much of the market is served by this mechanism. The small group market is characterized by many carriers in most states. Purchasers are typically small employers with 2 or 3 to perhaps 100–500 employees. The large group market encompasses employers with 500–1,000 to many thousands of employees. The large group is characterized by self-insured plans offered by employers, who bear

some or all of the underwriting risk and who typically buy ASO [administrative services only] services from established insurers or from firms specializing in this function.

The prevailing view is that health insurance markets are largely competitive (FTC/DOJ 2004). The argument is essentially that there is relative ease of entry into the market segments and, therefore, any effort to advance premiums over costs would be short-lived. One of the few studies directly examining the effects of insurer concentration on (employer) premiums is that of Dafny (2010). She examined the effects of insurer concentration on the premiums paid for fully insured plans by large employers over the 1998–2005 period. Her research strategy was to investigate whether firms that undergo favorable profit shocks subsequently face higher health insurance premiums. Her theory is that concentrated insurers and employers engage in bilateral negotiations, that employers are reluctant to switch plans in “good times,” and that insurers take advantage of this. She concluded that insurers were able to raise premiums in good times but only in markets where the insurance market was concentrated. The effect of the profit shock was most acute in markets with six or fewer carriers.

Recently Dafny et al. (2012) used 1998–2006 longitudinal data for the health plans offered by over 800 employers in nearly 140 geographic markets to examine the impact of the merger of two large health insurers, Aetna and Prudential Healthcare, in 1999. They found that the mean increase in the local health insurance market concentration, measured as the sum of the squared market shares of the insurers (i.e., Herfindahl index), resulting from this merger, temporarily were able to increase insurance premiums by approximately 7% on average. Cebul and colleagues (2011) also found evidence of insurer market power in the fully purchased group market. They argued that there are search frictions in the purchase of insurance that lead to excessive marketing, price dispersion, and plan turnover. Empirically they found evidence consistent with “moderate” search frictions that, nonetheless, led to higher prices sufficient to transfer over 13% of consumer surplus from employer groups to insurers and to increase employer group turnover by 64%.

Physicians have argued that insurers exploit monopsony power in driving provider prices below competitive levels. Feldman and Wholey (2001) explored this issue by examining the hospital prices and quantities obtained by HMOs. They found that greater HMO buying power over the 1985–1997 period was associated with lower hospital prices, as would be suggested by either monopsony power or the erosion of hospital monopoly power. However, hospital volume increased, consistent with reducing hospital market power but inconsistent with insurer monopsony power. In contrast, the aforementioned Dafny (2010) analysis concluded that the Aetna–Prudential merger did convey monopsonistic power on insurers vis-à-vis physicians with physician earnings growth declining by 3% and nurses (as substitutes) increasing by 0.6%.

Finally, an ongoing market concern in health insurance markets has been the use of most favored nation clauses (MFNs). An MFN clause in an insurer–provider contract stipulates that the insurer gets the lowest price that the provider agrees to give to any other payer. Lynk (2000) provides a statement of the theory and the only empirical evidence to date. MFN clauses can be viewed as anticompetitive in two ways. First, the clause can be viewed as the action of a dominate insurer trying to keep out rivals. Second, it can be viewed as a mechanism by which a cartel of providers enforces higher prices among themselves. Alternatively, it can be viewed as an efficiency-enhancing mechanism by which an insurer is able to obtain the lowest price acceptable from sellers of complex services in local market characterized by great dispersion in list prices, costs, and quality. Lynk found no evidence consistent with either of the anticompetitive rationales.

Duggan and Morton (2006) examine the related issue of government acquisition rules that affect private market prices. In particular, Medicaid uses the average private sector price to determine the price it will pay for prescription drugs. Since Medicaid has a large national market share, the hypothesis that Duggan and Morton advance is that drug manufacturers will strategically raise private sector prices for compounds for which Medicaid has a large market share. Examining prices for 200 drugs in 1997 and 2002, they conclude that a 10 percentage point increase in Medicaid’s market share was associated with a 7–10% increase in the average private price.

33.6.1 *Private Insurance Markets and PPACA*

It is clear that the nature and consequences of competition are among the least studied of areas in health insurance. An important research question arising from the PPACA legislation is the extent to which the exchanges encourage enhanced competition in the individual and small group markets.

33.7 Employer-Sponsored Health Insurance

33.7.1 *Worker Premium Sensitivity*

Much of the empirical analysis of employer-sponsored health insurance has focused on the extent of premium sensitivity among workers. Employers typically offer one or more health insurance plans and generally require workers to pay an out-of-pocket premium contribution for the coverage the worker selects. Most studies use this out-of-pocket premium as the relevant price of employer-sponsored coverage to the worker. The empirical evidence suggests that when faced with more than one option, workers are remarkable price sensitive. See [Morrissey \(2005\)](#) for a review.

The best of the early work was by [Feldman and colleagues \(1989\)](#) who examined 17 Minneapolis–St. Paul employers in 1984. These employers offered HMOs and a traditional fee-for-service plan to their workers. Focusing on single workers, to avoid complications of options available through an employed spouse, they found that narrow panel HMOs were excellent substitutes for each other but relatively poor substitutes for fee-for-service plans. A \$5 per month increase (in 1984 dollars) in monthly premiums for an HMO with 50% share of single coverage workers and 100% of the HMO share in the firm resulted in an estimated 21% reduction in the HMO's insurance share in the firm. However, if instead, it had only 50% of all the HMOs' share of the firm; it would lose 70% of its share. Workers were more willing to switch to a similar plan type for the same increase in premium. In less rigorous work that yields an underestimate of likely elasticities, [Dowd and Feldman \(1994/1995\)](#) concluded that the out-of-pocket premium elasticity was approximately -1.0 . These studies, however, suffer from not adequately controlling for differences across plan and firm offerings and they were unable to account for the health status of workers.

[Buchmueller and Feldstein \(1996\)](#) examined the effects of employers establishing a level dollar contribution to all the health plans they offer pegged at the least costly plan. In this arrangement, workers who value more generous benefits pay the entire premium differential with higher out-of-pocket premium contributions. Using data from the University of California system in 1994 and 1995 they concluded that a \$10 increase in the monthly employee premium contribution (EPC) was associated with 21% of faculty and staff switching plans. [Cutler and Reber \(1996\)](#) examined out-of-pocket premium sensitivity among Harvard University faculty and staff. They concluded that the rising premium costs for the most generous fee-for-service plan led to a death spiral in which healthier employees switched to less costly options and the fee-for-service plan eventually left the market.

[Royalty \(2000\)](#) have undertaken the most thorough of the investigations of the effects of out-of-pocket premium contributions. They examined changes in the Stanford University benefits offerings. They have the advantage of consistent benefit packages across plans and a survey of employees that allowed them to consider household wealth, the availability of other coverage, and the presence of chronic disease. Stanford's contribution to each of the four plans it offered was pegged as a percentage of the least costly plan. Since the covered services and co-pays were the same across all the plans, higher out-of-pocket premiums reflected only a broader panel of providers. Usefully, Royalty and Solomon computed two alternative premium elasticities: one from the employee's perspective and

one from the insurer's. The employee's is based on the percentage change in the out-of-pocket premium contribution; the insurer's is based on the percentage change in the full premium. From the employee perspective the elasticities ranged from -0.43 to -0.76 . From the insurer perspective the full elasticities ranged from -2.15 to -3.54 across the plans offered. Importantly, they also found that households with one or more chronic conditions were 4 percentage points more likely to choose the plan with the widest choice of providers and 4 percentage points less likely to choose the plan with the least choice. Similarly, older workers were more likely to choose the plan with greater choice; a worker 10 years older was 5 percentage points more likely to choose the plan with the most choice. Higher family income and greater educational attainment were also associated with a greater probability of selecting the plan with the greatest choice of provider. Finally, Royalty and Solomon tested for differences in premium elasticities among groups of workers. They found that those with no chronic conditions had premium elasticities three times that of those with ongoing health problems. This presumably arises because employees with chronic conditions have established relationships with health-care providers that they are only willing to replace for substantially greater premium savings. There were also considerably greater premium elasticities for younger than for older workers; again presumably because of health problems and established provider relationships. This final set of findings is consistent with work by [Stormbom et al. \(2002\)](#) who also found younger, healthier employees to be much more premium sensitive.

33.7.2 *Worker Take-Up Decisions*

A related issue is whether employees decline employer-sponsored coverage because of the out-of-pocket premium contribution. As of 2005 across all firm sizes, some 74 % of firms offered health insurance coverage. Nearly 81 % of those offered coverage were eligible for coverage, typically because they worked full time. However, only 84 % of those eligible for coverage took the coverage offered ([Morrisey 2008](#)). Work from the 1990s suggested that insurance take-up elasticities were on the order of -0.07 ([Chernew et al. 1997](#)). Such low elasticities, nonetheless, could result in large numbers of uninsured workers due to large increases in the magnitude of the increase in out-of-pocket premiums. However, more recent work by [Blumberg et al. \(2001\)](#), [Gruber and Washington \(2005\)](#), and [Royalty and Hagens \(2005\)](#) suggest that the take-up elasticity is closer to -0.007 . Similarly, [Okeke et al. \(2010\)](#) found that an exogenous 10 % increase in the out-of-pocket premium contribution in one large firm resulted in a 1 % increase in the probability of dropping coverage. Married workers were more price sensitive than singles and those in the lowest quarter of the wage distribution were nearly twice as likely to drop coverage. These results suggest that lowering the out-of-pocket premium contribution would not have significant effects on increasing coverage.

33.7.3 *Compensating Differentials*

A distinctive feature of private health insurance in the USA is that it is largely provided voluntarily through an employer. Until the implementation of the PPACA in 2014, no employer is required to offer health insurance to its workers. Labor theory takes the view that employer-sponsored health insurance is an element of the compensation bundle. Workers are paid their marginal revenue product. The compensation may take many forms: wages, vacation time, pensions, etc. Thus, to add health insurance to competitive compensation means that something else must be removed from the bundle; otherwise, the worker is paid more than her productivity warrants and profits will not be maximized.

Health insurance will be offered in this scenario only if two conditions are met. First, the worker must value health insurance as a form of compensation. If she does not value the coverage, the addition of health insurance to the compensation bundle with the commensurate reduction in other compensation leaves her worse off. Second, it must be the case that health insurance is less costly to obtain through the employer than purchased independently. Three reasons are typically advanced for why health insurance is less costly purchased through an employer. The first is favorable selection. The ability to hold a job is a reasonably clear and low-cost signal that the individual is healthier than a random draw of the population, implying that claims experience will be lower. The second reason is the tax treatment afforded employer-sponsored health insurance in the USA. Compensation provided in the form of health insurance is not subject to federal or state income or payroll taxes. This tax exclusion can easily reduce the effective price of health insurance by 40 % or more. (See the following section.) Finally, there are administrative cost savings associated with purchasing coverage through an employer. These include cost savings from tasks performed by the employer's human resources division, reduced marketing costs arising from selling coverage to dozens to thousands of employees at one time rather than selling to each person individually, and cost savings arising from the economies of search that tend to be greater for larger firms than for individuals.

Compensating differentials have a remarkably broad set of managerial and policy implications. Managerially, a decision to increase co-pays in a company insurance plan makes workers worse off; in a competitive labor market other forms of compensation must adjust or the best workers will seek employment elsewhere. Rising health insurance premiums imply that money wages will increase more slowly than they otherwise would. From a policy perspective, for example, compensating differentials imply that a requirement that an employer provide insurance coverage for his workers will result in lower wages and/or reductions in other benefits. An exception to this blanket conclusion arises in the presence of binding minimum wage laws. In this context wages cannot adjust downward in the face of required insurance offerings. Instead, one would expect to see a reduction in employment for those at or near the minimum wage.

The empirical evidence on the extent of compensating differentials has been remarkably difficult to obtain. The reason for this is reasonably straightforward. In principle one would like to regress wages on the generosity of any health insurance coverage provided, the nature of other benefits, marginal tax rates, and relevant employer and worker characteristics. A key component of this model is a measure of worker productivity. More productive workers will get both higher wages and more health insurance, *ceteris paribus*. Productivity is typically measured (badly) as years of schooling and experience with the result that a positive correlation exists between wages and health insurance (and other benefits) such that it is difficult to measure the extent of any compensating differentials.

The strongest evidence of compensating differentials with respect to health insurance is the now classic work by Gruber (1994). He used Current Population Survey data from the 1970s to examine the effects of state laws that mandated the inclusion of maternity benefits in employer-sponsored health insurance coverage in a differences-in-differences-in-differences model. The states of New York, New Jersey, and Illinois enacted such laws in late 1976 and worker wages of those affected and unaffected by the law, before and after enactment, were compared to similar people in five states that did not enact the law. Affected workers were married women of childbearing age; unaffected workers were single men and women aged 40–60 years of age. Others were excluded. Gruber found that the effect of the mandate was to reduce the wages of affected workers by 5.4 %. This result implies not only that wages adjust to the inclusion of health insurance in the compensation bundle but also that the compensating differential is at the individual rather than the group level.

Sheiner (1999) looked at the relationship between the age of employed men and wage compensation across US markets with differing health-care costs. Her argument was that, other things equal, there would be higher wages at each age in markets with lower health insurance costs because of smaller compensating wage differentials. Indeed, using the Current Population Survey for the 1978–1990 period, she found that when interacted with health insurance costs each additional year

of age was associated with a \$113 reduction in wages. Miller (2004) examined the *changes* in wages for a cohort of 3,200 men over the years 1988 through 1990. This has the empirical advantage of essentially holding worker productivity constant. He found that those who lost health insurance over the period had wages that rose by 10–11 %.

33.7.3.1 Obesity, Smoking Behavior, and Compensating Differentials

The most interesting recent empirical research on compensating differentials comes from work by Bhattacharya and Bundorf (2009) and Cowan and Schwab (2012). They use a compensating differential context to explore the incidence of the costs of obesity and smoking, respectively, on workers.

Bhattacharya and Bundorf argue that obese workers will incur higher health-care costs and that these higher costs will be reflected in higher insurance claims experience which, in turn, results in lower wages. To test this hypothesis they used 1989 through 2002 data from the National Longitudinal Survey of Youth (NLSY). During this period people in the survey ranged in age from roughly 24 to 32 at the beginning of the 14-year window of observation. They limited their analysis to those who were employed full time and either always covered by employer-sponsored health insurance or who never have employer coverage. The key comparison is the difference in hourly wages of obese and those of normal weight with health insurance relative to the same difference among those without coverage. Controlling for other factors they found that the obese with insurance coverage had hourly wages that were, on average, \$1.45 lower. They did not find similar results for other forms of employee benefits such as pensions, childcare, and dental insurance. Moreover, consistent with the obesity literature, they found that this effect was driven by relatively large effects for obese women (a statistically significant \$2.64 per hour wage effect) with small and statistically insignificant effects for men. They then use the MEPS to show that over this age group there were no statistically significant health-care cost differences for obese relative to normal weight men but the annual health-care cost differences for women are on the order of \$1,460.

Cowan and Schwab (2012) used a model analogous to that of Bhattacharya and Bundorf with the same NLSY and MEPS data. Their interest, however, was in whether the hourly wages of smokers with employer-sponsored health insurance were lower than those without coverage relative to the same comparison for nonsmokers. In addition to gender differences, Cowan and Schwab also examined age effects on the argument that older workers who smoke were likely to have higher health-care costs that were in some sense the result of their cumulative smoking experience. They found that the differential wage offset was on the order of \$1.25–\$1.85. Like Bhattacharya and Bundorf, they found no differential effects for other forms of employer benefits. Unlike the earlier work, however, they did find effects for both men and women, with somewhat larger wage offsets for men. In addition, they found much larger effects for older workers than younger ones. As an aside, it is noteworthy that this research suggests that the introduction of a supplemental premium for smokers in an employer-sponsored plan as some have suggested would imply that smokers will receive wage increases to compensate them for this premium supplement because they have already been paying for the health-care costs through wage offsets.

33.7.3.2 Compensating Differentials and the PPACA

Thus, the recent research adds impressive evidence to the otherwise slim research on the presence of compensating wage differentials. It is also worth noting that the empirical work increasingly suggests that the wage adjustment occurs at the individual not the group level. The PPACA poses a number

of compensating differential questions, the most significant being whether the requirement to offer coverage results in lower wages for newly insured workers.

33.7.4 *Tax Treatment of Employer-Sponsored Health Insurance*

The tax treatment of employer-sponsored health insurance is a key factor in the structure of the US health insurance markets. Income provided to employees in the form of health insurance is not subject to federal or state income taxes nor is it subject to Social Security or Medicare payroll taxes. These foregone taxes, often called “tax expenditures,” are substantial. The exclusion of taxes on employer-sponsored insurance coverage substantially reduces the effective price of health insurance purchased through an employer. The size of this tax subsidy is easily demonstrated by considering a single employee earning \$50,000. With the standard deduction and no other income, in 2011, she was subject to federal income tax of 25 %, the employee shares of the Social Security and Medicare payroll taxes of 6.2 and 1.45, respectively, and except in the six states that do not have state income taxes, state income taxes on average add roughly another 5 %. In addition, she pays the “employer share” of the Social Security and Medicare taxes in the form of wages she never received. Thus, her marginal tax rate was 42 %. If she and her employer can shift \$100 from taxable wages to compensation in the form of untaxed health insurance, the tax liability is reduced by \$42. There is an obvious and large incentive to purchase health insurance and more generous benefits in the presence of this tax subsidy. Moreover, this subsidy shifts purchase decisions away from non-group to employer-sponsored group coverage.

A number of studies conducted in the 1980s and 1990s attempted to estimate the effects of the tax subsidy on the probability that an employee had health insurance and the generosity of that coverage. Most of these used differences in state income tax rates to identify the effects. The results vary substantially from one study to the next with estimates of firm elasticities of offering insurance coverage in response to the tax subsidy ranging from 0.6 (Leibowitz and Chernew 1992) to 2.9 (Royalty 2000). See Gruber and Lettau (2004) and Morrissey (2008) for reviews.

The best empirical work in this area is that of Gruber and Lettau (2004). They combined Treasury Department data on family taxes with Labor Department data on worker characteristics, compensation, and insurance coverage for the period 1983 through 1995. The compensation data were for the average for all workers holding the sampled type of job. This average worker could be single or married and file an itemized or non-itemized return. For each of these possibilities, Gruber and Lettau imputed the average spousal and unearned income based upon the state in which the establishment was located, its industry, the occupation classification of the job, and the wage rate. Given these characteristics and family incomes they then computed the relevant marginal tax rate for the household. Then, using the proportions of households married and itemizing deductions, married and not itemizing, and single itemizing and non-itemizing, they were able to compute the marginal tax and the marginal “tax price” of health insurance for the average or median worker in each establishment. The tax price is simply 1 minus the marginal tax rate.

Gruber and Lettau found that the overall elasticity of plan offering based on the tax price of the median worker was -0.25 . The elasticity with respect to the generosity of plan coverage was much greater, -0.70 . In addition, they developed estimates by firm size. Small firms, those with less than 100 workers, were much more price sensitive, with offer elasticities of -0.54 and expenditure elasticities of -1.34 . The relatively large expenditure elasticities suggest that in the face of lower marginal tax rates, firms and their workers would cast off lesser valued coverage. Examples might include dental and vision care and first-dollar coverage, particularly for routine health services. More recently Heim and Lurie (2009) used changes in the tax treatment of individually purchased coverage by the self-insured

to estimate the tax price sensitivity of health insurance. They used a panel of tax payer data from the 1999 to 2004 period and concluded that the elasticity of demand was approximately -0.73 .

33.7.4.1 Taxes, Employer-Sponsored Health Insurance, and the PPACA

A number of advocates have called for the elimination of the tax exemption. The Affordable Care Act calls for the imposition of an excise tax on the value of employer-sponsored health insurance exceeding \$10,200 for individual coverage and \$27,500 for family coverage. Others have recently called for the establishment of a cap of the value of employer-sponsored coverage with benefits in excess of the cap taxed as ordinary income (Feldstein et al. 2011). Gruber and Lettau (2004) provide some simulations of the impact of changing the special tax treatment of employer-sponsored health insurance. The complete elimination of the special tax treatment would reduce the number of firms offering coverage by over 15 % and reduce total insurance spending by 45 %. Maintaining the tax exclusion for payroll taxes but eliminating it for federal and state income taxes has the estimated effect of reducing the number of firms offering coverage by nearly 10 % while reducing total insurance expenditures by 20 %. These estimates are well beyond the range of their data, of course.

The PPACA “Cadillac Coverage Tax” and any changes in marginal tax rates stemming from Congressional efforts to reform the tax system or to shore up Social Security and Medicare entitlement programs will allow relatively direct tests of the tax-insurance coverage hypothesis.

33.7.5 Small Group Market

Much policy attention has been focused on the small group market. This is largely because those workers without health insurance are most likely to be employed in small firms. This characterization, however, really depends upon the definition of the small group. Firms with 50–199 employees are almost as likely to offer health insurance as are larger firms. In contrast, firms with less than 10 workers are least likely to offer coverage. Claxton et al. (2010) report that only 59 % of the smallest firms offered health insurance coverage in 2010. Some of this has to do with worker preferences for coverage and the differential costs of providing coverage across firm sizes. As discussed below, Monheit and Vistnes (1999) demonstrated that preferences for coverage were as important as demographic characteristics in explaining workers in jobs which lacked health insurance. On the cost side, Karaca-Mandic and her colleagues (2011) reported that the health insurance loading fee for firms falls sharply with firm size, falling from 34 % to 15 % to 4 % for firms with less than 100, 100 to 10,000, and more than 10,000 workers, respectively. Thus, one would expect that those who value health insurance the least would sort themselves disproportionately into firms that offer higher wages and no health insurance due to their relatively high cost of buying coverage.

33.7.5.1 State Insurance Reforms and the Small Group Market

A number of studies in the late 1990s and early 2000s evaluated the effects of state health reform initiatives in expanding coverage in the small group market. These reforms limited underwriting options, limited premium increases, and excluded small firms from state insurance mandates. In general there is little evidence that these laws affected coverage (Jensen and Morrissey 1999; Zuckerman and Rajan 1999; Marquis and Long 2001/2002). Subsequent research indicated that the laws increased rates of coverage for high-risk groups, lowering them for low-risk ones with little net

impact. [Buchmueller and DiNardo \(2002\)](#), for example, examined the introduction of pure community rating in the New York small group and individual markets. They did not observe an adverse selection induced death spiral of care. Instead, they found a more subtle shift away from indemnity to HMO coverage suggesting a shift of healthier individuals to lower cost, less comprehensive coverage. [Simon \(2005\)](#) found that the small group reforms decreased coverage for low-risk individuals in small firms while increasing coverage modestly for high-risk workers. [Davidoff et al. \(2005\)](#) found larger increases for high-risk workers but only small decreases for low-risk ones. In many of these studies the requirement of guaranteed issue was critical to finding effects.

33.7.5.2 Premium Sensitivity

A key issue in encouraging small employers to offer insurance coverage is the extent of their premium sensitivity. There has been remarkably little research on this topic. One of the difficulties, of course, is identifying the premiums that are relevant to firms that do not offer coverage. Early work by [Jensen and Gabel \(1992\)](#), [Leibowitz and Chernew \(1992\)](#), and [Feldman et al. \(1997\)](#) found large premium effects, in the range of 2.6–3.9% increases in offer rates for a 1% decline in premiums. In contrast, [Marquis and Long \(2001/2002\)](#) found very low elasticities (–0.14). The best of this work, however, is by [Hadley and Reschovsky \(2003\)](#). They used the a more sophisticated approach to inferring the premiums of firms not offering coverage and they estimate separate equations for small firms of different sizes. They concluded that the smallest firms, those with fewer than 10 employees, had elasticities in the neighborhood of –0.63 and the larger firms, those in the 50–99 worker range, had much less price responsiveness with an offer elasticities of –0.03.

33.7.5.3 Small Employers and the PPACA

A key PPACA research issue in the small group market is the extent to which the short-term employer tax credits encourage firms that are not required to offer coverage under the law to do so. A bigger question is the extent to which the small firms with relatively low-income employees will drop coverage, raise wages, and encourage their employees to obtain subsidized coverage through the individual exchanges.

33.7.6 *Employers as Agents for Their Employees*

33.7.6.1 Sorting

In the last decade there has been growing research interest in the “agent” role that employers play in acquiring and pricing health insurance coverage for their workers. [Goldstein and Pauly \(1976\)](#) developed a model of labor market sorting in which workers who do not value health insurance sort themselves into employment in firms that find it the most costly to offer health insurance. These workers accept an employment contract that features higher wages and no insurance. In some of the best early empirical work [Monheit and Vistnes \(1999\)](#) explored the extent to which worker preferences influence employment in firms that do not offer health insurance. They used the 1987 National Medical Care Expenditure Survey (NMCES) data. In addition to wage, insurance, and household characteristics, the NMCES included questions on respondent perceptions that they were healthy enough that they didn’t really need health insurance and whether they thought health insurance was worth its cost. Monheit and Vistnes estimated models of whether a respondent’s employer *offered*

coverage as a function of wages, expected out-of-pocket medical expenditures, the costs of search, and these preferences for insurance questions. They concluded that those who had strong preferences for coverage were 14 percentage points more likely to have a job offering coverage than were those with weak preferences, other things equal. The magnitude of this effect is analogous to the size of the usual employment and demographic characteristics found in many coverage analyses. [Moran et al. \(2001\)](#) found that with greater variance in worker characteristics (i.e., ages and incomes) in a firm, the more likely the firm was to offer multiple plans. This further strengthens the evidence that employer plans reflect worker preferences. More recently [Bundorf \(2010\)](#) examined employer decisions to offer a choice of health plans. She found that firms offering choice had lower average premiums, largely because workers disproportionately enrolled in less generous plans and concluded that the results are consistent with employers offering choice to accommodate diverse employee preferences. While not surprising perhaps, the empirical findings provide important new insight into employer actions with respect to health insurance.

33.7.6.2 Two-Earner Households

A key issue in employer-sponsored coverage is the presence of two-earner households. By the turn of the twenty-first century approximately 65 % of married couples under age 65 in the USA had both spouses in the labor force. If the compensation bundle does adjust to reflect worker preferences and employer costs, two-earner households present a challenge to providing a preferred compensation bundle at minimum cost. [Abraham and Royalty \(2005\)](#) have provided the most comprehensive work examining the implications of two-earner households on coverage. They conclude: “Overall, we find that the average effect of having two earners leads to a dramatic improvement both with respect to access and choice set generosity. . . [H]ouseholds with vulnerable workers, including part-time, self-employed, and workers in small firms, tend to fare worse on all dimensions, but that having a second earner serves to mitigate a significant proportion of the negative effects” (page 182). For example, they found that being employed part time reduced the probability of having employer-sponsored health insurance by 39–47 %. But being in a two-earner household reduced the probability of a part-time worker being without coverage by some 78 %. Being self-employed in a two-earner household reduced the overall probability of being uninsured by 36 %; working in a small establishment in a two-earner household reduced the overall probability of being uninsured by 49–58 %. The opportunity for one earner to take insurance and lower wages presumably allowed the other earner to take a job without benefits but with higher wages than would otherwise be the case.

33.7.6.3 Out-of-Pocket Premium Contributions

The interest in employers as agents has also led to research focusing on the size of the out-of-pocket premium contribution. A difficult problem faced by employers is trying to accommodate a workforce with diverse insurance preferences and choice sets in a world of imperfect compensating differentials. Increasingly the employee premium contribution [EPC] is viewed as providing a mechanism to sort workers into plans that best meet their preferences. A traditional one-earner household may prefer lower wages and family coverage. An employee in a two-earner household may prefer only single coverage with a higher wages; another two-earner household worker may prefer still higher wages and no coverage. Moreover, differing marginal tax rates and availability of public coverage for family members affect workers’ benefit–wage choices and the size of the premium contribution.

[Gruber and McKnight \(2003\)](#) using 1982–1996 Current Population Survey data found that EPCs rose with insurance premiums, reflecting the increased value of worker sorting when insurance is more expensive and that the employee premiums rose when marginal tax rates fell suggesting that

the sorting role of premium contributions takes on a larger role when the tax-sheltering element of employer-sponsored health insurance is lower.

Vistnes et al. (2006) used over 84,000 establishments from the 1997–2001 MEPS to directly test the effects of two-earner households on the size of the marginal EPC for family coverage. The marginal EPC is the difference between the family and single premium contributions. They argued that when there is a larger proportion of households with two earners in the employer’s labor pool, the marginal EPC will be larger. In addition, if women or younger workers are disproportionately second earners in the family, they will not value family coverage as highly as the primary earner. If so, they would prefer wages to insurance coverage. A higher EPC partially accomplishes this trade-off in that it allows a (secondary) worker to decline coverage and take home more wages. Their key result was that the marginal EPC for family coverage increased with the proportion of women employed by the firm but only in communities in which there was a substantial concentration of two-earner households.

Buchmueller et al. (2005) examined the effects of the introduction of the CHIP on the size of the EPCs set by employers. The CHIP program extends eligibility for public health insurance to children in working poor families. Prior to its introduction in 1997, the family income level making a 15-year-old child eligible for public insurance ranged from 10 to 225 % of the federal poverty line. By 2000 the range was from 100 to 400 % of the poverty level. These typically large expansions in eligibility across states might be expected to affect employer-sponsored coverage. Under the worker-sorting theory, we would expect that at least some newly eligible families would want to shift their children to the CHIP program, reduce their spending on employer-sponsored family health insurance coverage, and take home more of their compensation in the form of money income. This would be accomplished by raising the marginal EPC for family coverage. Using the 1997–2001 MEPS data Buchmueller and colleagues found that the effects on the size of the EPC depended upon the extent to which the potential labor pool was eligible for CHIP coverage. An employer with 20 % of her potential workforce eligible for public coverage raised the marginal cost of family coverage by \$119, on average (2001 dollars) over the period, controlling for other factors. When 50 % of the potential workforce was eligible for CHIP, there was an associated increase in the marginal family EPC to \$351 per year. There was no effect on the premium contribution for single coverage. Moreover, when 20 % of the potential workforce was eligible, the proportion of workers with family coverage declined by 1.4 percentage points. When 50 % were eligible, family enrollment declined by 4.6 percentage points. This change in family EPC provides a mechanism by which the well-known “crowd-out” of private coverage by public programs (Cutler and Gruber 1997) can be facilitated.

33.8 Individual Market

The individual, non-group market comprises only about 6 % of the coverage held by those under age 65. It has received disproportionate policy attention because of the role it was expected to and indeed does play in health-care reform. Beginning in 2014, subsidies for the purchase of non-group coverage will be available to virtually all US citizens and legal residents with household income between 100 and 400 % of the federal poverty line. For the lowest income members of this group, out-of-pocket spending on an approved health plan will be no more than 2 % of income.

Ziller and colleagues (2002) provided an excellent description of those who currently have individual coverage. Nearly three-quarters are employed. Part-time workers are twice as likely to have non-group coverage as full-time workers, but most of those with non-group coverage are employed full time. Nearly half are self-employed. People aged 55–64 have the highest proportion of their number covered by a non-group policy (11.3 %). While there is some concern about the truncation of

the observation window, over the 1996–2000 period, Ziller et al. estimated that nearly half of those covered are covered for less than 6 months and 17 % are covered for more than 2 years.

There is little useful evidence on the premium sensitivity of purchasers in the non-group market. However, there has been research examining the extent to which the non-group market pools dissimilar risks. [Pauly and Herring \(2001\)](#), using the 1997 Community Tracking Survey data, found only weak medical underwriting and substantial pooling of risks. [Marquis and Buntin \(2006\)](#) reach similar conclusions using data from three large California non-group insurers. [Pauly and Herring \(2007\)](#) revised this issue with more recent data, from the MEPS, the Community Tracking Survey, and the National Health Interview Survey. They conclude that the earlier relationships still hold. Premiums in the individual market increase with risk, much less than proportionately. “The most important risk factors in predicting higher premiums are the person’s age and sex; chronic conditions per se matter, but their effect [on premiums] is quite small relative to their effect on risk” (page 775). Some have argued that part of the reason for these results is the active role of brokers and agents in this market. To the extent that insurers differ in their approaches to underwriting, the effect of agents is to increase pooling by channeling higher-risk clients into the more weakly underwritten plans. [Hadley and Reschovsky \(2003\)](#) argue that these earlier findings largely resulted from self-selection on the part of high-risk individuals. To the extent that high-risk people migrate to public programs or to employer-sponsored coverage, then the pooling that appears in private non-group plans really only reflects a narrow band of reasonably healthy people. They provided evidence of plan enrollment by health status that was consistent with the self-selection hypothesis.

33.8.1 Research Using Internet Data

The most interesting research in the individual market takes advantage of Internet insurance sites. In particular [Pauly et al. \(2002\)](#) use data from *ehealthinsurance.com* to examine the dispersion of premiums for high- and low-risk individuals and whether the dispersion of premium offers was different than the dispersion of premiums actually purchased. They found that the dispersion of Internet “offer” premiums did not vary between low- and high-risk people. However, the dispersion of actual prices was smaller for high-risk persons. This is what one would expect from search theory. High-risk people will have higher claims experience and, therefore, their insurance will cost more. This gives them greater incentives to search for lower prices. The fact that the dispersion of actual prices is smaller for high-risk persons suggests that they searched more before settling on a particular product. Their second finding was that the premium sensitivity was lower for actual premiums than for offered premiums. This too is consistent with search theory and implies that greater search effort (particularly by high-risk people) offsets some of the expected higher medical claims expense they would incur.

Clearly, the data from the Internet provides an opportunity for much more research on the individual market.

33.8.2 Individual Market and the PPACA

There are several important research issues on the effects of the PPACA in the individual market. The first is the extent to which people will buy coverage within the exchange. The implementation of the exchanges requires the states to fund the exchanges in some way. Many states are likely to impose a fee on coverage sold through the state exchange, and others may impose a fee on all individual (or small group) products. Still others may fund their exchanges from general tax revenues. To the

extent that the funding creates differential premiums inside and outside the exchange, unsubsidized purchasers will likely focus their purchases on the lower priced source. Another issue, of course, is the extent to which the subsidies and penalties affect enrollment and the extent to which those legally obligated to buy coverage actually do so. Also of intense interest will be the extent to which high-risk and low-risk enrollees differentially enroll and how, if at all, the market and the regulators are able to account for this.

33.9 High-Deductible Health Plans

High-deductible health plans provide insurance coverage only after a deductible typically of \$1,200 or more per individual or \$2,400 per family have been reached. These plans are often, but not always combined with HSAs or Health Reimbursement Accounts (HRAs). Both HSAs and HRAs are tax-sheltered accounts designed to be spent on health services prior to the satisfaction of the deductible. In both cases unspent balances are carried over and available for use in a subsequent year. In an HRA the employer makes the contributions to and owns the account. In an HSA the employer, the employee, or both may contribute to the account. However, it is owned by the employee who retains ownership of the balance across time and across jobs. The HRAs were introduced in the late 1990s and HSAs were authorized in 2003. In 2011, an estimated 17 % of workers in US firms were enrolled in high-deductible plans (Kaiser/HRET 2011).

Advocates argue that these plans give consumers the incentive to economize on the purchase of routine services because they face something approaching the full price of their decisions. Ozanne (1996) provides the best overview of the economics of these types of plans. His two key insights are that the value of the plan increases with the marginal tax rate of the purchaser and that, under some circumstances, such plans may reduce the expected cost of health care below that of traditional coverage, implying that utilization should increase. Empirical work on the effects of high-deductible plans has been limited and early evaluations suffered from low take-up rates when provided as a plan option and by relatively short observation periods.

LoSasso et al. (2010) provide the best large-scale examination of the effects of the introduction of a high-deductible plan tied to an HSA. They compared the health-care spending of some 76,000 enrollees in over 700 small firms that switched from offering traditional plans to the HSA model exclusively or as an option over the 2005–2007 period. Using a differences-in-differences methodology and a variety of robustness checks, they found, they the HSA was associated with a 5–7 % reduction in health-care spending compared to traditional plans, much of this coming from reductions in pharmacy spending. They did find evidence of selection bias in the choice of health plans, but no such evidence in the trends in spending.

Borah et al. (2011) improved upon the LoSasso et al. study by examining only the exclusive switch to a high-deductible plan, in this case with an HRA, from a traditional plan. They also introduced a similar control group that does not switch. The downside of their study, however, is that they only examine a single switching firm and a single control firm over the period 2006–2009. Each firm had approximately 3,400 employees. Using differences-in-differences, changes-in-changes, and quintile differences-in-differences they examined effects on spending and use of services. Their results were consistent across methods. Overall, they found that the high-deductible health plan did not lower average medical expenditures as a whole. However, there were savings of approximately \$120 and \$600 per person per year for those with moderate health-care spending in the base year, defined as being in the 50th and 75th percentiles of spending, respectively. The implication is that those with low and high levels of spending had little incentive to change their health utilization behaviors.

33.9.1 *High-Deductible Plans and the PPACA*

Within the insurance exchanges, high-deductible plans, per se, are only available to people under age 30. However, it can be argued that a variant of the “bronze plan,” which must actuarially coverage 70 % of essential benefits, is a plan structure that uses a high deductible, albeit without a tax-sheltered HSA tied to it. The research issues are whether young adults will choose the high-deductible plans and the future of HSAs in general.

33.10 High-Risk Pools

In 2006, some 34 states had high-risk pools wherein “uninsurable” individuals could purchase subsidized health insurance. In addition, beginning in 2010, the Affordable Care Act provided a transitional federal mechanism for such individuals to obtain high-risk coverage in any state. While high-risk pools have proved useful in the past, they would be a critical part of a strategy to expand health insurance coverage if the individual mandate in the PPACA were repealed.

[Achman and Chollet \(2001\)](#) provide the most comprehensive description of the state programs. The states typically define an uninsurable as someone who has been denied coverage by one or more private carriers, has been charged premiums substantially above standard rates, or, sometimes, people with particular health conditions. The plans often have high deductibles and significant co-pays. There are lifetime maximums. Moreover, even though the plans are subsidized, the premiums are still relatively expensive, often set by law at a multiple of established standard rates; 125–150 % of standard rates are common. Nonetheless, all of the state high-risk pools lose money. The plans are typically funded by taxes on private insurance plans set at a pro rata share of their premium revenue. Many states allow these taxes as a credit against state corporate income taxes.

[Frakt et al. \(2004\)](#) have undertaken the most extensive research on high-risk pools to date. Using 1995–2001 data from the Current Population Survey, they found that, under reasonable definitions, about 1 % of the US population is uninsurable, 6 % of the uninsured. Demand was found to be very premium sensitive, with an estimated elasticity of -1.9 . However, very few people are in the existing high-risk pools, typically fewer than 5,000 people in most states. In their simulations, Frakt and colleagues concluded that if all states with risk pools set their premium at 125 % of the state’s standard rate, rather than higher levels, national enrollment would shift from the current 8 % of the uninsurable in high-risk pools to 11 %.

33.11 Insurance Regulation

Traditionally health insurance has been regulated at the state level in the USA. Early regulations dealt with reserve requirements and sales practices. States slowly began to specify the inclusion of specific coverages for individuals, such as newborns, providers, such as chiropractors, and services, such as alcohol abuse treatment, beginning in the 1950s. The prevalence of these “insurance mandates” began to expand substantially in the mid-1970s ([Laugesen et al. 2006](#)). [Bunce and Wieske \(2010\)](#) reported that more than 2,150 mandates were in effect across the states in 2010. One reason for the growth of state mandates is the enactment of the ERISA by the Congress in 1974. This law allows employer-sponsored plans that are self-insured under the terms of the legislation to be exempt from state insurance regulation ([Jensen et al. 1995](#)). Fully insured plans for which the purchaser bears no underwriting risk, however, are subject to the state insurance mandates. The [Kaiser/HRET \(2009\)](#)

reported that in 2009 nearly 60% of insured workers were in self-insured plans. Arguably, larger employers, who almost always offer self-insured plans, did not expend political capital to oppose insurance regulations that did not apply to them.

Federal regulation of this market has been modest. The Consolidated Omnibus Budget Reconciliation Act of 1986 (COBRA) required continuation of coverage and several pieces of legislation in 1996 added to the federal role. [Hing and Jensen \(1999\)](#) and [Laugesen and colleagues \(2006\)](#) note that many of the federal laws mimic state actions and, indeed, may have been enacted because a large majority of states had already done so. The federal role will expand significantly with the implementation of the PPACA because the federal government assumes greater responsibility for defining essential benefit packages of coverage, limitations on permissible underwriting factors, and requirements for minimum medical loss ratios that limit nonclaims related costs.

33.11.1 Costs and Coverage of State Insurance Mandates

A number of studies, beginning in the 1990s, sought to estimate the costs of insurance mandates. [Bunce and Wieske \(2010\)](#) provide a summary of a range of actuarial studies. In vitro fertilization, for example, is reported to increase premiums by 3–5%. Such estimates tend to overstate the true cost because they don't examine the cost of the coverage over and above what demanders are willing to pay. In addition, they ignore the costs of other health services that may be increased or reduced as a result of the new coverage. [Acs and colleagues \(1992\)](#) were the first to directly examine the effects of mandates on the cost of employer-sponsored health insurance. They concluded that an additional mandate increased average premiums per worker in large firms by \$1.50. Such estimates are not necessarily very useful. Mandated coverages vary substantially in their costs; these sorts of estimates are averages across expensive and inexpensive benefits. In addition, the enactment of a mandate provision is almost certainly endogenous. The legislature may have enacted the law because it was commonly offered or because residents perceived the coverage to be a substantial benefit.

The recent research on the effects of state insurance mandates has focused on individual mandates and sought to minimize endogeneity problems by using differences-in-differences, triple-difference models, and instrumental variables. [Bitler and Carpenter \(2009\)](#), for example, use the 1987–2000 Behavioral Risk Factor Surveillance Survey (BRFSS) to examine the impact of mammography screening legislation. They conclude that the mandates accounted for about 7% of the doubling of screening observed over the period. This conclusion resulted from a triple-difference analysis that compared screening in states that did and did not enact the mandate, before and after enactment, among women at ages that were and were not recommended for screening. [Klick and Stratmann \(2007\)](#) used 1996–2000 BRFSS data to examine the effects of mandates covering diabetes supplies, treatment, and services on obesity among those with diabetes. They hypothesized that by lowering the costs of future treatment, the mandate provided incentives for people to allow their health to deteriorate. In a triple-difference analysis they found that affected individuals (diabetics) in states with the law, after enactment, had greater increases in body mass index. Other studies that reflect this greater attention to the specific mandate and its potential endogeneity include [Baker and Chan \(2007\)](#) on direct access to obstetricians/gynecologists, [Sloan et al. \(2005\)](#) on a variety of patient protection laws, and [Liu et al. \(2004\)](#) on so-called “drive-by delivery” laws which are intended to prevent insurers from too aggressively limiting the number of hospital days associated with a maternity admission.

33.12 Medicare and Retiree Coverage

In the USA, Medicare provides health insurance to virtually all people age 65 and older as well as to the disabled of any age. Over the last decade two changes in the program have been particularly significant from an insurance perspective. One was the introduction of “Part D” prescription drug coverage. The other was the development and introduction of a more sophisticated payment system for Medicare managed care plans, called Medicare Advantage (MA), which heavily relies on the health status of enrollees to risk adjust payments. The research on Part D plans was discussed in the moral hazard section above.

33.12.1 *Risk Adjustment in the Medicare Advantage Program*

Traditionally Medicare paid managed care plans using a formula called the Adjusted Average Per Capita Costs (AAPCC). It paid MA plans 95 % of the average Medicare spending for Parts A and B in the county in which MA plan subscribers resided adjusted for their age, gender, Medicaid status, and nursing home residence. As is well known, the MA program benefited from substantial favorable selection due to disproportionate enrollment of healthier beneficiaries (Batata 2004). Newhouse et al. (1989) found that the AAPCC variables accounted for less than 2 % of the variation in spending across an insured population. They also found that adding measures of prior utilization to the AAPCC variables increased the explanatory power to 6.4 % of variance. Medicare adopted the Hierarchical Condition Categories (HCCs) approach and began phasing it in 2003. Under this model MA plans are paid according to a base payment rate established for their county augmented for each beneficiary enrolled based upon gender, 12 age categories, two location categories (community and institutional dwelling), six Medicaid categories together with 76 HCCs, and their interactions reflecting ongoing health conditions of the beneficiary. Compared to a simple age/sex risk adjuster, Pope et al. (2004) found that the HCC model predicted future claims better for each quintile of the claims payment distribution. The HCC reduced the overpayment of the least costly quintile of beneficiaries from 166 % to only 23 %, for example, and paid the fourth quintile of beneficiaries at 2 % over costs compared to the 5 % underpayment implied by the age/sex model. As Newhouse (2010) notes, however, there has yet to be an evaluation of the effects of this change.

Two recent contributions provide considerable insight into the effects of the risk adjustment refinements on Medicare Advantage enrollment and Medicare costs more generally. Morrissey et al. (2013) used the 5 % Medicare Parts A and B longitudinal claims files to examine trends in the claims experience of those switching into and out of Medicare Advantage plans over the 1999–2008 period. They found that Medicare spending in the 6 months prior to joining a Medicare Advantage plan ranged from 73 to 91 % of those residing in the same county who never switched. In multivariate work there was no effect of the phasing-in of the HCCs on the extent of favorable selection. Over the same period, the claims experience of those switching back to traditional Medicare had expenditures, relative to those residing in the same county who were always in traditional Medicare, of 117–151 %. The multivariate work found that the introduction of the HCC model was associated with a reduction in the disenrollment of those in the lower quintiles of the cost distribution.

Brown et al. (2011) independently provided a theory that can explain these findings. They argued that when Medicare introduced the more sophisticated risk adjustment mechanism, MA firms reduced their effort to select enrollees along the characteristics included in the new model but invested more in selecting along dimensions that were not included. As Brown and his colleagues put it: “. . . enrollees shifted from being low cost to being low cost conditional on the risk score” (page 2). This is consistent

with the lack of effect on enrollment and smaller disenrollment of lower cost people noted above. Brown and colleagues used data from the Medicare Current Beneficiary Survey from 1994 through 2006 and found that differential payments after the phase-in of the HCCs increased by some \$30 billion in 2006.

33.12.2 Supplemental Coverage for Medicare Beneficiaries

While Medicare provides coverage for over 38 million beneficiaries aged 65 and older, the vast majority have some form of supplemental coverage. The [Kaiser Family Foundation \(2010a, b\)](#) reported that in 2008, 33% of beneficiaries also had employee-sponsored coverage either as still active workers or a coverage supplemental to Medicare. Nearly one-quarter were in a Medicare Advantage plan that typically offers a broader array of benefits albeit usually with a narrower panel of providers. Seventeen percent purchased a private Medicare supplement, called Medigap coverage, which essentially paid the co-pays and deductibles associated with Medicare-covered services. Fifteen percent were covered by Medicaid as well as Medicare and only 10% had traditional Medicare exclusively.

Employer-sponsored retiree coverage is largely a large firm benefit, but its provision has been declining. [Kaiser Family Foundation \(2010a, b\)](#) data indicate that even among firms with 5,000 or more workers, the percentage offering retiree coverage has declined from 60% in 2004 to 48% in 2010. While the cost of coverage is the usual explanation for this shift, as yet there appears to be no careful analysis that explores the roles of increased labor force mobility, compensating differentials or any link to the analogous shift from defined benefit to defined contribution pension plans.

Medigap plans are regulated by the states within a structure of 10 plan types that were specified by Congress. As [Chollet \(2003\)](#) observed the most popular plan by far covered hospital, skilled nursing home, and physician co-pays and deductibles and a few other minor benefits. [Robst \(2006\)](#) has examined the underwriting provisions of these plans. He found that policies that quote a premium that does not raise with age and community-rated plans cost more for younger purchasers, guaranteed issue plans have higher premiums, and plans that have a limited panel of providers cost less. [Finkelstein \(2004\)](#) found that the decision of Congress to mandate that only 10 specific types of Medigap coverage could be offered had the effect of reducing the proportion of the elderly with Medigap coverage by approximately 25% in the first 3 years of the mandate, with no evidence that people migrated to other forms of supplements. [Bundorf and Simon \(2006\)](#) examined state decisions to require community-rated Medigap plans. They found that this increased coverage of high-risk individuals by 2.8 percentage points but reduced coverage for low-risk folks by 2.5 percentage points.

Purchasers of retiree health plans are price sensitive. [Atherly et al. \(2004\)](#) found premium elasticity for Medicare Advantage plans (from the insurer perspective) to be more than -4.5 . [McLaughlin et al. \(2002\)](#) found substantial competition between Medicare Advantage and Medigap plans with higher Medigap premiums leading to increases in Medicare Advantage enrollment. PPACA provides for substantial reductions in funding for MA plans. An important research question will be the effects of these cuts on the enrollment, coverage offered, and the premiums of these plans.

The presence of all forms of additional coverage for retirees has the effect of increasing Medicare expenditures. For retirees, Medicare is the primary payer and employer-sponsored or Medigap policies pay according to their contracts only after Medicare has paid what it would ordinarily pay. [Khandker and McCormack \(1999\)](#) found that those with Medigap coverage had Medicare spending that was

15 % greater than those with Medicare only; those with employer-sponsored coverage had Medicare claims that were nearly 23 % higher. It is for this reason that some in Congress are proposing to limit the first-dollar coverage that Medicare supplements provide or assess a surcharge due to their effects on Medicare (Cassidy 2011).

33.13 Medicaid, the Children's Health Insurance Plans, and Long-Term Care

Medicaid is a federal–state program in which the federal government provides broad terms of eligibility and coverage and the states have considerable flexibility in establishing thresholds of eligibility and the generosity of coverage. The CHIP was established in 1997 and provides coverage to children above the Medicaid eligibility level in each state. In some states CHIP is simply an expanded eligibility category in Medicaid; in other states it is a separate program. State Medicaid/CHIP programs differ widely. In 2010 some 58 million US residents received services through Medicaid or the CHIP program.

One of the ongoing issues in Medicaid has been the ability of state Medicaid programs to reduce program costs by shifting to managed care. Early work by Leibowitz et al. (1992) indicated that voluntary participation in Medicaid managed care increased costs due to favorable selection. Holahan et al. (1998) reported that Medicaid managed care programs had grown rapidly and that there was little evidence of cost containment, in part due to a goal of protecting providers who specialized in caring for the poor and uninsured. The Kaiser Family Foundation (2010a, b) reported that in 2010 some 20 states intended to expand their Medicaid managed care programs. Duggan and Hayford (2011) used federal mandates from the years 1991 through 2003 to estimate the effects of Medicaid managed care expansions on program costs. They found that the mandate-induced increases in enrollment, on average, had a near-zero effect on Medicaid spending. Their effects varied, however. In those states with low Medicaid relative to commercial payment levels for providers, Medicaid managed care actually increased expenditures, while lowering them in states with previously generous payment regimes.

Three of the more interesting research topics in Medicaid in the last decade have been (1) the effects of program expansions on private coverage, the so-called crowd-out, (2) the effects of the CHIP program features on coverage and health care for children, and (3) the role of Medicaid in the long-term care market.

The classic work on crowd-out was provided by Cutler and Gruber (1997). They found that for every two children added to the Medicaid program as a result of its 1988 expansion, one dropped private coverage. More recent work on the CHIP expansions of the late 1990s reached similar conclusions. LoSasso and Buchmueller (2004) found take-up rates among eligible children of about 9 %. They also concluded that the 46.6 % of those newly added to the CHIP rolls had private insurance coverage. Children in higher-income eligible families were more likely to have dropped private coverage. They also found, however, that a waiting period of 5 months was sufficient to eliminate most of the crowd-out. Levin et al. (2011) examined the expansion effects on older teens. They concluded that the CHIP expanded coverage by 3 percentage points overall and by 7 percentage points for those with family income below 150 % of the poverty line.

The CHIP program has introduced modest premium contributions and co-pays. Manton and colleagues (Manton and Talbert 2010; Manton et al. 2009; Keeney et al. 2007) have found that even small monthly premium contributions affect enrollment. Across the individual states studied premium contributions of \$5, \$10, or \$20 per month reduced enrollment by 3 to 5 to 8 %, respectively. Co-pays

for health services in this population have effects similar to those found the RAND Health Insurance Experiment (Artiga and O'Malley 2005).

33.13.1 *Medicaid and Long-Term Care*

Medicaid is the largest single payer of long-term care services and directly pays nursing homes for some 40 % of the services they provide. Moreover, only about 10 % of those over age 65 have a private long-term care insurance policy (Finkelstein and McGarry 2006). An ongoing policy question has been why a more robust private market has not developed. On the demand side, researchers have speculated that there was a lack of demand due to an unwillingness of consumers to believe that they would be candidates for nursing home care. On the supply side, many have argued that lack of knowledge about the magnitude of the adverse selection and moral hazard problems in the market inhibited risk adverse insurers from entering. See Morrisey (2008) for a review. However, a more direct explanation is provided by the empirical literature. People don't buy long-term care insurance because they already have it in the form of Medicaid. Sloan and Shayne (1993) argued that after the passage of the Medicare Catastrophic Coverage Act of 1988, the income and assets of community dwelling spouses were much better protected from a requirement that the household "spend down" its resources to be eligible for Medicaid. They found that over 83 % of seniors likely to use a nursing home were either immediately eligible for Medicaid or would be eligible within 6 months of entry into a home. More recently, Brown et al. (2008) concluded that Medicaid eligibility could explain lack of private insurance purchases for between 66 and 90 % of the wealth distribution. Thus, the private market has not developed because it was essentially crowded out by the public program.

33.14 **Concluding Comments**

Health insurance in the USA is characterized by a diverse and dynamic set of separate private markets. There is substantial public involvement both through the direct provision of public coverage for the poor and the elderly and tax subsidies for the purchase of private coverage. Public involvement is poised to grow dramatically with the implementation of the Affordable Care Act. As recently as 30 years ago there was little rigorous descriptive or analytic investigation of these markets. The results of the RAND Health Insurance Experiment were just beginning to be published. That situation has changed markedly. The market segments are now well described. The volume, innovation, and sophistication of the empirical research are truly impressive. Moreover, the variety of unanswered questions and the new questions posed by the Affordable Care Act suggest that this will continue to be a growth area for empirical insurance research.

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Chapter 34

Longevity Risk and Hedging Solutions

Guy Coughlan, David Blake, Richard MacMinn, Andrew J.G. Cairns, and Kevin Dowd

Abstract Longevity risk—the risk of unanticipated increases in life expectancy—has only recently been recognized as a significant global risk that has materially raised the costs of providing pensions and annuities. We first discuss historical trends in the evolution of life expectancy and then analyze the hedging solutions that have been developed for managing longevity risk. One set of solutions has come directly from the insurance industry: pension buyouts, buy-ins, and bulk annuity transfers. Another complementary set of solutions has come from the capital markets: longevity swaps and q-forwards. This has led to hybrid solutions such as synthetic buy-ins. We then review the evolution of the market for longevity risk transfer, which began in the UK in 2006 and is arguably the most important sector of the broader “life market.” An important theme in the development of the longevity market has been the innovation originating from the combined involvement of insurance, banking, and private equity participants.

34.1 Introduction

The first decade of the twenty-first century saw the emergence of the “life market,” a new institutional market in which assets and liabilities linked to longevity and mortality are traded. The life market has so far developed slowly but has the potential to grow into a very large global market in the coming years, driven, in particular, by a widely anticipated expansion in longevity risk management. This expected expansion reflects the increasing recognition of the threat to the provision of retirement income posed by unanticipated advances in life expectancy. This so-called longevity risk means that

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the cost of providing pensions and annuities to retirees may be very much higher than expected, leading to significant financial losses for insurers, pension plans, corporations, and governments.

Despite its slow initial growth, this market has witnessed impressive innovation, much of which has come from the interplay of the differing perspectives of the insurance, investment banking, and private equity industries. This has led to the development of new capital markets solutions for transferring longevity risk alongside more traditional insurance solutions. It has also spurred significant innovation in the design and implementation of insurance solutions themselves.

This chapter is focused on the development and structure of the longevity market and surveys both insurance and capital markets channels for longevity risk transfer. It places particular emphasis on the different perspectives of the various market players and the role of innovation in market development.

In Sect. 34.2, we discuss historical trends in the evolution of life expectancy and the problem longevity risk poses for the retirement industry. In Sect. 34.3, we define the market for longevity risk transfer and discuss its origins and development. We describe the key market participants and the role that the capital markets play in providing complementary solutions to traditional insurance solutions. Section 34.4 discusses the development of the longevity market since its birth in the UK which we argue dates from 2006. Section 34.5 presents a framework for evaluating the effectiveness of longevity hedges and illustrates this with a case study involving a US pension plan. Section 34.6 reviews the innovations that have been a feature of this market, before Sect. 34.7 presents our conclusions.

34.2 Longevity Risk

34.2.1 *Trend Versus Risk*

Life expectancy has been rising in almost all the countries of the world for both males and females.¹ Figure 34.1 shows the steady increases in period life expectancy over the past 50 years for 65-year-old males and females in England and Wales (EW) and in the USA. This reflects the increasing length of time that both sexes spend in retirement in all developed countries. Furthermore, Fig. 34.2 shows that the maximum life expectancy at birth for females across developed countries has been increasing almost linearly at the rate of nearly 3 months per year for more than 150 years.²

Although aggregate increases in life expectancy can place burdens on both public and private defined benefit (DB) pension systems, they would not necessarily do so if they were fully anticipated. Indeed, governments and pension plan sponsors have begun to respond to increases in life expectancy by requiring individuals to pay higher pension contributions when they are in work and/or to work longer. Pension plan members do not relish either prospect, as has been demonstrated through public statements by trade union officials, industrial action, and protests in a number of countries. Despite this, separately or in combination, these measures can be used to maintain the viability of pension systems in both the public and corporate sectors. The UK government, for example, is raising the

¹There are only a few exceptions: a current example is Zimbabwe, where life expectancy at birth has fallen to 37 for males and to 34 for females.

²There is no sign of this trend abating according to a recent study: “Life expectancy in Europe is continuing to increase despite an obesity epidemic, with people in Britain reaching an older age than those living in the United States, according to study of trends over the last 40 years. In a report in the *International Journal of Epidemiology*, population health expert David Leon of the London School of Hygiene and Tropical Medicine said the findings counteract concerns that the rising life expectancy trend in wealthy nations may be coming to an end in the face of health problems caused by widespread levels of obesity. The report comes as news of the U.S. mortality rate fell to an all-time low in 2009, marking the 10th consecutive year of declines as death rates from heart disease and crime dropped. In total, rates declined significantly for 10 of the 15 leading causes of death, including cancer, diabetes, and Alzheimer’s disease” (Kelland 2011).

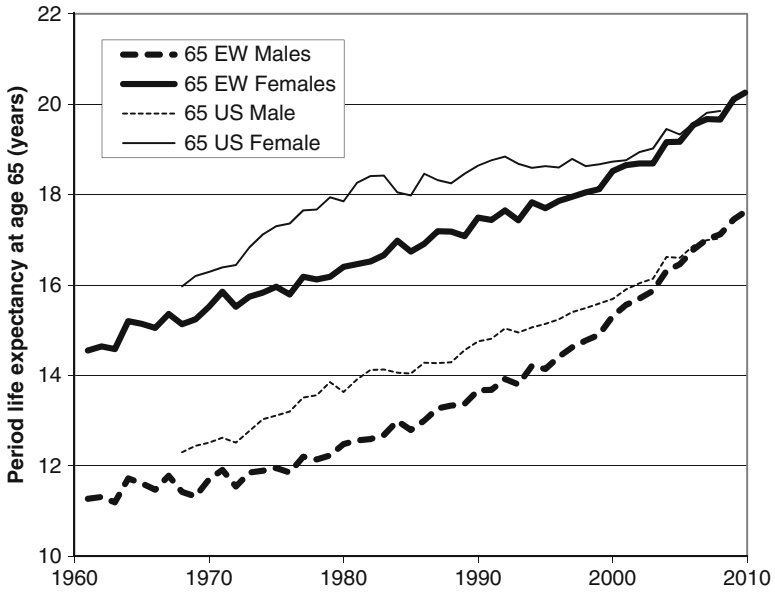


Fig. 34.1 Period life expectancy at age 65 in the USA and England and Wales 1961–2010 (Source: LifeMetrics)

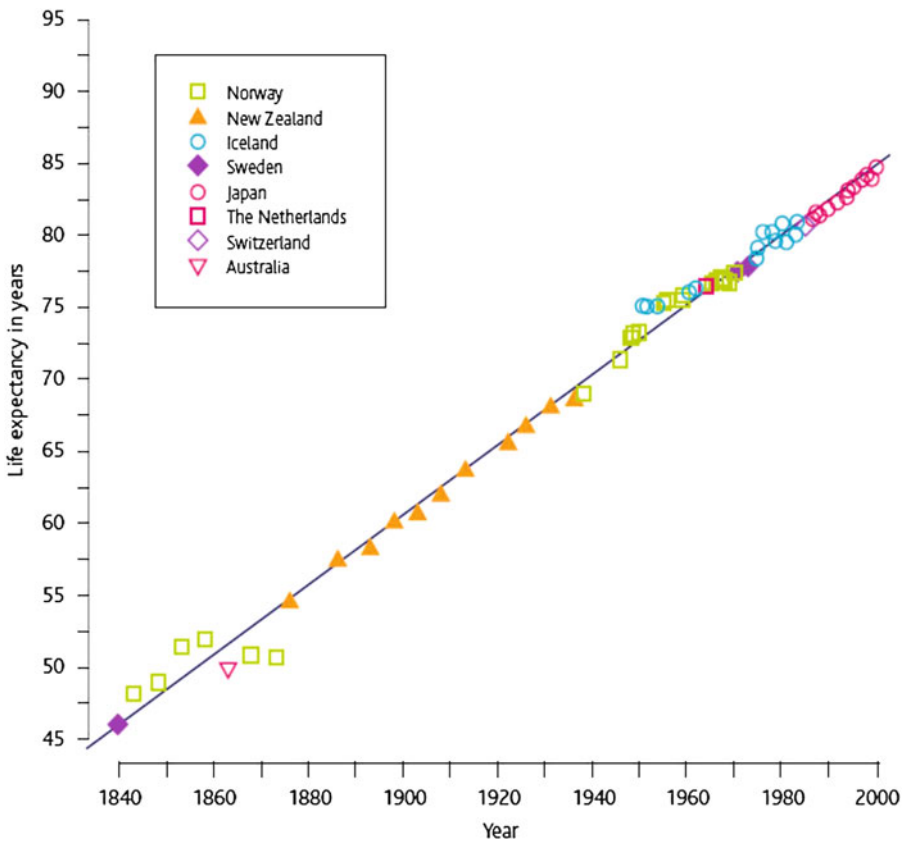


Fig. 34.2 Record female life expectancy since 1840 (Source: Oeppen and Vaupel (2002))

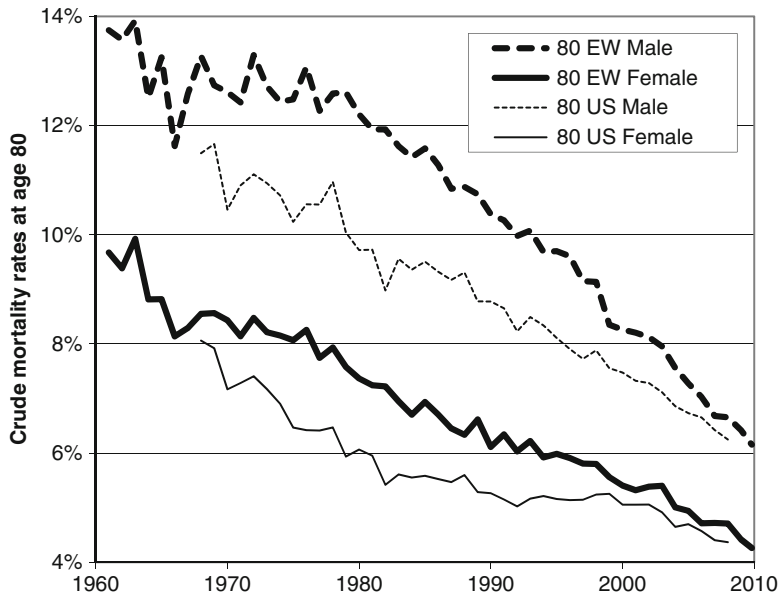


Fig. 34.3 Mortality rates for 80-year-olds in the USA and England and Wales 1961–2010 (Source: LifeMetrics)

Table 34.1 Impact of an unexpected fall in future mortality rates of 1% per year below expectation

| | 45-year-old pre-retirement | 65-year-old retiree (pensioner) |
|---|----------------------------|---------------------------------|
| Impact on life expectancy | +2.7 years | +1.0 years |
| Impact on cost of providing a fixed pension | +7% | +3% |
| Impact on cost of providing an inflation-linked pension | +11% | +5% |

Source: Coughlan et al. (2008b)

state pension age (SPA) for women from 60 to 65 between 2010 and 2018 and then raising the SPA for both men and women to 66 by 2020, to 67 by 2028, and to 68 by 2046. It has also removed the default retirement age in private pension plans. In 2010, 8% of the UK workforce above age 65 was still in work.

So it is not the aggregate increase in life expectancy per se that is challenging the viability of pension systems almost everywhere. Rather, it is a combination of (1) uncertainty surrounding the trend increases in life expectancy and (2) variations around this uncertain trend that is the real problem. This is what is meant by longevity risk and it arises as a result of unanticipated changes in mortality rates. It is only fairly recently that the stochastic nature of mortality rates has begun to be recognized. Figure 34.3 shows that aggregate mortality rates (in this case those of 80-year-olds in the USA and England and Wales) have been generally declining, but that changes have an unpredictable element, not only from one period to next but also over the long run.

A large number of products in the pension and life insurance industries count longevity as a key risk, DB pension plans and annuities being important examples. These products expose the providers to the risk of unanticipated changes in the mortality rates of the relevant reference populations over very long periods of time. In particular, the remarkable increases in survival at older ages since the second half of the twentieth century (see, e.g., Kannisto 1994, Vaupel 1997) represent a trend of growing concern to annuity providers and DB pension plan sponsors.

To be more specific, annuity providers are exposed to the risk that the mortality rates of annuitants will fall at a faster rate than accounted for in their pricing and reserving calculations. Annuities are commoditized products selling on the basis of price, and profit margins have to be kept low for competitive reasons. If the mortality assumption built into the price of annuities turns out to be a gross overestimate (and, as a result, the longevity prediction a gross underestimate), this will reduce, or even eliminate, the profit margins of annuity providers. The impact on DB pension plans is similar. If the mortality assumption built into the budgeted cost of pension provision turns out to be a gross overestimate, then pension plan sponsors—public sector and corporate alike—will see funding deficits emerge, necessitating possibly significant additional contributions to fill the gap.

34.2.2 *Impact of Longevity Risk*

As we have already noted, the cost of providing a pension or annuity depends on the expected long-term trend of future mortality rates. If the realized trend involves higher mortality improvements (i.e., lower mortality rates) than expected, then the cost of that pension or annuity can be significantly higher than expected. So longevity risk is not only a “volatility” risk (as most investment risks are) but also a “trend” risk (unlike most investment risks). Moreover it is a slowly building, cumulative trend risk. Mortality rates in future years depend on the cumulative mortality improvements between now and then, which only become significant over long timescales. Table 34.1 shows the increase in the cost of providing a pension or an annuity if mortality rates fall by just 1% more than the expectations of pension plans and annuity providers.³ The impact can be very substantial, particularly for younger pre-retirement beneficiaries and particularly if the pension includes an adjustment for inflation or cost of living.

34.3 Longevity Market Structure

This section reviews the structure of the market for longevity risk transfer. It describes the different segments of the market, the various participants in the market, and the range of products that have been used to transfer longevity risk.

34.3.1 *Defining the Longevity Market*

The market for longevity risk transfers is a part of the broader life market that encompasses transactions of different kinds, many of which have existed for a considerable time. These transactions include:

- Pension buyouts (also referred to as pension plan terminations), which transfer pension liabilities and all the associated risks and obligations to insurers. These are insurance solutions.

³The figure of 1% is taken to standardize the measurement of the sensitivity, or elasticity, of pension costs to changing mortality rates. As such, this sensitivity is analogous to the concept of duration in finance which measures the sensitivity to changes in interest rates. For this reason, it is often referred to as “mortality duration” or “q duration” (Coughlan et al. 2007a, 2008b).

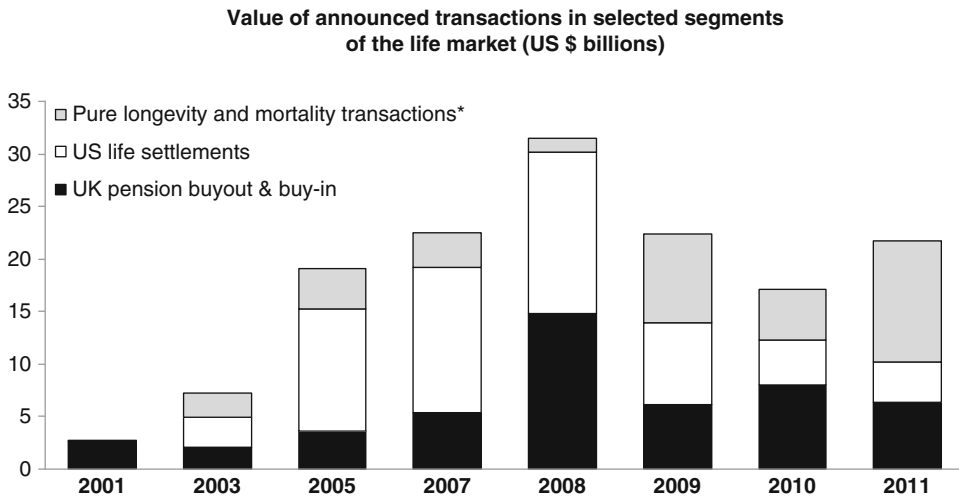


Fig. 34.4 Value of publicly announced transactions in selected segments of the life market, 2001–2011. *Includes longevity swaps (insurance and capital markets format) and mortality catastrophe transactions (Source: Sanford Bernstein, ABI. Mercer Oliver Wyman, J.P. Morgan, Life Settlement Solutions, Inc., Fasano Associates, Swiss Re Capital Markets, Aite Group, Hymans Robertson, Artimis, J.P. Morgan)

- Pension buy-ins which transfer a portion of the longevity risk and investment risk to insurers through the bulk purchase of annuities by the pension plan. These are insurance solutions.
- Bulk annuity and reinsurance deals which transfer annuity portfolios between insurers/reinsurers. These are also insurance solutions.
- Longevity bonds which transfer longevity risk from a pension plan or annuity portfolio to another party in the form of a security. These are capital markets solutions.
- Longevity swaps which transfer just longevity risk from a pension plan or annuity portfolio to another party. These can be either insurance or capital markets solutions.
- Mortality catastrophe bonds and swaps which transfer the risk of a devastating (catastrophic) rise in mortality due for example to a pandemic or natural disaster, from a life insurer or reinsurer to other parties. These are capital markets solutions.
- Life securitizations which transfer the risks associated with a particular block of insurance business to the capital markets in the form of a security. These are capital markets solutions.
- US life settlements transactions which transfer small portfolios of US life assurance policies to investors. These are capital markets solutions.

Figure 34.4 shows the development of public transaction values for selected life market segments from 2001 to 2011. Until 2009, a challenging year following the collapse of Lehman Brothers, the market had shown impressive growth, which only began to resume in 2011.

In this chapter, our focus is on the first five transaction types in the above list which are classified as “macro-longevity” transactions since they all involve a large pool of lives: pension buyouts, pension buy-ins, bulk annuity transfers, longevity bonds, and longevity swaps. These constitute the most important practical solutions for transferring the longevity risk linked to the provision of retirement income and define what we consider to be the “longevity market” for the purposes of this chapter. They are described in more detail below. We do not consider, in particular, the segments of the life

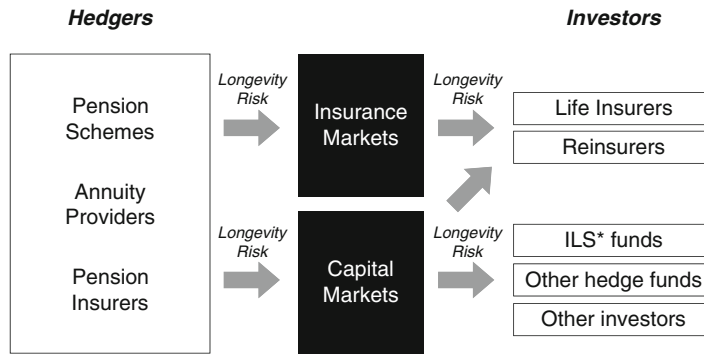


Fig. 34.5 The longevity risk transfer market. *ILS = insurance-linked securities

market associated with (1) hedging of mortality exposure by life insurers, (2) life securitizations, or (3) life settlements transactions (also called “micro-longevity” transactions).⁴

In defining the longevity risk transfer market, it is important to include transactions executed in both capital markets and insurance formats. These are alternative but complementary channels for achieving the same goal. The market operates by transferring longevity risk from DB pension plans and insurers to end holders of the risk, often via an intermediary, as shown in Fig. 34.5.

34.3.2 Longevity Market Participants

Three primary kinds of participants are usually involved in longevity transactions:

- **Hedgers:** These include insurers or annuity providers and pension plans that are naturally exposed to longevity risk and are seeking to reduce or eliminate it.
- **Investors:** These include insurers and reinsurers as well as capital markets investors. The latter include insurance linked securities (ILS) funds, hedge funds, sovereign wealth funds, family offices and endowments.
- **Financial intermediaries:** These include banks and other financial institutions that facilitate risk transfer and in many cases stand between hedgers and investors. Note that financial intermediaries such as banks are unlikely to be longterm holders of significant amounts of longevity risk but they may temporarily warehouse the risk to facilitate liquidity provision.

Capital markets investors are a new and important group of participants in the longevity market. While the number of investors that are in a position to invest directly in longevity risk is currently limited, a much larger number are in various stages of evaluating it as an asset class and developing the necessary skills and infrastructure. To them, longevity represents a new investment opportunity offering a positive risk premium and the benefit of diversification by virtue of having very low correlations with traditional asset classes.

⁴A life settlement involves the sale of a life insurance policy to a third party for more than its cash surrender value, but less than its net death benefit. The third party takes on the obligation to pay the premiums on the policy and receives the eventual benefit payout. As such, the third party is exposed to the longevity risk of the insured life. The securitization of pools of life settlements began in 2004 and these pools have generally been small, typically containing the policies of at most a few hundred individuals—hence the term “micro longevity”. The first life settlement securitization was a \$63 million issue by Tarrytown Second LLC in 2004, which was backed by life policies with a face value of \$195 million.

Financial intermediaries can be useful for capital-markets-based longevity transactions for three reasons:

- *Liquidity provision.* By providing liquidity to both sides of the market, it is unnecessary for hedgers to wait for interested investors to enter the market before hedging and vice versa. Moreover, the hedge remains in place if an investor redeems its longevity investment.
- *Credit intermediation.* By fulfilling the role of counterparty to both hedgers and investors, credit counterparty exposure can be left with institutions such as banks that are best equipped to manage it.
- *Repackaging.* Many investors want to take longevity risk in different forms from that in which hedgers want to shed it. By standing in the middle, intermediaries can tranche exposures into different parcels to meet the specific needs of different investors and hedgers.

34.3.3 *The Capital Markets as a Channel for Longevity Risk Transfer*

We have already noted that the capital markets are a complementary channel for longevity risk transfer. The development of a vibrant channel for longevity risk transfers to the capital markets is widely seen as beneficial for the insurance industry in terms of facilitating the efficient management of capital and building additional insurance capacity. In particular, the capital markets bring a number of benefits including:

- *Additional capacity for bearing longevity risk.* The universe of end holders of longevity risk is expanded beyond insurers and reinsurers to include capital markets investors.
- *Greater diversity of counterparties.* Hedgers are not restricted to transact just with insurers and reinsurers but can also transact with investment banks, exchanges and other intermediaries.
- *Liquidity.* Appropriately designed capital markets contracts have the potential to be highly liquid which is not the case with insurance contracts.
- *Fungibility.* Longevity hedges or investments transacted with one institution have the potential to be unwound with another institution offering better pricing.
- *Counterparty credit exposure management.* Longevity hedges transacted as capital market derivatives are required to be fully collateralized on an economic or marked to market, basis to reduce counterparty credit exposure. In the past, this requirement has generally not been the case with insurance transactions although it is now changing for longevity transactions.

There are three main differences between capital markets and insurance-based longevity transactions:

- The legal form of the contract (insurance contract vs financial contract).
- The counterparty facing the hedger, which for insurance based hedges must be an insurer, while for capital markets hedges there is no specific requirement.
- The nature of the end holder of the risk is different. With insurance-based hedges the risk will end up with insurers and/or reinsurers, whereas for capital markets hedges the end holders of the risk can include capital markets investors.

Despite these differences, the two kinds of transactions, when appropriately structured, achieve a similar result in economic terms. The choice between the two comes down to relative pricing and the preferences of, and restrictions faced by, the counterparties.

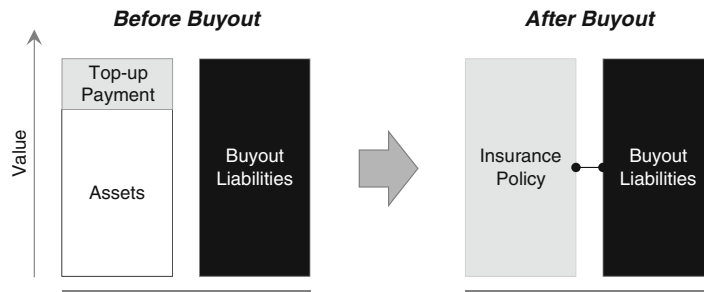


Fig. 34.6 The impact of a buyout on a DB pension plan. Note that the pension assets and liability are removed from the sponsor's balance sheet

34.3.4 Buyouts, Buy-Ins and Bulk Annuity Transfers

The traditional solution for managing the longevity risk in a DB pension plan or an annuity portfolio is to transfer the liability, along with all its risks, to an insurer (or reinsurer) via a contract of insurance (or a reinsurance treaty), using the insurance channel described above.

Buyouts are the endgame for DB pension plans in that they remove the pension liability from the balance sheet of the sponsor.⁵ This process typically involves transferring the assets and liabilities of the pension plan to an insurer, along with a top-up payment required to bring the assets up to the level of the so-called buyout liability (Fig. 34.6). The buyout liability is typically larger than the accounting liability (under both IFRS and US GAAP), as it reflects what are typically higher and more realistic longevity assumptions, discounting based on the swap curve, expenses, and a risk premium. According to one UK pension consultant, 2011 buyout pricing was approximately at a 15% premium to the accounting liability for pensioners and 25% for non-pensioners (LCP 2011).

Buy-ins involve the bulk purchase of annuities by the pension plan to hedge the risks associated with a subset of the plan's liabilities, typically associated with retired members. The annuities become an asset of the plan and reflect the mortality characteristics of the plan's membership in terms of age and gender. Buy-ins are often used as a staging post on the road to full buyout. They can be thought of as providing a "downsizing" of the pension plan in economic terms but not necessarily in accounting or regulatory terms. They enable the plan to lock-in attractive annuity rates over time, without the risk of a spike in pricing at the time they decide to proceed directly to a full buyout. Buy-ins also offer the sponsor the advantage of full immunization of a portion of the pension liabilities for a much lower (or even zero) up-front cash payment relative to a full buyout. Since the annuity contract purchased in a buy-in is an asset of the pension plan, rather than an asset of the plan member, the pension liability remains on the balance sheet of the sponsor. A common type of buy-in in the UK has been the pensioner buy-in, in which the liabilities associated with retirees who are currently receiving their pensions are matched with an annuity (see Fig. 34.7). Pensioner buy-ins are cost-effective because, for a given liability value, there is less risk associated with pensioners than with younger preretirement members of the plan.

"Synthetic buy-ins" are a relatively recent development, which provide essentially the same economic effects as a buy-in but without annuity contracts. They are implemented using swaps: a longevity swap to remove longevity risk and interest rate and inflation swaps to remove the interest

⁵Buyouts are therefore only suitable for DB pension plans which have closed not only to new members but also to future accrual of pension entitlements by existing plan members.

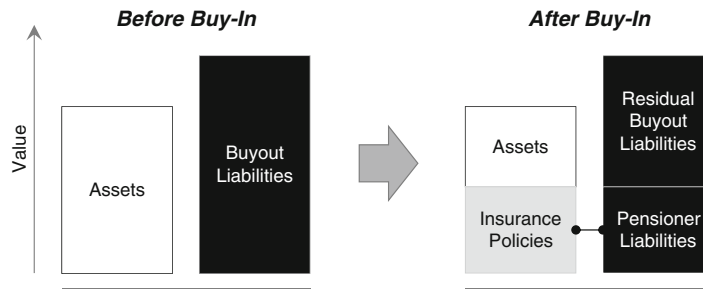


Fig. 34.7 The impact of a pensioner buy-in on a DB pension plan. Note that the buy-in liabilities and by-in assets remain on the sponsor’s balance sheet

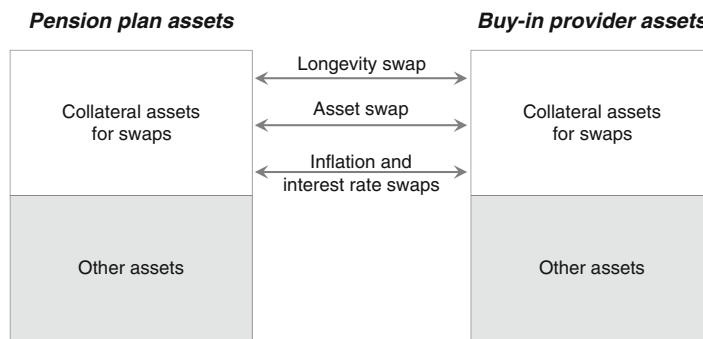


Fig. 34.8 A synthetic buy-in for a DB pension plan

rate and inflation risks associated with the liabilities. They can also include an asset swap or a total return swap (TRS) which is used to reduce funding costs (Fig. 34.8).

So-called noninsured buyouts involve transferring pension liabilities to institutions that are not regulated insurance companies. This keeps the pension plan in the pension regulatory regime, rather than transferring it to the insurance regulatory regime. These transactions are effected by selling an entity containing the pension plan to another company which takes over responsibility for that plan. Noninsured buyouts offer the promise of being more affordable for the sponsor but are subject to considerable scrutiny by regulators and plan fiduciaries. The detailed way in which these transactions are structured can differ significantly from case to case. They first came to prominence in 2007 when there were four such deals executed in the UK, as discussed below. The endgame for the transferred pension fund is still likely to be a full buyout with an insurance company at a later date.

There are different ways in which an insurer or reinsurer can transfer the bundle of risks associated with annuity exposure. This can be done, for example, in full (analogous to pension plan buyouts) where the individual policies are transferred to a new insurer.

Alternatively, there are partial risk transfer solutions such as “quota share” reinsurance treaties in which the reinsurer accepts a stated percentage of each and every risk within a defined block of annuities on a pro rata basis. Participation in each risk is fixed and certain. In contrast to a pension buy-in which transfers 100% of the risk associated with a subgroup of individuals, a quota share transaction transfers a percentage of the risk associated with each individual’s policy.

34.3.5 Solutions for Hedging Pure Longevity Risk

The solutions currently available for hedging pure longevity risk can be classified broadly according to three characteristics:

- *Format*: Insurance versus capital markets
- *Design*: Customized (or indemnity) versus index (or parametric)
- *Structure of instrument*: Swap versus forward, versus out-of-the money hedge

The “format” characteristic refers to the legal nature of the contract. Most longevity swaps executed so far have been in insurance format, although the first actively publicized longevity swaps were in capital markets format, as was the first swap with a pension plan. A mix of formats is even possible in the same deal. For example, hedging with a capital markets swap and then passing that risk onto a reinsurer in insurance format via a transformer entity.

The “design” characteristic reflects the nature of the longevity risk associated with the hedging instrument and can be broken down into two categories: customized and index hedges. A customized hedge is one in which the performance of the hedging instrument is linked to the actual longevity experience of the individuals associated with the exposure that is being hedged. An example is the actual members of a pension plan or the actual annuitants in an annuity portfolio. By contrast, an index hedge is one in which the performance of the hedging instrument is linked to an index reflecting the longevity or mortality experience of what is typically a larger pool of lives, such as a national population. Customized hedges have the advantage of potentially providing a nearly perfect hedge, whereas index hedges will generally leave an element of residual risk, called basis risk, because the population associated with the exposure is different from the population associated with the hedging instrument.

Recent research has shown that when appropriately calibrated, index hedges can be 85% effective in reducing longevity risk (Coughlan et al. 2011). These hedges bring other advantages in terms of standardization, transparency, greater appeal to investors, and the potential for higher liquidity. Index hedges are also extremely well suited to hedge the longevity risk associated with (preretirement) deferred pension and deferred annuity benefits. For these individuals, longevity risk is all value risk not cash flow risk, and because indices reflect the longevity trend risk that is used in valuation and pricing, index-based hedges can provide effective hedges for this risk. Furthermore, preretirement pension members often have options in terms of taking a lump sum and the size of their spouse’s pension, so that the longevity risk is not well defined or easy to quantify, and, as a consequence, a long-term customized hedge can be inappropriate and expensive. Furthermore, customized hedges are generally not available for deferreds, except if they are part of a pension plan which also has a large number of pensioners, or if they are older deferreds whose retirement is relatively close.

Another difference between these two types of hedges is that customized hedges are generally designed to hedge liability cash flows, whereas index hedges are generally designed to hedge the liability value, i.e., the present value of the liability cash flows. Customized hedges have, however, been used to hedge the liability value.

Labeling instruments as either customized or index hedges, however, is perhaps too simplistic an approach for classifying the types of instruments that are in the market. Even at this early stage of market development, hybrid hedges that combine some of the features of each have emerged. For example, hedges of pension liability value have been constructed using a specific bespoke index that is based on the realized mortality experience of the actual pension plan members.

The actual “structure” of the hedging instrument is the third characteristic of pure longevity risk transactions. The most common structure used to date has been the survivor longevity swap (frequently abbreviated to simply “longevity swap”). This, however, is far from being the simplest hedging instrument. For this reason, we begin our discussion with the mortality forward, or q-forward, instrument.

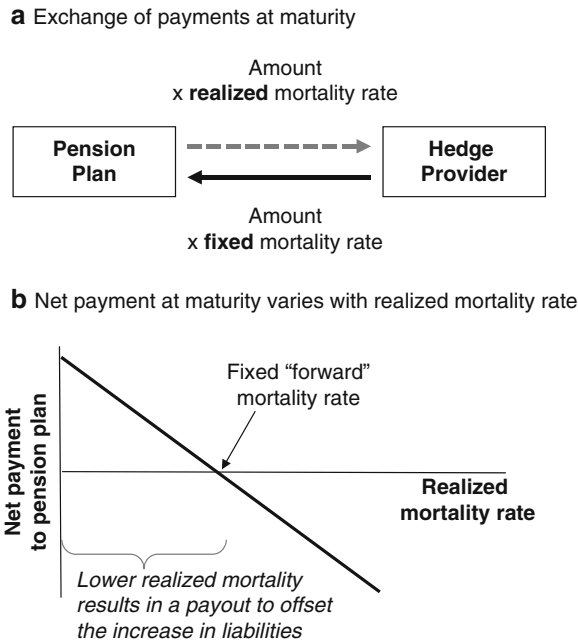


Fig. 34.9 A q-forward involves (a) the exchange of cash flows at maturity, leading to a payout (b) that increases as realized mortality rates fall

34.3.6 Mortality Forward (*q*-Forward)

A mortality forward rate contract is often referred to as a “q-forward” because the letter “q” is the standard actuarial symbol for mortality rates. It is the simplest type of instrument for transferring longevity (and mortality) risk (Coughlan et al. 2007b) and was the first type of capital markets longevity hedge to be executed. This was a deal between UK pension insurer Lucida and J.P. Morgan and is described in the next section.

The importance of q-forwards rests in the fact that they form basic building blocks from which other, more complex, life-related derivatives can be constructed. When appropriately designed, a portfolio of q-forwards can be used to replicate and to hedge the longevity exposure of an annuity or a pension liability or to hedge the mortality exposure of a life assurance book.

A q-forward is defined as an agreement between two parties in which they agree to exchange an amount proportional to the actual, realized mortality rate of a given population (or subpopulation), in return for an amount proportional to a fixed mortality rate that has been mutually agreed at inception to be payable at a future date (the maturity of the contract). In this sense, a q-forward is a swap that exchanges fixed mortality for the realized mortality at maturity, as illustrated in Fig. 34.9a. The variable used to settle the contract is the realized mortality rate for that population in a future period.

The fixed mortality rate at which the transaction takes place defines the “forward mortality rate” for the population in question. If the q-forward is fairly priced, no payment changes hands at the inception of the trade, but at maturity, a net payment will be made by one of the two counterparties (unless the fixed and actual mortality rates happen to be the same). The settlement that takes place at maturity is based on the net amount payable and is proportional to the difference between the fixed mortality rate (the transacted forward rate) and the realized reference rate. Figure 34.9b shows the settlement for different potential outcomes for the realized reference rate. If the reference rate in the reference

year is below the fixed rate (i.e., lower mortality), then the settlement is positive, and the pension plan receives the settlement payment to offset the increase in its liability value. If, on the other hand, the reference rate is above the fixed rate (i.e., higher mortality), then the settlement is negative and the pension plan makes the settlement payment to the hedge provider, which will be offset by the fall in the value of its liabilities. In this way, the net liability value is locked-in regardless of what happens to mortality rates. The plan is protected from unexpected changes in mortality rates.

34.3.7 *Survivor Forward (S-Forward)*

A survivor forward or “S-forward” is similar in concept to a q-forward but instead uses survival rates rather than mortality rates. It is an arrangement between two parties in which they agree to exchange an amount proportional to the actual, realized survival rate of a given population (or subpopulation), in return for an amount proportional to a fixed survival rate that has been mutually agreed at inception to be payable at the maturity of the contract. As such it involves the exchange of (1) a notional amount multiplied by a pre-agreed fixed survival rate in return for (2) the same notional amount multiplied by the realized survival rate for a specified cohort over a given period of time (Coughlan et al. 2008b; Dawson et al. 2010).

If the maturity of the contract is 1 year, then a survivor forward is the inverse of a mortality forward. But if the contract maturity is greater than a year, this simple relationship no longer exists, since survival rates over periods longer than a year are nonlinear functions of the annual mortality rates. A survivor forward is therefore more complex than a q-forward, since it is a function of several mortality rates at different ages and different times. Nevertheless, it can be a useful building block in certain situations.

34.3.8 *Longevity Swaps*

A longevity swap can be either a capital markets derivative or an insurance contract. In either case, it is an instrument which involves exchanging actual pension payments for a series of pre-agreed fixed payments, as indicated in Fig. 34.10 (Dowd et al. 2006). Each payment is based on an amount-weighted survival rate.

In any longevity swap, the hedger of longevity risk (e.g., a pension plan) receives from the longevity swap provider the actual payments it must pay to pensioners and, in return, makes a series of fixed payments to the hedge provider. In this way, if pensioners live longer than expected, the higher pension amounts that the pension plan must pay are offset by the higher payments received from the provider of the longevity swap. The swap therefore provides the pension plan with a long-maturity, customized cash flow hedge of its longevity risk. Figure 34.11 shows an example of the flow of longevity swap payments, which is based on the pioneering Canada Life-J.P. Morgan transaction of July 2008 (Trading Risk 2008; Life and Pensions 2008).

34.3.9 *Variants on Longevity Swaps*

One variant on the standard longevity swap is the transaction executed by Aegon and Deutsche Bank in January 2012. This transaction was a so-called “out-of-the-money” longevity swap as it only transferred the longevity risk associated with a very large increase in life expectancy (or equivalently, a

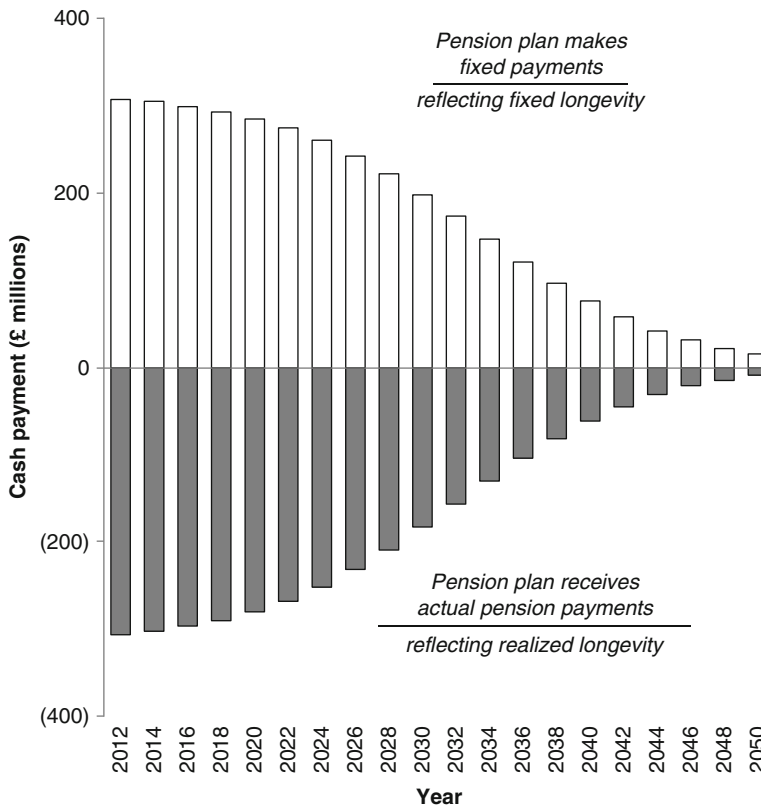


Fig. 34.10 A longevity survivor swap involves the regular exchange of actual realized pension cash flows and pre-agreed fixed cash flows

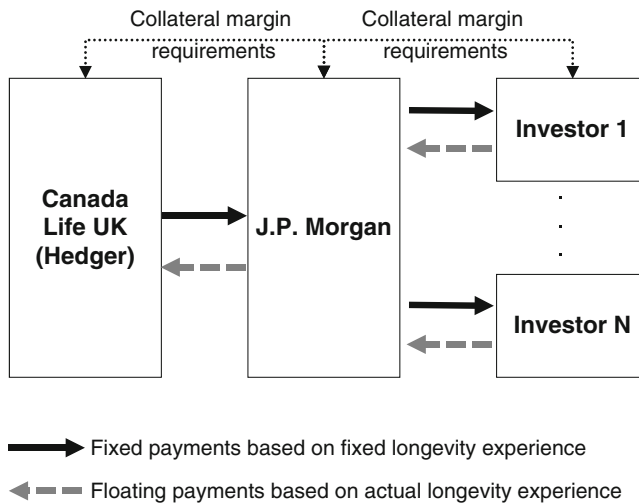
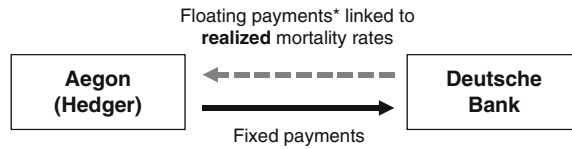


Fig. 34.11 The longevity survivor swap transaction between Canada Life and J.P. Morgan in July 2008

a Regular payments over the 20-year life of the transaction



b Payment at maturity (after 20 years)

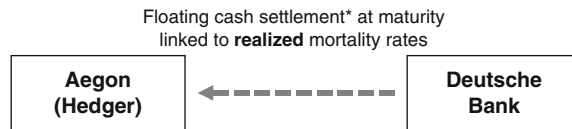


Fig. 34.12 Deutsche Bank-AEGON out-of-the-money longevity swap involves regular payments and a final commutation payment at maturity. *Note: Floating payments are capped and floored

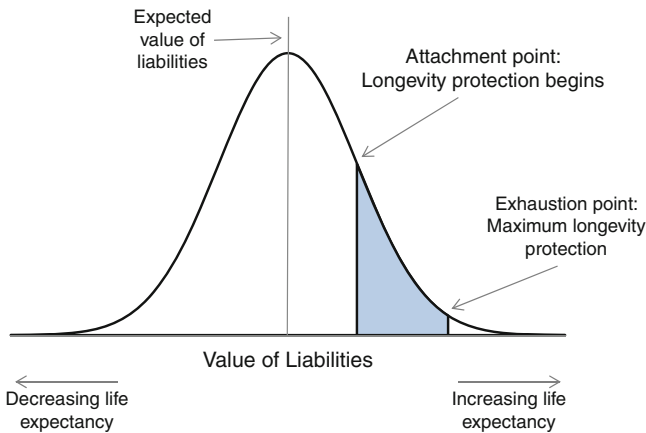


Fig. 34.13 Deutsche Bank-AEGON out-of-the-money longevity swap provides protection only if life expectancy increases beyond a certain level

very large and sustained fall in mortality rates). The hedger (Aegon) receives no incremental payment for modest increases in life expectancy until a certain threshold, or “attachment point,” is breached. Thereafter Aegon receives payments that increase with increasing life expectancy until a certain maximum level of protection is achieved when life expectancy rises to a very extreme level (the so-called exhaustion point). This swap is effectively a standard longevity swap except that the floating payments have caps and floors on them. See Fig. 34.12.

Some of the other details of the transaction are summarized in Fig. 34.13. It was a 20-year index-based swap in capital markets format, where the index corresponded to Netherlands national population data. Like the Aviva-RBS transaction in 2009, this swap also included a commutation payment at maturity designed to provide longevity protection for all liability cash flows occurring beyond the maturity date.

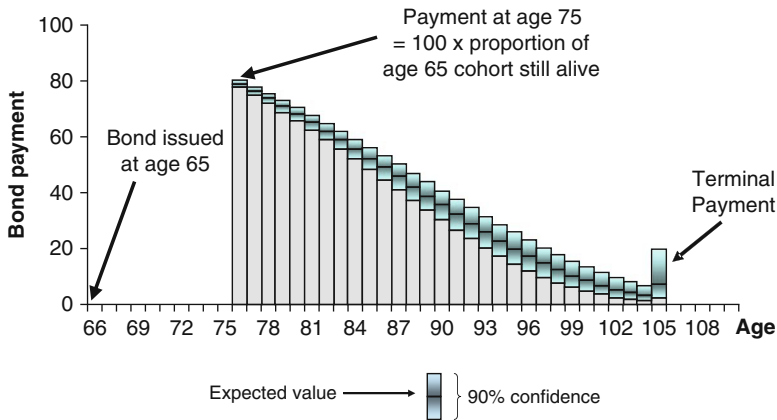


Fig. 34.14 A deferred longevity bond for a cohort of 65-year-old males. Bond payable from age 75 with a terminal payment at age 105 to cover post-105 longevity risk

34.3.10 Longevity Bonds

Since before the start of this market, there has been much talk about longevity bonds, as a means to hedge longevity risk. A longevity bond (or a survivor bond as it was originally called) is a bond that pays coupons that are proportional to the number of survivors still alive on the coupon payment date from a specified population cohort, say, the population of 65-year-old males alive on the issue date of the bond (Blake and Burrows 2001; Dowd 2003; Blake et al. 2006a, b). The cash flows of a plain vanilla longevity bond are identical to those on the floating leg of a longevity swap. Recently, however, longevity bonds have been proposed with different structures. Figure 34.14 shows the potential range of cash flows on a deferred longevity bond as discussed in Blake et al. (2010). The bond’s cash flows are indexed to the mortality experience of 65-year-old males from the national population of the UK. There is a 10-year deferral period before payments commence and there is a terminal commutation payment at age 105 to cover post-105-year age longevity risk. If more people survive to each age than expected, then the bond will pay out more; if fewer people survive, the bond will pay out less.

Despite several attempts, no pure longevity bond has yet been issued. The Swiss Re Kortis bond which we shall discuss in more detail later was not a true longevity bond, because it involved transferring the risk associated with the *spread* between the longevity trends for two different groups of individuals, rather than the trend itself. Perhaps the most well known bond not to be issued was the EIB-BNP Paribas longevity bond (Azzopardi 2005) that was announced with much fanfare in 2004. It was unsuccessful for several reasons connected with its structure and the lack of education of its target market (Blake et al. 2006a).

In 2006, the World Bank engaged the insurance regulator in Chile, the *Superintendencia de Valores y Seguros* (SVS), on longevity hedging (Zelenko 2011). The SVS showed a willingness to promote longevity risk management and to provide explicit regulatory capital relief to insurers who hedged the risk. An initial feasibility project was then conducted with the involvement of BNP Paribas in 2008, but the effort stalled due to the high cost of the proposed World Bank-issued longevity bond structure. Then the World Bank turned to the J.P. Morgan longevity team in 2009, who developed a more cost-effective 25-year maturity longevity bond structure that was designed to provide an effective hedge, with minimal basis risk, for all Chilean insurers. The longevity bond was to be issued out of a collateralized SPV, with Munich Re providing the longevity hedge to the entity and J.P. Morgan

managing the cash flow mismatch between the various payment streams (Coughlan 2009; Life and Pensions Risk 2010).

This bond, like the others before it, faced a number of obstacles and was not successful. Some of the most significant included:

- The separation between the investment and actuarial departments at Chilean insurers meant that there was no clear focus for decision-making responsibility.
- The insurers' perception of longevity risk was that it was not significant and therefore not in need of hedging. As a result they regarded the cost as relatively high despite the capital relief and despite the return on the bond being above government yields.
- Basis risk was perceived as slightly too high despite being minimized by indexing the bond to the universe of actual annuitants.

34.3.11 *The Potential Role of Governments in Issuing Longevity Bonds*

In principle, longevity bonds could be issued by private-sector organizations. Some argue that pharmaceutical companies would be natural issuers, since the longer people live, the more they will spend on medicines.⁶ While the theory may be correct, the scale of the demand for longevity bonds far exceeds conceivable supply from such companies. Further, significant credit risk would be associated with the private-sector issuance of an instrument intended to hedge an aggregate risk many years into the future.

Recently there have been calls for governments to issue longevity bonds in order to help catalyze the longevity market by providing a visible and transparent longevity pricing point (Blake and Burrows 2001; Blake et al. 2010). The government may be better able to issue longevity bonds in the required volume and also has an interest in promoting an efficient and well-functioning annuity market, safeguarding the solvency of insurance companies, and facilitating the efficient spreading of longevity risk via the development of a capital market in longevity risk transfers. The International Monetary Fund has recognized government involvement in a longevity bond market as potentially useful, as have the authors of an OECD working paper and the World Economic Forum.⁷

Although the government would play a key role in getting the market started, eventually its role could be limited to providing only tail risk protection. That is, once the market for longevity bonds has matured, in the sense of producing stable and reliable price points in the age range 65–90, the capital markets could take over responsibility for providing the necessary hedging capacity in this age range, in the form of, say, longevity swaps. All that might then be needed would be for the government to provide a continuous supply of deferred tail longevity bonds with payments starting at, say, age 90.⁸ Figure 34.15 illustrates the cash flows on such a bond. These bonds would allow for full hedging of longevity risk and also permit potential longevity investors to avoid assuming long-duration tail longevity risk, a risk for which they have no appetite.

Some contend (e.g. Brown and Orszag 2006) that the government is not a natural issuer of longevity bonds because of its large existing exposure to longevity risk through the social security system and pensions for public employees. Here several considerations may be relevant. First, the government would receive a longevity risk premium from issuing the bonds, that is, the price at

⁶See Dowd (2003).

⁷International Monetary Fund (2012), Antolin and Blommestein (2007), and World Economic Forum (2009)

⁸Pension plans and annuity providers might still be willing to invest in government-issued longevity bonds covering the age range 65–90 if they are competitively priced compared with capital market hedges.

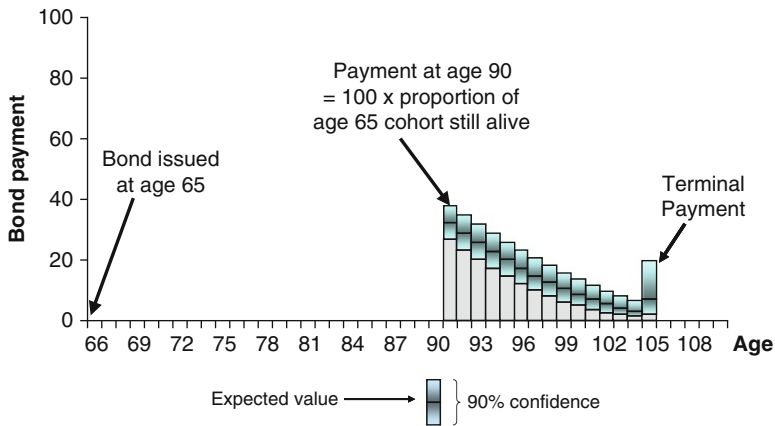


Fig. 34.15 A deferred tail longevity bond for a cohort of 65-year-old males. Bond payable from age 90 with a terminal payment at age 105 to cover post-105 longevity risk

which the government will be able to sell the bond would exceed the expected present value of the coupons payable on the bond, discounted by the interest rate on government securities of comparable maturities; the reason is that insurance companies holding longevity bonds would need to hold less capital against the risk of mortality improvements being more rapid than expected. Second, the government could control the ultimate cost of the pensions by increasing the official retirement age should longevity increase dramatically.⁹ Third, the issuance of longevity bonds should result in a more efficient annuity market and hence higher incomes in retirement, perhaps reducing the need for means-tested retirement benefits. Fourth, the benefits to government finances would start to accrue immediately, whereas the tail risk protection provided by deferred tail longevity bonds would only start to be payable 25 years in the future when the first insured cohort turns 90. Finally, one could argue that the risk is consistent with the government's role of facilitating intergenerational risk sharing. However, the reception from governments in several different countries has at best been lukewarm so far.

34.4 Evolution of the Longevity Market

34.4.1 The Birth of the Longevity Market

Although transactions of the type listed above have been around for some time, we consider 2006 to mark the birth of the longevity market as we know it. The start of the market can be traced back to the establishment and authorization of Paternoster, a new monoline insurer set up specifically to acquire UK DB pension plans. Prior to this time, the buyout market in the UK comprised pension plans that were being wound up, often due to the insolvency of the sponsor. The market was characterized by a large number of small transactions typically totaling £1.5–2 billion a year, virtually all provided by two UK insurers: Legal & General and Prudential PLC (UK).¹⁰

⁹Governments throughout the world are beginning to do this in any case and will have to continue doing so if longevity continues to improve.

¹⁰Not to be confused with the US insurer of the same name.

Paternoster received regulatory authorization from the Financial Services Authority (FSA)¹¹ in June of 2006 and was followed by the launch of a number of similar specialist insurers including Pension Insurance Corporation (PIC), Synesis (which was later acquired by PIC), and Lucida, all of which were backed by investment banks and private equity investors. In February 2007, Goldman Sachs established its own pension insurer, Rothesay Life.¹² These new entrants shook up what was a very sleepy and low-volume market for pension buyouts, eventually galvanizing a number of mainstream life insurers and reinsurers from the UK and elsewhere to enter the UK longevity market and sharpen their tools.

Paternoster conducted its first pension buyout in November 2006 of the Cuthbert Heath Family Plan, a small plan with just 33 pensioners. It went on to dominate the buyout market in 2007 winning a 50% share of the £2.94 billion transacted from 21 deals. Legal & General, the long-standing incumbent, achieved 40% of the market but from 162 deals. An important transaction milestone in this new market took place in January 2007 when the first deal over £100 million (a pensioner buy-in) was completed for Hunting PLC, an energy services provider to oil and gas companies. By the end of that year, the market had begun to take off, with seven deals over £100 million closed and nearly £2 billion of transactions completed in the fourth quarter alone.

The following year, 2008, saw tremendous growth with buyout/buy-in volumes rising from £2.9 billion to £7.9 billion, with Legal & General and PIC dominating the market, accounting for a 46% market share between them. Prudential PLC (UK) won its first sizable deal in September with a £1.05 billion collateralized buy-in for Cable & Wireless. But it was a smaller transaction, the £360 million pensioner buy-in executed by Friends Provident with Aviva, which was the first insurance deal to include a collateral arrangement. Rothesay Life also won its first deal during the year with a £700 million buyout of the Rank pension plan. It was reported that Rothesay beat off competition from more than 10 other providers, including insurers such as Legal & General, Prudential, Paternoster, and Synesis Life, as well as other investment banks offering longevity swap solutions. In November, another newcomer, US insurer MetLife, closed its first transaction, worth £130 million, with Vivendi.

In 2009, PIC eclipsed Legal & General to become the leading buyout/buy-in provider by volume, but overall volumes were down over 50% at just £3.7 billion. Following the Lehman Brothers collapse in September of the previous year, the established UK insurers had limited appetite for taking on risk, preferring to focus on capital management and cash generation. As a result, the newer entrants, such as Lucida, MetLife, and Rothesay Life, were able to increase market share. This year also saw the first pension plans implementing longevity swaps to hedge longevity risk. We defer our discussion of the longevity swap segment of the market until a little later, but it is significant to note that between June and December five different plans (three of them with the same sponsor) put on longevity swaps totaling £4.1 billion. So the overall volume of longevity risk transferred out of pension plans totaled £7.8 billion for the year.

By the end of 2010, nearly £30 billion of longevity transactions of various types (buyouts, buy-ins, and longevity swaps) had been completed in the UK since 2006. The total volume transacted in 2010 was £8.3 billion which was a modest increase on 2009. The 2010 figure was dominated by three large transactions: British Airways £1.3 billion synthetic buy-in, GlaxoSmithKline's £900 million buy-in, and BMW (UK)'s £3 billion longevity swap. Rothesay Life had also now taken the lead position in terms of market share.

Up to the end of the third quarter of 2011, total buyout/buy-in volumes stood at £2.1 billion and longevity swap volumes at £1.8 billion. Since then, the Turner & Newall (T&N) Retirements Benefit Scheme completed the largest UK buyout to date, a £1.1 billion deal with Legal & General (Jones 2011). T&N was a subsidiary of bankrupt US vehicle component manufacturer Federal Mogul,

¹¹The FSA has now been replaced by the Financial Conduct Authority and the Prudential Regulation Authority.

¹²Paternoster was itself acquired by Rothesay Life in January 2011.

and the deal leaves members with reduced pensions. The transaction was structured initially as a buy-in with the insurance policy held as an asset of the plan but will be converted to a buyout once the plan is wound up. Then the final 2 months of the year saw a £3 billion longevity swap completed by the Rolls-Royce Pension Fund, a second £1.3 billion longevity swap by British Airways, and a £1 billion longevity swap by Pilkington. This brought the total volume of longevity risk transfer to over £11 billion for the year.

34.4.2 *Noninsured Buyouts*

In 2007, the UK market witnessed the execution of the first “noninsured” buyouts. It is notable that one of these transactions was executed by an investment bank, Citigroup, which acquired the closed pension plan of Thomson Regional Newspapers in August 2007, by buying the sponsoring company for £200 million. That same year, another US investment bank, J.P. Morgan, filed a Private Letter Ruling on a new approach to noninsured pension risk transfers with the US tax authorities.

Pension Corporation (the parent of PIC) was behind the other three deals to close in 2007. They were all in different industrial sectors: Thorn (engineering), Thresher (retail), and Telnet (communications). The Thorn acquisition was completed in June 2007, and then some 18 months later in December 2008, PIC effected a full insurance-based pension buyout that valued the liabilities at £1.1 billion.

Noninsured buyouts are not generally included in market size figures.

34.4.3 *Longevity Swaps*

At the same time as Paternoster and the other monoline insurers were getting organized, several investment banks began making plans to enter the market. Over the course of the next couple of years, two investment banks—J.P. Morgan and RBS—established themselves as pioneers and innovators in the market place, each developing and executing highly innovative longevity risk transfer transactions. These transactions were the first capital markets longevity swaps and served as the prototypes for all the longevity swaps that have followed.

Both the birth of the longevity swap market and the birth of capital market solutions for longevity risk can be traced back to these deals. Although a number of longevity swap transactions took place as early as the 1990s, these deals were private, non-publicized insurance transactions and not part of a concerted effort to develop a longevity market. It was not until 2008, when momentum to establish the market began to build across the insurance and banking industries, that we saw the first such transactions announced publicly and the disclosure of many of their key details. It was these transactions that truly launched the market for longevity swaps.

The first such swap was a longevity hedge executed as a derivative in capital markets format by Lucida PLC, a pension buyout insurer, in January 2008 (Lucida 2008; Symmons 2008). The instrument was a q-forward linked to a longevity index based on England and Wales national male mortality for a range of different ages.¹³ The hedge was provided by J.P. Morgan and was novel not just because it involved a longevity index and a new kind of product, but also because it was designed as a hedge of value rather than a hedge of cashflow. In other words, it hedged the value of the annuity liability, not the actual annuity payments.

¹³The index used was the LifeMetrics Index which is discussed later in the chapter.

Following swiftly on the heels of this deal, J.P. Morgan recorded a second publicly announced transaction in July 2008, this time with Canada Life in the UK (Trading Risk 2008; Life and Pensions 2008). The hedging instrument in this transaction was different from that used by Lucida. It was a 40-year maturity £500 million longevity swap that was linked not to an index but to the actual mortality experience of the 125,000-plus annuitants in the annuity portfolio that was being hedged. It also differed in being a cash flow hedge of longevity risk. But most significantly, this transaction brought capital markets investors into the longevity market for the very first time, as the longevity risk was passed from Canada Life to J.P. Morgan and then directly on to investors (see Fig. 34.11). This has become the archetypal longevity swap upon which other transactions are based.

The third capital markets longevity swap to be completed was a hybrid of the first two, involving a hedge of both cash flow and value. It was a £475 million hedge provided in March 2009 by RBS for UK insurer Aviva, based on the actual mortality experience of annuitants. The longevity risk was also syndicated to a group of capital markets investors but in this case with a reinsurer—Partner Re—playing the role of lead investor (Towers Perrin 2009; Trading Risk 2010).

June 2009 saw the execution of the first longevity swap implemented by a UK pension plan. Babcock International implemented a series of customized longevity swaps totaling some £1.2 billion to hedge the longevity risk in its three UK pension plans. These were capital markets swaps transacted with Credit Suisse. Although the structure of the swap was not new, being essentially the same as that of the Canada Life-J.P. Morgan swap, it was significant in that it demonstrated the practical relevance of longevity swaps for pension plans.

Continued product innovation soon blurred the distinction between longevity swaps and pension buy-ins. An example of this is a synthetic buy-in. The first synthetic buy-in was transacted in July 2009 by the pension plan of RSA Insurance Group. This was essentially an asset-swap-funded longevity swap executed in insurance format with Rothesay Life which also incorporated hedges of inflation risk and interest rate risk. An important component in this £1.9 billion transaction was a TRS—of UK government securities (gilts) for higher-yielding government-backed Network Rail bonds—whose cash flows were used to fund the longevity swap. The key to the successful completion of this synthetic buy-in was the effective combination of insurance and capital markets capabilities across Rothesay Life and its parent, Goldman Sachs (Tsentas 2011).

December of the same year marked another milestone when the Royal County of Berkshire Pension Fund implemented the first longevity swap by a public sector pension plan. This £750 million swap covered 43% of the pension liabilities and was provided by Swiss Re in insurance format.

Another insurance-based longevity swap followed shortly afterwards in February 2010, when BMW (UK) transacted with Deutsche Bank's insurance subsidiary, Abbey Life (Stewart 2010). This time the swap was enormous, protecting nearly £3 billion of pension liabilities corresponding to some 60,000 pensioners, comprising both retirees and contingent pensions for spouses and dependants. In this transaction, Abbey Life also drew on the structuring expertise and longevity modeling experience of Paternoster, which at the time was also partly owned by Deutsche Bank.

Then, in January 2011, the Pall (UK) Pension Fund completed an index hedge of the longevity risk associated with the deferred (i.e., preretirement) members of the plan (Davies 2011; Mercer 2011). Despite being just £70 million in size, this hedge was significant in two respects. It was the first hedge of the longevity risk of younger preretirement members and the first hedge by a pension plan to use a longevity index. It was transacted with J.P. Morgan and involved a portfolio of q-forwards linked to a longevity index of national male mortality rates for England and Wales,¹⁴ calibrated to hedge the value of the deferred pensioner liability over a 10-year horizon.

August 2011 saw ITV PLC, a UK media company, announce the completion of a capital markets longevity swap between the ITV Pension Scheme and Credit Suisse (ITV 2011; Pensions World 2011).

¹⁴The index used was again the LifeMetrics Index.

The £1.7 billion swap hedges the longevity risk associates with 12,000 pensioners (retirees and their dependants). In November 2011, Rolls-Royce announced an even larger £3 billion longevity swap that it transacted with Deutsche Bank to cover the longevity risk of the 37,000 pensioners in its DB pension plan (Stapleton 2011; Deutsche Bank 2011). Then in December, British Airways announced a second synthetic buy-in involving £1.3 billion of liabilities, provided by Rothesay Life (Artemis 2011).

34.4.4 Transactions Between Insurers and Reinsurers

Most of the attention in the longevity market has been focused on transactions—buyouts, buy-ins, and longevity swaps—executed by pension plans. The pension consulting community, in particular, has largely ignored a sizable and important segment of the market, namely, that between different players in the insurance industry. Surprisingly, even the Longevity Chief Risk Officers (CRO) Briefing published by the CRO Forum in November 2010 focused almost exclusively on the pension segment. The insurance segment, however, is important because it deals with transactions between counterparties for which longevity is their business and a core skill. It also currently provides the vast majority of risk-bearing capacity to the market through reinsurance transactions and is instrumental in determining the availability of hedges to pension plans and their pricing.

Transfer of longevity risk between insurers is one part of this market segment. For example, in February 2007, Equitable Life completed the transfer of £4.6 billion of nonprofit UK pension annuities to Canada Life. Announced in May 2006, this deal was not completed until approval was obtained from the UK High Court to transfer the 130,000 individual policies to the new insurer. This was the same portfolio that Canada Life subsequently partially hedged with the capital markets longevity swap it executed with J.P. Morgan in July 2008. This latter deal reflects a second part of this market segment involving transactions between insurers and capital markets participants. Other examples of this include the J.P. Morgan-Lucida and RBS-Aviva longevity swaps and the Kortis bond issued by Swiss Re in 2010.

It is worth commenting further on the Swiss Re Kortis bond as it was the first successful securitization of longevity risk (Mortimer 2010). The bond is a small \$50 million BB+ rated issue maturing in 2017 and bought by capital markets investors. It provides cover to Swiss Re in the event that there is a divergence in mortality improvements between males aged 75–85 in England and Wales and males aged 55–65 in the USA, since Swiss Re has reinsured annuity business in the UK and life business in the USA. So it really transfers the risk associated with the spread between longevity trends for different populations, rather than true longevity risk. Nonetheless, it has still been hailed as a highly innovative transaction and was awarded the 2011 Structured Finance Deal of the Year by the *Banker* publication.

The other part of this segment involves reinsurance, whereby an insurer transfers part or all of its longevity risk to a reinsurer. An early example of this was the £1.7 billion transaction that Friends Provident signed with Swiss Re in April 2007. This deal was an insurance-based longevity swap which included a transfer of assets and was based on 78,000 pension annuity contracts written between July 2001 and December 2006. This was not the first insurance-based longevity swap executed, but some details about it, albeit very sketchy, started appearing in the market at a crucial time in its development. To this day, little is known about the structure of this deal, which was not subject to the same disclosure, publicity and transparency of the other longevity swaps we have discussed. As a result, its impact on the development of the market was minimal.

There are currently several reinsurers providing capacity to the UK longevity market, including Pacific Life Re, RGA, Swiss Re, Munich Re, Partner Re, SCOR, and Hannover Re. Reinsurers are currently the end holders of a large proportion of the risk that insurers and investment banks take on in providing longevity swaps and buyout/buy-in solutions to pension plans. By way of example,

for the massive £3 billion BMW longevity swap, Abbey Life had lined up a syndicate of reinsurers including Pacific Life Re, Hannover Re, and Partner Re to immediately pass on part of the risk. In May 2011, Prudential (USA) entered the UK market as a longevity reinsurer, providing £100 million of reinsurance to Rothesay Life. It has quickly emerged as a credible reinsurance competitor participating in three deals in a very short time.

34.4.5 *Looking Beyond the UK*

The UK has led the way in the longevity de-risking of pension plans, but certain other countries are showing some progress in this direction, in particular the USA, Canada, the Netherlands, and Australia.

The USA and Canada have fledgling buyout markets, but the level of awareness of, or concern about, longevity risk in the industry is still minimal. However, the US market received a boost in May 2011, when Prudential (USA) announced a \$75 million buy-in—the first of its kind—that it provided to the pension plan of Hickory Springs Manufacturing Company.

Canada is a market which sees a regular flow of DB pension buyouts and buy-ins, with an annual market size of around CAD \$1.5 billion. According to Sun Life Financial, buyouts have been a feature of the Canadian pensions landscape for over a century. Moreover, eight insurance companies regularly quote an annuity proxy rate that is published by the Canadian Institute of Actuaries. In 2011 the biggest buyout conducted in Canada was CAD \$400 million. Although buy-ins have been happening in Canada for many years, the first UK-style buy-in that was executed as part of a de-risking plan took place in 2009. This buy-in was CAD \$50 million in size and provided by Sun Life Financial. In May 2011, a new regulation was approved by the Ontario government to allow Nortel to execute a de-risking program and transfer the whole plan to another provider, which need not necessarily be an insurer (Pichardo-Allison 2011). Nortel had been Canada's biggest company and had filed for bankruptcy in 2009, leaving its underfunded CAD \$2.5 billion pension plan without a viable sponsor. This regulatory change included a one-time approval for Nortel pensioners to commute their benefits (i.e., take a lump sum). Contrary to what was initially reported, the purchase of annuities has not yet been completed but is expected in 2013/2014. More recently, in 2012 Sun Life announced a second buy-in worth CAD \$20 million for an unnamed Canadian DB pension plan.

In June 2012 General Motors Co. (GM) announced a huge deal to transfer up to \$26 billion of pension obligations to the Prudential (USA) (General Motors 2012). This is by far the largest ever longevity risk transfer deal globally. The transaction is effectively a partial pension buyout involving the purchase of a group annuity contract for GM's salaried retirees who retired before December 1, 2011 and refuse a lump-sum offer in 2012. To the extent retirees accept a lump-sum payment in lieu of future pension payments, the longevity risk is transferred directly to the retiree.¹⁵ The deal is a "partial buyout" rather than a buy-in because it involves settlement of the obligation. In other words, the portion of the liabilities associated with the annuity contract will no longer be GM's obligation. Moreover, in contrast to a buy-in, the annuity contract will not be an asset of the pension plan but instead an asset of the retirees.

Pension buyouts have been a feature of the industry in the Netherlands for a number of years but have been typically small in size, EUR20–50 million. In November 2009, the Hero pension plan implemented the first buy-in in the Netherlands, a EUR44 million deal with Dutch insurer, AEGON. The pension plan was looking to execute a buyout, but being just 100% funded on a buyout basis was concerned that market volatility might push the buyout out of reach before the necessary consent

¹⁵In fact, the lump sum is only being offered to limited cohorts of plan members.

from participants and the regulator could be obtained (Aegon 2010). The buy-in ensured that the funding level was locked-in and provided time to get these approvals. Then the buyout followed in early 2010. AEGON also closed a larger buyout in early 2011, with a EUR270 million deal for the Nutreco pension plan (Cobley 2010).

Then in February 2012, Deutsche Bank executed a massive EUR12 billion index-based longevity solution for AEGON in the Netherlands (Deutsche Bank 2012). As described in Section 34.3, this solution was based on Dutch population data and enabled AEGON to hedge the liabilities associated with a portion of its annuity book. Because the swap is out of the money, the amount of longevity risk actually transferred is far less than that suggested by the EUR 12 billion notional amount. Nonetheless the key driver for this transaction from AEGON's point of view was the reduction in economic capital it achieved. It is understood that most of the risk was intended to be passed to investors in the form of private bonds and swaps. This was the first such deal executed in continental Europe, but contrary to what was claimed in the press release, it was not the first longevity transaction to target directly the capital markets. That first was achieved by J.P. Morgan 4 years earlier in 2008.

While Australia does not boast a large defined benefit pension market for which longevity risk is a huge concern, it has nonetheless seen two longevity swap hedges executed by local insurers (Swiss Re 2010). Swiss Re provided these insurance-based swaps to hedge the longevity risk associated with the insurers' lifetime annuity portfolios by transferring longevity risk via a reinsurance treaty. Under the treaty, each insurer pays a stream of regular fixed premium amounts and receives a stream of regular floating annuity benefits. The two Australian insurance companies involved have wished to remain anonymous.

34.4.6 The Life and Longevity Markets Association

In February 2010, a group of insurers and investment banks launched a new trade association to promote the trading of longevity risk as an asset class. Called the Life and Longevity Markets Association (LLMA),¹⁶ its objectives included the development of standards, templates, and methodologies to facilitate the development of the market. It was started with 8 members and has since grown to 12. The members at the time of writing are Aviva, AXA, Deutsche Bank, J.P. Morgan, Legal & General, Morgan Stanley, Munich Re, Pension Corporation, Prudential PLC (UK), RBS, Swiss Re, and UBS. Over the course of 2010, LLMA released publications on longevity index design, product definitions, and a pricing framework. In 2013 it initiated a project on basis risk.

34.5 Framework for Longevity Hedging

34.5.1 Introduction

Hedges that do not provide full indemnification of longevity risk leave the hedger exposed to a residual basis risk, which must be measured and monitored. This has become essential with the advent of new types of longevity hedges, for example, those based on longevity indices, those designed to hedge value rather than cash flow, and those for which certain elements of the risk are excluded or simplified (e.g., hedges that exclude the longevity risk associated with spouses). Basis risk and hedge

¹⁶See www.llma.org.

Table 34.2 Framework for assessing hedge effectiveness

| | |
|--------|--|
| Step 1 | Define hedging objectives <ul style="list-style-type: none"> • Metric • Hedge horizon • Risk to be hedged (full or partial) |
| Step 2 | Select hedging instrument <ul style="list-style-type: none"> • Structure hedge • Calibrate hedge ratio |
| Step 3 | Select method for hedge effectiveness assessment <ul style="list-style-type: none"> • Retrospective vs. prospective test • Basis for comparison (comparing hedged and unhedged performance, valuation model, etc.) • Risk metric • Simulation model to be used |
| Step 4 | Calculate the effectiveness of the hedge <ul style="list-style-type: none"> • Simulation of mortality rates for both populations • Evaluation of effectiveness based on the simulations |
| Step 5 | Interpret the hedge effectiveness results |

effectiveness in relation to longevity risk transfer has been modeled by several authors, including [Coughlan et al. \(2007a\)](#), [Plat \(2009\)](#), [Li and Hardy \(2011\)](#), and [Coughlan et al. \(2011\)](#).

In this section, we summarize the framework for evaluating longevity basis risk and assessing hedge effectiveness recently published by [Coughlan et al. \(2011\)](#) and apply it to a case study involving a US pension plan that implements an index-based longevity hedge.

34.5.2 *Hedge Effectiveness Framework*

In any hedging situation, it is essential to understand and monitor the effectiveness of the hedge and the nature of any residual risk that is not fully offset by the hedging instrument. Longevity hedging is no exception. But because of the long-term nature and complexities associated with longevity risk, it is not straightforward to accurately assess hedge effectiveness. The study by [Coughlan et al. \(2011\)](#) sets out a non-prescriptive, model-independent framework that focuses on the hedging objectives and the nature of the risk that is being hedged to develop a methodology that is appropriate. The full description of the framework can be found in [Coughlan et al. \(2011\)](#), but Table 34.2 provides a summary of the five key steps. Note that this framework has been tailored specifically to longevity risk and is based on a more general hedge effectiveness framework developed by [Coughlan et al. \(2004\)](#).

A necessary prerequisite for implementing these steps is a thorough understanding of the nature of the longevity exposure that is being hedged and the nature of the basis risk between that and the hedging instrument.

34.5.3 *Case Study: Longevity Hedging of a US Pension Plan*

To illustrate this framework we now apply it to a case study involving an index-based longevity hedge of a hypothetical US pension plan. The case study has two components:

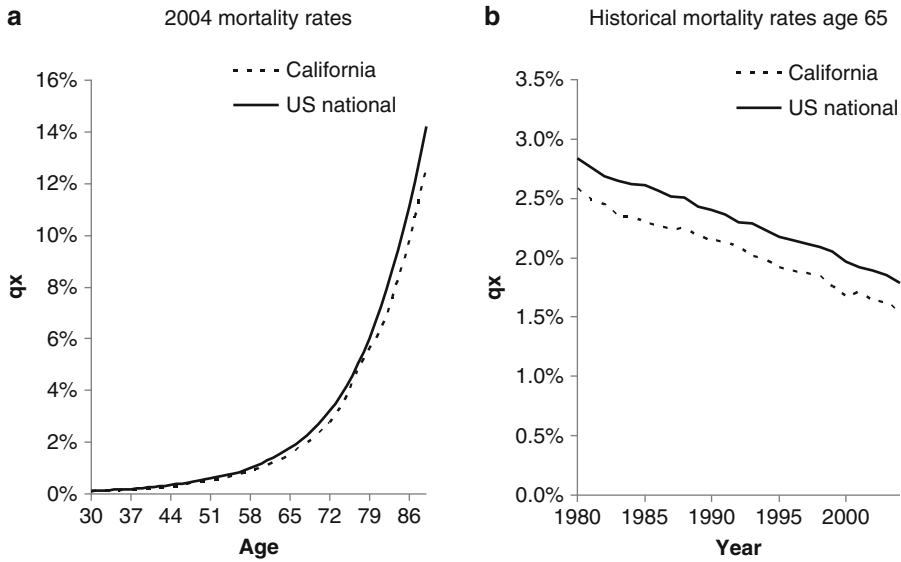


Fig. 34.16 A comparison of male mortality rates for California and the US national populations, (a) spot mortality curves for 2004 and (b) historical evolution of graduated mortality rates for 65-year-old males, 1980–2004

- Empirical analysis of basis risk between the longevity risk of the pension plan and that associated with the hedging instrument
- Evaluation of the effectiveness of a longevity hedge based on a longevity index for the US national population

This case study builds on a similar UK case study that gave very similar results (Coughlan et al. 2011).

We assume that the pension plan in this case study has the same mortality experience as the population of the state of California. This mortality experience differs from that of the US national population and gives rise to longevity basis risk and a degree of hedge effectiveness. In 2008, California boasted a population of 36.8 million, representing 12% of the US national population and a GDP per capita of 11% above the national average,¹⁷ reflecting a higher level of affluence than the nation as a whole. This greater affluence is reflected in historically observed lower mortality rates and higher mortality improvements. Note that this population is far larger than any DB pension plan and the mortality data will have much less noise. In this respect it is not representative of a typical DB plan.

The data cover the 25-year period 1980–2004 and are sourced from the Centers for Disease Control and Prevention (CDC) and the National Census Bureau.

34.5.4 Basis Risk Between the Two Populations

Figure 34.16 shows a graphical comparison of male graduated mortality rates for California and the US national population. Note the difference in the level of mortality rates: California mortality is lower than national mortality. What is also evident is that the long-term downward trends are

¹⁷US Census Bureau and US Bureau of Economic Analysis, 2008 figures

Table 34.3 California male mortality rates as a percentage of US national male mortality rates, averaged over age

| Ratio of mortality rates (California/US national) | 1980 (%) | 2004 (%) |
|---|----------------|----------|
| | Overall: 40–89 | 92 |
| Younger: 40–64 | 90 | 87 |
| Older: 65–89 | 94 | 89 |

Table 34.4 Annualized male mortality improvements for the US national and California populations, averaged over age groups, 1980–2004

| Mortality improvements 1980–2004 | National (% pa) | | California (% pa) | Difference (percentage points) |
|----------------------------------|-----------------|-------------------|-------------------|--------------------------------|
| | National (% pa) | California (% pa) | | |
| Overall: | | | | |
| 40–89 | 1.48 | 1.65 | | 0.17 |
| Younger: | | | | |
| 40–64 | 1.44 | 1.57 | | 0.13 |
| Older: 65–89 | 1.51 | 1.73 | | 0.22 |

Table 34.5 Aggregate correlations of changes in male mortality rates for individual ages between the California and US national populations, 1980–2004

| Individual ages | Correlation between absolute changes in mortality rates (%) | | Correlation between improvement rates (relative changes) (%) | |
|-----------------|---|------------------------|--|------------------------|
| | Individual ages: 40–89 | Individual ages: 50–89 | Individual ages: 40–89 | Individual ages: 50–89 |
| | 10-year horizon | 97 | 97 | 66 |
| 5-year horizon | 68 | 65 | 83 | 77 |
| 1-year horizon | 41 | 41 | 52 | 41 |

Note: Correlations are calculated across time (using nonoverlapping periods) and across individual ages (without any age bucketing), using graduated mortality rates

similar, suggesting that there might be a long-term relationship between the mortality rates of the two populations. The observed improvements in mortality are evolving similarly and not diverging.

Table 34.3 compares the average levels of mortality rates for the two populations, showing that California mortality in 2004 averaged 88% of national mortality, having fallen from 92% in 1980. Over the period 1980–2004, observed mortality improvements (Table 34.4) have averaged 1.65% p.a. for California males, compared with 1.48% p.a. for the national population. Furthermore, it is interesting to note that the younger preretirement ages have experienced lower improvements than the older post-retirement ages.

We now examine correlations. Table 34.5 lists the aggregate correlations for changes in mortality rates over different horizons calculated from individual ages. Note that these aggregate correlations in year-on-year changes based on individual ages are quite small, just 40–50%, but they increase with the length of the time horizon. Correlations are around 65–85% for a 5-year horizon and up to 97% for a 10-year horizon.¹⁸

¹⁸Note the lowish result of just 66% for the correlation of relative changes for ages 40–89 over a 10-year horizon. This seems to be the result of noise, as the correlation rises to 87% over the slightly wider age range 35–89.

Table 34.6 Aggregate correlations of changes in male mortality rates for 10-year age buckets between the California and US national populations, 1980–2004

| Age buckets: 50–59 60–69 70–79 80–89 | Correlation between absolute changes in mortality rates (%) | Correlation between improvement rates (relative changes) (%) |
|---|--|--|
| 10-year horizon | 99 | 94 |
| 5-year horizon | 60 | 77 |
| 1-year horizon | 54 | 51 |

Note: Correlations are calculated across time (using nonoverlapping periods) and across 10-year age buckets, using graduated mortality rates

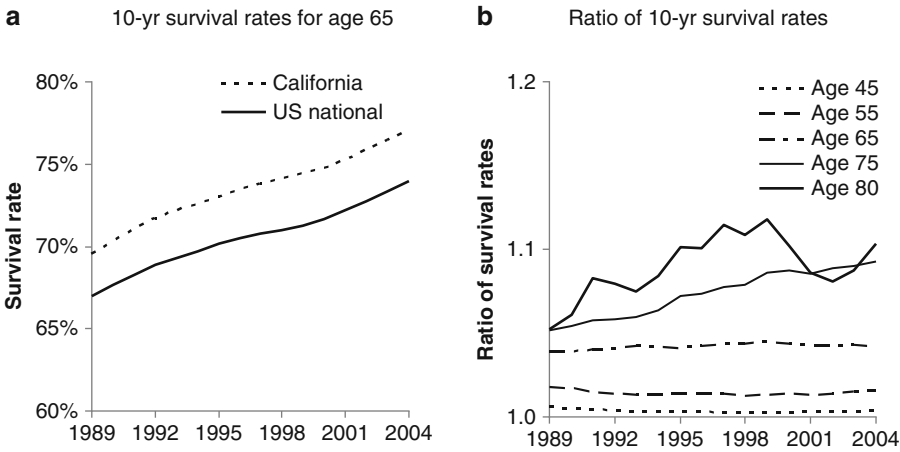


Fig. 34.17 Historical 10-year male survival rates for California and the US national populations based on data over the period 1980–2004: (a) historical evolution of 10-year cohort survival rates for males reaching 65 in different years between 1989 and 2004 and (b) ratio of the 10-year cohort survival rates for California to the 10-year survival rate for the US national population for males reaching various ages in different years between 1989 and 2004

Using 10-year age buckets rather than individual ages leads to higher correlations for 1-year and 10-year horizons of 51–54% and 94–99 %, respectively, as shown in Table 34.6. We should note that for long horizons and bucketed ages, there are a limited number of data points, and the correlation results should be considered as indicative only. However, taken together with the results of the other analyses below, they support the existence of a strong long-term relationship between the mortality experience of the two populations.

Having examined mortality rates and mortality improvements, we now consider a different metric: cohort survival rates (i.e., survival rates calculated from actual mortality data for the cohort). Figure 34.17a shows the evolution of 10-year cohort survival rates for the two populations for 65-year-old males over the period 1989–2004. Survival rates for both populations have been increasing over time, but, more importantly, the ratio between survival rates has been more or less constant over time, except at very high ages, as shown in Fig. 34.17b.

The latter chart suggests a relatively stable long-term relationship between the survival rates of the two populations, with the ratio of California to national survival rates greater than unity for all ages and increasing with age. The average cohort survival ratios over the period are listed in Table 34.7 and

Table 34.7 Key statistics on the male survival ratio between California and US national male populations. The survival ratio is defined as the 10-year survival rate for California to the 10-year survival rate for the national population over the period 1989–2004

| 10-year survival ratio (California/US national) | Age 45 | Age 55 | Age 65 | Age 75 | Age 80 |
|---|--------|--------|--------|--------|--------|
| Average survival ratio | 1.00 | 1.01 | 1.04 | 1.07 | 1.09 |
| Standard deviation | 0.001 | 0.002 | 0.002 | 0.014 | 0.018 |
| Coeff. of variation (std. dev./average) | 0.1% | 0.2% | 0.2% | 1.3% | 1.7% |
| Worst case (max/average) | 0.2% | 0.4% | 0.3% | 2.0% | 3.5% |

Notes: Survival rates are calculated for each age cohort using graduated mortality rates. The quoted age represents the age at the start of the 10-year period

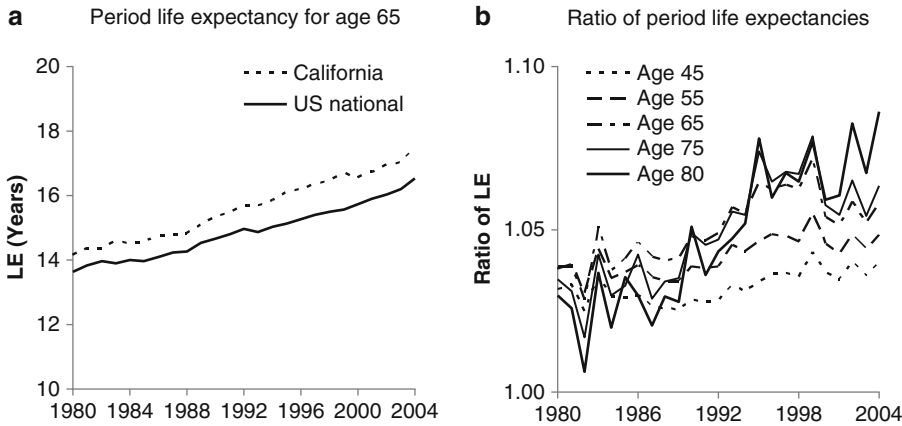


Fig. 34.18 Evolution of male period life expectancy for the California and US national populations, 1980–2004: (a) life expectancy for 65-year-old males measured in years and (b) ratio of life expectancy for the California population to the life expectancy for the national population for various ages

are all close to unity, with Californian males aged 80 experiencing only a 9 % higher survival rate to age 90 than the nation overall.

We now turn to another metric: period life expectancy (i.e., life expectancy calculated from the mortality data for a particular year, without any assumed improvements in mortality rates). From 1980 to 2004, period life expectancy increased significantly for both populations at all ages. Figures 34.18 and 34.19 show that the California data exhibit both higher and greater increases in period life expectancy than the national data. Despite this, the ratio of life expectancies has been relatively constant as shown in Fig. 34.18b. In particular, the ratio of California to US national life expectancies has, over the 25-year period, averaged 1.03 at age 45, 1.05 at age 65, 1.05 at age 75, and 1.05 at age 80. Moreover, as Fig. 34.19b shows, the percentage increases in life expectancies have been very similar, only beginning to diverge above age 75, which again might be due to assumptions about the mortality rates at higher ages.

We now compare the historical cash flows from paying pensions (i.e., annuities) for different cohorts in each population (Fig. 34.20). As before, we minimize the noise in comparing the two populations by calculating cumulative cash flows over periods of 10 years (Fig. 34.20a). The calculation assumes that the annuity pays \$1 each year to each surviving member of each population. Figure 34.20b shows the ratio of 10-year cumulative annuity cash flows for the Californian male population to those of the national population. Each line represents the ratio over time for the same initial age.

We note the following features, which are similar to the UK case study presented in Coughlan et al. (2011):

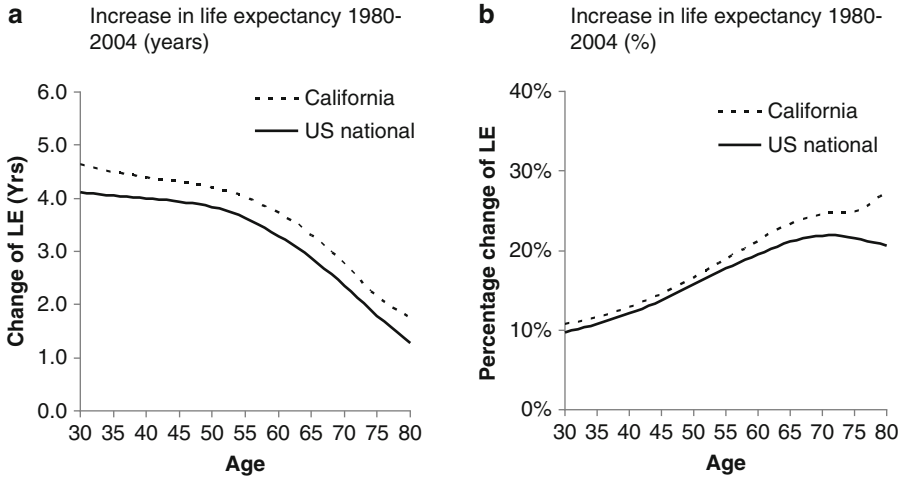


Fig. 34.19 Increase in male period life expectancy for the California and US national populations, 1980–2004: (a) increase measured in years and (b) increase in percentage terms

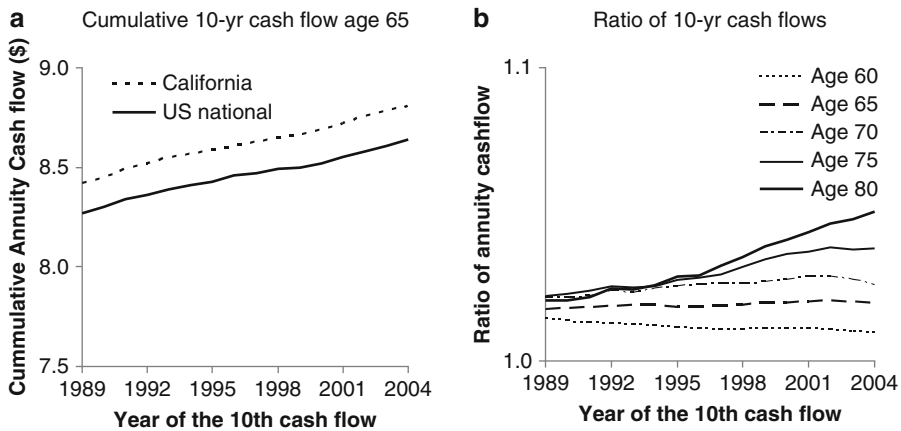


Fig. 34.20 Cumulative cash flows over 10-year horizons for liabilities (annuities) based on the California and US national male populations over the period 1989–2004: (a) cumulative cash flows for 65-year-old males and (b) ratio of cumulative cash flow for the California population to that for the national population

- The ratios are all greater than unity, reflecting higher survival rates for the Californian population. The ratio varies from approximately 1.01 to 1.05 depending on the cohort and the year.
- The ratios are reasonably stable. In particular the ratio for the cohort with an initial age of 60 varies between 1.01 and 1.04 over the period while that for an initial age of 70 varies between 1.02 and 1.03.

34.5.5 Hedge Effectiveness Calculation

Given the long-term, stable relationship between the US national and California populations in terms of their mortality experiences, the long-term effectiveness of an appropriately calibrated hedge of the latter using a hedging instrument based on the former should be high.

We have evaluated an example of a static hedge of longevity risk in a hypothetical pension plan with the same mortality behavior as males in the state of California and a hedging instrument linked to the LifeMetrics Index of male mortality for the US national population. We perform the same kind of retrospective hedge effectiveness test as the UK example reported in [Coughlan et al. \(2011\)](#).

Step 1: Hedging objectives

The pension plan consists entirely of deferred male members currently aged 55 whose mortality characteristics are the same as Californian males and who will receive a fixed pension of \$1 for life beginning at retirement in 10 years' time (the hedge horizon) at age 65. The hedging objective is to remove the uncertainty in the *value* of the pension at retirement due to longevity risk.

Step 2: Hedging instrument

The hedging instrument is a 10-year deferred annuity swap that pays out on the basis of a survival index for the US national population for 55-year-old males. As we are considering a hedge of value, we assume that the hedging instrument is cash-settled at the hedge horizon at the market value prevailing at that time. In other words in 10 years' time, the pension plan receives a payment reflecting the market value of the hedging annuity at that time in return for making a fixed payment at that time. So the hedging instrument involves a net settlement that is the difference between the fixed payment and the market value of the hedging annuity in 10 years' time. The hedge was calibrated using the method (see Appendix) described in [Coughlan et al. \(2011\)](#) resulting in a hedge ratio of 1.07 implying that to hedge a \$1 liability requires \$1.07 of the hedging instrument.

Step 3: Method for hedge effectiveness assessment

We perform a retrospective effectiveness test, based on historical data. The basis for comparison that we use is twofold involving evaluation of (1) the correlations between the unhedged and hedged liability and (2) the degree of risk reduction. Since the objective is to hedge the value of the pension liability we focus on a risk metric corresponding to the value at risk (VaR) in 10 years' time, where the VaR is measured at a 95% confidence level relative to the median. We measure hedge effectiveness by comparing the VaR of the pension before and after hedging. We use historical mortality data to directly evaluate historical scenarios for the evolution of mortality rates over a 10-year horizon from which the VaR of the pension liability can be calculated. Note that other risk metrics generally give similar results.¹⁹

The hedge effectiveness is calculated in terms of relative risk reduction (denoted *RRR*):

$$RRR = 1 - \text{VaR}_{(\text{Liability} + \text{Hedge})} / \text{VaR}_{\text{Liability}}.$$

We construct scenarios for the hedge effectiveness analysis in a model-independent way directly from the historical mortality data (as described in [Coughlan et al. 2011](#)). With available historical data limited to 25 years we form historical scenarios by combining the set of realized mortality improvements with the set of realized mortality base tables from each year. In particular, we construct scenarios for each population by applying realized mortality improvements coming from the full historical set of 15 overlapping 10-year periods (1980–1990, 1981–1991, . . . , 1994–2004) to each of the realized mortality base tables defined by the observed mortality rates in each of the 25 years (1980

¹⁹As part of the original study, we also analyzed other metrics for risk, such as standard deviation and conditional VaR. These all gave similar results to this analysis.

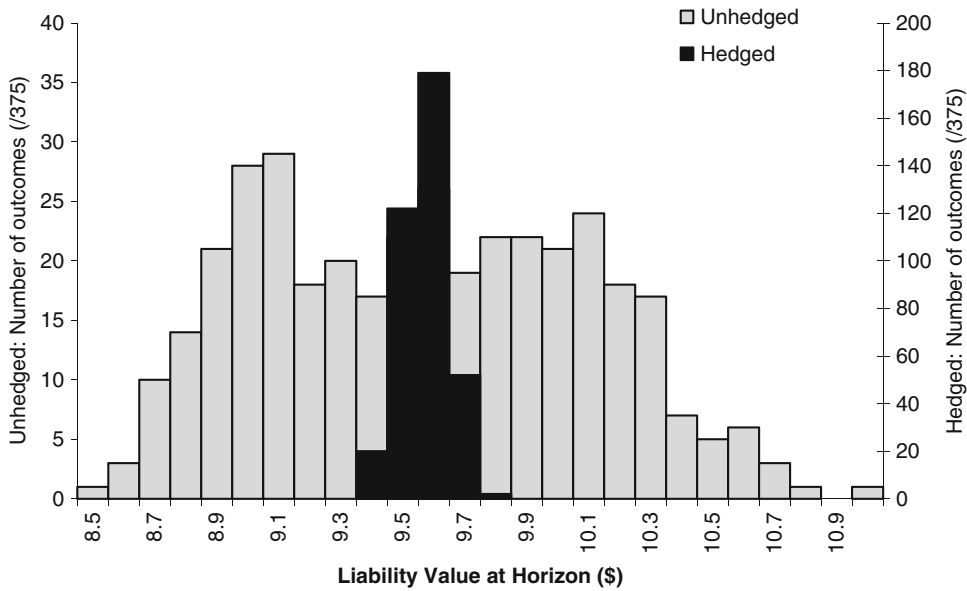


Fig. 34.21 Hedge effectiveness analysis using an index-based hedging instrument linked to US national male mortality to hedge the longevity risk of a pension plan with the same mortality characteristics as the California male population

1981 ... 2004). This leads to 375 scenarios. Note that these 375 scenarios have enough dispersion for hedge effectiveness evaluation to be meaningful as can be seen in the histogram of results (Fig. 34.21).
Step 4: Calculation of hedge effectiveness

The results of the analysis are shown in the histogram in Fig. 34.21. The histogram shows that the hedge is highly effective, reducing the impact of longevity risk on the value of the pension liability in 10-years' time by 86.5% with a correlation between the values of the liability and the hedging instrument of 0.99.

Step 5: Interpret the hedge effectiveness results

The results of this hedge effectiveness analysis lead to the conclusion that the index-based longevity hedge is effective in significantly reducing the longevity risk associated with the pension plan liabilities. Note that this result is model independent in the sense that it uses actual historical data to provide correlated mortality scenarios for both the exposed population and the hedging populations without the need for a specific stochastic mortality model.

This result is consistent with the result of a similar case study based on UK data over a longer period which is presented in Coughlan et al. (2011). The important implication from these two examples is that appropriately calibrated index-based longevity hedges can be effective in reducing (but not completely eliminating) the longevity risk associated with DB pension plans.

34.6 Innovation in the Longevity Market

The development of the longevity market since 2006 has witnessed considerable innovation, much of which has been the result of the interplay between investment banks, insurers, reinsurers, and academics. This has involved the adaptation and extension of concepts and techniques from other disciplines such as investment banking, private equity, and demographic science. It should be hardly surprising that the diverse perspectives of different players in this market have driven much

of this innovation. The involvement of capital markets participants (investment banks and ILS investors) provided an alternative channel for longevity risk transfers and a fresh context for product development, collateralization, and risk management. Similarly, the new monoline pension insurers (Paternoster, Lucida, and Pension Corporation) brought to the market a sharp transactional focus and discipline typical of the private equity industry, together with an openness to new approaches.

The resulting innovation has taken a number of different forms:

- Product innovation
- Conceptual innovation
- Analytical innovation
- Data innovation

34.6.1 Product Innovation

In terms of product innovation, the market has witnessed the emergence of a significant number of new transactional structures including both capital markets and insurance solutions. New capital markets instruments have been conceived with the express purpose of transferring longevity risk, including q-forwards, S-forwards, longevity swaps, and longevity trend spread bonds. The use of a longevity index in longevity hedging products, instead of the actual experience of the exposed population, was another innovation championed by J.P. Morgan and taken up by Swiss Re with their Kortis bond (Swiss Re had earlier pioneered indices in mortality catastrophe hedges, but their application to longevity hedges was considered challenging). The noninsured buyout pioneered by Citigroup and Pension Corporation can in a sense also be considered a capital markets solution, albeit of a different kind.

In a similar way, a number of insurance solutions have been developed and refined over time, including pension buy-ins, non-distressed pension buyouts for solvent sponsors, and insurance-based longevity swaps. Refinements to these products include, for example, improved security, inspired by the collateralization techniques common in the financial markets. The market has also seen the development of hybrid solutions that involve both insurance and capital markets elements, such as synthetic buy-ins. Although the idea was in circulation in the banking community since 2007, it is probably no surprise that this hybrid solution was first put into practice by the combination of an investment bank (Goldman Sachs) and its insurance subsidiary (Rothesay Life).

34.6.2 Conceptual Innovation

As for conceptual innovation, a number of new ideas were developed and implemented based on a new risk transfer paradigm. This was the paradigm of risk management, instead of risk indemnification. Risk management involves the reduction of risk in a selective and cost-effective way, without necessarily moving to full elimination. The longevity market has seen a number of significant conceptual advances following from this paradigm, but in particular:

- *Hedges of liability value.* These involve hedging the longevity risk in the value of a pension or annuity liability at a future time, instead of each individual liability cash flow. Examples of these are the q-forward hedges implemented by Lucida and by Pall. The hedge provided by RBS to Aviva in 2009 also included a value hedge.
- *Hedges based on a longevity index.* These involve hedges that make a compensating payment when longevity as measured by a broad population index increases beyond expectations.

The risk management paradigm has also led to the concept of measuring the effectiveness of hedges and quantifying the residual basis risk coming from hedge strategies that don't involve full indemnification, such as index-based hedges. Until this time, basis risk arising from index-based longevity hedges was something that the industry believed was always too large for such hedges to ever be effective—but no one had managed to quantify it in a systematic framework. By adapting and applying the same analytical framework from the financial markets that has been successfully used to assess hedge effectiveness²⁰ under derivative accounting standards SFAS 133 and IAS 39, recent work²¹ has shown that well-calibrated index-based hedges can indeed be highly effective with respect to hedging objectives, achieving up to 85% effectiveness.

34.6.3 Analytical Innovation

Analytical innovation in the longevity market has taken many different forms, with academics and practitioners joining forces to develop practical models and frameworks. The hedge effectiveness framework just mentioned is one example. Another is stochastic mortality modeling.²² A particularly important development has been the emergence of two-population mortality models, to which several research groups have contributed.²³ Two-population mortality models are essential tools in two main kinds of situation:

- They are necessary to evaluate the basis risk in situations where the hedging population is different from the exposed population for example when an index-based hedge is used to reduce longevity risk or when an annuity portfolio is used to hedge a life insurance portfolio.²⁴
- They are necessary to help forecast mortality in situations in which the exposed population is too small or has a limited history. In this situation a two-population model enables the exposed population to be modeled by reference to a larger, related population which may have more and better quality data.

Another innovative mortality model to emerge recently was that developed by the insurance modeling firm RMS, which caught the attention of the market when it was used for the Swiss Re Kortis bond. RMS took the “structural modeling” approach used for building models of natural catastrophes and developed a process model of causes of death, combined with research into likely drivers of future mortality improvement (RMS 2011).

²⁰See Coughlan et al. (2004) for the original presentation of the hedge effectiveness framework.

²¹See the following contributions on hedge effectiveness and basis risk: Coughlan et al. (2011), Li and Hardy (2011), and Plat (2009).

²²See Cairns et al. (2009, 2011a) and Dowd et al. (2010a,b).

²³See the following contributions on two-population modeling: Li and Lee (2005), Jarner (2008), Jarner and Kryger (2011), Cairns et al. (2011b), and Dowd et al. (2011).

²⁴Multi-population mortality modeling is also useful for insurers with different populations, e.g., life/annuity books; males/females; smokers/nonsmokers; and policyholders from different regions or countries. In this case, basis risk is useful since it allows for some element of diversification which in turn reduces VaR relative to a situation with perfect correlation.

34.6.4 Data Innovation

There have been three main innovations connected with data that have had an influence on the development of the market: postcode (or zip code) mapping, LifeMetrics, and Club Vita.

A number of innovations have taken place around the application of geodemographic profiling to mortality and longevity analysis (Richards 2008). This involves using socioeconomic data connected with where people live to develop better estimates of mortality rates for the members of specific pension plans or the annuitants in annuity portfolios. Early pioneering work on this was done by Richard Willets and Laurence Andrews at Prudential PLC (UK) but was never published. Commonly called postcode analysis, it has been improved and refined over the years with access to marketing databases and advances in analytical techniques.

The second example of data innovation was provided by LifeMetrics,²⁵ which included a series of longevity and mortality indices calculated according to a rigorous set of rules that has been used by many market participants for developing hedging instruments, forecasting future mortality, pricing longevity and mortality exposures, quantifying longevity risk, and evaluating hedge effectiveness. LifeMetrics was launched in March 2007 by J.P. Morgan and was made freely available to users. While we have classified it under the heading of data innovation, LifeMetrics is more than just a data set. It consists of a framework for longevity risk management, software for modeling longevity risk, and a series of longevity indices in four different countries (Coughlan et al. 2007a, c, 2008a).²⁶ The framework blended actuarial and financial perspectives on longevity to help establish a common language for longevity risk management that was accessible to all participants across the insurance, pension, banking, and investment management industries. It also served an important education role. The software provided practical tools to model longevity risk (using stochastic mortality models) and the longevity indices provided broad visibility on current and historical longevity metrics in different countries, as well as data for risk analysis and the pricing of longevity transactions. The LifeMetrics Index for England and Wales was used in the hedging transactions executed by Lucida and the Pall (UK) Pension Scheme, and aspects of the LifeMetrics framework were used in the Canada Life longevity swap. In April 2011, the LLMA acquired the LifeMetrics Longevity Index from J.P. Morgan.

In November 2008, Hymans Robertson, a UK pension consultant, launched Club Vita, an organization that enables UK pension plans to pool their mortality data in return for regular analysis and reporting on longevity. It is described as “a longevity experience-sharing club” (Hymans Robertson 2008), which was designed to provide pension plans with better and more timely information on longevity trends for particular subsets of the population. In 2011, more than 130 of the UK’s largest pension plans were contributing data and the club boasted a total data set consisting of 5.6 million member records over a 20 year period, of which 1.8 million are pensioner records (including 0.6 million deaths). The data set contains very useful demographic and socioeconomic information, such as gender, employment status (e.g., manual/non-manual), postcode, affluence measures (salary and pension amount), retirement age, and retirement type (normal/ill-health). Among its members Club Vita counts the UK’s Pension Protection Fund (PPF)²⁷ which joined in 2010. It is interesting to note that Club Vita is probably the only innovation to have come from the pension consulting industry to have so far made a significant and lasting impact on the market.

²⁵www.lifemetrics.com

²⁶The LifeMetrics indices were developed by J.P. Morgan, in collaboration with the Pensions Institute and Towers Watson.

²⁷A statutory fund established by the UK Pensions Act 2004 “to provide compensation to members of eligible defined benefit pension schemes, when there is a qualifying insolvency event in relation to the employer, and where there are insufficient assets in the pension scheme to cover the Pension Protection Fund level of compensation.”

34.7 Conclusions

The longevity market has grown steadily since its birth in 2006 but has been slower to develop than most industry participants expected. This has been ascribed to the conservative nature of the pensions industry, unrealistic mortality assumptions used by pension actuaries in many countries, and a lack of education on longevity risk and pricing. Nevertheless, a good deal of progress has been made in terms of education and implementing transactions, driven by the innovation inspired by different types of market participants. With the total amount of pension-related longevity exposure globally estimated at \$25 trillion,²⁸ the opportunity for the market is huge. Furthermore, with most of this residing with governments and corporations that are ill-equipped to manage it, there is considerable scope for much more longevity risk transfer.

This market will develop over time, helped by more realistic mortality assumptions used in statutory pension valuations, more regular and more timely valuations of pension liabilities, the elimination of smoothing in pensions accounting, and continued education. To meet the anticipated growth of the market, more capital will have to be found to support the transfer of longevity risk to other parties. This capital is likely to come both via the reinsurance industry and the capital markets.

Appendix: Hedge Calibration

Hedge calibration refers to the process of designing the hedging instrument to maximize its effectiveness in reducing risk, relative to the hedging objectives. It involves two elements:

1. The determination of the appropriate structure and characteristics of the hedging instrument (eg., type of instrument, maturity index to be used).
2. The determination of the optimal amount of the hedge required to maximize hedge effectiveness. This involves determining optimal “hedge ratios” for each of the subcomponents of the hedging instrument.

As a simple example, consider a hedging instrument with just one component designed to hedge the value of a pension liability at a future time, which we call the “hedge horizon.” Suppose we have bought h units of the hedge for each unit of the liability: h is the hedge ratio. Then the total (net) value of the combined exposure is

$$V_{\text{Total}} = V_{\text{Liability}} + h \times V_{\text{Hedge}}.$$

The optimization element referred to above involves selecting h to maximize hedge effectiveness by minimizing the uncertainty in V_{Total} . It can be shown that assuming the values are normally distributed and risk is measured by standard deviation, then the optimal hedge ratio is given by (Coughlan et al. 2004)

$$h_{\text{Optimal}} = -\rho(\sigma_{\text{Liability}}/\sigma_{\text{Hedge}}),$$

where $\sigma_{\text{Liability}}$ and σ_{Hedge} are the standard deviations of the values of the liability and hedging instrument, respectively, at the hedge horizon, and ρ is the correlation between them. It is evident from this simple example that basis risk analysis is an essential prerequisite for optimal hedge calibration.

²⁸See Richardson (2010) for a Swiss Re estimate of market size.

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Chapter 35

Long-Term Care Insurance

Thomas Davidoff

Abstract This chapter summarizes the considerable variation in limitations to “activities of daily living” and associated expenditures on long-term care, with an emphasis on US data, then takes up the question of why the market for private insurance against this large risk is small. Donated care from family, otherwise illiquid home equity, and the shortened life and diminished demand for other consumption associated with receiving care may all undermine demand for long-term care insurance. Selection and moral hazard problems also affect the supply of public and private long-term care insurance.

This chapter explores the market for insurance against expenditures on long-term care for limitations to “activities of daily living” (ADLs) such as bathing, dressing, and eating. An organizing theme is understanding why the market for private insurance is small, even though out-of-pocket expenditures are highly variable across individuals and may be very large.¹ Section 35.1 describes how ADL limitations vary with age and how the type of care used and expenditures on care vary with family structure and the extent of limitation, with an emphasis on US data.

Section 35.2 briefly characterizes existing public and private long-term care insurance schemes. Public systems pay a larger share of long-term care costs than private insurance throughout the developed world. Because public schemes are commonly progressive both in funding and in coverage, relatively wealthy households in some countries are exposed to potentially very large losses. Section 35.3 considers reasons why demand for insuring against long-term care expenditures may be weaker than demand for insuring against other potentially catastrophic losses, even ignoring social insurance. Donated care from family, otherwise illiquid home equity, and the shortened life and diminished demand for other consumption associated with receiving care may all undermine demand for long-term care insurance. Section 35.4 discusses selection and moral hazard concerns associated with both public and private insurance design.

Some factors that shape the private long-term care market are worthy of further attention but get relatively short shrift here. First, political outcomes, voter attitudes, social insurance programs, and demand for private insurance are jointly determined. For example, reducing public provision

¹This theme is shared with other summaries of the literature, e.g., [Brown and Finkelstein \(2009\)](#).

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of long-term care insurance might increase demand for private insurance and might thereby reduce support for social insurance coverage. Second, regulation, economies of scale, and other supply-side factors may act to raise premiums for private products and thereby limit demand. Third, consumers may have difficulty obtaining or processing information concerning the distribution of likely future long-term costs, the terms of contracts with insurers, or the relationship between long-term care expenditures and the “marginal utility of wealth.” Fourth, I have ignored interesting dynamic considerations such as the consumer’s choice of date at which to purchase private insurance and the optimal time path of renewal options and premiums over the insured’s lifetime.

35.1 The Cost of Long-Term Care

As people age, they become increasingly likely to face difficulty with activities of daily living. Long-term ADL limitations generate demand for care that typically involves either large time commitments from family or expensive nursing services. Norton (2000) concludes that long-term care is the largest expenditure risk facing the elderly in the USA. Economists seeking to explain seeming violations of basic predictions of life-cycle savings models, such as absence of demand for life annuities and slow decumulation of housing and other assets, have turned to demand for savings as a precaution against long-term care expenditure risk as an explanation.²

In a survey of 12 countries, OECD (2005) reports that a median of 1% of GDP is spent on long-term care, and this figure excludes the opportunity cost of the time family caregivers, who mostly go unpaid (some countries, such as Germany, compensate family caregivers through their social insurance system). Increased longevity, the aging of “baby boomers”, and increased real costs of a constant level of care underlie predictions that long-term care costs will rise over time, as they have in the past. Comas-Herrera et al. (2006) project that long-term care costs will double as a share of GDP in each of Germany, Italy, Spain, and the UK over the next 50 years. Figure 35.1 plots log real spending on nursing home and home health care in the USA between 1960 and 2010 from the National Health Expenditure survey. Total US spending on nursing homes and home health care in 2010 was over \$200 billion, according to these accounts prepared by the Centers for Medicare and Medicaid Services. Both time series have increased dramatically over the last five decades, with 2010 levels of real nursing home expenditures 25 times greater than 1960 levels and 2010 home health-care levels more than 150 times their 1960 levels. Between 1990 and 2010, nursing home expenditures grew by 91% and home health-care expenditures by 235%. Holding the quantity and quality of care constant, CareScout (2011) reports based on a panel of providers that nominal costs for a private nursing home room rose in the USA by 4.35% annually between 2005 and 2011; over the same period, annual growth in the US Consumer Price Index was 2.5%.

While ADL limitations can occur at any age, the elderly are at much greater risk than the rest of the population. Congressional Budget Office (2004) reports that approximately two-thirds of US expenditures on long-term care for individuals with ADL limitations go to care for the elderly. National Center for Health Statistics (2009) shows that in the 2003–2007 National Health Interview Surveys, 3% of respondents aged 65–74 were limited in the performance of at least one ADL, rising to an 18% incidence of limitation among those 85 and over. The occurrence of ADL limitations is greater in the Health and Retirement Study (HRS), but as in the NHIS, the probability of any limitations and the mean number of limitations rise sharply with age. The top panel of Fig. 35.2 plots

²Examples, building on the generic analysis of precautionary savings in Leland (1968), include Palumbo (1999), Hubbard et al. (1995), De Nardi et al. (2010), Davidoff (2009), Sinclair and Smetters (2004), Turra and Mitchell (2004), among many others.

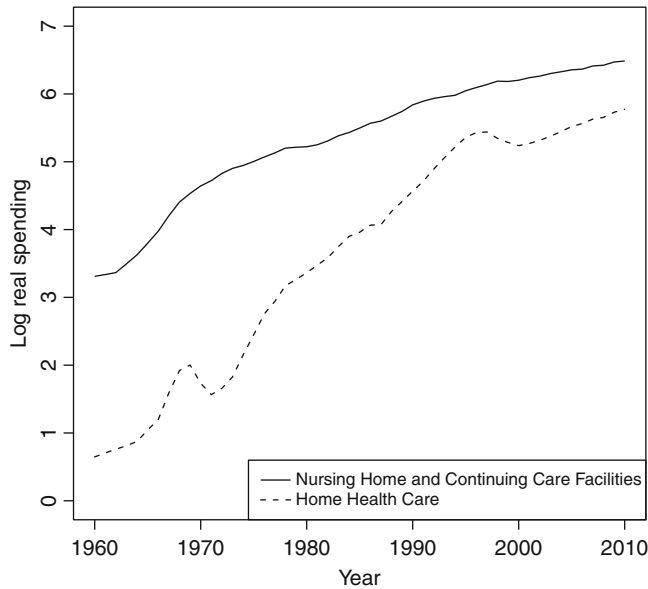


Fig. 35.1 Log real expenditures on nursing homes and home health care, 1960–2010. National Health Expenditure Data deflated by US CPI for all goods

the fraction of respondents at each integer age with at least one limitation in the 2008 wave of the HRS. Notably, the probability of an ADL approaches 100% at sufficiently advanced age. The bottom panel plots the mean number of ADLs (between 0 and 5 for each respondent) by age; the mean exceeds one starting around age 90.³ [Congressional Budget Office \(2004\)](#) recognizes offsetting effects on the future path of long-term care expenditures: seniors are becoming healthier, with the fraction impaired by ADL limitations likely to fall sharply from approximately 25% to approximately 15% between 2000 and 2040. However, with increased health comes increased longevity, and the population of seniors, particularly those over 85, will rise by more than enough to compensate. Thus CBO predicts that the probability of use of long-term care over a lifetime for those turning 65 will slowly rise over time.

The cost of prolonged assistance with ADLs may be large relative to the recipient household's resources. Long-term care may be delivered at the disabled individuals' home, at a location to which the disabled individual commutes, or at a nursing home or other residential facility. [CareScout \(2011\)](#) reports median costs in the USA for a year of a range of services: the median cost for full-time service from a home health aide is \$43,000;⁴ receiving care for a year at a day health care center to which an individual commutes costs a median of \$15,600; residing in an assisted living facility costs a median of \$39,135; semiprivate and private rooms in a nursing home have median costs of \$70,445 and \$77,745. [Prudential \(2010\)](#) cites an "average" cost of a year in a private room in a nursing home of over \$90,000, with semiprivate rooms an average of a 15% less costly.

Home health care is used less intensely than nursing homes. [Kemper et al. \(2005/2006\)](#) estimate that an individual turning 65 in the year 2005 will consume nursing home and assisted living facility costs of approximately \$39,000 over their lifetime. Mean lifetime home health service consumption is

³Unweighted data taken from the RAND HRS data file.

⁴The mean hourly wage for a home health aide in the 2007 National Home and Hospice Care Survey was approximately \$11.

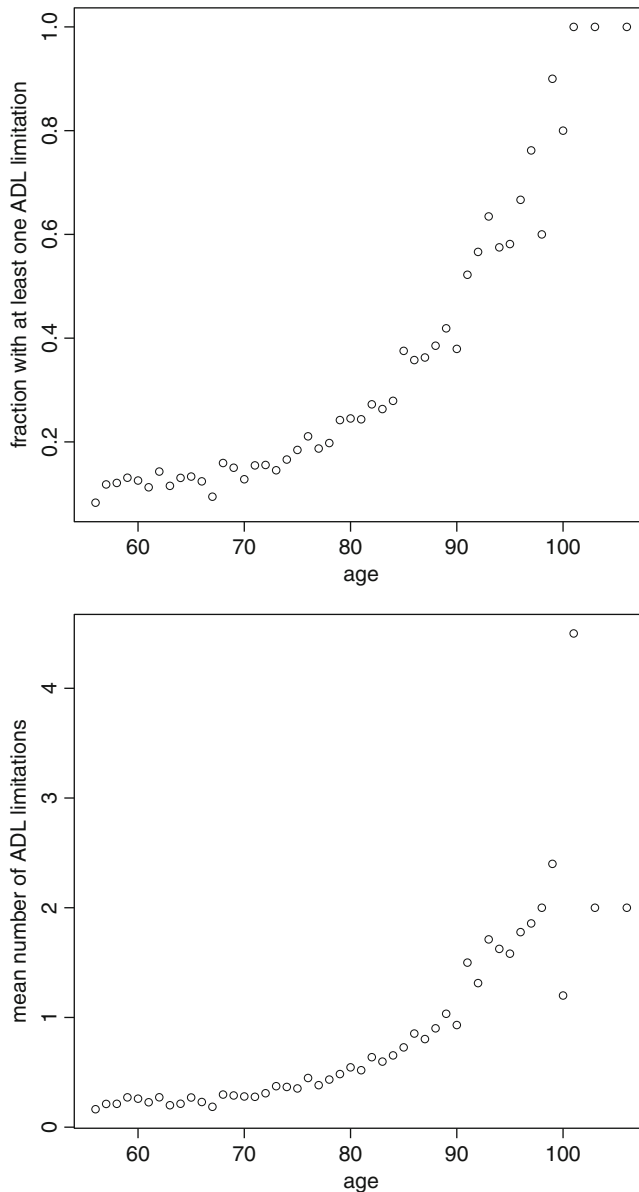


Fig. 35.2 Age and activities of daily living (ADLs) in the 2008 wave of the Health and Retirement Study (RAND summary data). *Top Panel:* percentage of respondents with at least one ADL limitation. *Bottom panel:* mean number of ADL limitations

estimated at \$8,200. However, the National Health Expenditure Data reported in Fig. 35.1 show that the ratio of home health care to nursing home expenditures has been growing in the USA from 5% in 1980 to 49% in 2010.

Fujisawa and Colombo (2009) find that a significant majority of long-term care providers in OECD countries are family members. Houser and Gibson (2008) estimate that the largely uncompensated time of family caregivers represents approximately 60% of the true economic cost of long-term care delivery in the USA. Family care appears to be preferred to institutional care, due to both

the connection to the caregiver and the familiar fact documented by [Bayer and Harper \(2000\)](#) that the elderly have a strong aversion to leaving their homes. In a survey of EU residents, [European Commission \(2007\)](#) finds that 30% believe that the best means of providing care to disabled elderly is for them to move in with their children; 27% and 24% believe that the dependent elderly should remain at home and obtain care from professionals and children, respectively. Just 10% view moving into a nursing home as the best alternative. Consistent with the preferred nature of family care, [Lakdawalla and Schoeni \(2003\)](#) show in HRS data that having Alzheimer's disease and being single are associated with the same increase in the probability of nursing home entry, conditional on a host of health and demographic covariates. This cross-sectional relationship may have aggregate time series implications: [Lakdawalla and Philipson \(2002\)](#) argue that an aging population need not increase long-term care costs if the increase in husbands' lives leads to a decrease in women's institutionalization.

The top panel of [Fig. 35.3](#) plots the fraction of respondents in the 2008 wave of the HRS reporting at least one ADL limitation that live in a nursing home, by age, both for married individuals and for individuals with no spouse and no children. Nursing home residence is far more prevalent among singles with no children than among married individuals, as has been found in numerous prior studies. Notably, in the HRS data, married individuals with at least one ADL limitation are less likely to be in a nursing home than singles with no children unconditional on ADL limitations. Conditional on ADL limitation, the use of professional home health care is more evenly distributed across married and single individuals in HRS. Still, I find that in the 2008 wave of the HRS, among those with at least one ADL limitation, only approximately 2% of married individuals report having spent more than \$10,000 on out-of-pocket expenditures for home health care or nursing home services; among singles with no children, the incidence of at least \$10,000 in expenditures is greater than 6%. The bottom panel of [Fig. 35.3](#) plots an indicator for use of home health care in the HRS by age and family structure.⁵

Expenditures on long-term care are unevenly distributed across the population, both because only a (sizeable) minority of individuals ever receive long-term care and because the duration of any care received varies a lot, with a long right tail. Even conditional on age and ADL limitation, the duration (and hence expense) of care varies widely. [Dick et al. \(1994\)](#) find, consistent with [Kemper and Murtaugh \(1991\)](#), that there is a 35% probability of some nursing home use while alive conditional on surviving to 65. However, they conclude that "few of the elderly have prolonged stays and that those who do account for most nursing home utilization. Thus there is a non-negligible but small risk of 'catastrophic' " nursing home use. [Kemper et al. \(2005/2006\)](#) present simulations of long-term care use based on data from the National Long-Term Care Survey, the Current Population Survey, and the HRS that are consistent with this characterization. They find that 42% of individuals turning 65 in the year 2005 will use zero costly (not family provided) long-term care before death; 19% will use care costing 0–\$10,000; 22% will generate between \$10,000 and \$100,000 in expenditures; 11% will use \$100,000 to \$250,000 of care; and 5% will use over 250,000. Projected out-of-pocket expenditures are much lower due to public insurance.

⁵Expenditure figures are based on reported nursing home or home health-care out-of-pocket payments, with a lower bound used in lieu of a dollar amount in some cases. Linear probability regressions show the probability of a nursing home stay is increasing in all quantities between 0 and 5 of ADL limitations and in the interaction of each level of ADL limitation with an indicator for single with no children. Conditional on at least one ADL limitation, there is no significant correlation between being single with no children and use of a professional home health care service.

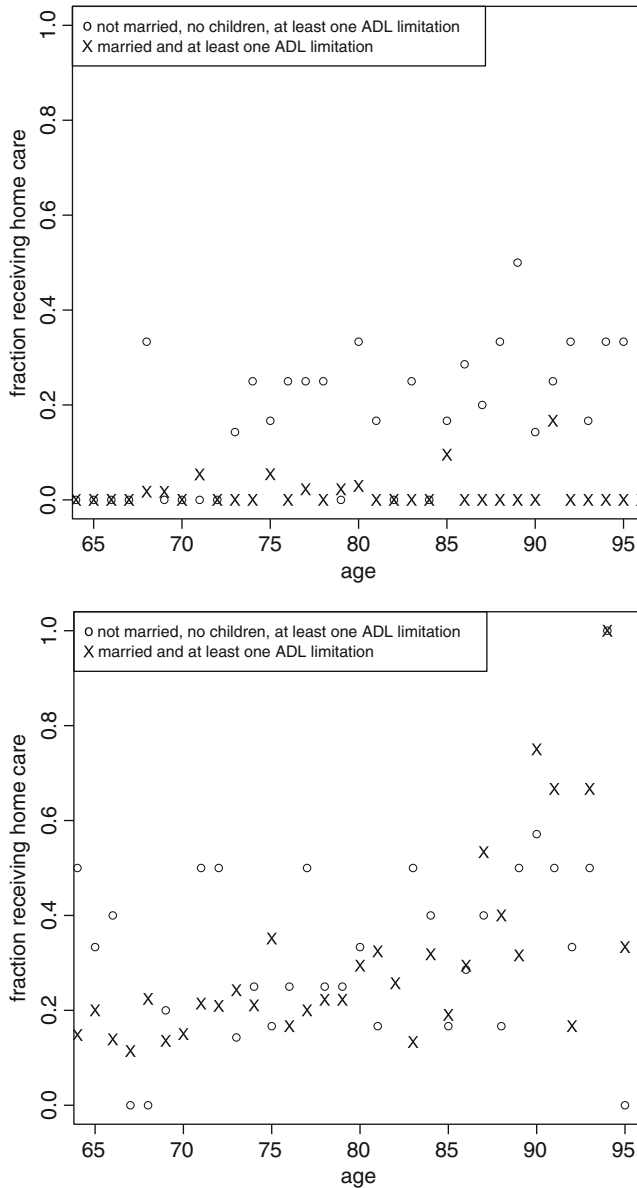


Fig. 35.3 Fraction of respondents with at least one ADL limitation living in a nursing home (*top panel*) or receiving home health care (*bottom panel*) by age and family structure (2008 Wave of the Health and Retirement Study)

35.2 Private and Public Insurance

Tumlinson et al. (2009) provides a description of typical costs and benefits in private US policies. The USA warrants particular attention because it is the largest and most studied private long-term care insurance market. Most US long-term care policies offer reimbursement for expenditures incurred associated with nursing homes, some home care services, limited reimbursement for informal care provided by family and friends, and sometimes negotiated compensation for preventive steps such as home renovation with an eye to reducing the probability of falls.

Several contract features are standard in US contracts. For the premiums to be tax deductible (up to a cap) for the insured, the insured must have the option but not the obligation to renew coverage at the end of a premium period, and the insurer must not reimburse medical services otherwise paid for by Medicare. Regulations generally preclude premium growth based on changes in individual age or health but permit increases due to changes in aggregate costs.

Insurer underwriting rules out coverage for some households and places successful applicants into different risk pools based on observable characteristics. Premiums grow with generosity, single status, and age at policy start, with the last feature reflecting the long delay that is common between enrollment and the first use of benefits. As [Brown and Finkelstein \(2007\)](#) emphasize, policies do not price on gender despite the greater risk of long life and extended care posed by women. Inflation protection renders policies front-loaded, such that lapsed policies can prove quite profitable, but insurers cannot force renewal beyond a 1-year horizon. [Tumlinson et al. \(2009\)](#) show variation in quotes for standard risk classified consumers. Married 40-year-olds jointly seeking a maximum benefit of 3 years of expense reimbursement would pay approximately \$1,000 per year starting at enrollment. A single 70-year-old seeking a 5-year maximum benefit would pay \$6,000 per year.

Given the uncertain and potentially very large magnitude of expenditures on care, one might expect to see large markets for private long-term care insurance. In fact private long-term care insurance markets are small relative to total expenditures throughout the developed world. For example, [Congressional Budget Office \(2004\)](#) reports that private insurance funds approximately 4% of the economic cost of US long-term medical expenses. The National Health Expenditure tables show 9% of nursing care facilities and continuing care retirement community expenditures were funded by private insurance in 2010. [OECD \(2011\)](#) reports approximately 7% of long-term care costs are covered by private long-term care insurance in the USA, but that the USA has by far the largest private insurance share of 14 countries surveyed. [Brown and Finkelstein \(Forthcoming\)](#) find that 14% of respondents in the Health and Retirement Study hold private long-term care insurance, indicating that coverage is far from complete when compared to the less than 10% of costs covered by long-term care insurance. They estimate that men who purchase insurance can expect roughly 72% of long-term care costs to be covered, whereas women can only expect roughly 61% coverage. Caps on reimbursement imply that even the insured are exposed to a significant part of the right tail of expenditure risk.

[Brown and Finkelstein \(2007\)](#) find that 65-year-olds face an average load (or gap between expected present value of payouts less expected present value of premiums) of 18%. This load is close to zero for women, but much greater for men. The fact that single women do not have much greater demand for insurance than single men, despite the much lower loading they face, is striking and suggests that factors other than price serve to limit demand.

The extent of long-term care insurance coverage in the USA appears to be similar to the rate of homeowner insurance for earthquake risk in California ([Zanjani 2008](#)), a source of similarly large losses with relatively low probability over owners' tenure. By contrast, [Scheffler \(1988\)](#) reports that 70% of those eligible in the USA purchase Medigap insurance; Medigap covers medical expenses for Medicare enrollees that are not covered under standard Medicare but does not provide long-term care coverage. Likewise, 70% of US households hold life insurance.⁶

A critical feature of long-term care insurance demand is the role of government. Governments of developed countries uniformly pay a large share of the direct costs of formal long-term care. In a survey of 23 member countries, [OECD \(2011\)](#) reports a mean of 83% of long-term care expenditures in 2007 was funded by general revenues or social insurance funds. [Congressional Budget Office \(2004\)](#) estimates that Medicaid and Medicare pay 60% of US costs. This dominant role is consistent with widespread support for the notion that the public sector should provide for the disabled elderly.

⁶American Council of Life Insurers, *Fact Book 2011*

[European Commission \(2007\)](#) finds 93% agreement with the statement “Public authorities should provide appropriate home care and/or institutional care for elderly people in need,” but only 25% agreement with the statement “If a person becomes dependent and cannot pay for care from their own income, their flat or house should be sold or borrowed against to pay for care.”

Funding of long-term care in Western democracies varies within a general framework of mandated progressive contributions for benefits that are either constant or declining in income and asset wealth. [Merlis \(2004\)](#) describes variation from universal coverage through subsidized and mandated insurance (Germany and Japan) or through general tax-funded services (Sweden and Denmark) to means-tested support paid through subsidized insurance contributions made over the life cycle (Canada, England, USA). [OECD \(2011\)](#) provides a similar classification of universal systems, means-tested “safety net” programs, and mixed systems. Public insurance payments for care in France and Canada are relatively smoothly decreasing in patient income and largely independent of asset wealth. In the USA, Medicaid eligibility is 0–1 and depends on both low income and low assets. Medicaid is a “payer of last resort” and hence taxes long-term care insurance proceeds, with some exceptions in the case of “partnership” programs described below. However, Medicare is available to all Americans of retirement age and covers for short-term skilled nursing but does not pay for prolonged care and is not meant to cover assistance with activities of daily living.

Figure 35.4 shows the evolution since 1960 in the USA of Medicare, Medicaid, private insurance, and out-of-pocket payments as shares of total nursing home and home health-care costs (top panel) and in log real dollars spent on nursing home and health-care costs (bottom panel). The out-of-pocket share has declined almost continuously from 71% in 1960 to around 21% in 2010. Since about 1990, growth in out-of-pocket expenditures has been relatively modest as Medicaid and particularly Medicare have grown more rapidly. The Obama administration recently gave up an effort to generate a self-sustaining uniform long-term care insurance product “CLASS” that would have provided up to \$50 per day in expense reimbursement.

An important element of Medicaid coverage in the USA is that not all nursing facilities accept Medicaid reimbursement, in large part because Medicaid imposes caps on reimbursement. [U.S. General Accounting Office \(1990\)](#) reports that Medicaid recipients have a harder time finding facilities than non-Medicaid patients. This delay is associated with worse health outcomes, and the facilities that accept Medicaid appear to offer lower amenity and treatment quality than private-pay facilities. However, many facilities that accept private-pay only on admission will allow patients to “spend down” assets so that they may be reimbursed by Medicaid in the event of a long stay. [Grabowski et al. \(2008\)](#) find that patients in mixed Medicaid and private-pay facilities who spend down into Medicaid coverage do not suffer a decline in the quality of care as measured by health outcomes. They may, however, suffer a decline in amenity if they are transferred to a different wing of the facility after transition into Medicaid.

35.3 Is the Marginal Utility of Wealth Correlated with Limitations to Activities of Daily Living?

The small portion of long-term care costs paid for by private insurance is a “puzzle” that has attracted considerable attention. Summaries of the growing literature on the question include [Brown and Finkelstein \(2009\)](#), [Brown and Finkelstein \(Forthcoming\)](#) and [Pestieau and Ponthiere \(2010\)](#). The following discussion draws heavily on these studies and considers reasons why consumers with concave utility might not insure themselves against stochastic long-term care needs, even absent government intervention. Given the large and progressive role of government coverage, this analysis is most salient at higher levels of permanent income: it is not much of a puzzle that a poor individual

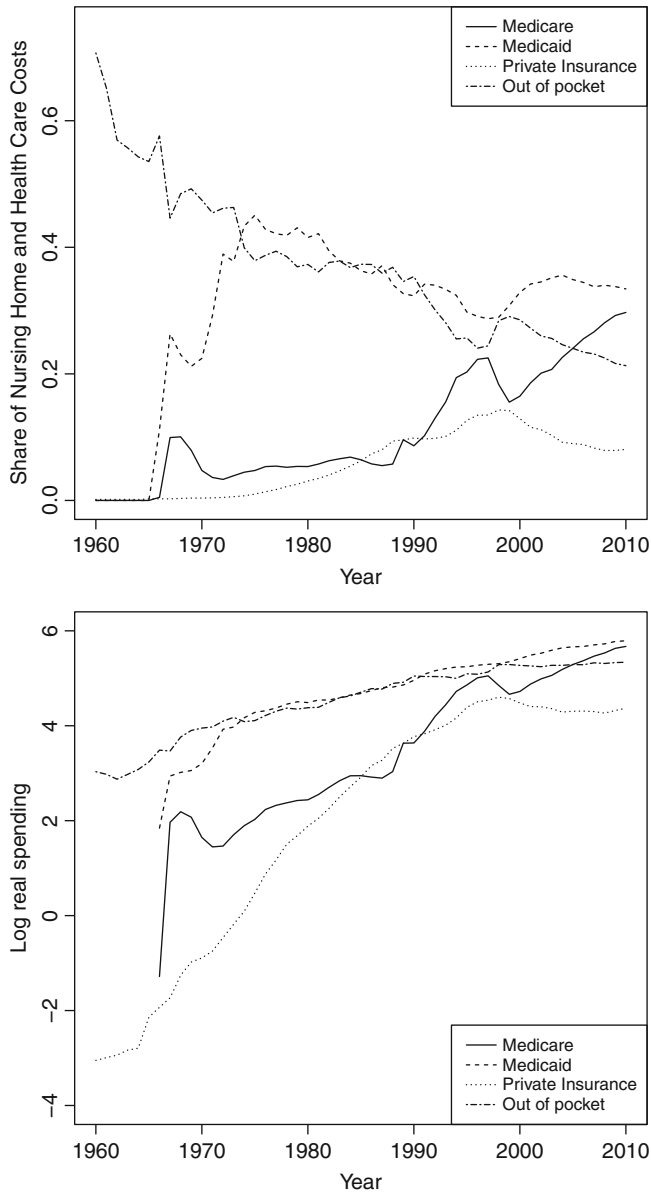


Fig. 35.4 *Top panel:* Share of nursing home and home health-care expenditures by source. *Bottom panel:* Real nursing home and home health-care expenditures by source. US National Health Expenditure Data, deflated by US CPI for all goods

who will surely qualify for Medicaid coverage in the event of extended disability would not choose to pay thousands of dollars a year for private coverage.

To frame the discussion, I start with a single-period model that can incorporate some intertemporal considerations. A consumer (possibly a couple) derives utility from two sources: expenditures on care, k , and expenditures on all other goods. The consumer is endowed with w_0 of the non-care good and may engage in an insurance program that pays the consumer $i [b(k, x) - a]$, where i is the units of insurance purchased, b is a function mapping from diagnosis x and expenditures k to a reimbursement,

and a is a constant premium paid regardless of health state. An actuarially fair policy would set $a = Eb(k, x)$. The consumer's utility can thus be written $u(w_0 - k + i [b(k, x) - a], k, x + z)$. I assume u is increasing and concave in its first argument (non-care expenditures) and concave, but not necessarily increasing, in its second argument, k . Utility over both non-care and care expenditures is shaped by both observable diagnosis of a need care x and unobservable drivers of expenditures z . z represents an index of factors that an insurer may not observe, such as family structure and variation in individual experience of a given diagnosis. A key property is that $u_{23} > 0$, so that care is more attractive when health is poor. k could be decomposed into a list of services multiplied by the quality level of each service, but I avoid this to economize on notation.

The welfare gain to purchasing a unit of insurance is given by

$$\frac{\partial Eu}{\partial i} = EbEu_1 + cov(b, u_1) - aEu_1. \tag{35.1}$$

Naturally insurance will be more attractive if the premium a is small relative to the expected payout Eb . A critical question regardless of pricing is whether the covariance between insurance payouts and marginal utility is positive. Given that the remarkable empirical fact to be explained is not a low level of coverage conditional on insurance but rather the absence of insurance coverage at all, I consider the consumer's problem with $i = 0$ and ask whether marginal utility is likely to rise with medical expenditure needs in the absence of insurance.

Optimal care expenditures k upon realization of need $x + z$ imply

$$u_2(w_0 - k, k, x + z) - u_1(w_0 - k, k, x + z) = 0. \tag{35.2}$$

Define indirect utility v for a given stochastic draw as

$$v(w_0, x, z) = \max_k u(w_0 - k, k, x + z). \tag{35.3}$$

By an envelope condition, integrating over stochastic outcomes x and z , expected marginal utility is

$$Ev_1 = \int_x \int_z u_1(w_0 - k(x, z), k(x, z), x + z) f(x, z) dz dx. \tag{35.4}$$

To determine whether marginal utility increases in diagnosis, differentiate the optimality condition (35.2) and use the definition of indirect utility (35.4) to obtain

$$\frac{dEv_1}{dx} = \int_z \left[u_1 \frac{df(x, z)}{dx} + \left[u_{13} + [u_{12} - u_{11}] \frac{dk}{dx} \right] f(x, z) \right] dz \tag{35.5}$$

$$\frac{dk}{dx} = - \frac{u_{23} - u_{13}}{u_{11} - 2u_{12} + u_{22}}. \tag{35.6}$$

$$\frac{dEv_1}{dx} = \int_z \left[u_1 \frac{df(x, z)}{dx} + \frac{u_{23} [u_{11} - u_{12}] + u_{13} [u_{22} - u_{12}]}{u_{11} + u_{22} - 2u_{12}} f(x, z) \right] dz. \tag{35.7}$$

Insurance is only likely to be desirable to the extent that expression (35.7) is positive over a sufficiently large range of x values that the covariance between insurance payouts and marginal utility is positive. The first term on the right-hand side of Eq. (35.7) reflects the fact that x and z may be correlated, although a diagnosis of observable limitation (x) would presumably incorporate information about unobservable conditions z that are associated with x . Hence this first term is likely to be small or zero in magnitude.

Assuming x and z are uncorrelated, a set of jointly sufficient conditions for marginal utility of wealth to increase in diagnosis is: (i) the marginal utility of care grows more quickly with need than demand for non-care consumption shrinks with need ($u_{23} + u_{13} > 0$); (ii) utility is more concave in non-care than care consumption ($u_{11} < u_{22}$); and (iii) the marginal utility of non-care consumption falls more rapidly in non-care than care consumption: $u_{11} - u_{12} < 0$. That these conditions are sufficient follows from the concavity of u and hence the negativity of the denominator of the second term in (35.7).

Part of condition (i) that desired care expenditures increases with poor health ($u_{23} > 0$) is not open to much doubt. However, the magnitude of this effect may not be large for those who are married or have children. As described above, conditional on age and ADL limitations, nursing home use is less common for those with spouses or children. Pauly (1990) observes that in the absence of a bequest motive, care paid for (or directly supplied) by children is effectively free. Children may wish in that case to pay for insurance. The act of providing care for a spouse may or may not affect the level of the caregiver's utility, but the effect on the marginal utility of wealth for the potential caregiver or the insured is not clear (the effect is presumably more likely to be positive to the extent that care is a substitute for earnings). Parents may not allow the children to pay for insurance if family care is preferred and bequest strength is weak. Since most long-term care is provided by family, these are not minor considerations, and they rationalize the fact that married couples receive considerably better pricing for long-term care insurance jointly than they would individually. Given that long-term expenditures reflect the joint risk of activity limitation and absence of family care, it may not be surprising that life insurance is far more prevalent among respondents in the Health and Retirement Study (approximately 62% in the 9th wave) than long-term care insurance (approximately 12%).⁷

Condition (i) for marginal utility to increase in observable need x is jeopardized by the likely negativity of u_{13} , the effect of observable medical need on the marginal utility of non-care consumption. This negativity may arise from at least three sources. First, the need for care is correlated with reduced longevity. Pauly (1990) summarizes evidence that life expectancy falls significantly conditional on poor enough health to require long-term care. Consistent with this observation, Fig. 35.5 shows that conditional on age, the fraction of individuals surviving through the 9th (2008) wave of HRS by age is much lower for individuals reporting at least one ADL limitation (plotted with an "X") in the 4th wave (1998) than among those reporting no ADL limitations in the 4th wave (plotted with an "o"). Those in a nursing home in wave 4 (plotted with a "Y"), presumably in worse than average states of limitation given at least one ADL problem, have very little probability of surviving to the 9th wave. Most wealth is not annuitized, so the marginal utility of wealth rises with age and expected longevity. Thus the relative marginal utility of wealth when in need of care versus when healthy is determined in part by a "horse race" between the added expenditures of optimal care costs against the reduced expenditures required to fund a constant level of non-care expenditures while alive.

Even conditional on life expectancy, the marginal utility of non-care expenditures would likely fall as health deteriorates. Travel and fancy restaurants, for example, must yield less enjoyment while suffering from ADL limitations, and almost no consumption can be enjoyed while confined to intensive care in a nursing facility. Indeed Pauly (1990) assumes $u_1 = 0$ conditional on a need for long-term care. Finkelstein et al. (2009a) cite several contributions that offer ambiguous evidence on the relationship between the marginal utility of wealth and overall health. Many of these studies, however, conflate multiple terms in Eq. (35.7). Taking care not to conflate terms, Finkelstein et al. (2009b) find a significantly negative effect of chronic health problems on the marginal utility of consumption among the elderly.

⁷Brown (1999) presents results that suggest caution in the interpretation of life insurance as a precaution against long-term care expenditures: life insurance policies are generally quite small, and many appear to be held for tax, rather than insurance, purposes.

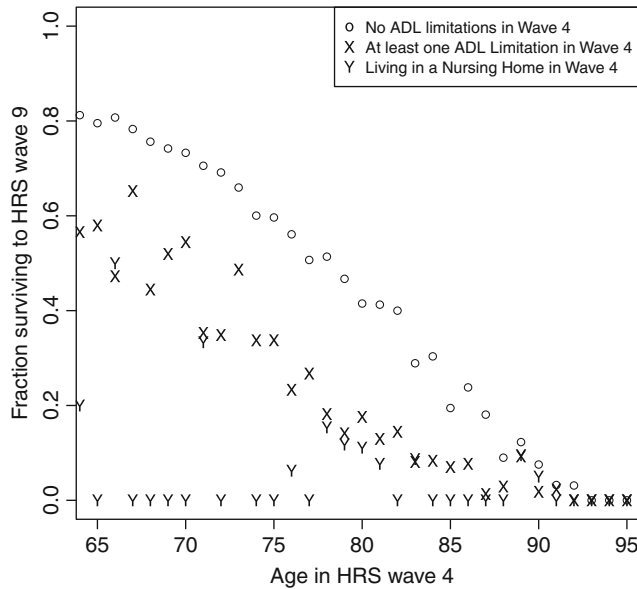


Fig. 35.5 Fraction of respondents in the 4th Wave of the Health and Retirement Study (1998) surviving to the 9th wave (2008). *Circles*: no ADL limitations in wave 4. *“X”*: one or more ADL limitations in wave 4

A third significant factor rendering u_{13} negative, raised by Skinner (1996) and Davidoff (2010), is that home equity may act as a precautionary buffer against large out-of-pocket long-term care costs. Venti and Wise (2000), Megbolugbe et al. (1997), and Walker (2004), among others, show that nursing home stays are highly correlated with sale of a home among the elderly. Figure 35.6, taken from Davidoff (2010), shows that HRS homeowners are much likelier to sell their homes if they enter a nursing home and that prolonged stays in nursing homes are associated with continued elevation of the hazard out of homeownership. ADL limitations are also associated with exit from homeownership. Among wave 8 respondents who had no ADL limitations in wave 4 and none in wave 8, 80% remain homeowners in wave 8. Among those with no limitations in wave 4 but at least one limitation in wave 8, 61% remain homeowners. Among those with at least three ADL limitations in wave 8, just 43% remain homeowners.

Sale of a primary residence is highly correlated with liquid wealth because home equity release through increased mortgage debt is uncommon among the elderly and because home equity represents a large share of wealth and a large fraction of likely long-term care expenditures conditional on ADL limitation. Davidoff (2010) observes that 12% of homeowners over age 62 in the 2004 wave of the HRS owed any mortgage debt, and among this 12%, median mortgage debt to value was just 33%. Much of this mortgage debt is held over from working years, with the median ratio of home equity to home value 84% among owners in their 60s and 96% among owners in their 90s. Davidoff (2010) also shows that 79% of respondents aged 62 or older in the 2004 wave of the HRS respondents are homeowners. Among owners, median equity is \$110,000 and the median ratio of home equity to total wealth is 55%.

Among the wealthiest quintile of households, for whom public insurance is unlikely to cover long-term care costs, 84% of respondents report home equity over \$100,000. That is, 84% of those who might plausibly be interested in private insurance have home equity that is greater than 84% of the distribution of lifetime long-term care expenditures conditional on positive expenditures calculated by Kemper et al. (2005/2006). Table 35.1 confirms these findings in the 2008 wave of the HRS/AHEAD survey, presenting mean values of a long-term care insurance coverage indicator housing and home

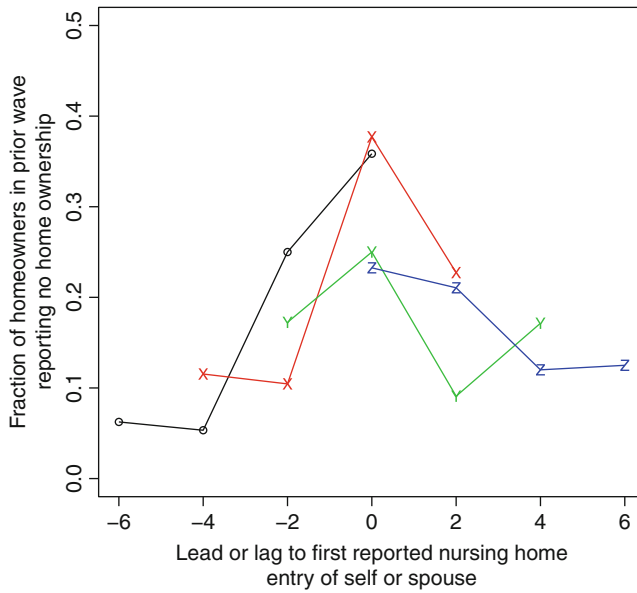


Fig. 35.6 Figure 1: Exit rates from homeownership at, and after first report of self or spouse living in a nursing home among those 62+ and alive in the HRS/AHEAD panel. o represents all 1998 homeowners who first entered a nursing home in 2006, X first entered a nursing home in 2004, Y first entered in 2002, and Z in 2000. 0 is the survey year of first report of living in a nursing home, e.g. 2006 for the o cohort

Table 35.1 Wealth quantile (out of 20), median net value of primary residence, fraction covered by long-term care insurance, and median ratio of net value of primary residence to nonhousing wealth, respondents over age 70 to the 2008 Health and Retirement Study/AHEAD

| Wealth quantile | Median net residence value | Long-term care coverage | Netvalueofprimaryresidence Nonhousing wealth |
|-----------------|----------------------------|-------------------------|---|
| 1 | 0 | 0.05 | 0.00 |
| 2 | 0 | 0.02 | Infinite |
| 3 | 0 | 0.03 | 0.00 |
| 4 | 0 | 0.03 | 0.00 |
| 5 | 20,000 | 0.03 | 5.20 |
| 6 | 40,000 | 0.08 | 5.00 |
| 7 | 50,000 | 0.07 | 3.67 |
| 8 | 48,500 | 0.05 | 2.12 |
| 9 | 60,000 | 0.09 | 1.76 |
| 10 | 60,500 | 0.09 | 1.15 |
| 11 | 99,000 | 0.17 | 1.34 |
| 12 | 99,500 | 0.17 | 0.88 |
| 13 | 125,000 | 0.14 | 0.88 |
| 14 | 117,500 | 0.22 | 0.59 |
| 15 | 130,000 | 0.19 | 0.49 |
| 16 | 130,000 | 0.19 | 0.38 |
| 17 | 150,000 | 0.19 | 0.32 |
| 18 | 150,000 | 0.28 | 0.20 |
| 19 | 200,000 | 0.31 | 0.18 |
| 20 | 269,000 | 0.26 | 0.10 |

equity for each of ten nonhousing wealth deciles for individuals (unweighted) over age 70. To the extent that marginal utility declines faster in liquid wealth than in unspent home equity, for most plausible candidates for long-term care, the marginal utility of wealth while in need of care may well be lower than in good health, once both care expenditures and home equity are accounted for.

Simulations suggest that in the realistic setting in which private savings are not annuitized and home equity is not spent until a sale, the correlations between ADL limitation and both longevity and home equity spending may sharply curtail demand for long-term care insurance for households with weak bequest motives. [Sinclair and Smetters \(2004\)](#) show that for sufficiently high-risk aversion, the presence of calibrated uninsured health shocks can eliminate demand for life annuities. [Turra and Mitchell \(2004\)](#) provide similar results.

[Davidoff \(2009\)](#) calibrates expected lifetime utility for a healthy 62-year-old facing uncertainty over length of life and health, with health and mortality transitions following the model of [Robinson \(1996\)](#). In a world with fully liquid home equity, the value of the right to take on an actuarially fair and complete long-term care insurance more than doubles when all savings are annuitized rather than held in a bond. When most savings are annuitized, the welfare gain to taking on an optimal long-term care insurance policy for a homeowner with \$100,000 in liquid savings and \$200,000 in home equity is more than 10 times greater when home equity is liquid than when equity is only liquidated on sale (which only occurs upon entry into long-term care).

Condition (ii), $u_{11} < u_{22}$, that the marginal utility of expenditures decline more rapidly for non-care rather than care seems plausible. In a given time period, long-term care expenditures induced by poor health can easily exceed expenditures on all other goods when the same household is in good health. Two considerations operate in the opposite direction: first, among households wealthy enough to consider private insurance as a substitute for public provision, utility may be close to linear in wealth. Second, some long-term care expenditures are luxuries, such that u_{22} may be more negative than the jumps in expenditures with poor health suggest.

Both [De Nardi et al. \(2010\)](#) and [Lockwood \(2011\)](#) use simulated moment methods to find that life-cycle savings choices among older Americans are consistent with preferences under which bequests are a superior good and utility over bequests is closer to linear than is utility over own consumption. [Lockwood \(2011\)](#) argues that these preferences justify weak demand for long-term care insurance among the higher-income households for whom Medicaid coverage is a poor substitute. These households will hold a lot of wealth to leave as bequests, but if insurance is worse than fairly priced, the near linearity of bequest utility will not generate demand for insuring the bequest against long-term care expenditures. A caveat to this interpretation is that Lockwood finds more concavity in bequest utility when long-term care insurance purchases are not used to estimate the model. The functional form of utility over bequests in both contributions is constant relative risk over consumption plus an intercept, implies increasing relative risk aversion past some level of wealth, and may be inconsistent with a dip in long-term care purchases at very high wealth levels indicated in [Table 35.1](#). It is worth further investigation to see if the dip at highest wealth levels is significant and if utility parameters would have to change to fit this pattern.

u_{22} may be quite negative. Some of the right tail of long-term care expenditures reflects payments for a level of amenity in surroundings that may yield very little improvement in health outcomes. In British Columbia, publicly subsidized nursing homes monthly costs generally charge a total of \$3,000 per month. Private rates range from 4,000 to 8,200 per month depending on the quality and location of the facility, but industry participants suggest that licensing requirements imply that the quality of care for ADL limitations may not be very different in public- versus private-pay facilities. In the USA, there is considerable flexibility in choice of expenditures on the bundle of location, amenity, and intensity of care. [CareScout \(2011\)](#) cites a range from \$46,355 (Texas) to \$130,305 (Connecticut) in state mean nursing home costs for a year in a semiprivate room. Even within New York State (and thus within a Medicaid regime), Genworth reports that a year in a nursing home in Buffalo has a

median cost of approximately \$110,000 versus over \$160,000 in Manhattan.⁸ Within California, costs range from \$73,000 for a semiprivate room in Stockton to just under \$100,000 for a semiprivate room in San Francisco to \$130,000 for a private room in San Francisco. Privacy, proximity to relatives and amenity are presumably less of a necessity than receiving care at all. Thus the difference between the marginal utility of care generated by the last \$50,000 spent on care in Manhattan or San Francisco and the marginal utility of the first 100,000 conceivably may not be much less negative than the difference in non-care utility generated by the last \$50,000 and the first \$100,000 spent on other goods over the remaining life cycle.

The third condition for marginal utility to rise in medical need that $u_{11} - u_{12} < 0$ requires that non-care consumption is not a perfect substitute for care consumption. Most plausibly, $u_{12} > 0$ so that there is substitution, but $u_{11} - u_{12} > 0$ such that substitution is imperfect. The natural sources of crowd out are the portion of long-term care costs that are associated with room and board. OECD (2011) states that room and board can represent up to 50% of long-term care costs (OECD 2011).⁹ Back-of-the-envelope calculations based on cost survey data from CareScout (2011) and Prudential (2010) suggest a somewhat lower cost share. Alternatively, combined mean expenditures on food and rent for consumer units that rent their housing in the US Consumer Expenditure Survey are under \$17,000. Charges for institutional room and board for single individuals at undergraduate colleges average around \$10,000 based on casual empiricism.

Summarizing, several considerations add ambiguity to the relationship between the marginal utility of wealth and need for care. Recourse to family care and home equity attenuate the financial costs associated with a need for care. Limited consumption needs while in care due to inability to enjoy consumption and the bundling of room and board with care likely render the marginal utility of a fixed level of expenditures while in care lower than the marginal utility of the same level of expenditures while healthy. Some of the right tail of long-term care expenditures represents improvements in the quality of room and board, and the marginal utility of these improvements may not be large relative to the gain from money allocated to non-care expenditures.

35.4 The Design of Long-Term Care Insurance

Private insurers face an environment in which public insurance, family care, and home equity provide substitutes for a large fraction of the population. There is reason to suspect that households who demand private insurance despite the presence of substitutes may be bad actuarial risks.

Governments face the problem of how to structure any intervention into markets. Optimal tax theory provides some reason to question a role for public intervention at all: Corlett and Hague (1953) and Atkinson and Stiglitz (1971) show that subsidies to particular commodities are typically undesirable if a perfect system of income taxation already exists. Indeed, in their theory of public design, Cremer and Pestieau (2011) observe that high-ability individuals are on average longer-lived than low-ability individuals; this argues for a tax on long-term care insurance to soften moral hazard problems inherent to a redistributive income tax scheme.

⁸It is unlikely that a retiree living in Manhattan would wish to move into a facility in Buffalo, but she might be more willing to do so than to live in extreme poverty after any exit from long-term care while alive.

⁹Rental housing provided as part of nursing home expenditures represent a negative contribution to the expression u_{12} . This is different from the undoing of the “asset commitment” to home equity induced by the liquidation of home equity, attributed above to the term u_{13} . The first effect relates to present dividends, the latter relates to future dividends flowing from the original home.

Public opinions studied by [European Commission \(2007\)](#) show clear support for government intervention into long-term care markets, and there are economic rationalizations for this view. First, compulsory insurance avoids problems of selection. [Finkelstein and McGarry \(2003\)](#) show that purchasers of long-term care insurance have offsetting characteristics that lead to no clear relationship between nursing home use and insurance purchase: purchasers not only believe that they are likelier to develop ADL limitations but also engage in more preventive care. However, [Murtaugh et al. \(1995\)](#) observe that between 13% and 30% of retirees (who represent the bulk of long-term care purchasers) would be unable to purchase policies due to insurer underwriting policies. If insurers were unlikely to face adverse selection, they might find it more profitable to eliminate underwriting requirements and charge higher average premiums.¹⁰ Individuals face the risk of being in a poorly priced risk pool if they are allowed to purchase insurance but are less than fully healthy at the date of purchase.

Selection concerns suggest that an optimally designed elective insurance system would involve purchase of insurance starting early in working life. The incidence of ADL limitation is not zero during working years, and information asymmetries are weaker over long horizons than short horizons (see, e.g. [Chalmers and Reuter 2009](#) with respect to longevity risk): young workers may not know much more about their own joint probability of survival and ADL limitation decades than insurers. Indeed, consistent with the theory of dynamic adverse selection laid out in [Dionne and Doherty \(1994\)](#), [Finkelstein et al. \(2005\)](#) show that individuals who let long-term care contracts lapse (thereby foregoing subsidized payments) enter nursing homes less frequently than those who keep contracts in force, indicative of worsening adverse selection with age.

Absent government intervention, consumers with foresight might enter into dynamic contracts early in life, avoiding the poor pricing that arises from selection in contracts entered into late in life. It is not obvious, however, that rational young consumers would want to commit to a long-term contract. Liquidity constraints (e.g., due to down payment constraints) might swamp the gain from informational symmetry, deferring purchase to at least middle age. The existence of, and uncertainty over, the adequacy of home equity and family substitutes to long-term care insurance also presumably argue against early purchase. Even existing contracts, which are typically purchased around retirement, feature lapse rates of approximately 7% per year ([Finkelstein et al. 2005](#)). [Brown and Finkelstein \(Forthcoming\)](#) show that even for 65-year-olds, the average effective load on contracts rises from 18% to 51% once lapses are accounted for. [Merlis \(2003\)](#) argues that favorable pricing from early purchase would evaporate if not for lapses. It is not at all clear (particularly with inferior public insurance available) that lapses occur in states of the world with relatively low marginal utility. Long-term care typically occurs late in life, and the high fraction of working age households purchasing life insurance suggests that survival to retirement is correlated with relatively low lifetime marginal utility. Thus contracts that transfer away from those who lapse may not be preferred by risk averse consumers to worse priced contracts that are entered after the resolution of life-cycle uncertainty.

[European Commission \(2007\)](#) provides evidence suggesting that younger people do not accurately assess the likelihood of future limitation. The fraction of respondents to a survey asking “Do you expect that at some stage during your life, you will, for a prolonged period of time, become dependent upon the help of others because of your physical or mental health condition?” answering that this event is “unlikely, but you would not exclude this possibility” or “almost certain” of no future dependency falls continuously with age from 46% between ages 15 and 24 to 16% among those 85 or older. [RoperAsw \(2011\)](#) and others have shown that many Americans are confused about whether or not their private insurance or future Medicare coverage will pay for long-term care and that most have imprecise understanding of long-term care costs. [Cutler \(1996\)](#) elaborates on another consideration

¹⁰[Sloan and Norton \(1997\)](#) report evidence of adverse selection on prospective health, but no favorable selection on risk aversion in earlier waves of the HRS. [Courbage and Roudaut \(2008\)](#) find that individuals in poor health and with strong bequest motives are more likely to take on long-term care insurance in SHARE survey data covering France.

that affects the desirability of long-term care contracts: a large part of long-term care expenditure risk relates to price inflation, a risk that cannot be diversified away by insurers. Merlis (2003) shows that paying an insurer expected lifetime costs would be beyond the means of many households, particularly older households. However, the ability to pay for insurance is in part endogenous to savings that reflect reaction to Medicaid and other public provision.

In light of these considerations, it seems unlikely that governments will leave long-term care insurance entirely to the private sector anytime soon. Naturally, public provision may crowd out private insurance throughout the income distribution. In the USA, Medicaid pays after private insurance and only if income and assets are low (subject to “partnership arrangements”). Allowable income and wealth are greater when there is a “community spouse” outside of care.

Means-tested support for long-term care generally implies taxation of private savings and insurance. Generalizing the analysis in Brown and Finkelstein (2007) with respect to preferences, but reducing the problem to a single period, utility using the US Medicaid program may be approximated by

$$v^{\text{medicaid}}(w_0, x, z) = \max_{k \in [0, \bar{k}(x)]} u(\max(\min(w_0 - k, \bar{w}), \underline{w}), k, x + z). \quad (35.8)$$

In Eq. (35.8), \bar{w} is a maximal amount of wealth and income that may be retained after entry into Medicaid. Some resources may be hidden with friends or relatives despite Medicaid look-back policies, and couples may generally retain home equity (see Greenhalgh-Stanley (2011) for a discussion). The lower bound \underline{w} reflects the fact that Medicaid will pay for resources once assets and income have been run down to a sufficiently low level.

US states vary in their treatment of housing assets. Generally speaking, a Medicaid recipient or community spouse may reside in a home and retain home equity without impact on Medicaid eligibility. However, if no living spouses remain in the home, and a recipient moves to a nursing facility with no “intent to return,” states may place a lien on future sale proceeds or deny coverage. States generally do not capture home equity while the recipient is alive. Some states aggressively enforce liens against single recipients after death or transfer of the home. Medicaid prohibits the enforcement of liens against surviving spouses and in some cases against siblings or adult children who have lived with the recipient more than 2 years prior to entry into Medicaid.¹¹

Conditional on wealth, Medicaid utility (35.8) can only be less than uninsured utility (35.3) if the constraint on the level of care imposed by Medicaid \bar{k} binds with sufficient force or if resources w_0 are sufficiently large relative to the allowance \bar{w} . Assuming k is normal, Medicaid will become a worse substitute for the better of self-insurance or private insurance as resources w_0 rise. Mechanically, with w_0 sufficiently large, the lower bound on non-care consumption provided by Medicaid becomes less valuable.

Private or self-insurance is more attractive to the extent that features such as attractive and convenient surroundings, more personalized care, and better food are important, that is, as the constraint \bar{k} binds with more force. Survey evidence from 887 individuals aged 54–90 presented by Ameriks et al. (2007) suggests that these amenities loom large in the financial planning of the elderly. Respondents were asked in a hypothetical world in which they were 85, and had \$200,000 in total wealth, whether they would prefer to (a) give all of the money to heirs, but receive care in a nursing home that takes Medicaid payment, or (b) give \$150,000 to heirs and spend \$50,000 on superior care in a private facility. Eighty-five percent chose option (b).

Consistent with these observations, Brown and Finkelstein (2007) estimate that for approximately 60% of the US population, a combination of self-insurance and Medicaid is a better way to finance long-term care than is private insurance. Table 35.1 lists quantiles of HRS wave 4 nonhousing

¹¹Regulations are discussed at <http://aspe.hhs.gov/daltcp/reports/hometreat.htm>.

assets against the fraction of respondents at that wealth decile covered by long-term care insurance. Supporting an important role for Medicaid and the calibration of [Brown and Finkelstein \(2007\)](#), the rate of private coverage rises in assets, with a rate of increase that becomes sharper past the mean of the distribution. However, mean coverage never exceeds 31% for any of 20 wealth quantiles.

Either public or private insurance that conditions on use (k in the notation above) rather than diagnosis (x) would seem to invite moral hazard on use of care. The fact that nursing home use is highly responsive to the presence of potential family caregivers suggests that use might also be sensitive to after-insurance price. A surprising finding in this light is that nursing home use does not appear to be responsive to financial incentives conditional on observable characteristics. [Grabowski and Gruber \(2007\)](#) show, based on variation across time and states in six different types of Medicaid policies and microdata from respondents in the US National Long-Term Care Survey, that the decision to enter a nursing home depends at most insignificantly on the extent of public subsidies. They interpret this finding as consistent with households using nursing homes only when family or home health aide support is not feasible; this is broadly consistent with the preferences and attitudes expressed in the [European Commission \(2007\)](#) survey. [Cutler and Sheiner \(1994\)](#), using only cross-state variation, find evidence of moral hazard, but other similar studies find no such evidence.

Having sufficiently low wealth and income to qualify for Medicaid is an outcome of both lifetime resources and consumption and investment choices. Whether due to bequest motives or savings for a possible period of life after receiving care, spending assets down to a sufficiently low level to pass income and tests will presumably be less attractive as resources rise. [Hubbard et al. \(1995\)](#) argue that means-tested public insurance may explain the fact that households with low permanent income save at a lower rate than households with higher permanent income and this pattern is confirmed in [De Nardi et al. \(2010\)](#). [Gruber and Yelowitz \(1999\)](#) confirm empirically that expansion of Medicaid increased the consumption and reduced the savings of targeted households.¹² Savings may fall both because potentially marginal households face a high implicit tax on savings due to the discrete nature of eligibility and because the need for precautionary savings against care expenditures is reduced among households likely to qualify for Medicaid.

There is evidence that households “game” eligibility through asset choice. [Engelhardt and Greenhalgh-Stanley \(2010\)](#) show that state laws that encourage the use of home health-care services increase homeownership rates among the elderly, and [Greenhalgh-Stanley \(2011\)](#) shows that state recovery rules that are generous towards estates also increase homeownership rates among older married couples. In particular, Greenhalgh shows that in states that actively recover home equity from singles, the difference between the ownership rates of singles and couples (whose homes are only subject to Medicaid recapture in the rare event that both members receive Medicaid-financed care) is more negative. Given that Medicaid discourages nonhousing accumulation, it is not clear whether a distortion that makes home equity a favored form of savings is more desirable than taxing housing and other forms of savings at equally punitive rates.

Recognizing the moral hazard induced by Medicaid coverage of qualifying long-term care expenses, the USA offers partial tax deductibility of long-term care insurance premiums. Several states have also devised “partnership” policies which permit purchasers of long-term care policies to exempt more assets from Medicaid eligibility tests than they would otherwise be able to exempt, in the event that care expenditures exceed contracted benefits. [US Government Accountability Office \(2007\)](#) estimates that 80% of partnership policyholders would have bought conventional plans in the absence of the partnership program, such that the program is a small net cost to the Medicaid system.

From the analysis in Sect. 35.3, it seems likely that long-term care insurance demand is depressed not only by public provision, particularly for lower wealth households, but also by absence of

¹²[Gittleman \(2011\)](#) shows that the reduction in savings are less easily detected in the National Longitudinal Survey of Youth, 1979 than in the Survey of Income and Program Participation data used by [Gruber and Yelowitz \(1999\)](#).

annuitization and the strong positive correlation between nursing home use and home equity liquidation.

Combining long-term care insurance with annuities has been proposed both due to not only demand complementarities described in Sect. 35.3 but also on “supply-side” selection grounds. [Murtaugh et al. \(2001\)](#) use the 1986 National Mortality Followback Survey to show that life expectancy is much less for individuals with enough limitations to be underwritten out of long-term care than for otherwise similar individuals. Thus the risk of long-term care need is less among the long-lived than the short-lived, and the risks facing annuity and long-term care providers are negatively correlated. They show that actuarially fair pricing of a bundled annuity and long-term care policy could reduce premiums by 3–5% while weakening underwriting standards to screen out only 2% of 65-year-olds as opposed to the then prevalent 23% exclusion. Bundling thus promises to improve pricing, resolve a major liquidity problem in annuity demand (by reducing the need for cash in the event of ADL limitation), and increase the relative marginal utility of wealth in the event of care need (by annuitizing wealth and equalizing marginal utility with across longevity outcomes). [Webb \(2009\)](#), assuming a perfectly negative correlation between survival and long-term care risk, lays out the theoretical case for a pooling equilibrium in a bundled contract that may not be achievable in stand-alone annuities or long-term care insurance contracts.

Bundled long-term care insurance and annuities are currently available in the US ([Lysiak 2007](#)), but demand does not appear to be strong. [Davidoff \(2009\)](#), building on [Davidoff et al. \(2005\) \(2005\)](#), offers a demand-side explanation for why this seemingly compelling product is only very rarely traded. Annuities and long-term care are complementary in that an ADL limitation that occurs soon after annuity purchase will require immediate liquidity, but annuities are inherently illiquid (see, e.g., [Direr 2007](#) and [Sheshinski 2010](#)). However, annuities and long-term care are substitutes in that they both offer greater expected benefits to those who are longer-lived, in that ADL limitation risk grows with age. To the extent that liquidating home equity reduces the need for liquidity in the event of long-term care, the complementarity between long-term care insurance and annuities is weakened, but the force of substitution is not. Home equity, long-term care insurance, and annuities are all “back loaded.” A complete and bundled solution to the problems of uncertain longevity, stochastic care needs, and home equity illiquidity may be required to develop thick markets for any of annuities, long-term care, or reverse mortgages.

As detailed in [Ahlstrom et al. \(2004\)](#), the American Homeownership and Economic Opportunity Act of 2000 provides a waiver of guarantee fees for reverse mortgage borrowers who use loan proceeds to purchase long-term care insurance, but the US Department of Housing and Urban Development has not yet implemented this proposal. How home equity bundling would affect equilibrium is an open question for research. Reverse mortgages embed a bet against borrower longevity on the lender’s part,¹³ so the same case for bundling long-term care insurance with annuities may be made for bundling with reverse mortgages. Bundling an annuity and a reverse mortgage might invite worse selection problems in these small markets than already exist. The complexity and informational problems of a three-part insurance solution, which would involve complicated bets on interest rates, home prices, health, and longevity, may well be beyond the capabilities of insurers and consumers for some time.

¹³Witness the disastrous “viager” contract that Andre-Francois Raffray offered 90-year-old Jeanne Calment in 1965 (source: Mazonis)

35.5 Conclusions

Long-term care insurance is currently dominated by compulsory government programs that are progressively funded and typically also provide benefits that decline in wealth and income. There is evidence that the sharp means testing in Medicaid in the US yields reduces the level of savings and shifts the composition of savings towards housing, which is relatively protected. Medicaid may also reduce labor supply over the life cycle. Whether benefits for long-term care in Medicaid depress the accumulation of wealth is a more open question.

There is no clear evidence that costly nursing home use in lieu of family or professional care at home is increased by public payment. Absence of moral hazard on use may arise from widespread preferences for care at home and undertaken by patients' spouses or children. This may argue for the reimbursement model of insurance in the USA over the indemnity model which is more prevalent in the French public and private insurance systems (see [OECD 2011](#) and [Pestieau and Ponthiere 2010](#)). The extent of moral hazard on the use of home care is not known. Whether cash payments based on diagnosis are superior to reimbursement also depends on the correlation between observable diagnosis and true need for care, a set of quantities that has not been compellingly estimated.

Why public support for social insurance of long-term care insurance is as strong as survey data suggest is an open question. Per [Atkinson and Stiglitz \(1971\)](#), there might be efficiency gains to limiting social insurance schemes to income redistribution, with the long-term care insurance coverage left to private contracts between consumers and firms. An obvious possibility is that voters are both altruistic and myopic, so that there is majority support for aid to the needy elderly without recognition of the present or future tax costs. To the extent that the political process represents an exercise in social welfare maximization, some combination of adverse selection into private insurance, supply-side barriers to competition and failure of foresight on the part of some consumers may rationalize public intervention. [Cremer and Pestieau \(2011\)](#) provide a rationalization for the system seen in the USA and France. When there are limits to the efficiency of a redistributive tax, they conclude that a progressive social insurance benefit formula is optimal and that private long-term care insurance should be subsidized on average, but taxed on the margin. In this way, the wealthy self-insure but middle earners purchase private insurance, alleviating the tax burden and moral hazard problems of subsidies for care of the poor. Failure of the CLASS legislation in the USA highlights that there is not infinite political support for public provision of long-term care payments.¹⁴

There is scope for private long-term care insurance in markets such as the USA where eligibility involves stringent income and asset tests and where facilities that admit patients on Medicaid are less available and offer lower amenity than private-pay facilities. Approximately 10% of older Americans take on private long-term care insurance, with the fraction sharply rising in wealth up to roughly 30% between the 90th and 95th percentiles of nonhousing wealth. An apparent dip in participation at highest wealth levels may help inform the characterization of preferences over bequests.

The presence of potential family care, housing wealth, and uninsured longevity risk make stand-alone long-term care insurance and particularly a long-horizon commitment to insurance difficult to sell. There is some evidence of a failure to plan for ADL limitations among younger households.¹⁵ Long-term care insurance bundled with annuities alone or with reverse mortgages alone do not appear to be popular. Future research could usefully explore an option to purchase long-term care that is tied to death of a spouse, as spousal death removes a potential free caregiver and some commitment to home equity and makes costly nursing home entry much more likely. Multiproduct combinations of

¹⁴The fact that CLASS was self-financed may be taken as evidence of a link between myopia and popular support for public payments.

¹⁵[Brown and Finkelstein \(Forthcoming\)](#) report searching in vain for directly relevant evidence concerning consumer irrationality or present bias in the long-term care insurance market but survey some relevant results from related markets.

home equity liquidation with spousal life, own longevity, and long-term care may be necessary to spur consumer demand above 30% at high wealth levels but would involve enough dimensions of selection and moral hazard to warrant fear from suppliers, and further analysis from economists. An important near-term research task is to refine our understanding of the correlation between the lifetime present discounted value of long-term care expenditures and longevity. [Webb \(2009\)](#) and [Kemper et al. \(2005/2006\)](#) premise their analysis of gains to bundling on a negative correlation, but [Brown and Finkelstein \(2007\)](#) find that longer-lived women are a worse actuarial risk to long-term care insurers than are shorter-lived men.

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Chapter 36

New Life Insurance Financial Products

Nadine Gatzert and Hato Schmeiser

Abstract This chapter provides an overview of new life insurance financial products. After a general market overview, Sect. 36.2 presents different forms of traditional and innovative life insurance financial products and their main characteristics. Since unit-linked and equity-indexed type contracts represent the basis for most innovative products in recent years, Sect. 36.3 presents basic aspects of the modeling, valuation, and risk management of unit-linked life insurance contracts with two forms of investment guarantees (interest rate and lookback guarantees) and different underlying investment strategies. In Sect. 36.4, variable annuities are discussed and focus is laid on challenges for insurers in regard to pricing and risk management of the various embedded options. Section 36.5 finally puts the customer's perspective in the center of the analysis, along with a discussion of current developments regarding product information documents and performance and risk-return profiles, which is of special relevance for new and traditional products.

36.1 The Worldwide Life Insurance Market and the Need for Innovation

The two global financial crises in the last 10 years have substantially impacted the life insurance industry. In general, major drivers for the life insurance market and innovative products become apparent when looking at the history and reasons for increases and decreases in premium volume and equity capital bases over the past years. The following numbers in the text refer to Fig. 36.1.

Looking at the situation 12 years ago in the year 2001, life insurers in industrialized countries were especially challenged due to losses in stock markets and the downturn of the economy, which also implied a strong decline in the demand for unit-linked life insurance products (Swiss Re 2002). The reduced sales in unit-linked products were thereby partially compensated by a higher number of contracts sold with guaranteed returns and private pensions, such that overall, life insurance premiums only declined by 2.7%. However, the stock market drop after the financial crisis caused by the burst of the dot-com bubble led not only to a reduction in premium income but also to considerable declines in equity capital and investment yields along with low interest rates. The induced downgrades of

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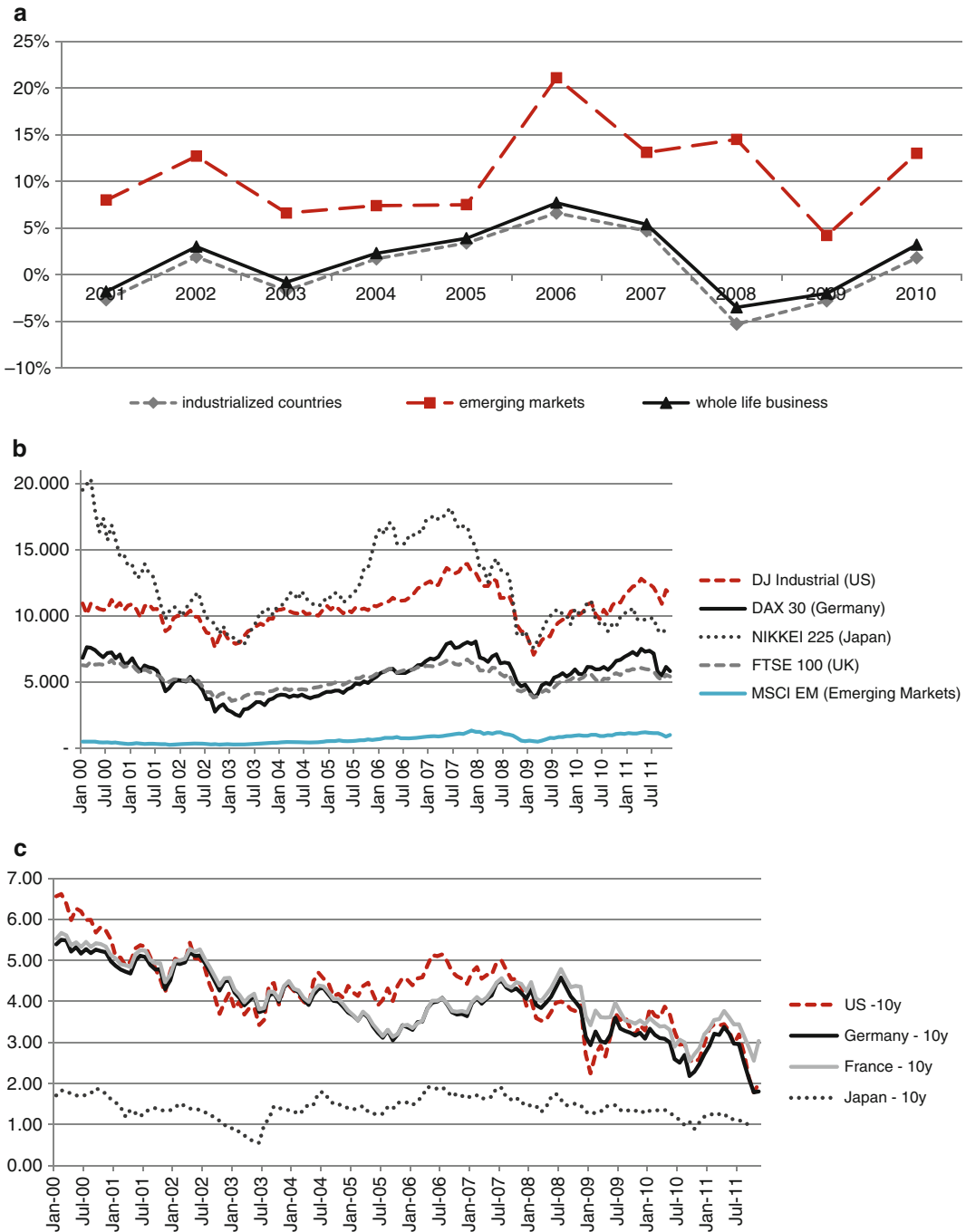


Fig. 36.1 Real premium growth in the global life insurance industry, stock market development, and long-term interest rates from 2000 to 2011. (a) Real premium growth in the global life insurance industry (Swiss Re 2002–2011). (b) Stock market development (Datastream). (c) Long-term interest rates development (Datastream)

corporate bonds forced insurers to substantial write-offs, in particular in the year to follow. The global slowdown in growth was thereby mainly driven by the Latin American and South Korean markets. However, as pointed out by [Swiss Re \(2002\)](#), at that time, the life insurance industry still represented a growth industry as growth in premium income still generally exceeded growth in the gross domestic products.

In 2002, premiums exhibited an increase of +3.0%, which was mainly driven by higher sales in the emerging markets (+12.7%), while industrialized countries grew by +1.9% after the severe losses in 2001. As in previous years, growth was mainly driven by deterioration of social security systems and the resulting increasing demand for annuities and pension products ([Swiss Re 2003](#)). However, insurers still had to substantially write down the values of corporate bonds due to lower ratings, which caused stress for their balance sheets.

After the improvements in 2002, premiums in industrialized countries fell again in real terms by -1.7% in 2003, mainly due to adverse developments in the USA and UK, while emerging markets once more showed an increase of +6.6%. Reasons for customers' hesitation in buying traditional savings products comprised the reduction of surplus participation rates due to losses in capital investments (fall in stock market and low interest rates). This particularly impacted the UK life insurance industry as with-profit policies' payouts and terminal bonuses were reduced, which are optional and can generally be cut by the insurer, if necessary. At the same time, customers were still not sufficiently convinced of unit-linked products because of the recent experiences at the financial market and doubts about the outlook of future capital market developments ([Swiss Re 2004](#)). Term life and pension products again sold well, also due to increased risk awareness and the demographic development in general. Furthermore, credit risk declined and corporate bond ratings improved. However, due to strong reductions of the stock portions in their asset allocation, life insurers did not fully benefit from increasing stock markets and at the same time suffered from low interest rates in the fixed income segment, despite a starting increase in interest rates towards the end of the year.

From 2004 to 2007, life insurance business considerably recovered and growth rates in the life insurance industry accelerated from +2.3 to +3.9%, up to +7.7% in 2006, the highest growth rate since 2000, and to +5.4% in 2007 ([Swiss Re 2005–2008](#)). This favorable development was mainly driven by pension reforms in Western Europe, tax advantages for pension products, and a higher profitability. In addition, a stronger capital base along with positive macroeconomic indicators and a strongly increasing stock market enhanced this development, which especially impacted unit-linked business in a positive way. As further key drivers, [Swiss Re 2007](#) points out the housing market boom as well as successes in bancassurance. However, in some countries, specific adverse developments limited the growth rates. For instance, the German market showed lower rates in 2005 due to tax reforms that reduced tax advantages for traditional life insurance products, while growth in the U.S. market was hampered due to higher short-term interest rates that made an investment in life insurance less attractive. Positive impact was in contrast generated by the demographic development and the ageing population as well as government incentives to shift from public to private pension schemes, which at the same time implied a shift from traditional life insurance towards annuities and a trend towards single premiums. The reduction of guaranteed interest rates, costs, and bonuses further contributed to a higher profitability for life insurers.

As the second financial crisis in this 10-year period hit the markets in 2008 and a fear for recession came up, it was especially the sales of unit-linked policies that declined, leading to an overall premium growth of -3.5% ([Swiss Re 2009](#)). In the US market, for instance, the unit-linked variable annuities business even declined by a double-digit number ([Swiss Re 2009](#), p. 10). In addition, capital market losses and high costs for investment guarantees embedded in life insurance contracts negatively impacted life insurer's profitability and solvency capital base, emphasizing the importance of an adequate pricing and risk management of embedded guarantees in traditional and innovative life insurance contracts.

The market overall recovered in 2009 due to actions taken by central banks and other institutions that stabilized the credit market and supported the economy ([Swiss Re 2010](#)). However, growth

rates still fell by -2% due to again heavy negative reactions of the U.S. (-15%) and UK (-12%) markets that observed double-digit declines in life business, while in Germany and France, the sales of traditional life policies with guarantees increased in the aftermath of a higher uncertainty in financial markets following the crisis and low interest rates.

In 2010, a positive growth rate of $+3.2\%$ in real terms was globally achieved in line with a recovery of the global economy and a thus increasing demand, composed of an increase by $+1.8\%$ in industrialized countries and $+13\%$ in emerging markets (Swiss Re 2011). As in the previous year, US and UK premium volumes declined but at a slower rate. The life insurance industry continued to recover from the financial crisis in 2008, also driven by lower surrender and lapse rates as well as higher investment returns. However, profitability remained at a low level, also due to the low level of interest rates.

The development over the last 10 years clearly emphasizes main drivers for growth in the life insurance industry, in particular macroeconomic factors (GDP, general economic situation) and financial market conditions (uncertainty in stock markets and level of interest rates), regulation and tax politics regarding tax advantages of life products, governmental action with respect to public and private pension schemes that increases the necessity of private pensions, and the demographic development along with an ageing population in general that is driving the demand for different types of life insurance products. This also implies a need to create new products that account for the changing situation, which especially concerns unit-linked policies with innovative concepts of investment guarantees that account for policyholders' fears regarding capital market uncertainty and their potential mistrust with respect to traditional pure unit-linked products. The need for innovation to provide target group-specific products can also be seen from Fig. 36.2, where the development of the global insurance densities and penetration rates are displayed.

While in the emerging markets, i.e., in Latin America, Asia, and Africa, insurance density has been strongly increasing over the last 10 years (see right graph in Fig. 36.2a), the density sank slightly in the industrialized countries after the financial crisis in 2008–2009, indicating a market potential with respect to adequate products that account for customers' fears in regard to the capital markets (see left graph in Fig. 36.2a). When looking at the insurance penetration rates in Fig. 36.2b, one can generally observe a decrease for emerging markets and industrialized regions since 2001 and 2006, respectively. However, as illustrated in Fig. 36.2c for the case of Europe, insurance densities still vary considerably for different countries. Switzerland (“CH”) and Denmark (“DK”), for instance, have the highest insurance density in Europe, which makes further growth difficult and require insurers even more to develop new innovative products in order to increase their market shares.

In the future, the importance and thus the demand in the life insurance industry with focus on annuity products can generally be expected to further grow for the reasons listed above, which will even be enhanced, especially in regard to the demographic development and the problems with public pension schemes. Furthermore, the demand for life insurance in emerging markets, too, is expected to increase strongly over the next years (Swiss Re 2011). However, life insurers have to face and deal with several challenges, especially in light of the increasingly visible volatility clusters of the capital markets and the European sovereign debt crisis, which would force insurers not only to a heavy write-down of government bonds but also of corporate bonds issued by banks that invested in these affected European government bonds. Such issues have to be taken into account when developing new products that are equipped with different types of guarantees, which may be more costly than expected by insurers.

Furthermore, pressure is enhanced as the risk-based regulatory framework Solvency II is developed in Europe and even discussed globally. The introduction of Solvency II, which is planned after 2013, will likely increase capital requirements due to the comprehensive and integrated consideration of all types of risks, including market, insurance, and operational risks, thus potentially reducing the profitability. By these means, it will thus also substantially impact the product landscape. Particularly traditional products with valuable long-term guarantees will be subject to considerably higher capital

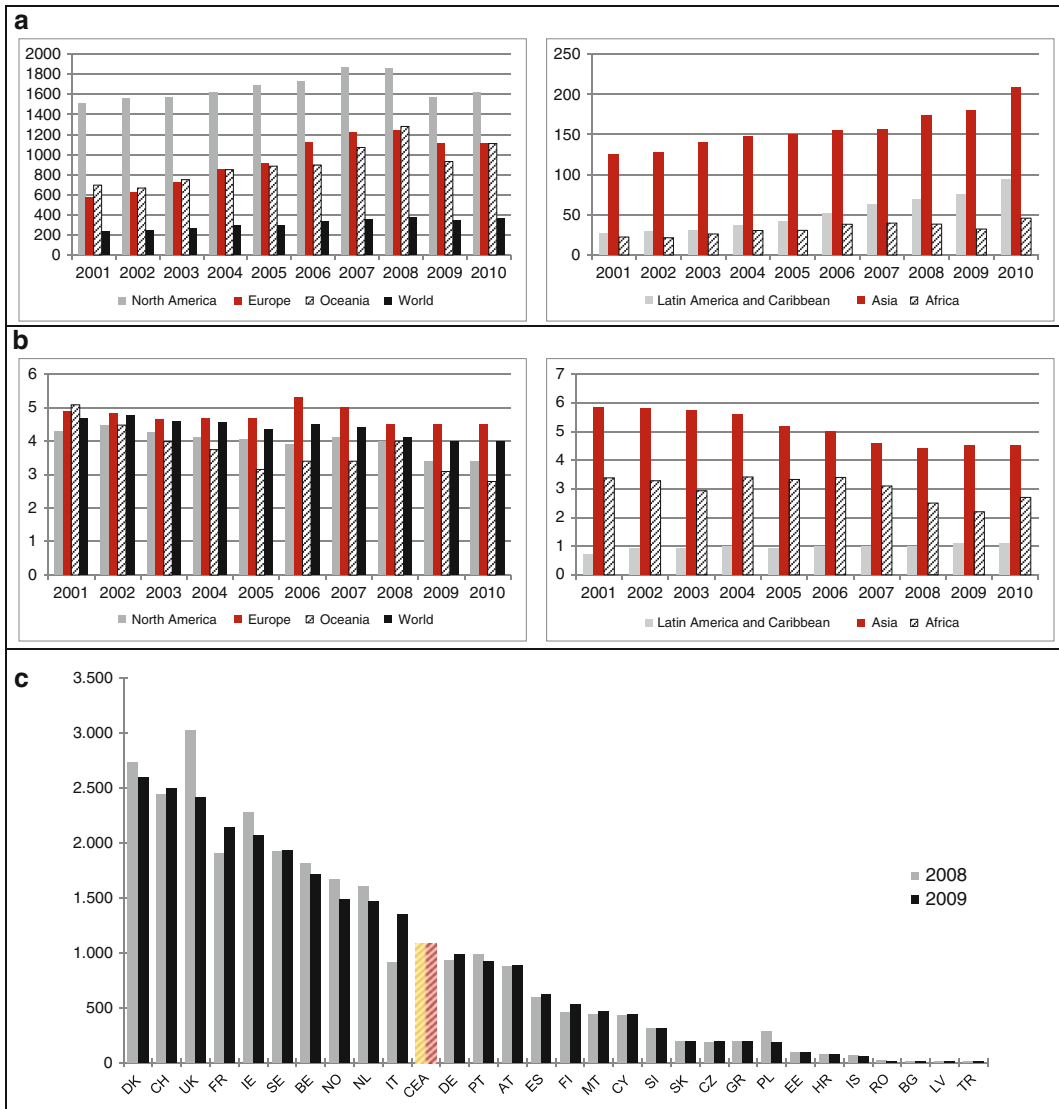


Fig. 36.2 Development of worldwide insurance density and penetration from 2001 to 2010 and insurance density in Europe for 2008 and 2009. (a) Insurance density (premiums per capita in USD) (Swiss Re 2002–2011). (b) Insurance penetration (premiums in % of GDP) (Swiss Re 2002–2011). (c) Average premiums per capita 2008 and 2009 in Euro by country (CEA 2010)

charges. This requires risk-adequate premiums from policyholders in order for insurers to be able to conduct adequate risk management or, if policyholders’ willingness to pay does not suffice, to adjust the product’s guarantees and options accordingly.

Against this background, new life insurance financial products will likely be unit- or equity-linked type, thus transferring at least part of the market risk to the policyholders and providing a higher degree of transparency and individuality as compared to traditional products. In this context, different financial guarantee concepts as well as products that combine traditional and unit-linked designs will become increasingly important, enabling policyholders to participate in positive market developments and at the same time having downside protection by means of a guarantee, which is priced and secured

by the insurer. Thus, one main focus of the remainder of this chapter is laid on presenting different product types ranging from traditional to new financial products as well as the modeling, pricing, and evaluation of such innovative product types with different variations of guarantees from the insurer's and the policyholder's perspective.

36.2 From Traditional to New Life Insurance Financial Products

The following section provides an overview of the transition from traditional life insurance products to new life insurance financial products for the accumulation and the decumulation phases, thereby presenting central product characteristics and discussing main differences between traditional and innovative product types.

36.2.1 The Accumulation Phase

36.2.1.1 Term Life Insurance

Term life insurance contracts pay a death benefit, the so-called face value, to the beneficiary of the contract in case the insured person dies during a contractually fixed contract term. Premiums can be a single upfront or a regular payment (see [Bowers et al. 1997](#)). Pure term life insurance policies provide coverage for financial responsibilities of the policyholder such as, e.g., mortgages or other debts, daily living belongings, or education for dependent family members. Furthermore, they are typically attached to other types of insurance contracts as well, such as unit-linked products. Besides this basic form, various variations of term life insurance contracts can be found in insurance practice. For instance, the death benefit may increase or decrease in time and partly depend on a participating mechanism (see also next subsection), or the policy may be annually renewable for an ex ante fixed premium level. In addition, in case of whole or universal life insurance contracts as typically offered in the USA, the contracts run lifelong and thus provide a payoff with certainty when the insured person dies. Term or whole life insurance products are important components of life insurance products and are typically added or included in, e.g., unit-linked or traditional participating life insurance contracts.

36.2.1.2 Traditional Participating Life Insurance

Traditional participating life insurance contracts (with-profit policies) are composed of a term life insurance contract as described in the previous section and a savings part. Hence, the premiums paid into the contract can be split into two components. In what follows, we only focus on the savings component and the corresponding premium and payout. The savings part is generally characterized by a guaranteed minimum interest rate paid on the savings premium and a participation in the company's excess profit that is calculated according to a previously specified surplus distribution mechanism. In addition, an (optional) terminal bonus payment may be provided.

The insurer jointly invests the premiums of all policyholders as well as the contributions made by equityholders in the capital market, such that it cannot be deduced which part of the assets belong to an individual policyholder. The traditional contract design is mainly determined by three key contract parameters. The first is a guaranteed minimum annual interest rate g , which must be compounded on the policyholders' reserves. In several countries, this minimum interest rate is determined by law and

changed periodically depending on capital market conditions. In Germany, for instance, this interest rate is guaranteed for the whole duration of the contract, which constitutes a substantial value for the policyholder and a considerable risk for the insurer if it is not correctly priced and secured. The value of these guarantees becomes particularly evident under Solvency II, where a substantial risk capital must be held in this case. Therefore, a variation of the guaranteed rate in traditional products can be found by a dynamic adjustment of the guarantee after a certain time period depending on the average interest rate level (as is done in France, for instance) or by directly linking the guarantee to an average yield to maturity of government bonds.

The second parameter is the annual surplus participation rate, which is generally regulated as well in order to ensure that policyholders receive an adequate share of insurer's investment earnings (in book values), as these are mainly generated based on the policyholders' savings and excess premiums. In times of positive market developments, policyholders thus participate in the insurer's investment returns that are higher than the guaranteed interest rate. One major problem in this regard is the complexity and opaqueness of the surplus participation scheme that is generally not transparent and may not be well defined in mathematical terms. Often, the surplus distribution is based on a smoothing scheme that reduces the volatility of investment returns by buffering the surplus in a buffer account, which increases the stability of the surplus payment. In the case of so-called cliquet-style guarantees, as soon as the annual surplus participation is annually credited to the policyholder's account, it becomes part of the guarantee and thus at least earns the guaranteed interest rates in the following years (see, e.g., [Grosen and Jørgensen 2000](#)). As an alternative to these cliquet-style guarantees, participating life insurance contracts may feature a point-to-point guarantee, where only a minimum payment at maturity is guaranteed (see, e.g., [Grosen and Jørgensen 2002](#)). In general, particularly the type of smoothing scheme used can have a considerable impact on the contract value (see, e.g., [Guillén et al. 2006](#)). The last parameter, which has an influence on the liabilities, is the terminal bonus distribution. It may optionally be added to the policyholder's account at maturity, e.g., depending on the initial contribution rate (see, e.g., [Gatzert and Kling 2007](#)).

Participating policies further typically feature numerous implicit options, including, e.g., settlement options (lump sum, fixed income, etc.), premium payment options, the surrender option, the flexible expiration option, and many more (see [Trieschmann et al. 2005](#)). In many cases, closed-form solutions for the payoff to the customer cannot be derived due to the high complexity and opaqueness, and hence, standard formulas of option pricing may not be used. Hence, numerical approximation techniques (in particular Monte Carlo simulation) are used in insurance practice.

36.2.1.3 Unit-Linked Products

Similar to participating life insurance contracts, unit-linked policies generally consist of a combination of a term life insurance contract and a savings part. However, in contrast to the traditional products, the benefits paid out to the policyholders from the savings component depend on the development of some specific underlying investment fund. Premiums are thus invested individually and the product is more transparent as compared to participating life insurance contracts. In this basic form without additional guarantees, policyholders fully bear the investment risk. Hence, in general, the savings part of a unit-linked product is identical to an investment in a traditional mutual fund.

The policyholders can typically choose from selected investment funds and sometimes even from individual stocks. The savings premium is derived by subtracting the term life insurance premium from the total gross premium (without accounting for costs) and is invested in units of the underlying investment according to the policyholder's choice at the prevailing price at the payment date. Like any investment in mutual funds, the account value (market value) is given by the number of units acquired, multiplied with the price of one unit. Unit-linked products are often extended by additionally offering different types of investment guarantees and can also be based on constant proportion portfolio

insurance (CPPI) strategies. A more detailed description of different guarantee forms along with a basic modeling framework and the valuation of embedded guarantees are provided in Sect. 36.3.3.

36.2.1.4 Universal Life

Universal life insurance policies are lifelong contracts and essentially comprise a death benefit insurance contract (without fixed contract term, i.e., whole life insurance) with fixed face value, while the insurance company invests the remainder of the insurance premium (after subtracting the risk premium for the death benefit protection) in the capital market, thus building up reserves. In contrast to traditional participating life insurance policies or whole life policies, universal life products are highly flexible in that they offer the possibility to vary the death benefit amount as well as the amount and/or timing of the premium payments during the contract term. Mortality and expense charges are deducted periodically. The resulting remainder of the insurance premiums is then credited to a cash value account (the reserves). Here, the policyholder has to ensure that his or her account value is sufficient to cover the costs of each period. The insurance company pays a quoted current interest rate on the cash value account (Cherin and Hutchins 1987). Furthermore, in case of surrender, the policyholder would receive the cash value account less a surrender charge. The latter is reduced over time to encourage policy retention (Promislow 2011). Even though these kinds of products offer a high degree of flexibility, they are currently not common in Europe, partly due to tax advantages that depend on the payment of regular level premiums over a certain time span as it is, e.g., the case in Germany.

36.2.1.5 Dynamic Hybrid Products

Dynamic hybrid contracts have attracted a considerable amount of attention in recent years as innovative life insurance and deferred annuity products, particularly in the German market, and aim to combine ideas of traditional products (the conventional premium reserve) and the upside potential of unit-linked policies. While thus offering some degree of security, they also provide the potential of gaining higher returns than traditional insurance products. Dynamic hybrid contracts are characterized by a regular (often daily or at least monthly) rebalancing process between a riskless and a risky investment. The strategy is generally procyclical as in case of falling stock prices, funds are shifted towards the riskless asset, while in case of rising stock prices, the asset allocation is shifted towards the risky asset (see also Sect. 36.3.2). This process is intended to ensure that all embedded investment guarantees can be met. In the so-called 2-fund hybrid products, the accumulation benefits are fully or partially guaranteed by allocating a portion of the portfolio to the conventional premium reserve. The remainder is then invested in risky assets such as an equity investment fund or a so-called guaranty fund, which ensures that the investment fund cannot drop below a critical value (commonly 80%). In contrast to static hybrid products, the portfolio is distributed between the premium reserve and the risky assets in the dynamic 2-fund approach (instead of distributing the regular premium payment between the two funds) and depends on the performance of the latter.

Dynamic 3-fund hybrid policies are meant to provide the potential for even higher returns through a more efficient construction of the guarantee. In these products, the first fund is a guaranty fund or may even be structured as a high watermark guaranty fund that involves a lookback guarantee, thus locking in the highest fund value over time as a guarantee. As a result, less money needs to be allocated to the insurer's conventional premium reserve that represents the second fund and delivers returns independent of the development in the stock markets. Finally, the third fund consists of risky equity investments. Again, the distribution among the three funds depends on the general market environment. Some dynamic hybrid products contain the option to adjust the guarantee during the term

of the contract in order to lock in capital gains. Furthermore, within the risky part of the product, many insurance companies offer their policyholders the possibility to choose among different investment funds or to switch assets without a charge at certain reference dates (Kochanski and Karnarski 2011).

In the case of classical CPPI strategies, the cash lock risk arises, i.e., in case of falling market prices, there is a risk of being locked into the riskless portfolio since otherwise the guarantee cannot be met before maturity. In such a scenario, a reallocation into risky assets and a further participation in market upturns is no longer possible. The risk that the fund value falls below the buffer during the contract term can be secured, e.g., by means of crash puts, which ensure that the risky asset can still be sold at the market. Alternatively, the underlying fund can be structured as a guaranty fund itself as described above. In the more recent product class of dynamic hybrid products, the rebalancing process is conducted individually for each policyholder following an iCPPI (individualized constant proportion portfolio insurance) strategy, which depends on the individual contract specifics, its remaining time to maturity, and the development of the financial markets. Hence, by means of the iCPPI strategy and the individual rebalancing after each period, the funds can be shifted towards the risky investment again (especially in case of additional premiums) and the cash lock is at most temporary. In addition, due to the individual management of the fund, the frequency of rebalancing the portfolio may be reduced by only acting upon more severe stock losses and the costs thus be lowered as compared to traditional CPPI strategies.

36.2.2 *The Decumulation Phase*

36.2.2.1 **Immediate and Deferred Annuities and Fixed Term and Lifelong Annuities**

Besides the accumulation phase, particularly the decumulation phase is of special relevance in order to ensure a sufficiently high living standard for policyholders during retirement. In the case of *immediate annuities*, policyholders pay a single premium and immediately receive pension payments. This is commonly done in case of payouts available from a life insurance product, for instance. Alternatively, policyholders can acquire a *deferred annuity*, where single or annual premiums are paid during the accumulation (or savings) phase. As laid out in the case of life insurance products in the previous subsection, the amount to be annuitized at the end of the accumulation phase depends on the contract type and thus on investment returns, interest rate guarantees, and/or surplus participation and smoothing schemes assumed during the savings phase. The accumulated amount is then transformed into a *lifelong annuity*, where the insurer covers the longevity risk, or an *annuity with fixed term*. Here, too, the amount of the pension payment heavily depends on the type of the pension scheme, the underlying investment fund, and smoothing mechanism, if applicable, which can have a considerable impact on the retirement benefits.

36.2.2.2 **Traditional (with Profit) Annuities**

Traditional deferred annuities, also referred to as with-profit pensions, are similar in the accumulation phase as in the case of traditional participating life insurance contracts, in that there is no individual investment for each policyholder, but premiums are instead invested jointly by the insurer for the whole pool of contracts, thus implying that the surplus participation and investment part that belong to the policyholder remain opaque and the concrete mechanisms are fairly unknown. In addition, the surplus credited to the policyholders' individual accounts depends on the insurer's investment return, the type of guarantee included in the contract, the size of the bonus reserves, as well as competition.

There may also be a bonus smoothing between the portfolio of annuities and a portfolio of traditional participating life insurance contracts (e.g., [Jørgensen and Linnemann 2011](#)).

During the payout phase, typically a certain pension amount is guaranteed to the policyholder, which is entitled to surplus depending on the contract characteristics. *Fixed (level) annuities* are guaranteed in their absolute size and not adjusted over time (thus without accounting for inflation), while *increasing annuities* grow by a contractually defined percentage in each period, which can, e.g., be inflation-linked. In Europe, annuities are often subject to participation in the insurer's surplus that is generated based on the risk, costs, and investment results. The surplus can thereby be used to increase the guaranteed annuity for the remainder of the contract term by treating the bonus amount as a single premium for a new contract with the same time to maturity as the original one (see [Bohnert et al. 2012](#)). The additional annuity amount is thereby calculated based on actuarial calculation principles. Alternatively, surplus may also be used as a direct payment that increases the annuity only once.

36.2.2.3 Unit-Linked Annuities

Analogously to the unit-linked life insurance case, the amount available for annuitization at the end of the accumulation phase of unit-linked annuities depends on the development of a mutual fund that is individually observable and can typically be influenced by the policyholder by choosing the riskiness of the underlying fund by means of the portion invested in high-risk assets. The size of the annuity is adjusted regularly based on the current fund value, using actuarial methods based on an interest rate and mortality assumptions. Alternatively, depending on the concrete contract design, the insurer assumes a specific growth rate of the underlying mutual fund based on which the initial annuity amount is calculated. If the actual fund return is below or above this rate, the annuity is reduced or increased, respectively. In some cases, the underlying fund may also be a guaranty fund, which ensures that the maximum loss is restricted to a certain percentage.¹ In addition, unit-linked products can be equipped with additional guarantee as in case of life insurance.

36.2.2.4 Variable Annuities

Variable annuities are unit-linked products that are well established especially in the United States and Japan, but are still being developed and newly introduced in innovative ways in Europe, for instance. The policyholder makes a single upfront payment or regular premium payments, which are (partly) invested in different asset forms. In return, the policyholder (or the beneficiary, respectively) receives benefit payments from the insurance company at preset dates during the contract term. The value of these payments is based to some part on the performance of the underlying investment. In addition, variable annuities offer embedded options to the policyholder, also called guarantees or riders that can be divided into two categories: living or death benefits ([Junker and Ramezani 2010](#); [Milevsky and Posner 2001](#); [Ledlie et al. 2008](#)).

Variable annuities are retirement vehicles and serve as a financial protection for surviving dependents. In case of death of the policyholder, typically at least the policyholder's original investment is paid out to the beneficiary, regardless of the performance of the underlying investment. However, many insurance companies offer death benefits that exceed the original investment by the policyholders and/or the current contract's account value ([Milevsky and Posner 2001](#)).

Over the years, various forms of living benefits have been developed. The most common forms are guaranteed minimum income benefits (GMIB) and guaranteed minimum withdrawal benefits

¹See, e.g., www.annuities-online.com/AnnuityOverview.htm.

(GMWB). In case of a GMIB, the policyholder is guaranteed a regular minimum payout (e.g., a pension payment) starting at a preset future point in time. These payments are independent of how the underlying investment performed in the meantime. GMWB present another possibility for policyholders to protect themselves in times of downside markets. This form of living benefit guarantees that policyholders can withdraw a predefined amount at certain points in time. Further forms of life benefits are guaranteed minimum accumulation benefits (GMAB) and lifetime guaranteed withdrawal benefits (GLWB). In many countries, variable annuities are additionally attractive due to the possibility to defer income and capital gains taxations in the accumulation phase. More details regarding variable annuities are provided in Sect. 36.4.

36.2.2.5 Equity-Indexed Annuities

Other forms of unit-linked products that can be classified in between traditional annuities and pure unit-linked contracts are *deferred equity-indexed annuities*, which particularly in the accumulation phase are linked to the development of a specified index and have first been presented in the USA in 1995 (see [Tiong 2000](#)). The index-linked interest is determined according to a formula that takes into account the changes in an equity index, e.g., the S&P 500 or a basket of equities or mutual funds (see, e.g., [Hardy 2003](#); [FINRA 2010](#); [NAIC 2011](#); [Tiong 2000](#)). They typically exhibit a minimum guarantee on the premium, e.g., 90% of the premium paid and additionally a 3% annual interest rate (not in case of surrender) in the USA and money-back guarantee (sum of premiums) in Germany, for instance. The additional interest credited to the policy value is periodically determined according to a formula that takes into account the development of the underlying index and the contractually defined features such as the participation rate, the interest rate cap, and the indexing method.

The *participation rate* determines how much of the increase in the index is used to increase the policy value. For example, if the index gain is 10% and the participation rate is 80%, then 8% is credited to the policy. The index-linked interest rate is reduced in case a *spread, margin, or asset fee* is imposed by the insurer, which may be implemented instead or in addition to the participation rate ([FINRA 2010](#)). There may also be a *cap* and/or a *floor* on the annual interest credited to the policy by defining an upper or lower limit. Thus, if the cap is 6% in the above example, the interest rate would be 6% instead of 8%, while a floor of, e.g., 0% would ensure that the index-linked interest rate would not become negative. Even if there is no floor, the minimum guaranteed interest must always be met by the insurer. Depending on the contract design, participation rate, cap, and floor may be adjusted by the company after a certain time period, and companies may also guarantee a minimum participation rate during the whole contract term or fix a certain range, i.e., a maximum and minimum participation rate ([NAIC 2011](#)).

Another important contract feature is the *indexing method*. In case of the *point-to-point* method, the index-linked interest is determined based on the change in the index during a certain time period or at the end of the accumulation phase (see [NAIC 2011](#)). In case of an *annual ratchet (reset)*, the index-linked interest is calculated annually by comparing the index value at the end of the contract year with the value from the beginning of the year. The annual interest is then used to increase the policy value. Since the interest rate is determined annually anew, the interest is locked in and the policy value cannot decline, even if the index falls in the next period (see [Tiong 2000](#)).² A *high watermark* (lookback) feature calculates the change in the index at specified points in time during the contract term, e.g., at anniversary dates, as compared to inception of the contract. At the end of the accumulation phase, the index-linked interest is determined based on the highest value achieved over the contract term. As the high watermark and the ratchet feature are very valuable, they are

²A more detailed analysis of different types of ratchets (simple or compounding the returns monthly or annually) in equity-indexed annuities can be found in [Hardy \(2004\)](#).

often combined with lower participation rates (see [Tiong 2000](#)). Hence, there is typically a trade-off between the different features.

The index may thereby be calculated by *averaging* the daily or monthly index value instead of using the actual value, which may reduce the amount of interest earned on the index. In addition, in case simple interest is paid, there is no cliquet-style interest rate effect as the interest is not subject to additional interest. Finally, dividends are typically excluded from the index value. In general, the policyholder may be allowed to choose from several broad indices.

Further variations of equity-indexed annuities include, among others, flexibility in regard to additional premium payments during the contract term, partial withdrawals at the end of the accumulation phase and during the decumulation phase, a guaranteed annuity option, or a flexible decrease or increase of the accumulation phase for a limited time span.

One example for the new product class of equity-indexed annuities in Germany is IndexSelect, introduced by Allianz in 2007, which combines traditional and equity-indexed features and is based on the Dow Jones EURO STOXX 50 index.³ A monthly cap is defined that is annually adjusted and communicated to the customer 3 weeks before the policy's anniversary date. Based on this information, the policyholder has to decide whether to participate in the index (taking into account the newly set cap) or to receive the "riskless" return of Allianz that is credited to the pool of traditional life insurance products (in the conventional premium reserve) that is composed of the guaranteed interest rate and a surplus participation rate. In the newest version of the product, the customer can even annually fix a certain percentage according to which the participation in the index is conducted, while the remainder is compounded with the "riskless" return. The monthly returns of the index during each year add up to the total annual interest. While negative monthly returns are fully taken into account in the calculation, positive monthly returns are subject to the respective cap for the year (e.g., 4%). The floor for the annual index-linked interest rate is set to 0%, such that the policy value cannot be reduced. Once positive interest is credited to the policy, it is locked in and subject to future interest, thus generating cliquet-style interest rate effects. The guarantees offered to the customer are also financed by not taking into account dividends in the index development and by keeping positive returns above the cap. The risk is further reduced by annually adjusting the cap. Among other features, the product also allows for additional (limited) payments during the contract term, lowering the premiums in case of unemployment or a birth of a child, and further includes a guaranteed minimum annuity after the accumulation phase, which, however, may be subject to adjustments in case other options are exercised during the contract term. Overall, with its special features, the product constitutes an alternative to traditional products that features a higher upside potential and at the same time a lower but more stable return than classical equity-indexed annuities.

36.2.2.6 Formula-Based Smoothed Investment-Linked Annuities

Another innovative life insurance financial product is a product class referred to as *formula-based smoothed investment-linked annuity*, which has first been introduced by a Danish life insurance company in 2002 in a product line called TimePension. The new product class has been described in, e.g., [Guillén et al. \(2006\)](#) and [Jørgensen and Linnemann \(2011\)](#), where the latter specifically focus on the payout phase and the possible adjustments of pensions over time. [Jørgensen and Linnemann \(2011\)](#) further compare the new product with traditional with-profit pensions with bonus payment and a market-based unit-linked product. For all three products, the amount to be annuitized at the end of the accumulation phase depends on investment returns and other contract determinants including

³See [ITA \(2010\)](#) for more detailed information about the product.

guarantees and bonus features. Based on the accumulated value, the amount of the initial pension payment is determined.

Jørgensen and Linnemann (2011) lay out that TimePension is intended to combine the best of two worlds: the individuality and transparency of a unit-linked scheme (including higher portions invested in high-risk assets, e.g., 50% in stocks) and the idea of smoothing returns as is done in the traditional with-profit pensions, which allows stabilizing pension benefits over time. This is reflected by decomposing the value of the policyholder's (individual) investment fund into two accounts, namely the policyholder's (pension benefit) account and an individual smoothing ("equalization") account that belongs to the policyholder and the insurer according to a specific predefined ratio and serves as a buffer for smoothing investment returns. The smoothing mechanism is—in contrast to traditional with-profit products—transparent and mathematically well defined but still represents an element of collectivity. First, the minimum policy interest rate credited on the policyholder's account is determined monthly based on, e.g., a weighted average of the yield to maturity on leading Danish government bonds. Second, after reconsidering the balance between the two accounts, the additional interest transferred from the smoothing account to the policyholder's account is defined by a certain fraction of the smoothing account. This amount is thus higher if the smoothing account is high and reduced in years where it is low or even becomes negative. The latter also implies that the interest may be negative (Guillén et al. (2006), p. 233), which according to Life & Pension (2009) allows a better exploitation of upward turns in stock market, as traditional products "are always too late."

In a newer version of the product, a ratchet on the policyholder's account value is implemented which ensures nonnegative growth. In the decumulation phase, the annuity payment is derived at each point in time (monthly or annually) based on the current policyholder's account (book) value, which serves as a single premium for a "new" contract with reduced time to maturity and a higher age of the insured. In addition, pension payments reduce the fund value. During the payout period, the customer may also be guaranteed an annual minimum income from an annuity certain and lifelong pension scheme, respectively, which is determined at retirement. In addition, a money-back feature is included during the payout phase (see Life & Pension 2009) that allows cashing out at present value to the beneficiaries in case of the policyholder's death during a guaranteed payment period. The guarantees included in the policies pose a risk to the insurer that can be hedged by a simple vanilla option-based strategy using put and call options (see Life & Pension 2009). In particular, a classic zero-cost collar as a macro hedging strategy can be applied over the entire TimePension portfolio.

In a comprehensive simulation analysis, Jørgensen and Linnemann (2011) show how TimePension in fact combines features and payout characteristics from unit-linked and traditional products in that the expected pension payout is highest among the three schemes considered (also due to the highest portion invested in stocks), thus working similar as the unit-linked product, while at the same time ensuring stable payouts as in case of the with-profit scheme, whereas unit-linked products typically exhibit considerably higher variations and adjustments in payouts. It thus combines the desirable characteristics of both worlds. Thus, even though Guillén et al. (2006) show that smoothing is an illusion in market terms, the described mechanism used in TimePension does provide advantages in real-world terms by offering higher expected benefits than traditional products and lower variations as compared to unit-linked contracts when taking into account investment expenses (Jørgensen and Linnemann 2011). One main reason for this result is the comparably low costs for the included guarantees in the newer version of the product, which in part are already secured by the smoothing mechanism itself (Life & Pension 2009, p. 19) as well as by a hedging scheme that can be more easily established due to the transparent and well-defined mechanism (see Guillén et al. 2006). The hedging mechanism is thus easier and overall less costly than, e.g., the dynamic hedging programs implemented in case of variable annuities (Life & Pension 2009).

Another central finding in Guillén et al. (2006) is that the formula-based smoothed investment-linked annuity implies an individualized dynamic investment strategy that is in accordance with an optimal asset allocation of utility maximizing agents derived based on modern models of intertemporal

consumption and portfolio choice. In particular, during the accumulation phase, the exposure to the risky asset will be reduced the closer the date of retirement comes.

36.2.2.7 Substandard Annuities

While the previous pension products focused on the financial innovations and standard annuities, future products may also additionally focus on biometric aspects where the annual annuity depends on the insured's health status. As, for instance, laid out in [Gatzert et al. \(2012\)](#), there are three types of *substandard annuities*.⁴ *Enhanced annuities* are offered to individuals with a slightly reduced life expectancy and offer higher pensions depending on environmental factors (e.g., postal code), lifestyle factors (e.g., smoking, marital status, occupation), and disease factors (diabetics, high blood pressure, overweight). Impaired (life) annuities specifically refer to more severe health impairments including heart attack, cancer, and multiple sclerosis, among others, while *care annuities* are focused on seriously impaired persons who already have started to incur long-term-care costs. The risk classification process for substandard annuities requires a special underwriting of the applicants and can be beneficial for insurance companies in terms of profitability. Despite this fact, except for the well-established UK market, these products are still not very common. However, against the background of the demographic development and an increasing demand for annuities in the next years, these products may represent an attractive way for insurers for gaining market shares by offering individual annuities depending on an insured's life expectancy, thereby ensuring that underwriting is conducted in a thorough way to reduce underwriting risk, i.e., the probability of assigning policyholders to a wrong risk class.

36.2.3 Central Differences of Life Insurance Products and Key Features of New Innovative Life Insurance Financial Products

The previous two subsections illustrated that new life insurance financial products generally aim to combine the best features from traditional and unit-linked products and to reduce their disadvantages with respect to pricing and risk management as well as their risk-return profiles for the customers.

One important feature of traditional participating life insurance is the typically included long-term interest rate guarantee. While these guarantees may generally be favorable from the policyholders' perspective, they are highly valuable and can pose a considerable risk to the insurer in case of insufficient reserving or risk management. In addition, participating life insurance contracts are typically combined with different forms of complex types of options. Furthermore, premiums are not invested individually but by the insurer for the whole pool of contracts. Hence, it is not clear, which part of the assets belongs to the individual policyholder. The participation feature implies a complex surplus distribution mechanism that often depends on legal requirements and involves a smoothing scheme, where returns (risk, cost, and investment returns) of the insurer are buffered.

One further main difference to unit-linked products is that in case of traditional life insurance, book values are typically taken as the basis of computation, which enables the insurer to influence the underlying and its volatility to some extent and which in turn also has an impact on the surplus participation. The use of book values can be beneficial for customers in an adverse capital market environment, since the contracts participate in the insurer's hidden reserves that have been accumulated in the past. In an adverse capital market, insurance companies typically have to dissolve

⁴See, e.g., [Ainslie \(2001, p. 16\)](#), [Brown and Scahill \(2010, pp. 5–6\)](#), and [Cooperstein et al. \(2004, pp. 14–15\)](#).

hidden reserves in order to be able to provide the guaranteed interest rate and an adequate surplus. However, from a customer's point of view, not much transparency is provided in these kinds of products regarding the underlying, the complex surplus mechanisms based on book values, and the prices of embedded options. In addition, participating insurance contracts do not offer much flexibility, e.g., regarding the withdrawal of parts of the investment before maturity. However, aside from their opaqueness and complexity, they do provide very stable and safe returns due to implemented smoothing schemes and the pooling of contracts that reduces volatility but in turn limits the upside potential. Furthermore, as risk management is mainly conducted via pooling and smoothing based on book values, model risk is reduced as in general, no complex dynamic hedging programs need to be in place.

In contrast to traditional participating life insurance contracts, unit-linked products are more transparent as premiums are individually invested in an underlying mutual fund that is individually observable. In addition, a clear modular structure with additional contract components such as additional guarantees and term life insurance is possible. In case of higher shares in risky assets, there is also a higher upside potential, which, comes along with more volatile returns and unstable annuities.

One major problem in traditional products is thus the long-term guarantee and the insufficient transparency, which is what innovative products try to circumvent by integrating an individual underlying fund and by adjusting the guarantees. However, the way of combining traditional and unit-linked aspects differs considerably. Dynamic hybrid products apply the financial concept of iCPPI by shifting the policy value from the conventional premium reserve (the traditional element) as the riskless asset to a guaranty fund (and possibly a third fund) as the risky asset depending on the capital market development in order to generate the guarantee without additional major hedging measures. In this setting, dynamic hybrid contracts profit from long-term interest earned by the long-term invested premium reserve, even though capital can be withdrawn short term. This basically implies a transfer from policyholders having traditional contracts that are pooled towards policyholders with dynamic hybrid products. An advantage is the higher upside potential and the reduced model risk as the guarantee is ensured by means of the investment strategy.

An innovative variant of equity-indexed annuities offered in Germany is clearly of unit-linked type but introduces a traditional element by annually offering policyholders the choice between obtaining the safe return, i.e., the interest credited to conventional policies consisting of a guaranteed interest rate and additional surplus generated for the collectivity of policyholders, and participating in an equity index according to a simple and clearly defined formula. The formula ensures that policyholders have at least a money-back guarantee and also a higher upside potential than in case of traditional contracts, but less volatility and less upside potential than in case of a classical unit-linked policy.

The Danish formula-based smoothed investment-linked annuities in contrast, concretely combine traditional and unit-linked aspects in that premiums are invested individually in a mutual fund. The minimum interest rate is linked to an average yield to maturity of government bonds, which reduces the risk for the insurer. The product includes a buffer account that is adapted from traditional participating policies and serves to smooth invest returns over time, where a smoothing algorithm is used to determine the additional annual interest. By means of the smoothing account, the product thus offers more stable returns than unit-linked products and at the same time higher expected returns than traditional products. Risk management is not only partly conducted by the smoothing account but also requires hedging, which, due to the well-defined and transparent formula, is well doable.

One important advantage of variable annuities is their modular structure and the flexibility in regard to the type and level of guarantee. However, in order to secure the guarantees, dynamic hedging programs are implemented, which are prone to model risk and basis risk, which will be discussed in more detail in Sect. 36.4.

Thus, one central key aspect in future innovative products will be the type of guarantee as well as how they are secured, e.g., based on dynamic hedging programs, smoothing algorithms, and/or or the investment strategy. In addition to downside protection, flexibility is very important, e.g., accessing

part of the underlying investment funds before maturity of the contract. In addition, at inception, many life insurance products include a guaranteed annuity payout after the accumulation phase. However, the described different forms of guarantees are accompanied with considerable costs for the customer and thus generally reduce the upside potential of the investment. Hence, the choice of the product, the embedded options, and the structure of the underlying clearly depend on the customer's individual preferences and the associated costs of risk management measures will be vital, where more research is needed along with a comparison of the performance and risk of these new products.

36.3 Evaluating UnitLinked Products with Interest Rate and Lookback Guarantees: Basic Modeling Aspects

As a large part of innovative products is of unit-linked type with a modular structure and embeds some type of guarantee, the following section exhibits central mechanisms as well as basic aspects regarding the modeling, pricing, and risk management. Focus is laid on how a mutual fund with different types of guarantees—an interest rate guarantee and a lookback guarantee—can be quantitatively analyzed. In addition, as some new product classes such as dynamic hybrids use a CPPI mechanism to secure the embedded guarantee, different underlying fund strategies are compared using a conventional fund and a CPPI-managed fund.

36.3.1 Market Development and Main Product Components

Unit-linked life insurance products have become increasingly attractive in households' financial planning since the 1990s and still represent the main important field for innovation regarding new life insurance financial products with different types of guarantees today. From 1997 to 2001, for instance, the share of unit-linked insurance premiums as a percentage of total life insurance premiums increased from 21% to 36% in Western Europe (Swiss Re 2003), with life insurers having invested 1,020 billion euros in unit-linked policies. While the premium income associated with these products annually increased by +24% until 2000, traditional contracts only increased by +5%. However, the demand for unit-linked policies also strongly depends on financial market conditions, as after the financial crises in 2001 and 2008, a strong decrease in premium volumes could be observed. Furthermore, policyholders showed a stronger demand for capital protection features and investment guarantees in their policies (Swiss Re 2003).

One major reason for the overall increasing attractiveness of unit-linked policies besides the participation in positive market developments and thus the upside potential is the higher degree of transparency and flexibility in contrast to traditional participating insurance policies. The development of the underlying mutual fund can be observed anytime by the policyholder, and, in addition, these financial life insurance products are often presented in modular form. Unit-linked life insurance products, for instance, can in general be divided into the following components:

- A savings part, which is driven by the savings premium invested in the underlying mutual fund. The terminal fund value is then paid out at maturity in case of survival. Hereby, depending on individual risk preferences, policyholders can typically choose between different funds that differ in their risk level, eg., regarding the stock portion
- A term life insurance part, which provides a death benefit payment in case the policyholder dies during the contract term. The benefit amount may be fixed or depend on the fund development over time.

- An investment guarantee, which implies a minimum payoff at maturity to prevent a (subjective) default situation for the policyholder, where the fund value falls below a critical level (e.g., the sum of premiums paid into the contract or the premiums compounded with the rate of inflation). The specific type of investment guarantee differs and should also be chosen according to the policyholder's risk-return preferences in regard to the terminal payoff distribution. In addition, the more risky the chosen underlying fund is, the higher are the guarantee costs due to more extensive risk management measures that have to be taken out by the insurer.

The gross premium associated with the contract is accordingly composed of the savings premium, the risk premium, the guarantee costs, and administration costs that are subtracted from the gross premium. Savings premiums may thereby be paid monthly, annually, or as a single upfront payment; guarantee costs can be charged as constant payments that are subtracted from or paid in addition to the gross premium or—often found in practice—as an annual percentage fee that is subtracted at the end of each year from the fund value. The type of premium payment method thus has to be distinguished and can have a considerable impact on the terminal payoff distribution (see [Gatzert 2013](#)).

Alternatively, instead of explicitly charging guarantee costs, the guarantee can be secured via the asset strategy, e.g., by implementing a CPPI strategy. In this case, no additional guarantee costs have to be paid by the policyholder, as the guarantee is already provided by means of managing the mutual fund itself, and thus no additional (external or internal) risk management measure have to be taken by the insurer.

36.3.2 *Underlying Fund Embedded Investment Guarantees, and Risk Management Aspects*

In general, the investment guarantees embedded in these contracts can be of substantial value and can be managed in different ways. An insurer can either price the investment guarantee using, e.g., risk-neutral valuation, thus receiving the adequate premium by the policyholder for any risk management instrument, such as hedging, reinsurance, or additional equity capital. To evaluate investment guarantees and their impact on performance and risk-return profiles from the customer's perspective, first the case of a conventional fund is considered, which serves as the basis for risk-neutral pricing of guarantees. Second, since the application of the CPPI strategies is one important novelty in establishing new life insurance financial products, we further present the CPPI mechanism, which also serves as the basis for dynamic hybrid products as described in the previous section but is also applied in guaranty funds.

36.3.2.1 *Modeling the Underlying Fund Value*

The unit price of the conventional underlying fund S_t at time t with a constant drift and standard deviation can, for instance, be modeled using a geometric Brownian motion under the objective measure \mathbb{P} :

$$dS_t = S_t(\mu dt + \sigma dW_t),$$

with $S_0 = S(0)$, a constant drift μ , volatility σ , and a standard \mathbb{P} -Brownian motion (W_t) , $0 \leq t \leq T$, on a probability space $(\Omega, \mathcal{F}, \mathbb{P})$, where (\mathcal{F}_t) , $0 \leq t \leq T$, denotes the filtration generated by the Brownian motion and T is the maturity of the contract. The solution of this stochastic differential equation is given by (see, e.g., [Björk 2009](#))

$$S_t = S_{t-1} \cdot e^{(\mu - \sigma^2/2)t + \sigma(W_t - W_{t-1})}$$

$$= S_{t-1} \cdot e^{(\mu - \sigma^2/2) + \sigma Z_t},$$

where Z_t are independent and standard normally distributed random variables. Under the risk-neutral pricing measure \mathbb{Q} , the drift changes to the risk-free rate (which may also be modeled stochastically). Alternatively, the underlying fund can be modeled using, e.g., the [Heston \(1993\)](#) model, which accounts for stochastic variance $V(t)$, modeled with a [Cox et al. \(1985\)](#) process, and thus enables a more adequate reflection of stylized facts of capital markets, which may be particularly relevant for life insurance products with guarantees whose value depends on the fund's development over time. Stylized facts include, e.g., fat tails or a leptokurtic distribution, volatility clusters, and clusters of extreme returns:

$$\begin{aligned} dS_t &= S_t(\mu dt + \sqrt{V_t} dW_t^S) \\ dV_t &= \kappa(\theta - V_t)dt + \sigma\sqrt{V_t} dW_t^V, \end{aligned}$$

with long-term variance θ , a speed of mean reversion of κ , and a volatility of σ . As in the case of a geometric Brownian motion, $S_0 = S(0)$ with constant drift μ and standard \mathbb{P} -Brownian motions (W_t^S, W_t^V) with $0 \leq t \leq T$ on a probability space $(\Omega, \mathcal{F}, \mathbb{P})$, where (\mathcal{F}_t) , $0 \leq t \leq T$, is the filtration generated by the Brownian motions. In addition, the coefficient of correlation between the unit price and its instantaneous variance is given by $dW_t^V dW_t^S = \rho dt$. An adequate financial market model is particularly important for products with a dynamic asset allocation, where jumps and extreme returns may considerably increase the value of guarantees. For both asset models, the development of the total fund value F for regular premium payments P at time t is then given by

$$F_t = (F_{t-1} + P) \frac{S_t}{S_{t-1}}, F_0 = 0.$$

36.3.2.2 Investment Guarantees: Interest Rate Versus Lookback Guarantee

In the following, focus is laid on the financial part of the unit-linked product only (see [Huber et al. \(2011\)](#) for an inclusion of the risk premium), and, more generally, constant premium payments P are assumed at time $t_0 = 0, t_1, \dots, t_{N-1}$ (e.g., for monthly payments, $\Delta t = t_j - t_{j-1} = 1/12$) for a contract term of T years, where $t_N = T$.

In case of an *interest rate guarantee*, the premium is compounded with a guaranteed rate of g until maturity, yielding to a guarantee payment G_T at maturity:

$$G_T = P \cdot \sum_{j=0}^{N-1} e^{g(T-t_j)}.$$

For $g = 0$, at least the sum of premiums paid into the contract is guaranteed. At maturity, the investor thus receives the terminal payoff L_T , which consists of the value of the investment in the underlying fund or at least the guaranteed payment G_T , i.e.,

$$L_T = \max(F_T, G_T) = F_T + \max(G_T - F_T, 0),$$

which corresponds to the underlying fund value at maturity plus a put option on this value with strike price G_T .

The fund with the *lookback guarantee*, in contrast, pays the highest value of the unit price of the underlying fund S_t that has been attained during the policy term, multiplied with the number of shares

that the policyholder acquired during the contract term. Thus, at maturity T , the terminal payoff depends on the previous $N-1$ unit prices and can be written as (see Gerber and Shiu 2003):

$$L_T = P \cdot \sum_{j=0}^{N-1} \frac{\max_{j \in \{0, \dots, N-1\}} S_{t_j}}{S_{t_j}}.$$

Therefore, if the unit price of the underlying fund remains constant over the whole contract term, the policyholder would at least receive the sum of premiums paid into the contract, which corresponds to the case of $g = 0$ in case of the interest rate guarantee.

In case of a conventional fund, the additional costs for these guarantees have to be charged by the insurer in addition to the savings premiums and strongly depend on the riskiness of the underlying mutual fund. Evaluation of the guarantee can be conducted with risk-neutral valuation by calculating the expected value of the terminal payoff less the value of premiums paid into the contract under risk-neutral measure \mathbb{Q} and discounting with the risk-free interest rate r (which can also be modeled stochastically), implying

$$\Pi_0 = E^{\mathbb{Q}}(e^{-rT} L_T).$$

36.3.2.3 Constant Proportion Portfolio Insurance-Managed Fund

Instead of using a conventional fund and explicitly pricing the guarantee embedded in the product, the guarantee can alternatively be secured by using a dynamic asset allocation strategy such as CPPI (see Black and Jones (1987), O'Brien (1988), Black and Perold (1992)). Here, the maturity guarantee is achieved by dynamically reallocating the investment in the fund between a risky and a riskless asset. However, such portfolio insurance programs are also subject to major risks, as high transaction costs, market liquidity risk, discontinuous price process, or unexpected changes in the volatility of the underlying stocks may prevent a successful reallocation and thus imply a failure of the strategy (Rubinstein and Leland (1981), p. 66). This also includes the cash lock risk, i.e., being locked into the riskless portfolio in case of falling market prices since otherwise the guarantee cannot be met before maturity, which implies that a reallocation into risky assets and a further participation in market upturns are no longer possible.

The risky investment can be modeled using, e.g., a geometric Brownian motion A_t , while the riskless investment is given by a bond B_t with a constant riskless interest rate r , implying a development of the unit price according to

$$S_{t_j} = S_{t_{j-1}} \cdot \left(\alpha_{t_{j-1}} \cdot \frac{A_{t_j}}{A_{t_{j-1}}} + (1 - \alpha_{t_{j-1}}) \cdot \frac{B_{t_j}}{B_{t_{j-1}}} \right) = S_{t_{j-1}} \cdot \left(\alpha_{t_{j-1}} \cdot e^{r_{t_j}^A} + (1 - \alpha_{t_{j-1}}) \cdot e^{r \Delta t_j} \right),$$

where the share invested in the risky asset is denoted by time α_{t_j} . The total value of the fund at time t_j is analogous to the conventional fund given by

$$F_{t_j} = (F_{t_{j-1}} + P) \cdot \frac{S_{t_j}}{S_{t_{j-1}}}, F_0 = 0.$$

The risky asset portion in period $[t_i, t_{i+1})$ is dynamically readjusted at discrete points in time t_j depending on the development of the current fund value and the so-called cushion C_{t_j} for the risky investment, which is given by the difference between the current fund value F_{t_j} and the present value of the guarantee G_{t_j} . The guarantee at time t_j to be secured until maturity in the case of the lookback and the interest rate guarantee, respectively, is given by (see [Gatzert and Schmeiser 2009](#))

$$G_{t_j}^{\text{Lookback}} = P \cdot \sum_{i=0}^j \frac{\max_{0 \leq k \leq j} S_{t_k}}{S_{t_i}} \quad \text{and} \quad G_{t_j}^{\text{Interest}} = P \sum_{i=0}^j e^{g(T-t_i)},$$

in both cases implying a cushion of

$$C_{t_j} = (F_{t_j} + P) - e^{-r(T-t_j)} \cdot G_{t_j}.$$

The stock exposure in period $[t_i, t_{i+1})$ can be limited to α_0 and is given by the product of the multiplier (or leverage) m , which corresponds to the customer's risk aversion as higher values of m imply higher participation in the risky asset, and the cushion C , i.e.,

$$\alpha_{t_j} = \min \left\{ \max \left(\frac{m \cdot C_{t_j}}{F_{t_j}}, 0 \right), \alpha_0 \right\}.$$

36.4 Variable Annuities: Main Features Pricing and Risk Management

One variation of unit-linked products with various embedded options is variable annuities.⁵ Due to their transparent modular product design and the possibility to add and choose between various types of guarantees, unit-linked variable annuities have gained increasing interest in recent years in Europe. However, several providers encountered problems in regard to their risk management due to an insufficient pricing and basis risk in hedging. The following section is thus intended to illustrate the basic concept and risks associated with these products and to emphasize the relevance of the way how dynamic hedging programs are established and how costly it is to ensure that guarantees offered to customers can be kept. These insights and considerations regarding the general risk assessment are also of relevance for the development of other new life insurance financial products.

36.4.1 The Market for Variable Annuities in the USA and the EEA

In the U.S. market, extensive growth rates of variable annuities could be observed as measured by sales units or managed assets until the beginning of the financial crisis in October 2007 (for the following, see [Junker and Ramezani \(2010\)](#)). Between 2003 and 2007, for instance, sales and asset volume increased by more than +40% and +50%, respectively. In 1998, the asset volume in the U.S. market was less than 800 billion USD but continued to grow—with a small decrease between 2000 and 2002—until it arrived at a volume of around 1,500 billion USD in 2007. Hence, new business in

⁵We subsume similar life insurance products that do not contain any embedded options or guarantees to the group of unit-linked products (see Sect. 36.2.1). The data provided in this section are based on variable annuities that include investment guarantees in respect to death and/or living benefits.

variable annuities showed growth rates of more than 100 billion USD p.a. in the years between 2000 and 2007. During the financial crisis, however, many providers of variable annuities got into serious financial trouble. The six largest publicly listed variable annuity providers in the U.S. market, for instance, lost around 90% of their market capitalization. As a response to the crisis, some companies decided to withdraw from the segment while others completely revised their product line with respect to embedded options, risk management, and adequate pricing (see also Sect. 36.4.3). In 2009, the asset volume of variable annuities in the U.S. market was less than 1,200 billion USD, but has rebounded to 1,500 billion USD at the end of 2010 according to data from the Insured Retirement Institute (available via www.ironline.org). Compared to the USA, the market for variable annuities is much smaller in the European Economic Area (EEA). According to a study by the European Insurance and Occupational Pensions Authority EIOPA,⁶ which is based on larger insurance groups only, the EEA variable annuity market volume was 168 billion euro (188 billion euro) based on technical provisions at the end of 2009 (end of first quarter of 2010).⁷ In Japan, the variable annuity market faced a volume of almost 1,000 billion JPY in 2002 (see [Winkler 2012](#)). After a rapid growth of +133% p.a. until 2005 and a volume of more than 4,000 billion JPY, the market went down to 750 billion JPY in 2010. In Korea, in contrast, a steady growth could be observed from around 50,000 billion KRW market volume in 2003 to more than 83,000 billion KRW in 2010 (see [Winkler 2012](#)).

36.4.2 Product Characteristics and Main Features

Variable annuities can be characterized as unit-linked life insurance contracts with investment guarantees as described in Sect. 36.3 but constructed as pension products, which—in exchange for single or regular premiums—allow the policyholder to benefit from the upside potential of the underlying investment funds and to be partially protected when the investment loses value.⁸ Variable annuities can be designed as deferred or immediate annuities. In general, the customer can choose from a variety of underlying investment funds. Some contracts additionally allow changing the underlying funds at predefined points in time. In many cases, variable annuities include a minimum death benefit (i.e., in case of death during the accumulation phase, at least the premiums paid into the contract will be paid out to the beneficiaries) and contain flexibility in using some part of the contract's assets before termination of the contract. Embedded options in variable annuities can thereby be divided into the two general groups of living benefits and death benefits, whereby five different types regarding these two forms can be observed in the market (for the following, see [Junker and Ramezani \(2010\)](#); for additional information, see [Milevsky and Posner \(2001\)](#); [Ledlie' Corry \(2008\)](#)):

- *Guaranteed minimum death benefit (GMDB)*: A predefined minimum amount is paid to the contract's beneficiary if the policyholder dies. Important designs in this context include:
 - (a) *Return of premiums*: In the case of the policyholder's death the maximum of the premiums paid into the contract and the account value (adjusted for withdrawals) are paid out to the beneficiary.

⁶The EIOPA is part of the European system of financial supervision consisting of three European supervisory authorities and the European Systemic Risk Board. It is an independent advisory body to the European Parliament and the Council of the European Union.

⁷See EIOPA-11/031, available via www.eiopa.europa.eu.

⁸See EIOPA-11/031, available via www.eiopa.europa.eu.

- (b) *Roll-up*: The payment to the beneficiary equals the premiums paid into the contract (adjusted for withdrawals) compounded with a guaranteed interest rate (so-called roll-up rate).
 - (c) *Ratchet*: The beneficiary receives the highest value at the contract anniversary dates in case of the policyholder's death adjusted for withdrawals.
 - (d) *Maximum out of (b) and (c)*: The policy's beneficiary receives the greater of the annual ratchet or the roll-up amount.
 - (e) *Reset*: The death benefit will be adjusted in accordance to the account value (adjusted for withdrawals) at contract anniversary dates. In contrast to (c), the death benefit may also decrease over time.
- *Guaranteed minimum accumulation benefit (GMAB)*: After a predefined number of years a certain amount of money is guaranteed to the policyholder, independent of the development of the underlying investment fund.
 - *Guaranteed minimum withdrawal benefit (GMWB)*: In this case the customer is allowed to withdraw a predefined percentage of the account value given at the beginning of the payout phase, independent of the development of the underlying investment fund. The contract owner may also receive provisions—depending on the development of the underlying—that lock in any growth in the contract, thus extending withdrawals and increasing the benefit amount. Sometimes the percentage of the total investment that one can withdraw is increased if the customer does not make withdrawals during the first years of the contract. For instance, a GMWB with an annual reset leads to a certain bonus (in percent) for each year in which no withdrawal has been made.
 - *Guaranteed minimum income benefit (GMIB)*: The policyholder receives a guarantee in regard to the annuity payouts provided by the seller of the contract.
 - *Guaranteed lifetime withdrawal benefit (GLWB)*: This guarantee provides a smaller percentage of the account value compared to GMWB, starting from the beginning of the annuity payout phase until the policyholder's death. Here, the provider typically covers a considerable longevity risk too. At certain points in time (usually once every 5 or 10 years), the issuer compares the annuity's current account value to the original account value used to determine the minimum guaranteed withdrawal. If the actual account value is greater, the issuer applies the withdrawal percentage to the current account value thus increasing the minimum guaranteed withdrawal amount.

Additional options as mentioned for GMDB under (a)–(e) can be used in different forms in the context of the guarantee forms described above. Table 36.1 gives an overview of the combinations used in insurance practice.

36.4.3 Pricing and Risk Management

The following Table 36.1 provides an overview of the options described in Sect. 36.4.2 and shows a range of current market prices for the guarantees provided by the product sellers for the US market. In addition, the table lays out to what extent the different guarantees can be found in variable annuity contracts (see Hasekamp 2010; Holler and Klinge 2006; Montminy 2009; Mueller 2009; Raham 2011).

In general, the following key factors influence the price and risk of the different guarantees and options typically provided in variable annuity contracts:

- The volatility of the underlying investment funds (in general, guarantee prices will increase with increasing volatility)
- The market interest rate (option prices will in general increase with decreasing market interest rates)

Table 36.1 Guarantee forms and costs of variable annuities (US market)

| | GMDB | GMAB | GMWB |
|---|---|---|---|
| Type of guarantee | <i>Guaranteed minimum death benefit</i> | <i>Guaranteed minimum accumulation benefit</i> | <i>Guaranteed minimum withdrawal benefit</i> |
| Additional options (examples) | (a) Return of premiums (b) Roll-up (c) Ratchet (d) Maximum of (b) and (c) (e) Reset | (a) Return of premiums (b) Roll-up (c) Ratchet (d) Maximum of (b) and (c) (e) Reset | (a) Return of premiums (b) Ratchet (c) Bonus and ratchet until withdrawal (d) Higher percentage for older ages |
| Guarantee costs (basis points of account value) | 15–35 bps | 50–150 bps | 60–150 bps |
| Percentage of policies including guarantee | N.a. | 6% | 4% |
| Type of guarantee | GMIB <i>Guaranteed minimum income benefit</i> | GLWB <i>Guaranteed lifetime withdrawal benefit</i> | |
| Additional options (examples) | (a) Return of premiums (b) Roll-up (c) Ratchet (d) Maximum of (b) and (c) (e) Reset | (a) Ratchet (b) Bonus and ratchet until withdrawal (c) Higher percentage for older ages | |
| Guarantee costs (basis points of account value) | 50–100 bps | 40–200 bps | |
| Percentage of policies including guarantee | 37% | 60% | |

- The contract duration
- The exercise behavior of the policyholder (in particular in regard to surrender or withdrawals)
- The development of mortality rates of the policyholders in the portfolio
- The general model setup for the valuation of the embedded options (e.g., assumptions regarding the distributions)
- The contract volume and payment method (single or regular premium payments)

Taking into account the policyholder's option to surrender the contract, closed-form solutions for the GMLB and GMDB option values can be derived in the case of an exponential mortality law as shown in [Milevsky and Salisbury \(2002\)](#). The authors take into account that the investor can lapse the contract and instantaneously repurchase an identical investment to reestablish a new basis for the guarantee. In the absence of transaction costs, optimal exercise strategies and corresponding option values are derived. Numerical examples provided by the authors indicate that these kinds of options were overcharged in the US market in the 1990s.

In [Milevsky and Salisbury \(2006\)](#), GMWB options are evaluated and found to be usually underpriced in the market. Besides a case in which deterministic withdrawal strategies are assumed, the GMWB option is additionally evaluated under optimal policyholder behavior. As a main result, it is optimal to in general at least withdraw the annually guaranteed withdrawal amount. In an arbitrage-free model setup, the fair price for the embedded options would theoretically allow the provider to finance any risk management measure that ensures the fulfillment of the guarantees with certainty. Possible risk management measures are, e.g., equity capital, outsourcing to a third party, reinsurance, or hedging. In practice, a mixture of this kind of risk management forms takes place. The reason for this is that, *inter alia*, no perfect hedging for the provider is possible and, hence, the (considerable) remaining risks need to be covered via other risk management measures.

In general, some part of the risk associated with variable annuities is hedgeable for the product provider ([Hasekamp 2010](#)). In particular, certain parts of the capital market risk (e.g., equity risk, interest rate risk, currency risk) can be eliminated via static or dynamic hedging strategies. However, two different groups of risk sources can generally not be hedged via capital market instruments. The first group includes risks that are in principal measurable. Typical examples in this context are:

- Basis risk (deviations of the underlying investment funds from its benchmark (the benchmark itself can in general be hedged))
- Long-term interest rates and volatility (in general longer than 15 years)
- Longevity risk
- Part of the policyholder exercise behavior (lapses unrelated to capital market developments, financially rational lapses)

The second group contains risk sources that are in principal not measurable. Examples are:

- Moral hazard with respect to actively managed funds and their performance
- Certain policyholder exercise behavior (lapses due to changes in the tax regime or other regulatory events)

Prior to the beginning of the subprime crisis in October 2007, not much attention has been given to the group of non-hedgeable risks associated with variable annuities. In addition, ruinous price competition—in particular in regard to the costs of the embedded options—took place, and, in the end, the assumptions underlying the calculations—from equity market volatility to customer exercise behavior—proved to be unrealistic ([Junker and Ramezani 2010](#)). As a reaction to the huge losses of many variable annuity providers, companies started to use more prudent assumptions regarding the general calibration and the exercise behavior of their customers. In addition, the derivation of the necessary risk capital and its costs for the unhedgeable (but still measurable) risk sources were taken into account. In regard to the nonmeasurable risk sources, variable annuity providers are now much more cautious with respect to product design and embedded options.

From the policyholder's point of view, variable annuities offer several benefits. First, customers strongly participate in capital market gains and receive downside protection. Second, the products are very flexible as compared to traditional life insurance products (e.g., change of the underlying funds at predefined points in time, withdrawal possibilities before the contract matures). Third, the described investment guarantees, which are not part of traditional mutual funds, provide security in "key moments" of life (e.g., retirement, transfer to contract's beneficiary in case of policyholder's death). And, lastly, payments into and from variable annuities contracts are tax deductible in many countries.

36.5 The Value of Financial Guarantees in Life Insurance from the Customer Perspective

After having focused on the product characteristics, pricing, and risk management aspects, we now focus on the customer's perspective. For financial planning, customers need more detailed information about the performance and risks associated with the different life insurance products and their comparative characteristics. Using such information, they can decide based on their individual risk-return preferences regarding which product class to choose from. This is particularly important for new innovative products, which are not well known for consumers so far.

The evaluation of a life insurance contract may thereby differ depending on whether it is looked at from the policyholder's perspective or that of the insurer. When pricing contracts and embedded guarantees from the insurer's viewpoint using, e.g., risk-neutral valuation, replicability of cash flows is assumed, which may be in general a realistic assumption for providers. However, for customers, replication is not easily achievable, and evaluation is thus instead typically based on individual risk preferences. Since guarantees that are typically contained in new (unit-linked) life insurance financial products can be very valuable, one has to distinguish between these two perspectives and examine the value of financial guarantees in life insurance products not only from the insurer's viewpoint but also from the customer perspective to ensure a sufficient demand for newly developed products. In particular, the question arises whether customers are willing to pay the high costs associated with valuable guarantees, which will reduce the upside potential of their contracts.⁹

The willingness to pay of policyholders can be derived theoretically and empirically in different ways. Besides the use of performance measures based on risk-return models that are partly consistent with the maximization of expected utility, policyholder's willingness to pay can as well be derived using individual utility functions or, alternatively, based on experimental studies or empirical surveys taking into account behavioral insurance theory. Both approaches are presented shortly in the first two subsections. Information about how consumers make decisions is also of relevance when presenting risk-return figures for different products, which is illustrated in the last subsection.

36.5.1 Theoretical Option Pricing Versus Customers' Valuation of Embedded Guarantees

The theoretically fair price for a contract calculated by the insurer is typically based on the (preference-free) duplication of cash flows and can be considered as a lower bound to the premium that has to be charged to the policyholder, while the policyholder's maximum willingness to pay is typically based on individual preferences and represents an upper bound. By considering both values, one obtains a premium agreement range, in which the actual market premium can be established. In the following, it is illustrated how these two perspectives can be explicitly combined without specifying the concrete contract type. This procedure has been laid out in [Gatzert et al. \(2011a\)](#) for the case of participating life insurance contracts.

⁹It can be noted that there is a parallel to the executive compensation literature where a likely different valuation of stock options by the issuing company and the recipient (the executive) can take place; see, e.g., [Lambert et al. \(1991\)](#).

Here, the insurer uses risk-neutral valuation and derives the fair single upfront premium P_0 for the contract by taking the expected value with respect to the risk-neutral measure and discounting with the risk-free interest rate.¹⁰ The policyholder's willingness to pay P_0^Φ depends on risk preferences and diversification opportunities as well as on the respective contract characteristics, such as the type of contract and the level of the investment guarantee or the volatility of the underlying fund (see, e.g., [Mayers and Smith \(1983\)](#) and [Doherty and Richter \(2002\)](#) for the case of mean-variance preferences). For a specific contract setting, the premium agreement range is then given by $[P_0, P_0^\Phi]$. If $P_0^\Phi < P_0$, the policyholder would not purchase the contract and the insurer would not be willing to sell it for a lower price than P_0 . The terminal payoff L_T and thus also the premium agreement range thereby depend on the contract characteristics, such as, e.g., the guaranteed interest rate g (or the type of guarantee in the first place), the volatility of the underlying assets σ , and the contract term T . Therefore, an insurer would generally aim to maximize the premium agreement range in order to achieve higher market premiums while at the same time ensuring risk-adequate premium that allows purchasing adequate risk management measure to secure the guaranteed payoff at maturity.

The corresponding optimization problem can then be described as follows:

$$\underbrace{\max_{g, T, \sigma, \dots} P_0^\Phi}_{\text{Policyholder's WTP under the real-world measure } \mathbb{P}} \quad \text{such that } \underbrace{P_0 = e^{-rT} \cdot E^{\mathbb{Q}}(L_T(g, T, \sigma, \dots))}_{\text{Fair contract under the risk-neutral measure } \mathbb{Q}}$$

This procedure enables the identification of contract parameters that maximize customer value while at the same time ensuring that the contracts are priced fair from the insurer's perspective (using risk-neutral valuation). In addition, further constraints may be implemented, such as a ruin probability given by a regulator or an internal requirement due to a desired rating that has to be satisfied.¹¹ Results from analyses conducted in the context of participating life insurance contracts and mean-variance preferences show that an individual segmentation of customers and the adjustment of contract characteristics might be highly profitable for insurers, as doing so can result in substantial increases in policyholder willingness to pay and thus the demand, despite the fact that the contracts are priced fairly.¹²

36.5.2 Behavioral Insurance Aspects Pricing Transparency, and Its Potential Impact on Financial Life Insurance Product Demand

However, financial guarantees and new financial life insurance products should also be evaluated and designed against the background of the behavioral economics literature, which has discovered several anomalies in regard to expected utility theory due to irrational human behavior evolving from biases and heuristics. In particular, customers' probabilistic decisions with respect to financial planning have

¹⁰In this setting, only the financial part of the contract is taken into account without early death or surrender, i.e., focus is laid on a two-point-in-time setting that does not include time preferences.

¹¹For the optimization procedure, several approaches can be used, such as genetic optimization, differential evolution, or the Nelder–Mead simplex method. See [Kellner \(2011\)](#) for an overview of optimization methods with an application to insurance problems.

¹²In particular, depending on their preferences and diversification possibilities, customers may even prefer a product with higher shortfall risk relative to other contracts but that is simpler by only including one contract parameter, for instance. Concrete numbers for the case of participating life insurance policies using a simulation study can be found in [Gatzert \(2013\)](#).

been shown to be impacted by different mental models, which contradict the theoretical predictions of expected utility theory. This observation has led to the establishment of new theoretical models for choices among risky prospects, such as prospect theory (Kahneman and Tversky 1979), where value is assigned to gains and losses instead of total assets, and decision weights are used instead of probabilities. The Kahneman and Tversky (1979) value function is concave for gains, implying that individuals are risk averse in choices that involve sure gains, and convex for losses, inducing risk-seeking behavior in case of decisions with respect to sure losses. In addition, the value function is steeper for losses than for gains and steepest at the reference point. Further developments of this theory include cumulative prospect theory (Tversky and Kahneman 1992) and the model of intertemporal choice (Loewenstein and Prelec 1992).

In the context of insurance, default risk plays an important role with respect to insurance demand, which can be explained using prospect theory as firstly shown in an experiment by Wakker et al. (1997) regarding the demand for *probabilistic insurance policies*, which indemnifies the policyholder with a probability of strictly less than one and thus reflects a default situation. More recently, Zimmer et al. (2008, 2009) demonstrated in an experiment that participant's awareness of even a very small positive probability of insolvency considerably reduces their willingness to pay for insurance products. Mental models that come into play in the context of insurance purchase decisions and that evoke irrational behavior include, for instance, loss aversion, i.e., losses loom larger than corresponding gains (Tversky and Kahneman 1991), overconfidence, for example, by overestimating own knowledge and ability to control events while underestimating risks (Barberis and Thaler 2005), and risk perception (Slovic 1972; Slovic et al. 1977). Furthermore, presenting the same problem or information differently impacts the perception of the decision problem and the individual evaluation of probabilities and outcomes (Tversky and Kahneman 1981, 1986; Kahneman and Tversky 1984) and is referred to as framing. This observation also holds true in the financial decision-making process with risky or probabilistic choices (Johnson et al. 1993; Wakker et al. 1997).

Empirical and experimental studies have to account for the previously described effects, and particularly framing effects must be avoided with respect to the presentation of the payoff distribution (e.g., verbally, numerically, graphically, positively, or negatively). In an empirical survey based on an online questionnaire in May 2009 in Switzerland with 375 respondents, the participant's willingness to pay (in terms of a single premium) for an additional financial guarantee in a unit-linked life insurance product that would protect them from default for different guarantee levels turned out to be on average below the insurer's theoretical reservation price obtained using option pricing theory (see Gatzert et al. 2011b). The majority of participants were employed in the field of insurance and thus experienced in the topic and more likely to have a reference point against which to judge the products and guarantees. Thus, they were first asked to directly state their willingness to pay, which, due to the specific sample with finance or insurance background, allowed first insights into the understandability of the products and consumer's price knowledge of investment guarantees in unit-linked life insurance, despite the often arising problems of direct approaches (Vanhuele and Drèze 2002). In addition, questions were included with given option prices, where participants had to choose between different options (with or without guarantee).

The results showed that subjective prices are very difficult to derive for customers and that the willingness to pay can be significantly lower on average than the prices obtained using a financial pricing model. However, while the average willingness to pay was below the theoretical reservation price, there was still a substantial portion of participants that was willing to pay considerably more, while others did not want to purchase a guarantee at all. The main reasons for this observation certainly include the complexity of these products that are still not sufficiently transparent to customers despite the clear illustration of the payoff distribution. In addition, there is a trade-off, as—especially after the financial crisis of 2007/2008—customers require sufficiently high guarantees with respect to their terminal wealth in old ages, but at the same time, they are not necessarily willing to pay the high costs that are associated with these valuable guarantees. Furthermore, for potential customers, their own

diversification opportunities are important when making decisions in regard to financial guarantees and financial planning in general. Thus, already this specific sample indicated that especially when developing new products, complexity should be reduced.

Another important concept in the context of customer evaluation of price and product presentation is mental accounting, which is derived based on the characteristics of the value function of prospect theory (Thaler 1985, 1999). It predicts that multiple gains have a higher value if these positive events are separately presented instead of a combination as a whole sum, as the value function is concave and more flat. The value function is convex and steeper for losses, which is why customers prefer one single loss rather than several small losses of the same amount, which is particularly relevant with respect to the price presentation (bundled or transparently unbundled) of financial guarantees or insurance contracts in general. In this context, the importance of customer's evaluation of bundled products, price presentation, and framing effects has been emphasized in the literature (Johnson et al. 1999; Mazumdar and Jun 1993; Yadav and Monroe 1993; Yadav 1994). Beshears et al. 2010, for instance, focus on retirement saving products and show that an increase of cost transparency by debundling prices has no effect on portfolio choice, which is in contrast to consumer goods.

Thus, besides the willingness to pay for new innovative products, another important aspect with respect to new financial life insurance products arises from mental accounting and framing effects. In this context, a further study by Huber et al. (2011) empirically investigated the impact of different price presentation schemes (single or annual premium, annual percentage fee) of financial guarantees in unit-linked life insurance products with the same present value on customer evaluation (satisfaction and recommendation) as well as the purchase intention for a representative Swiss panel in May 2010 with 647 participants. The contract components were thereby divided into the savings premium, the risk premium for a death benefit, administrative costs, and costs for the financial guarantee (if included, then as a single premium, annual premium, or as annual percentage fee).

The results of the study showed that neither price bundling nor price optic had a statistically significant effect on the decision of participants with respect to the product, including consumer evaluation and consumer purchase intention, which is contrary to typical consumer goods. However, when taking into account customers' experience with insurance or investment products or consumers' price perception of the product, the relationship between the unit-linked product offer (for different price presentations) and customer evaluation and purchase intention became highly statistically significant. In particular, very experienced participants were less satisfied with a unit-linked product with guarantee if prices were unbundled or if an additional financial guarantee was included, whereas the differences in product offer evaluations of less experienced participants were not significant.

Thus, especially other factors enhance consumer evaluation and imply that, in line with findings from consumer goods and mental accounting, customers in tendency prefer bundled to unbundled price presentations, which only holds true for very experienced customers. As before, this observation might be due to the fact that products are complex and that, therefore, the price presentation is not a relevant issue in less experienced customers' decision processes, who do not note the differences. Alternatively, the decision makers in the considered sample might have been rational and used a present value calculation and all came to similar results for the products (even though all product variants were presented individually).

Recently, there has been considerable regulatory effort in many European countries to increase the transparency of life insurance products and to clearly present the premium composition to potential customers. As this may not be costless for policyholders, further research might investigate the usefulness of such requirements. From the insurer's perspective, the study shows that using such marketing mix strategies with respect to different price presentations may not ensure an increased acquirement of new customers. Instead, insurers should use more emotionally charged factors for their new life insurance financial products along with a reduced complexity and more customer orientation to acquire new customers.

36.5.3 *Performance and Risk-Return Profiles: Product Information for Consumers*

As described in the previous two subsections, customers base their decision on individual preferences, where behavioral insurance suggests that the way how risk-return profiles and performance figures as well as premiums are presented to consumers can have a substantial impact on decisions making. To support consumers' decision-making and consulting processes and to increase transparency in the market, the European Commission has launched an initiative to provide product information documents in a standardized way, including risk-return profiles and performance figures.

36.5.3.1 **Current Developments in the European Union**

On behalf of the European Commission, the Committee of European Securities Regulators (CESR) proposed a standardized product information document in regard to investment funds with the goal to increase competition and improve product comparability and market transparency (ZEW 2010, p.95; CESR 2010). The so-called *Key Investor Information Document* (KIID) refers to all types of investment funds (Undertakings for Collective Investment in Transferable Securities (UCITS)) in all countries in the European Union and has been put into effect in July 2009 (Directive 2009/65/EG July, 13 2009). The KIID has a maximum of two pages and should exhibit the risk, historical development, and costs as well as the use of benchmarks (ZEW 2010, p. 95). The KIIP will likely have a strong impact on product information requirements of packaged retail investment products (PRIIPs) that include investment funds, insurance-based investment products, retail structured securities, and structured term deposits, i.e., other complex investment vehicles including unit- or investment-linked life insurance and annuity products.¹³ The OECD, too, requests better and more transparent information about the performance and costs associated with pension products.¹⁴

The adequate presentation of risk-return profiles to consumers has been subject to discussion in several countries. While in Germany, the debate of how to design a product information document for life insurance and annuity contracts is still ongoing,¹⁵ other countries such as the UK, Netherlands, or Sweden have already conducted several studies in this regard and established information requirements. In the UK, for instance, rules regarding information requirements were first laid out in the Financial Services Authority's (FSA) *Conduct of Business Sourcebook* (COBS) in 2000. The so-called key features illustrations (earlier called "key features documents") include questions and answers that are individually filled out by the providers. The FSA adjusted the rules in 2005 by proposing the Quick Guide as a possible replacement for the key features documents and discussed possible further developments in 2006.¹⁶ After a review by the FSA in 2007 revealed that the quality of the key features documents was often insufficient, requirements were extended by the key facts in (FSA 2007). Further changes were discussed in 2011, including, e.g., the presentation of scenarios for return distributions and the impact of inflation on the expected pension payments.¹⁷ In the Netherlands, the regulatory authority set detailed rules since 2002 regarding the two-sided product information documents that also apply to pension products, which ensure a high degree of comparability between

¹³See ZEW (2010, p. 95), http://ec.europa.eu/internal_market/finservices-retail/investment_products_en.htm, European Commission KOM(2009) 204.

¹⁴See ZEW (2010, p. 96), OECD (2009, pp. 8, 10).

¹⁵See ZEW (2010), Institut für finanzdienstleistungen (2012).

¹⁶See FSA (2000, 2005, 2006).

¹⁷See FSA (2011).

providers as the regulators provide an official template for the so-called financial information leaflet and also conduct the risk valuation by means of an own tool.¹⁸ In the USA, one part of a draft law regarding product information requirements for 401(k) plans was proposed in April 2009 with the intent to increase transparency by disclosing the absolute costs (instead of percentages) as well as comparable performance figures of different providers.¹⁹ However, the draft law was not further pursued or followed.

36.5.3.2 Risk-Return Profiles and Performance Measurement

In regard to the presentation of risk-return profiles, research by the FSA in the UK revealed that short and precise product information is vital for consumers. Further aspects to take into account in the presentation include, among others, a simple and clear language, the length of the information (e.g., two sheets), an official logo, and the graphical design. Due to the complexity of the payoff structures in case of traditional and new life insurance products, typically simulation methods need to be implemented in order to assess the payoff characteristics of a product. This can be done based on, e.g., the quantitative models exhibited in Sect. 36.3.2. First, the probability that the maturity fund value falls below the guarantee or a critical level should be calculated in order to provide insight with respect to the relevance and necessity of guarantees. Second, the cumulative terminal payoff distribution should be exhibited to obtain further insight, which may be presented in different ways (using quantiles, boxplots, etc.). When comparing risk and return of the different types of guarantees and the different risk management strategies, comparability must be ensured, for instance, with respect to the amount of premiums paid into the contract, which can have a considerable impact on risk and return, but also by using the same underlying capital market scenarios. The generated scenarios also allow the derivation of risk classes that classify products from, e.g., low risk/low return to high risk/high return.

While histograms, stacked bar graphs, as well as boxplots are currently recommended in Germany to be displayed to customers for comparison, especially in the context of financial products (see [Institut für finanzdienstleistungen 2012](#)), performance measures that relate return and risk can also be used to evaluate the maturity payoff. In addition, performance measures such as the Sharpe ratio, Omega, and Sortino ratio, for instance, are even consistent with the concept of expected utility maximization (see, e.g., [Fishburn \(1977\)](#), [Sarin and Weber \(1993\)](#), [Farinelli and Tibiletti \(2008\)](#)). The Sharpe ratio ([Sharpe, 1966, 1992](#)) can be derived based on the difference between the expected maturity payoff and the value of premium payments at maturity (calculated by compounding the premiums with the risk-free rate) and divided by the payoff's standard deviation. By means of the standard deviation, this performance measure thus takes into account positive and negative deviations from the expected value. In contrast, the Sortino ratio and the Omega use lower partial moments as the relevant risk measure in the denominator, thus only taking into account downside risk, i.e., the risk that the terminal payoff of the product falls below the value of the premiums compounded to maturity (see, e.g., [Fishburn \(1977\)](#) and [Sortino and van der Meer \(1991\)](#)). In case of the Omega, the lower partial moment of degree one is used, where all negative deviations are weighted equally (see [Shadwick and Keating 2002](#)). In case of the Sortino ratio, the square root of the lower partial moment of degree two is applied, which thus puts more weight on negative deviations and thus expresses a stronger risk aversion of a decision maker.

Results in [Gatzert and Schmeiser \(2009\)](#) regarding the two guarantee types and underlying funds laid out in Sect. 36.3.2, for instance, show that the maturity payoff distribution is particularly sensitive

¹⁸See [ZEW \(2010\)](#), pp. 97, 100).

¹⁹[ZEW \(2010\)](#), p. 98) and <http://www.govtrack.us/congress/bills/111/hr1984/06/10/2012>).

in the case of a lookback guarantee with respect to the volatility of the underlying mutual fund, since upside or downside deviations imply a considerable increase in the guarantee value.²⁰ This also implies that this guarantee type can become very expensive, which is why in the case of using a CPPI strategy to secure the guarantee, the share in the risky investment must typically be very low, which in turn considerably reduces the upside potential of the terminal payoff. Such issues must be taken into account by consumers intending to purchase a unit-linked life insurance product with investment guarantee, whereby decisions will strongly depend on individual risk-return preferences with respect to the maturity payoff distribution. However, performance and risk-return figures in product information documents are not meant to be the sole source for decision making of consumers but should generally be used in addition to, e.g., personal advice.

36.6 Outlook on Future Life Insurance Financial Products

Regarding the future of life insurance contracts, in particular an increasing pressure on the cost side of the products can be expected. Nowadays, transactions costs are particularly high for participating life insurance contracts due to their complexity and the sales channels used. Participating life insurance contracts are typically based on book values and further combined with different and complex forms of options as well as long-term guarantees, which are desirable for policyholders but imply high-risk capital charges for insurers. From the customer's point of view, the transparency of these products regarding the underlying and the price of the embedded option is highly limited, which also hampers a performance measurement that could support the costumers' decision-making process. In addition, not much flexibility is offered in participating insurance contracts, for instance, regarding withdrawals before maturity.

In the future, customers and regulatory authorities will demand more price transparency for life insurance products, a process that already started in the European Union. Such a development could imply a price pressure on embedded option, too, and may lead—at least in Europe—to substantial advantages for (modular) unit-linked type insurance products with flexible and transparently priced investment guarantees, which in addition to their transparency and flexibility generally offer upside potential by allowing the policyholder to participate in positive market developments and, at the same time, ensure downside protection. In this context and against the background of the development of the financial markets over the last years, especially the investment strategy will become increasingly important (and also challenging) in order to ensure that guarantees promised to customers can in fact be met. Based on the transparent guarantee prices, customers can then decide whether they are willing to include an investment guarantee in their life insurance product or not. However, in addition to the costs of risk management—even if they are transparent—model risk associated with hedging and risk management programs in general will also be an important issue in the contract design.

New generations of product classes have already been brought forward on the market in recent years that try to account for these aspects, including, e.g., dynamic hybrid products, equity-indexed annuities, and formula-based smoothed investment-linked annuities. One key innovation aspect is thereby the aim to combine the best features of both the traditional and the unit-linked world, in that stable and safe returns offered by traditional life insurance products are joined with the transparent and individual unit-linked type products with upside potential. The combination of both worlds is probably most pronounced in case of the well-defined and transparent formula-based smoothing mechanism

²⁰Graf et al. (2012) also derive risk-return profiles using the internal rate of return based on a model with stochastic interest rates and stock returns with stochastic volatility. These risk-return profiles are then compared for different types of unit-linked and equity-linked products with and without guarantees as well as different ways of general charges.

of the Danish investment-linked annuities. In addition, the costs for guarantees are lower and in tendency less prone to model errors than in case of, e.g., variable annuities that rely on complex dynamic hedging or asset allocation programs. Furthermore, due to the annual adjustment of the minimum policy interest rate on a monthly basis using, e.g., a weighted average of the yield to maturity on leading government bonds, the risk for the insurer associated with the guarantee is considerably reduced.

However, one aspect that will play a central role in the development of new life insurance financial products besides the type and level of guarantees, transactions costs, and risk management issues in general is the regulatory environment and tax handling as well as government subsidization of pension products. Thus, the further development of innovative products will to some extent be country specific, but the consumers' need for guarantees and stability, individuality, flexibility, and transparency seems to us to be the common driver for future innovation.

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Chapter 37

The Division of Labor Between Private and Social Insurance

Peter Zweifel

Abstract This contribution starts from the observation that the past decades have seen a substantial change in the division of labor between private (PI) and social insurance (SI), to the advantage of the latter. The efficiency view of SI (to be expounded in Sect. 37.2) explains the existence of SI with the market failures of PI, namely moral hazard and adverse selection. In Sect. 37.3, a benevolent government is introduced that seeks to determine the optimal division of labor between PI and SI. However, moral hazard effects are found to plague SI at least as much as PI, while the empirical relevance of the adverse selection argument has recently been challenged. In Sect. 37.4, the exposition therefore turns to the public choice view, which emphasizes the interests of risk averse voters even with below-average wealth in redistribution through SI. This view predicts a crowding out of PI by SI also in markets without adverse selection, which has been observed. Section 37.5 turns to normative issues by proposing a test that indicates whether and in which lines of insurance the division of labor between PI and SI could be improved. The final section, Sect. 37.6, offers concluding remarks and an outlook on future challenges confronting both PI and SI.

37.1 Introduction

At present, private and social insurance jointly claim roughly one-third of a worker's pay in industrial countries, with the USA markedly below but other OECD countries above this benchmark (see Table 37.1 and footnote). Although measured as benefits in the case of social insurance (SI henceforth) and premiums paid for life and health coverage in the case of private insurance (PI) for lack of consistent international data, there is no doubt that PI and SI together constitute a major expenditure item in today's household budgets. Admittedly, personal lines of PI comprise more than just life and health, yet it is evident from Table 37.1 that even in the UK, one of the major markets for personal PI, the SI component is about twice as important as the PI component. In the USA, it is even about three times as important. Both the high GDP share of SI and PI combined and the preponderance of SI are mainly the result of a remarkable expansion of SI. In Germany, for instance, the SI share was already at a comparatively high value of 22.1% in 1980 but continued to increase to 26.6% until the year 2000, becoming roughly stable at 25.2% by 2009. The PI share was at 2.4% in 1990 (the first year with comparable data), nine times lower than the SI figure. By 2009, it has increased to 3.4%,

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Table 37.1 Social (SI) and private (PI) insurance in some OECD countries in percent of GDP

| Country | | 1980 | 1990 | 2000 | 2009 ^a |
|---------|----|------|------|------|-------------------|
| Germany | SI | 22.1 | 21.7 | 26.6 | 25.2 |
| | PI | n.a. | 2.4 | 3.0 | 3.4 |
| France | SI | 20.8 | 24.9 | 27.7 | 28.4 |
| | PI | n.a. | 3.4 | 6.7 | 7.4 |
| UK | SI | 10.5 | 16.8 | 18.6 | 20.5 |
| | PI | n.a. | 6.8 | 12.8 | 10.4 |
| Italy | SI | 18.0 | 20.0 | 23.3 | 24.9 |
| | PI | n.a. | 0.6 | 3.5 | 8.4 |
| Japan | SI | 10.4 | 11.3 | 16.5 | 18.7 |
| | PI | n.a. | 7.0 | 8.1 | 7.5 |
| USA | SI | 13.2 | 13.5 | 14.5 | 10.2 |
| | PI | n.a. | 4.1 | 4.5 | 2.9 |

Note: Putting labor's share at two-third of GDP, one arrives at a combined PI and SI share in workers' pay of 42.7% ($=25.2 + 3.4/0.67$) for Germany and 19.5% ($=10.2 + 2.9/0.67$) for the USA (as of 2009).

Sources: OECD Social Expenditure Database, several editions; Sigma of Swiss Re, several editions

SI: Includes benefits (e.g., for housing) that are part of public welfare

PI: Premiums paid for life and health insurance, estimated from graphs published by Sigma 4/1992, 6/2001, and 2/2010

^a2007 for SI

still more than seven times lower than the SI figure. Detail not reported in Table 37.1 but provided by OECD shows that the expansion of SI was led by health, with pensions second; accordingly, the term "social insurance" as used in this chapter is more comprehensive than "social security" in US language.

Much of the economics literature has justified the existence and even the preponderance of SI by its efficiency-enhancing properties, arguing that SI can mend or at least mitigate market failures of PI. A typical exponent of this view is [Sinn \(1996\)](#), who claims that SI offers a service PI cannot offer. Risk averse parents who want their children to live in a world with an income floor for the unlucky must rely on SI because PI cannot deal with this type of intergenerational risk. In a similar vein, [Casamatta et al. \(2000\)](#), examining the political sustainability of SI, theoretically describe conditions that shift the division of labor between SI and PI to the detriment of SI. However, the expansion of SI also has raised concerns. For instance, [Feldstein \(1995\)](#) has estimated that the privatization of US pensions would increase economic welfare by \$1.5 per dollar of net social security wealth. Accordingly, the concern in this camp is that SI may "crowd out" PI over time. An early piece of empirical evidence came from [Cutler and Gruber \(1996\)](#), who found that the 1987–1992 expansion of US Medicaid (a public program providing health insurance coverage to the poor) displaced private health insurance coverage at the rate of 50%.

This contribution seeks to shed light on this debate in four ways. First, it reviews the efficiency reasons supporting the view that there is a need for SI, possibly complemented by PI. The theoretical mainstay is provided by the famous [Rothschild-Stiglitz \(1976\)](#) model that can be combined with the "market for lemons" dynamics described by [Akerlof \(1970\)](#) to predict the possibility of a "death spiral" for PI markets in the presence of insurers' lack of information about consumers' true risk status. Second, some empirical evidence concerning the alleged "death spiral" and insurer behavior in the face of their lack of information is examined. At least for the time being, the conclusion is that the efficiency view of SI may well fail to explain the secular expansion of SI and the associated crowding out of PI. Third, the alternative public choice view emphasizing the interests of citizens and voters in wealth redistribution through SI is expounded. It accords well with evidence documenting

a crowding out of PI by SI. Fourth, normative issues are addressed by asking whether and in which lines of insurance the future division of labor between PI and SI could be improved.

37.2 The Efficiency View of Social Insurance

Theoretical explanations of the existence of SI usually refer to two main shortcomings of private insurance markets due to asymmetric information, moral hazard and adverse selection. It will be argued that moral hazard effects plague SI even more than PI; the emphasis of this section therefore is on adverse selection.

37.2.1 *Moral Hazard as a Market Failure of Private and Social Insurance*

Moral hazard is the consequence of the fact that the insured agent does not reap the full benefit of preventive effort anymore (since the insurer participates in any reduction of expected loss) while bearing the full cost of this effort. The observable consequence is a positive correlation between the degree of insurance coverage and the probability of loss (in the case of so-called ex ante moral hazard) and the amount of loss (ex post moral hazard). If this behavior is unobservable (“hidden action”), the insurer cannot sanction it by increasing the individual premium. To the extent that the loading contained in insurance premiums increases along with expected loss (e.g., because of increasing cost of administration and risk bearing), the true cost of insurance rises due to moral hazard.¹ Moral hazard effects therefore cause consumers to choose less than full coverage (the first-best solution), which amounts to a welfare loss.

However, one may note at once that SI is subject to the same moral hazard effects as PI unless one is willing to assume that institutions of SI can observe preventive behavior. In the case of health, accidents, disability, and old age, this is clearly not true, to the contrary. Whereas private insurers usually tailor the parameters of their contracts to individual behavior reflecting (the control of) moral hazard (e.g., by granting rebates for no claims), SI is strongly bound to the solidarity principle which requires equal ex-ante benefits for equal (rates of) contributions. Therefore, the argument that SI has an efficiency advantage over PI due to its lower loading holds with regard to the cost of administration at best. But administrative expense may well be endogenous, reflecting effort at controlling moral hazard. For instance, it is lower in Canadian health insurance (which continues to rely on fee-for-service) than in US health insurance (which has created managed care alternatives to combat moral hazard) (Danzon 1992). One might argue that compared to PI, SI can better count on physicians as agents for the verification of health claims. However, a study by Dionne and St. Michel (1991) finds evidence suggesting that physicians helped workers to benefit from an increase in generosity in the public workplace accident scheme of Quebec. According to the authors, this effect did not depend on the severity of the condition but rather on its observability. It was marked when the diagnosis was ambiguous but absent when easily cross-checked by another physician. Therefore, at least in this case it cannot be said that SI was able to enlist the support of physicians as intermediaries for reining in moral hazard.

The one remaining component of the loading is acquisition expense, which is negligible in the case of SI because SI constitutes a monopoly. The cost advantage of SI therefore has to be weighed against

¹Recall that the major part of an insurance premium is redistribution between those who do not suffer a loss and those who do. The true cost of insurance amounts to the loading in excess of the expected loss. It is for this reason that full coverage is predicted for risk averse consumers who are charged a fair premium (i.e., a premium without a loading).

the imposed uniformity of promised benefits, which entails an efficiency loss as soon as preferences with regard to insurance differ within the population.

37.2.2 *Adverse Selection: The Crucial Market Failure of Private Insurance?*

The crucial efficiency drawback of PI has to do with the other consequence of asymmetric information, adverse selection. The theoretical mainstay is provided by the [Rothschild-Stiglitz \(1976\)](#) model, which can be combined with the dynamics of [Akerlof's \(1970\)](#) "market for lemons," where good quality is driven out by bad quality. The model assumes that private insurers do not (and never will) know the true type of consumers, reflected by the probability of loss ("hidden type"). Therefore, a pooling contract reflecting the average probability in the population is the best PI can come up with. Since the trade-off between premium and coverage is valued differently by high and low risks, a challenger can always offer a contract with less coverage but a lower premium that appeals to the favorable but not the high risks. Note that this again induces a positive correlation between the amount of insurance coverage and the probability of loss, very much the same as in the case of (ex ante) moral hazard. However, contrary to the case of moral hazard, this time there is an incumbent insurer who is stuck with its high risks and forced to increase the pooling premium to maintain financial equilibrium. This only strengthens the incentive of favorable risks to leave the incumbent (who offers "good" quality in [Akerlof's](#) terms), triggering a "death spiral." Since the challenger still writes a pooling contract, it can in turn be attacked by a third competitor; the death spiral may therefore even continue to wipe out the entire PI market.

Before discussing the potential of SI to at least mitigate this allegedly crucial market failure of PI, it may be worthwhile to consider some empirical evidence. As noted above, a positive correlation between the amount of coverage and probability of loss is a sign of both types of asymmetric information. [Puelz and Snow \(1994\)](#) presented evidence suggesting that US automobile insurance was indeed characterized by adverse selection. However, as shown by [Dionne et al. \(2001\)](#) using data from Quebec, this conclusion cannot be upheld as soon as nonlinear terms of explanatory variables are included. Based on French automobile insurance data and conditioning on a large set of potential confounding variables, [Chiappori and Salanié \(2000\)](#) again find evidence of adverse selection. [Cawley and Philipson \(1999\)](#) test the model's prediction that unit premiums increase with the amount of coverage in order to compensate for the positive correlation between coverage and probability of loss. Their empirical analysis of term life insurance premiums shows that to the contrary, unit premiums fall with coverage. Moreover, low risks hold more coverage than high ones, contradicting the notion of a competing insurer siphoning off low risks with a low-premium, low-coverage alternative.

[Einav et al. \(2010a\)](#) argue that the more telling test of adverse selection is whether the cost to the health insurer (measured by healthcare expenditure) increases with exogenously varying premiums. Exogenous premium variation is crucial as it precludes reverse causation running from insurer's cost to premium in response to moral hazard effects. The authors benefit from such exogeneity because in 2004, Alcoa let the presidents of some forty business units set the contribution their employees had to pay for health insurance, without having access to information about their past healthcare expenditure. On the one hand, the authors find that employee's choices of contract have no recognizable relationship with a number of demographics. On the other hand, they do find that the insurer's marginal and average cost increases significantly with the premium (and hence decreases with the quantity demanded), pointing to adverse selection. Their data also allow them to estimate a demand curve and to determine the efficient equilibrium point where price equals marginal cost. The divergence caused by the break-even condition given adverse selection, price = average cost, results in a "Harberger triangle" indicating a welfare loss of some US\$10 per employee. Relative to the total welfare attainable from purchasing health insurance (the aggregated excess of marginal willingness

to pay over marginal cost), this amounts to some 3%. For all the theoretical emphasis on adverse selection as a source of inefficiency of PI, this is a remarkably small figure; however, there may of course be other instances and lines of insurance where the SI alternative could reduce or even avoid a more substantial welfare loss.

Einav et al. (2010b) derive another estimate of the welfare loss caused by adverse selection, this time in the UK annuity market. Between 1988 and 1994, they observe some 9,000 consumers who were mandated to purchase annuities but had the choice of a so-called guarantee period ranging from 0 to 5 to 10 years. During the guarantee period, annuitants would receive a fixed nominal benefit; in return, the longer this period, the lower the payment at death. An adverse selection effect arises since individuals with a high remaining life expectancy are predicted to opt for the 10-year period. The authors can test this prediction because they observe annuitants' mortality up to the end of 2005. Calibrating parameters such as the coefficient of relative risk aversion and the rate of time preference and assuming that consumers can correctly predict their remaining life expectancy, they determine optimal choices. However, they also account for another source of heterogeneity, namely the utility value of consumption during the guarantee period relative to the utility value of wealth at death (e.g., for bequests). They find that if the government were to neglect this second source of heterogeneity by mandating the 5-year period chosen by the great majority, it would forgo a possible efficiency gain over the observed market outcome amounting to \$423 per new annuitant. Turned the other way around, this is the welfare loss due to adverse selection effects that could be avoided by an optimal government mandate of 10 years; however, being no more than an estimated 2% of total annuitized wealth, this loss is small.

Findings of this type leave open one important question, whether a competitive market for PI would exist at all in view of the threat of "death spirals" occurring. A case study by Cutler and Reber (1998) suggests this threat could be real. When Harvard University employees had to come up with a much higher personal contribution to health insurance, those with a favorable cost record migrated from the contract with comprehensive coverage to a more restrictive (managed-care type) but cheaper alternative, while those with an unfavorable record kept their comprehensive policies. Within two years, the more generous contracts had to be withdrawn. However, it is not clear that the insurers writing them approached insolvency; rather, the evidence suggests that they withdrew loss-making contracts to find a new equilibrium, as theoretically described by Wilson (1977) and Miyazaki (1977). A similar shift towards managed-care type health insurance was observed by Buchmueller and DiNardo (2002) in the state of New York, where strict community rating was imposed in 1993, in contradistinction to Pennsylvania and Connecticut. Community rating prohibits insurers from grading premiums according to risk and therefore enforces the pooling contract that allegedly triggers the death spiral. The authors did not find any sign of an increasing number of individuals without coverage in New York, which would be the consequence of a death spiral ultimately leading to the disappearance of private health insurance.

37.2.3 *Separating Contracts and Efficiency Enhancement by Social Insurance*

Rothschild and Stiglitz (1976) already pointed to separating contracts as a possible response of private insurers to the adverse selection challenge. The inconclusive empirical evidence presented in Sect. 37.2.2 suggests that they may often be successful in this endeavor. The intuition is that through appropriate contract design, consumers of a certain risk type can be made to opt for the contract appropriate for them. However, it will be shown that this subjects the low risks to a rationing of coverage. Compulsory SI serves to relax this rationing and therefore acts like a complementary element enhancing the efficiency of PI (Dahlby 1981).

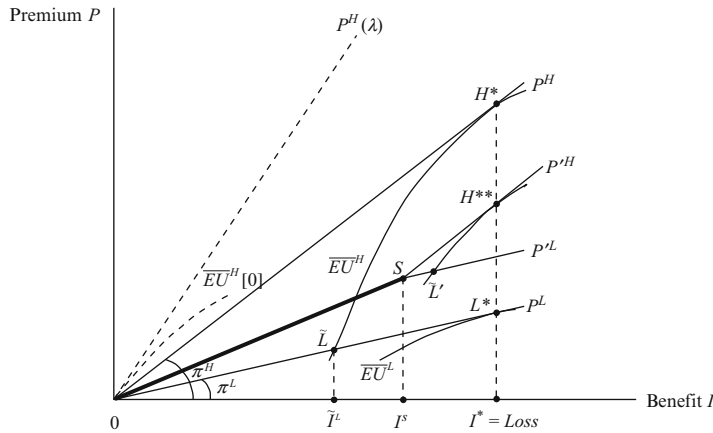


Fig. 37.1 Potentially Pareto-improving social insurance

In Fig. 37.1, the initial situation (no information asymmetry, prior to SI) is depicted as a benchmark. Along the two insurance lines P^H and P^L , a competitive insurer breaks even, with costs of administration and risk bearing neglected for simplicity [the insurance line $P^H(\lambda)$ will be explained below]. Premiums therefore simply cover expected loss given by $\pi^H \cdot LOSS$ and $\pi^L \cdot LOSS$, respectively. Indifference curves \overline{EU}^H and \overline{EU}^L reflect the subjective tradeoffs between additional coverage and higher premium. The slope of the \overline{EU}^H curve must be steeper than that of \overline{EU}^L because the high risks by definition are confronted with a higher probability of loss than the low risks; therefore they are willing to accept a higher extra premium in return for an increase in coverage I .

Generally the marginal utilities of wealth in the loss and the no-loss state are involved in the definition of such an indifference curve. However in the special case where the wealth levels are equal (ie., where the insurance benefit fully compensates for the loss) the two marginal utilities of wealth are equal as well. For the high risk, eg., the trade-off at this particular point amounts to the one between paying the additional premium with probability one in return of receiving the additional benefit with probability π^H . Therefore the indifference curve \overline{EU}^H must have slope π^H where benefit I equals the loss. This amounts to the optimum for this type of consumer because the tangency condition is satisfied. Hence points H^* and L^* denote the first-best optima of the high and the low risk, respectively in the absence of asymmetric information.

Since a pooling contract is not sustainable in the presence of informational asymmetry, the next step is to show how separating contracts can deal with the situation. For simplicity, assume that the insurer launches a high-premium full-coverage contract designed for the high risks, who therefore attain point H^* of Fig. 37.1. At the same time, it launches a low-premium contract which however would attract the high risks as well if it were to offer full coverage (according to indifference curve \overline{EU}^H , a high risk prefers point L^* to H^*). Indeed, benefits pertaining to this second contract cannot be extended beyond point L^{\sim} , where the indifference curve \overline{EU}^H intersects the insurance line labeled P^L . Evidently, separating contracts can avoid unsustainable pooling, but at a price. They entail a rationing of coverage for the low risks, who would be willing to pay the necessary premium for the additional coverage (note that L^* lies on a higher-valued indifference curve than L^{\sim}).

In this situation, SI can indeed improve the welfare of both risk types. Since SI is mandatory, it enforces a pooling contract; since it has a uniform benefit, its pertinent insurance line ends at point S (assuming partial coverage). For complementary PI, point S becomes the new origin. Neglecting moral hazard effects that could be caused by another insurer providing additional coverage, the loss probabilities remain unchanged, resulting in the new insurance lines $P^{H'}$ and $P^{L'}$, respectively. This permits the high risk to attain H^{**} , an improvement of welfare over H^* . The benefit of SI for the

low risk is that PI can now offer a complementary benefit up to \tilde{L}' (where the high risk's indifference curve through H'' intersects the new insurance line P'^L). The downside for the low risks is that they must pay the SI contribution up to point S , which reflects also the loss probability of the high risks. The welfare comparison between points \tilde{L}' and \tilde{L} is therefore ambiguous. An indifference curve drawn through \tilde{L}' with strong curvature (indicating marked risk aversion because willingness to pay for additional coverage increases quickly as the consumer moves away from full coverage) would intersect the original P^L insurance line to the right of point \tilde{L} , implying that SI with complementary PI affords a welfare gain. Conversely, an almost linear indifference curve through \tilde{L}' (indicating little risk aversion on the part of the low risk) would intersect the P^L insurance line to the left of point \tilde{L} . Therefore, SI may but need not be Pareto-improving according to this model.

Coverage provided by mandatory SI can even be strictly Pareto-improving as shown by Besley (1989). The crucial assumption is that SI is able to observe the risk type. However, the amount of coverage provided by PI must fall in order to limit moral hazard effects, an effect that was to be dubbed "crowding out" later (see Sect. 37.4). By way of contrast, Blomqvist and Johansson (1997) argue that in the absence of observability, moral hazard effects caused by PI spill over to SI, making a mixed system strictly less efficient than either the fully private alternative or comprehensive SI.

While this analysis on the whole motivates the existence of SI, it has three shortcomings:

1. It fails to explain why the political debate invariably focuses on the inability of high risks to obtain PI rather than the rationing of coverage imposed on the low ones.
2. It does not determine the optimal amount of SI (note that point S of Fig. 37.1 was chosen arbitrarily).
3. It does not explain the expansion of SI over time (from a few percent of GDP prior to World War II to around 15% by 1980 and some 25% at present in a typical industrial country) (OECD 2007; see also Table 37.1).

The first shortcoming can be remedied by assuming risk-specific transaction costs for PI that are reduced by SI [the argument is a modification of Newhouse (1996); see also Zweifel and Eisen (2012) Ch. 9.2]. In Fig. 37.1, let these transaction costs give rise to a proportional loading λ so large as to cause the high risks to go without any PI coverage at all, while the low risks continue to pay the actuarially fair premium ($\lambda = 0$). Graphically, the dashed indifference curve $\overline{EU}^H[0]$ through the origin indicates a higher expected utility than any point on the dashed insurance line $P^H(\lambda)$. In addition, let this loading reflect the price of risk bearing by PI, which is substantial in the case of high risks because, e.g., their losses not only have high expected value but also high variance and (positive) skewness. In this situation, SI, by imposing coverage up to point S , can serve to reduce the conditional variance and skewness of losses to be borne by PI. For simplicity, assume the loading to become zero, making the insurance line P'^H originating from S the relevant one, as before. The high risk is now predicted to move from zero coverage to point H^{**} of Fig. 37.1 entailing an even greater welfare gain than in the case discussed initially. In this sense, SI can be said to solve the problem of high risks not obtaining coverage.

The other two shortcomings are addressed in turn in Sects. 37.3 and 37.4, respectively.

37.3 The Optimal Amount of Social Insurance

As noted towards the end of Sect. 37.2.3, the efficiency view of SI leaves the optimal amount of coverage to be provided by SI relative to PI undetermined and with it, the optimal division of labor between SI and PI. There have been two strands of literature addressing this issue. One is to introduce a benevolent government as the agent who optimizes SI on behalf of a representative citizen. The other recognizes that the implementation of SI ultimately requires a majority support by voters.

37.3.1 A Benevolent Government Optimizing the Amount of Social Insurance

Health insurance constitutes a leading case where the government determines the division of labor between PI and SI, in particular by permitting citizens to purchase supplementary coverage offered by private insurers. This is the focus of [Petretto \(1999\)](#), whose model comprises three stages. First, the government introduces SI with a degree of coverage α ($0 < \alpha < 1$). Next, consumers select their preferred amount of PI, which is partial in response to the loading contained in the premium (in [Fig. 37.1](#), the high risks choose zero coverage because of a very high loading). This leaves them with some positive net expense in the loss state, which depends on the consumer's decision with regard to healthcare expenditure and labor supply (and hence available income). While the model is couched in health insurance terms, its three-layer structure is rather general. With regard to unemployment, for instance, SI imposes a rate of income replacement. Frequently, the employer acts as a private insurer by providing a severance package (the premium being a wage rate below the marginal product of labor). In the case of provision for old age, SI imposes a first layer in the guise of a (typically tax-financed) public pension. A second layer comes from PI either purchased individually in the guise of a whole life insurance contract or again provided by the employer and financed by a wage deduction.

The amount of loss falling on PI is not exogenous anymore (contrary to the exposition in [Sect. 37.2.1](#)) but now subject to an ex-post moral hazard effect. In the case of a health loss, this is the extra healthcare expenditure that would not be incurred without insurance coverage. In the case of unemployment, the worker may exert less search effort to find a new job. Similarly, retirees may seek to maximize their remaining life expectancy in response to a pension that is topped up by a PI contract. Here, the out-of-pocket component could be equated to the difference between pre-retirement consumption and achievable consumption over the life span remaining.

In keeping with the three layers, optimization occurs in three stages. First, the government sets an optimal uniform degree of coverage α of the possible loss by maximizing the sum of citizens' utilities. It is subject to a budget constraint that involves a uniform rate of taxation t on average labor income that depends on labor supply in the loss and the no-loss state. In the second stage, individuals select their (nonuniform) degree of private insurance coverage $1 - k_i$, with k_i denoting the rate of cost sharing. To simplify the analysis (and contrary to [Sect. 37.2](#)), the loss probabilities are assumed to be known; therefore, SI cannot be credited with relaxing the rationing constraint imposed on low risks by separating contracts. In the third stage, individuals decide about their amount of healthcare expenditure (or more generally, the amount of loss falling on the private insurer).

As usual, the model is solved backwards. As for the optimal degree of PI coverage, [Petretto \(1999\)](#) obtains

$$\frac{1 - k_i^*}{k_i^*} = \frac{u'[\text{Loss}]_i - \bar{u}'_i(1 + \lambda)}{\bar{u}_i(1 + \lambda)} \cdot \frac{1}{e_i}, \quad (37.1)$$

with $e_i > 0$ an elasticity (in absolute value) relating the loss borne by PI to the net cost borne by the insured.

This result is quite intuitive. The optimal degree of coverage in the PI layer [[the left-hand side of \(37.1\)](#)] is higher:

- The higher the degree of risk aversion of individual i . The marginal utility of income in the loss state, $u'[\text{Loss}]_i$ is higher than the weighted average \bar{u}'_i over the loss and the no-loss states (this is equivalent to the concavity of a risk utility function of the Von Neumann-Morgenstern type).
- The lower the proportional loading λ and hence the "true" price of insurance.
- The smaller the ex post moral hazard effect symbolized by the elasticity e_i . In a health context, e_i indicates how strongly the insured responds to a decrease of the net price of medical care with an increase in the demand for care. In an unemployment context, e_i would show how much search

effort decreases in response to the lowered opportunity cost of remaining unemployed. Note that this opportunity cost also depends on the amount of coverage α provided by the first layer.

The optimal value of α is implicitly given by the condition,

$$\begin{aligned} & \sum_i^n \text{Cov}(u'_i[\text{Loss}]_i, \text{NetLoss}_i) + n[\bar{u}'[\text{Loss}] \cdot \text{Cov}(\bar{u}'_i/\bar{u}', \overline{\text{NetLoss}_i}/\overline{\text{NetLoss}}) - 1] \cdot \overline{\text{NetLoss}} \\ & = \sum_i^n u'_i[\text{Loss}] [(1 - \alpha^*)(1 - k_i^*) + \alpha^*] \frac{\partial \overline{\text{NetLoss}_i}}{\partial \alpha} \end{aligned} \quad (37.2)$$

The marginal benefit associated with an increase of α is shown on the left-hand side. It consists of two components:

- The first term on the left-hand side amounts to a social risk-sharing gain. It is high if over the n individuals considered if there is a marked covariance between their marginal utility of wealth in the loss state and the amount of net loss they have to bear because PI is only partial. Here, one has to take into account that PI coverage demanded typically decreases when SI coverage expands [this “crowding-out” effect is taken into account in the contribution by [Chetty and Saez \(2009\)](#), to be discussed in Sect. 37.3.2 below]. Generally, the amount of covariance is high if the marginal utility of income is high in the loss state, i.e., if individuals exhibit strong risk aversion.
- The second term on the left-hand side of (37.2) is the social redistribution gain. Its main term is the covariance between the individual’s relative average marginal utility and his or her relative net loss. The two quantities are relative because they relate the individual to a mean marginal utility in the population (\bar{u}') and the mean loss striking the population ($\overline{\text{NetLoss}}$), respectively. The individuals considered have a strong interest in redistribution through SI if this covariance is high, i.e., if an individual who suffers from an above-average net loss simultaneously is characterized by an above-average marginal utility of income (which can be taken to reflect below-average income or wealth). The marginal utility of income prevailing in the population $\bar{u}'[\text{Loss}]$ is used to translate this benefit into utility terms.

Together, these two marginal benefits have to equal marginal cost at the optimum. Marginal cost consists of three multiplicative components:

- The last factor is the basic trigger. It shows how strongly the expected net loss associated with individual i reacts to an expansion of SI. This is the ex post moral hazard effect originating with SI (the probability of loss is observable by assumption, thus precluding ex ante moral hazard).
- The second factor shows that the degree of both SI and PI coverage acts as amplifiers. The main impulse comes from α^* itself. In addition, however, PI covers the remainder $(1 - \alpha^*)$ to the tune of $(1 - k_i^*)$.
- Finally, the first factor transforms these effects into a utility value, this time using the marginal utility in the loss state because ex post moral hazard occurs in the loss state by definition.

Equations (37.1) and (37.2) combined define an optimal division of labor between PI and SI.

37.3.2 Taking into Account Adverse Selection and Crowding Out

In view of the results presented in Sect. 37.2, a major challenge for determining the optimal division of labor between PI and SI is to take into account problems associated with informational asymmetry but also the fact that an expansion of SI does not increase total insurance coverage in step because PI

is displaced to some degree (the “crowding-out” phenomenon, which will be the topic of Sect. 37.4). This challenge has been taken up by [Chetty and Saez \(2009\)](#), who use unemployment insurance (UI) as their leading example. One might argue that this type of insurance is exclusively provided by SI. While the division of labor between PI and SI is indeed much more debated in the context of health insurance, there is a PI involvement in UI to the extent that employers provide severance pay. Both components of UI are financed by a payroll tax, one explicit (τ) levied by the government, the other, implicit (t_k) by the employer, who can observe the wage income W_k of type k . As in the preceding section, there is a benevolent government who seeks to maximize citizens’ expected utilities. Through setting τ , it also determines the benefit rate α of the preceding section if the SI scheme is to maintain its financial equilibrium. [Chetty and Saez \(2009\)](#) show that the optimum implicit contribution rate is given by

$$\frac{\tau}{1-\tau} = -\frac{1}{e_{\bar{W},1-\tau}} \frac{\overline{\text{Cov}}(\bar{u}'_k, \bar{W}_k)}{\bar{u}' \cdot \bar{W}} + \frac{1}{e_{\bar{W},1-\tau}} \cdot \sum_k s_k (t_k^* - r_k) e_k (t_k^* - t_k) \cdot \frac{\bar{u}' \cdot \bar{W}_k}{\bar{u}' \cdot \bar{W}}. \quad (37.3)$$

Note that the left-hand side of (37.7) is increasing in τ . The three effects of interest are represented as follows.

- *Moral hazard*: This is reflected by two parameters. The first is the elasticity $e_{\bar{W},1-\tau}$ which indicates how strongly (labor) income averaged over the loss and the no-loss state reacts to the amount that the worker retains per dollar earned and hence to the payroll tax τ levied by SI. The stronger this response, the more the benefits of SI in terms of income smoothing (see below) have to be adjusted downwards. It corresponds to the elasticity e_i in (37.1) from [Petretto \(1999\)](#), who however does not yet distinguish between moral hazard effects induced by the SI and PI layers. This is achieved here by the second parameter e_k , an elasticity indicating the response of \bar{W} to the overall retention per dollar earned, given by $(1-\tau)(1-t_k)$. The stronger this group-specific effect of PI (relative to SI), the more the scaling down of SI occasioned by $e_{\bar{W},1-\tau}$ has to be corrected in favor of SI again.
- *Adverse selection*: This is represented by $(t_k^* - t_k)$, the difference between the PI contribution rate (levied by the employer) in the absence of the self-selection constraint (t_k^*) and in its presence (t_k). This difference is positive due to the rationing effect of adverse selection (see Fig. 37.1 again), indicating a benefit favoring SI.
- *Crowding out of PI*: This is represented by the group-specific parameter $r_k > 0$ which is the elasticity of the PI retention rate $(1-t_k)$ with respect to the SI retention rate $(1-\tau)$. It represents what [Chetty and Saez \(2009\)](#) call a fiscal externality, which would be absent from informal insurance provided e.g., among members of the same household. Since both components of unemployment insurance are subject to budget balance, this elasticity indirectly indicates how much of employer-provided coverage is crowded out by SI (however, for simplicity the model does not contain a module representing optimizing behavior of either employers or employees in this respect). The greater the r_k , the smaller should be the optimal extent of SI, ceteris paribus. As will be shown in Sects. 37.4.2 and 37.4.3 below, crowding-out effects are indeed substantial, serving to reduce the social benefit that can be expected from a (continued) expansion of SI.

The remaining elements of (37.3) can be interpreted as follows. The $\overline{\text{Cov}}$ term represents the consumption smoothing benefit of SI and PI combined. For each group k of the population, their marginal utility of income averaged over the loss and the no-loss state \bar{u}'_k is compared with that of the population of the whole \bar{u}' . This ratio is high (due to the concavity of the risk utility function) when relative income (\bar{W}_k/\bar{W}) is low, resulting in a negative covariance, very much as in (37.2) above. The group-specific covariance values have to be averaged to obtain $\overline{\text{Cov}}(\cdot)$; together with the negative sign, this amounts to a benefit. It has to be qualified in terms of the moral hazard effect $e_{\bar{W},1-\tau}$ discussed above. The summation in the second term is over the population shares s_k and bears close similarity

to a covariance between (relative) marginal utilities and income levels again [although the last factor is not expressed as deviations from expected values, it still says that the benefit of SI is large if high (relative) marginal utilities of income coincide with low (relative) levels of wealth]. Here, the relative moral hazard effect of PI relative to SI given by $e_k/e_{\bar{W},1-\tau}$, the rationing due to adverse selection ($t_k^* - t_k$), and the leakage due to the crowding-out effect ($1 - r_k$) all enter as qualifying factors.

Clearly, the average of marginal utilities of income depends on their values in the loss and the no-loss state, which in turn are determined by the curvature of the risk utility function. The relationship with the coefficient of (relative) risk aversion is established by Chetty (2006) who also shows that in spite of later modifications, an influential finding by Bailey (1978) continues to be valid. It states that the optimal amount of UI benefits is determined by (1) the mitigation of the drop in consumption achieved by UI, (2) the coefficient of relative risk aversion, and (3) the elasticity of unemployment duration with respect to UI benefits. The analysis by Chetty and Saez (2009) shows that these parameters are indeed crucial. In (37.2), the mitigation of the drop in consumption is reflected by \bar{W}_k/\bar{W} , the role of (differences in) risk aversion indicated by \bar{u}'_k/\bar{u}' , while the elasticity of duration has become the elasticity of earnings $e_{\bar{W},1-\tau}$.

Finally, Chetty and Saez (2009) explicitly relate the SI contribution rate τ to a PI contribution rate \hat{t} , which is weighted by population shares, relative incomes, and relative marginal utilities,

$$\hat{t} = -\frac{\tau}{1-\tau} + \frac{1-\hat{r}}{e_{\bar{W},1-\tau}} \cdot \frac{-\text{Cov}(u', W)}{\bar{W}}. \quad (37.4)$$

Clearly, this defines an optimal crowding-out relation in that a higher (optimal) value of τ implies a lower value \hat{t} , ceteris paribus (first term on the right-hand side). However, the PI component is also to be credited for its contribution to consumption smoothing (indicated by the average covariance between marginal utility u' and income W , which is usually negative), qualified by the crowding-out factor, with \hat{r} symbolizing an average value of r_k weighted in the same way as t_k . Equations (37.3) and (37.4) together indeed define an optimal division of labor between PI and SI in the case of unemployment and similar risks such as workplace accidents.

37.4 The Crowding-out Phenomenon

37.4.1 The Public Choice View of Social Insurance

Contrary to the basic assumption adopted in Sect. 37.3, government in a democracy cannot act as a benevolent dictator but must act on behalf of citizens who know their risk type and position in the income and wealth distribution. Referring back to Fig. 37.1 above, it is evident that the high risks would always gain from a continued expansion of SI to the detriment of PI. At first sight, such a shift appears even more likely if individuals not only differ in terms of risk but also in terms of income. As voters they would have an incentive to see SI expanded because it also redistributes income from the rich to the poor. However, it is the median voter whose preferences are decisive in determining whether or not a proposal finds a majority in the political process. Indeed, the middle class may favor a mixed system because on the one hand it can benefit from the better deal offered by PI; on the other, SI enables a general expansion of coverage but would in the limit entail an excessive burden in terms of income redistribution (Gouveia 1997).

In the following the model by de Donder and Hindriks (2003) is presented because it seems best suited to explain the shifting division of labor between PI and SI once voters are offered a choice between them. In this way, it provides a strong theoretical basis for the crowding-out findings to be

reported in Sect. 37.4.2 below. Indeed, the model predicts support for SI against PI even by voters who are slightly richer and are slightly better risks than average regardless of the distribution of wealth and risk in the country. This sweeping prediction goes beyond Casamatta et al. (2000), who merely derive conditions that shift the division of labor between PI and SI in favor of SI. It comes at a price, however. Rather than the conventional expected-utility (EU) framework, Yaari's (1987) dual formulation is adopted by the authors. In this formulation, risk aversion is expressed not by the concavity of the risk utility function but by the concavity of a weighting function $\varphi(p)$ defined over probabilities p . This permits to express the utility V^P derived from a PI contract directly in terms of predetermined wealth W ,

$$V^P = \varphi(p)(W - P - k \cdot 1) + (1 - \varphi(p))(W - P) = W - P - \varphi(p)(1 - k), \tag{37.5}$$

with $\varphi(p) = (1 + A)p$ (A is explained below).

Therefore, utility amounts to a weighted average of wealth levels in the loss and the no-loss state, respectively. In the loss state, wealth is net of the premium P and the rate of coinsurance k on a loss that is normalized to 1. This normalization makes the loss a fixed quantity, thus precluding any moral hazard effect, in contradistinction to Sect. 37.2.3. In the no-loss state, the premium still needs to be paid. The two wealth levels are weighted by a weighting function $\varphi(\cdot)$ whose parameter $A > 0$ reflects risk aversion; for simplicity, A is assumed independent of W . Note that (37.5) implies choice of full coverage ($k = 0$) even if the premium exceeds its fair value p (which is commonly observed behavior). This differs from the prediction derived from EU theory (see Fig. 37.1 again). It is the consequence of the fact that risk aversion has a first-order influence here but merely a second-order influence in EU theory (stemming from the concavity of the risk utility function).

The SI contract can offer full coverage [$(1 - k) = 1$] since it suffers neither from moral hazard nor risk selection. On the other hand, contributions are scaled according to the individual's wealth compared to the average \bar{W} , reflecting the redistribution characteristic of SI. Therefore, the utility value of SI is given by (37.6),

$$V^S = W - (W/\bar{W})\bar{P} \tag{37.6}$$

Before comparing (37.5) and (37.6) de Donder and Hindriks (2003) proceed to impose the self-selection constraint that renders separating PI contracts viable, in analogy to Fig. 37.1. They apply the criterion introduced by Mailath (1987), $dV^P/d\hat{p} = 0$ for $\hat{p} \rightarrow p$, stating that an individual cannot gain by announcing a risk type \hat{p} arbitrarily close to the true one. This permits them to derive an optimal coverage function, relating k^* to p and A . One can now define a wealth level W^o where the two utilities are equal. After substitution of k in (37.5), the pertinent condition reads

$$W^o - (1 + A)p + Ap(p/\bar{p})^{1/A} = W^o - (W^o/\bar{W})\bar{P} \tag{37.7}$$

The new symbol \bar{p} is the maximum loss probability in the population; it is part of the optimal benefit function. Therefore, the last term on the left-hand side of (37.7) expresses the benefit in financial terms that an individual characterized by a loss probability p relative to \bar{p} can derive from the separating PI contract. Taking the log of this term and differentiating it w.r.t. A results in a positive value, indicating that this benefit increases with risk aversion, as one would expect. However, the weighting function $\varphi(\cdot)$ causes the premium paid [the term $-(1 + A)p$ on the left-hand side] to increase as well. Solving condition (37.7) for the wealth level W^o indicating indifference between PI and SI yields

$$\frac{W^o}{\bar{W}} = \left[1 + A - A \left(\frac{p}{\bar{p}} \right)^{1/A} \right] \frac{p}{\bar{p}} = [1 + \varphi(A, p)] \frac{p}{\bar{p}}, \tag{37.8}$$

with $\varphi(A, p) = A[1 - (p/\bar{p})^{1/A}]$.

This condition can be interpreted as follows. Consider an individual with the mean loss probability \bar{p} . Since $\varphi(\cdot) > 0$, W^o/\bar{W} must exceed one implying that such an individual votes in favor of SI although his or her wealth is above average. Conversely, assume that the pivotal voter has below-average wealth. In that event, he or she continues to support SI rather than PI if his or her loss probability p corresponds to the average \bar{p} ; indeed, it could even be somewhat below average. Ultimately, the reason for this dominance of SI lies with the term (p/\bar{p}) , which reflects the necessity of sustaining separating contracts. This detracts from the benefit of PI, whereas SI does not need to observe this restriction.

The final step is forming the derivative of V^s with respect to $1 - k^s$, which the authors show to be positive; in addition, its value does not depend on $1 - k^s$, which implies the corner solution with $1 - k^{s*} = 1$, i.e., full coverage by SI. Moreover, individuals with the crucial wealth level W^o turn out to be indifferent to an expansion of SI, while those with less wealth (the majority in a country with a skewed wealth distribution) prefer to have full SI coverage. For this reason, a mixed system cannot be sustained politically.

In this way, the analysis provided by [de Donder and Hindriks \(2003\)](#) comes close to explaining the expansion of SI since its inception. It could be interpreted as the transition to a political equilibrium in which a loss of a given type is covered by SI exclusively. The puzzle then becomes why this expansion seems to have slowed down recently (see [Table 37.1](#) again). A possible explanation is that several exogenous changes (eg., increased migration, to be discussed in [Sect. 37.6](#)) cause increasing costs of enforcement for SI, causing a loading in the SI contribution \bar{P} of [\(37.5\)](#) that may push the threshold value of W^o sufficiently below \bar{W} to establish a stalemate between supporters and opponents of SI.

37.4.2 Evidence on the Crowding-out Phenomenon: Private Saving

The work by [de Donder and Hindriks \(2003\)](#) presented in the preceding section predicts that SI replaces (“crowds out”) PI in the political process. The underlying reason is that PI is beset with the problem of adverse selection, which makes it more costly than SI, causing an expansion of SI to be efficiency-enhancing. But what if SI crowds out private saving, which cannot be claimed to be subject to adverse selection effects? After all, banks are hardly concerned about “risky depositors” who have to be staved off by paying them low interest rates. Using macroeconomic data and viewing so-called social security wealth (SSW) as exogenous (in contradistinction to [Sect. 37.3](#)), [Feldstein \(1974\)](#) seemed to present conclusive evidence of such an effect (see the Introduction again). However, [Leimer and Lesnoy \(1982\)](#) found his findings to be mainly caused by an error in the calculation of the SSW variable.

The decisive support for the “crowding-out” hypothesis with regard to private saving came from [Hubbard et al. \(1995\)](#), who provide both a theoretical basis and empirical evidence based on individual data. They note that many SI programs (eg., food stamps in the USA) are means-tested with regard to assets rather than with regard to earnings. These programs have two effects, both of which may depress private saving, thus causing what can be called a welfare-reducing “fiscal externality”. First, they reduce uncertainty concerning future consumption levels, making precautionary saving less important. Second, they increase (often sharply) the opportunity cost of accumulating wealth especially for low-income households who would otherwise qualify for the SI program. The data come from the US panel study of income dynamics (PSID). Using education of the family head as an indicator of lifetime income, the authors indeed find that wealth in 1984 (measured as the number of years it could replace estimated permanent income) does not have the same age profile across educational levels. It exhibits the hump shape predicted by the life-cycle consumption model only among households with a college degree; for low-income households, the age profile is rather flat. The authors consider three explanations for this difference: the bequest motive for high-income families, a higher share of

consumption during retirement covered by SI among low-income households, and a lower rate of time preference among the poor. They show that these explanations fail to provide a convincing explanation of observed patterns, leaving a fourth: asset means-tested SI.

Hubbard et al. (1995) then build a model designed to determine optimal consumption over an individual's lifetime that incorporates uncertainty with regard to lifespan, earnings (taking into account unemployment insurance, however), and out-of-pocket medical expenses. Estimates of uncertainty are derived from the error variances of regressions of these variables on (powers of) age. The consumption floor is derived from all SI programs that are asset means-tested (such as food stamps and housing assistance), but not, eg., unemployment insurance which is earnings-tested. They then solve the stochastic dynamic optimization problem and use its solution to simulate age profiles for consumption and wealth. When either uncertainty is neglected or the consumption floor provided by SI is set to the counterfactual value of \$1,000 (1984 prices), their simulations fail to replicate the age-wealth profiles observed in the PSID. However, when uncertainty is combined with the actual \$7,000 consumption floor, the replication is quite close. This permits the authors to conclude that asset-tested SI crowds out savings of low-income households.

Using PSID once more, Gruber (1997) analyzes the consumption smoothing benefits of US unemployment insurance. For the period 1968–1987 (but without the recession year 1973 for lack of data, likely causing an underestimate), he finds that an increase in the income replacement rate of 10 percentage points reduces the fall in consumption by 2.65% during the unemployment spell. If this fall were zero, then the concomitant reduction in income would be entirely to the detriment of private saving. However, the smoothing of consumption is only partial, implying that the crowding-out effect of unemployment insurance is partial as well.

Gruber and Yelowitz (1999) single out the US Medicaid program to test for the crowding-out effect of means- and asset-tested SI on private saving by low-income households. Between 1984 and 1993, expenses of Medicaid increased by 500%; however, this expansion occurred at a markedly different pace between US member states, creating a source of exogenous variation. Criteria for eligibility were relaxed; in particular, the income threshold was lifted from 1987. The authors create a variable they call “Medicaid eligible dollars” (MED) by multiplying, for each member of a family, the Medicaid benefit with an imputed likelihood of being eligible. Their dependent variable is the household's net wealth; it is indeed found to decrease by an estimated 2.9% for every \$1,000 of MED, pointing to a substantial crowding-out effect, according to which the expansion of Medicaid induced a reduction of 8.2% in wealth over time. The estimate of 2.9% drops to 2% if there had been no asset test but increases to 5.3% given an asset test, underscoring the importance of this feature prevalent in many SI programs.

37.4.3 Evidence on the Crowding-out Phenomenon: Private Health Insurance

The study by Gruber and Yelowitz (1999) does not provide evidence bearing on the crowding out of private insurance by public insurance [unless one is willing to acknowledge (precautionary) saving as a type of private self-insurance, as in Kimball (1990)]. This gap is filled by Cutler and Gruber (1996), whose theoretical background can be illustrated by Fig. 37.2. The straight line *ABC* depicts the budget constraint of an individual whose income is low enough to qualify for an SI program. Since “all other goods” corresponds closely to income, the slope of the budget constraint (inversely) reflects the amount of income that has to be sacrificed for additional insurance coverage, i.e., the premium per unit coverage provided by PI. If risk averse, the individual is characterized by an indifference curve making H^* the optimum; for a less risk-averse type, the optimum is L^* . Now let the government offer

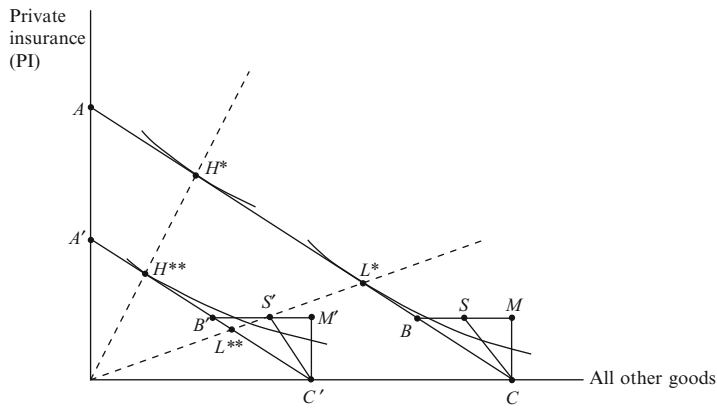


Fig. 37.2 The effect of public insurance on the demand for private insurance

an SI program with a take-it-or-leave-it benefit falling short of L^* at a subsidized contribution rate. This causes the budget constraint to become $ABSC$. If the program does not require a contribution, thus effectively amounting to public welfare, the budget constraint becomes $ABMC$. The H-type individual is unaffected; however, the L-type is predicted to typically opt for the SI program at point S (or M , respectively). These corner points dominate because both constitute accumulation points induced by many types of indifference curves with differing slopes. In either case, the amount of PI demanded decreases.

Now consider a poorer individual with budget constraint $A'B'C'$, with the two preference types unchanged (homothetic preferences are assumed). Absent the SI program, the H-type opts for H^{**} . When the program becomes available, the L-type shifts to it for sure (to point S' or M' , respectively). However, even the H-type is now predicted to opt for the SI alternative, with the result that SI crowds out PI regardless of type. The reason is that for a low-income individual, an SI option of a given amount has a much higher relative importance than for a higher-income individual, a difference which may swamp the influence of a preference structure that in principle favors the PI alternative (see H^{**} again). This effect is reminiscent of [Hubbard et al. \(1995\)](#), who also emphasized the impact of SI on low-income households. It may be counteracted to some extent when the amount of PI rather than the likelihood of having it is considered, since the transition from H^{**} to S' (or M') entails a larger reduction of PI coverage by the richer individual than the transition from H^{**} to S (or M) by the poorer individual.

[Cutler and Gruber \(1996\)](#) again take the expansion of US Medicaid (in particular benefits for mothers with children) as the exogenous impulse to study its impact on the demand for private health insurance. They ignore considerations of adverse selection in PI that might contribute to its being crowded out by the public alternative. To some extent, this can be justified by noting that much of US health insurance is contracted through employers, who by imposing open enrolment on health insurers prevent them from cream skimming. The authors start by noting that about two-thirds of mothers and children who became eligible had PI coverage initially. As in [Gruber and Yelowitz \(1999\)](#), they estimate the probability of eligibility for children and women of childbearing age. For children, eligibility has a positive effect on the take-up of Medicaid but a negative one on the likelihood of having private health insurance, amounting to a crowding out of 31% per percentage point of Medicaid expansion. For women, both the effect on take-up of Medicaid and (negative) on private health insurance are insignificant, but if taken at face value, they even suggest a crowding-out rate in excess of 100%. For the parents, the authors also check whether the expansion of Medicaid caused employers to curtail their offer of private health insurance coverage. However, their findings suggest that the decision to drop private coverage was made by the employees—possibly encouraged by their

employers. They arrive at an estimated 49% rate of crowding out, i.e., out of two persons additionally covered by Medicaid, one cancelled his or her private coverage.

In a follow-up study, [Gruber and Simon \(2008\)](#) review other work on the crowding-out effect of Medicaid. Notably, [Dubay and Kenney \(1997\)](#) had found much lower rates of crowding out by comparing changes in private enrolment over time in populations eligible and not eligible for the Medicaid program. Moreover, in 1998 the State Children's Health Insurance Program (SCHIP) was initiated; however, beneficiaries had to prove that they had been without private health insurance (usually due to a job loss) for between 6 and 12 months, depending on the state. Indeed, [Lo Sasso and Buchmueller \(2004\)](#) concluded that these waiting periods serve to significantly reduce crowding out. In their re-estimation using a different data set, [Gruber and Simon \(2008\)](#) are unable to replicate this finding, estimating overall crowding-out rates for SCHIP to be similar to those for Medicaid. As to Medicaid, they obtain rates ranging from 24 to 81%, bracketing their original estimate of 49%. This large variation is caused by differing assumptions regarding the changes in composition of the subgroup that has both private and public coverage.

Another instance of Medicaid displacing PI is coverage for long-term care (LTC). [Brown and Finkelstein \(2008\)](#) emphasize that contrary to the Medicare program (for the elderly), Medicaid (for the poor) does not permit PI to top up benefits; rather, PI (which provides partial coverage) must be used up until wealth falls to the low Medicaid threshold. Using a dynamic optimization algorithm, the authors derive willingness-to-pay (WTP) values for LTC coverage as currently offered in the presence of Medicaid, to find a value of \$20,700 (women) and -\$18,200 (men) at the 30th percentile of the US wealth distribution. The WTP values turn positive no sooner than at the 60th percentile. They then assume fair premiums for PI combined with full LTC coverage—only to still find negative WTP values up to at least the 50th percentile. The likely cause is the implicit tax on PI which reaches values close to 100% for wealth levels below the 30th percentile. As a consequence, full loadings on PI approach 100% in this domain, making coverage very expensive indeed. While the authors do not explicitly calculate crowding-out rates, their simulations clearly suggest substantial crowding-out effects of Medicaid in spite of the fact that its coverage is partial only.

A few other countries have experienced a crowding out of private LTC coverage by public programs, notably Japan, South Korea, and the UK, where the National Health Service covers LTC expenditure as well. However, the evidence is descriptive rather than quantitative ([Le Corre 2012](#)).

37.5 Could the Division of Labor Between Private and Social Insurance Be Improved?

For all their merits, the contributions discussed up to this point have one weakness in that they all consider one risk impinging on the individual at a time. However, PI and SI both consist of a multitude of lines of insurance, in response to the fact that there are a great many impulses affecting individual assets, which comprise wealth but also health and skills [[Zweifel and Eisen \(2012\)](#), Ch. 1.6]. For instance, an illness episode lowers not only the level of health but indirectly wealth (through reduced labor income) and skills (through depreciation of human capital). The same is true of an accident, of disability, and unemployment, resulting in a positive correlation between these three assets. [Ettner \(1996\)](#) finds a positive correlation between health and wealth, [Ashenfelter and Rouse \(1998\)](#) one for health and skills, and [Kenkel \(1991\)](#) one for health and skills. The basic intuition is that in this situation, a risk-averse individual benefits from PI and SI coverage jointly neutralizing these correlations. As will be shown below, this requires deviations of paid benefits from expected value to be negatively correlated across lines of insurance. Failure to satisfy this condition indicates the lines where the division of labor between PI and SI could be improved.

Table 37.2 Comparison of nominal rates of return on private and social insurance

| | 1960–2007 | | 1974–1979 | |
|--------|---------------|------------------|---------------|------------------|
| | Private r_G | Social \dot{W} | Private r_G | Social \dot{W} |
| USA | 6.92 | 6.89 | 8.07 | 10.03 |
| Sweden | 8.22 | 7.69 | 9.62 | 11.87 |
| UK | 8.58 | 8.55 | 13.01 | 17.04 |
| Japan | 5.25 | 8.33 | 7.90 | 13.46 |

Source: OECD economic outlook (2008)

Consider two out of the three assets, X and Y , say. Let X be health transformed into monetary units. Since both changes in the probability of survival and in the quality of life can be valued using WTP and time trade-off techniques, the asset “health” can be made commensurable to the other asset, Y [Zweifel et al. (2009), Ch. 2.4]. Let this asset Y be skills; their value can be ascertained from wage differentials on the labor market. Adopting a (μ, σ) -framework, expected returns of PI must be close to a (quasi-) risk-free rate of return because of regulators’ solvency concerns. As is well known (Samuelson 1958), SI also has a rate of return, given by the growth of the labor income from which benefits for the retired are paid. Benefits of social disability insurance tend to change in step with labor income as well. To the extent that social health insurance is financed through a payroll tax, its benefits develop very much in line with wage income, too (assuming budget balance for SI).

In all, the expected rate of return of private insurance can be approximated by the return on long-term government bonds (given that they constitute the most important asset of most insurers), (r_G), while that of social insurance, to the growth of wage income (\dot{W}). This constitutes an acceptable indicator even in countries where SI is integrated in the public budget, causing its benefits to depend on tax revenue; after all tax revenue importantly depends on labor incomes. Over a longer-run horizon, these two rates have not differed markedly according to internationally comparable OECD estimates (see Table 37.2). For example, between 1960 and 2007, the average nominal interest rate on long-term government bonds was 6.92% in the USA, while nominal earnings grew by 6.89% (US domestic sources even arrive at a somewhat lower rate). However, during the turbulent later 1970s, \dot{W} exceeded r_G . In Sweden, r_G has exceeded \dot{W} on the long run but again with a temporary reversal in 1974–1979. Thus the expected rates of return on private and social insurance may be set equal as a first approximation.

This allows the analysis of comparative performance to be limited to the variance component σ of (μ, σ) . Finally, since premiums and contributions to private and social insurance are predictable in most situations, they are treated as nonstochastic quantities in what follows, which permits focusing on the properties of the payment side.

Specifically, denote by $X^a + x$ the final value of health capital, with X^a the asset value after expected payment by insurance.² Under ideal circumstances, X^a would be a fixed (optimal) quantity. However, medical care may fail to restore the health stock to its optimal value; more importantly in the present context, any copayment gives rise to an unexpected variation (denoted by x).

Likewise, the total value of skills can be split into Y^a (after expected insurance benefits) and y (unexpected variation in benefits). Unexpected benefit variation even occurs in SI. For example, a beneficiary may learn that a degree of negligence was found on his or her part in a workplace accident, causing workmen’s compensation to be curtailed. Conversely, benefits may be higher than expected because e.g., the presence of a child triggers a supplementary benefit.

²Insurance premiums and contributions to social insurance are considered nonstochastic and therefore disregarded.

Table 37.3 Correlations of trend deviations in US private insurance, 1965–2004

| | PLID | PLIDI | PLAI | PHI |
|------------------|------------------------------|-------------------------------|------------------------------|-------|
| PLID | 1.000 | | | |
| PLIDI | -0.0534 (0.7435) | 1.000 | | |
| PLAI | -0.0227 (0.8896) | -0.3417 ^a (0.0282) | 1.000 | |
| PHI ^b | 0.4830 ^a (0.0033) | 0.1358 (0.4366) | 0.4584 ^a (0.0056) | 1.000 |

PLID: life insurers’ death payments; PLIDI: life insurers’ disability payments; PLAI: life insurers’ annuity payments; PHI: health insurance payments

^aCoefficient significant at the 5 and 1% level or better, respectively

^b1970–2004; another data source leads to different results

Under these circumstances, total asset variance is given by

$$\begin{aligned}
 \text{var}(X^a + x + Y^a + y) &= \underset{(+)}{\text{Var}(X^a)} + \underset{(+)}{\text{Var}(x)} + \underset{(+)}{\text{Var}(Y^a)} + \underset{(+)}{\text{Var}(y)} \\
 &+ 2\underset{(0)}{\text{Cov}(X^a, x)} + 2\underset{(+)}{\text{Cov}(X^a, Y^a)} + 2\underset{(0)}{\text{Cov}(X^a, y)} + 2\underset{(0)}{\text{Cov}(Y^a, y)} + 2\underset{(0)}{\text{Cov}(Y^a, x)} + 2\underset{(?)}{\text{Cov}(x, y)}.
 \end{aligned}
 \tag{37.9}$$

Here, $\text{Var}(X^a)$ and $\text{Var}(Y^a)$ remain positive to the extent that insurance stipulates a degree of copayment in response to moral hazard or as a property of separating contracts (see Sects. 37.2.1 and 37.2.3). Under the usual assumption that expected and unexpected components of insurance benefits are uncorrelated, $\text{Cov}(X^a, x)$ and $\text{Cov}(Y^a, y)$ can be set to zero. Moreover, expected benefits under one title (X , say) presumably are not related to unexpected benefits under another title (Y). Thus, $\text{Cov}(X^a, y) = \text{Cov}(Y^a, x) = 0$. Also, while expected benefits are negatively correlated with variations in the covered asset, some of the post-insurance variation usually remains. Thus, the positive covariance between the two assets will still show after payment of expected benefits, making $\text{Cov}(X^a, Y^a) > 0$. The one term related to insurance that can be used for minimizing total asset variance therefore is $\text{Cov}(x, y)$. The more strongly negative the covariance between unexpected deviations from expected benefits, the smaller total asset variance. Thus, the performance of the insurance system as a whole from the consumer’s point of view can be gauged by the direction and amount of correlation in its unexpected benefit components.

By fitting time series of insurance benefits to quadratic time trends to (roughly) account for both their expansion and inflation in the economy, residuals can be calculated that reflect unexpected deviations of benefits from their expected value. These residuals are then used to determine correlation coefficients $\rho_{x,y}$ between two lines of insurance. For a given pair of standard errors $\{\sigma_x, \sigma_y\}$, this coefficient indicates the size of $\text{Cov}(x, y)$ (see Schoder et al. 2013 for details).

In the case of the USA (Table 37.3), four lines of personal insurance can be distinguished, reflecting data availability. There are only two significantly positive correlations out of six, between unexpected benefit variations in life insurers’ disability payments (PLID) and health payments (PHI) [cell (1,3) of Table 37.3] and between PHI and life insurers’ annuity payments (PLAI) [cell (3,3)]. One correlation is significantly negative. In an earlier study, using data for 1972–1992, one positive and one negative correlation (out of six) were found [see Zweifel (2000) where the admissibility of a microeconomic interpretation of the aggregate data is also discussed]. Still, one might argue that risk diversification by PI could be better, calling for a shift in favor of SI. According to the philosophy of SI, a beneficiary should always be able to count on a minimum level of consumption (which corresponds to a minimum of total assets). On these grounds, a better record in terms of variance reduction might be expected for SI than for PI. Somewhat surprisingly, however, the evidence does not point to a superior performance of SI (see Table 37.4). Unexpected variations in benefits correlate positively in no less than 15 out of

Table 37.4 Correlations of trend deviations in US social insurance, 1980–2004

| | SDCB | SWCB | SOACB | SPSB | SSB | SFCB | SUB | SHB |
|-------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|--------|
| SDCB | 1.000 | | | | | | | |
| SWCB | 0.9336 ^a (0.0000) | 1.000 | | | | | | |
| SOACB | 0.3033 (0.1700) | 0.0989 (0.6615) | 1.000 | | | | | |
| SPSB | 0.3115 (0.1582) | 0.3846 (0.0771) | 0.3477 (0.1128) | 1.000 | | | | |
| SSB | 0.7867 ^a (0.0000) | 0.6613 ^a (0.0008) | 0.4395 ^a (0.0407) | −0.1444 (0.5215) | 1.000 | | | |
| SFCB | 0.7769 ^a (0.0000) | 0.7101 ^a (0.0002) | 0.2728 (0.2193) | −0.0626 (0.7821) | 0.8888 ^a (0.0000) | 1.000 | | |
| SUB | 0.6085 ^a (0.0027) | 0.6293 ^a (0.0017) | 0.4030 (0.0629) | 0.5833 ^a (0.0044) | 0.3508 (0.1094) | 0.2444 (0.2730) | 1.000 | |
| SHB | 0.9443 ^a (0.0000) | 0.8588 ^a (0.0000) | 0.3194 (0.1473) | 0.1141 (0.6132) | 0.8884 ^a (0.0000) | 0.8863 ^a (0.0000) | 0.4690 ^a (0.0277) | 1.0000 |

SDCB: disability cash benefits; SWCB: worker's compensation cash benefits; SOACB: old age cash benefits; SPSB: paid sick leave benefits; SSB: survivors' benefits total; SFCB: family cash benefits; SUB: unemployment benefits; SHB: health benefits

^aCoefficient significant at the 5% level or better

28 cases, and there is not a single negative correlation of statistical significance. An almost perfect positive correlation is noted for workers' compensation (SWCB) and disability benefits (SDCB) [cell (2,1)]. One may be tempted to argue that these two types of benefit are triggered by a common impulse. However, this is an argument explaining positive correlation between expected benefits, not unexpected deviations. Again, the earlier study based on 1972–1992 data found six positive correlations (but also three negative ones) out of 21 possible cases. Therefore, SI in the USA seems to expose rather vulnerable individuals to excessive asset variance.

A final consideration is that risk diversification could be also achieved by PI filling unexpected gaps left by SI and vice versa. However, when the four PI lines distinguished are juxtaposed with the seven lines of SI (not shown here), this expectation fails to be confirmed. Out of 28 correlation coefficients, none is significantly negative. On the whole, then, PI and SI fail to complement each other in a way that would contribute to a maximum reduction of consumers' total asset variance.

37.6 Conclusions and Outlook

This contribution takes as its starting point the well-known potential failures of private insurance (PI) markets, moral hazard, and adverse selection, which might justify government intervention, possibly in the guise of social insurance (SI). Since moral hazard effects are found to beset SI at least as much as PI, adverse selection constitutes the crucial market failure. Indeed, some degree of mandatory SI has the potential to improve the welfare of both high and low risks; the benefit for low risks is that private insurers can provide them with more complementary coverage without having high risks infiltrate the low-premium contract designed for them.

However, this analysis was found to be insufficient on three counts. First, the policy issue invariably is the inability of high risks rather than low risks to obtain sufficient PI coverage. This problem can be addressed by arguing that SI homogenizes the conditional loss distribution confronting private insurers offering complementary coverage, serving to reduce the especially high loading charged to

high risks. Second, the optimal amount of SI and hence the optimal division of labor between PI and SI is left undetermined. Since the first layer (provided by SI) and the second layer (provided by PI) together usually do not cover the loss fully (as in health insurance and unemployment insurance), there is a net loss remaining. However, this net loss depends on the gross loss which in turn varies with the combined degree of coverage. Therefore, there is an overall moral hazard effect which must be balanced against the benefit of risk pooling afforded by additional SI coverage. The third criticism is that while this optimization (presumably by a benevolent government) may determine the division of labor between PI and SI at a given point of time, it fails to explain the historical expansion of SI to the detriment of PI. For a theoretical explanation of this development, one has to take recourse to the interests of the voting public. Indeed, if one is willing to depart from the standard expected-utility framework, it becomes possible to predict that an expansion of SI will always find a majority

In the literature, this change in the division of labor has become known as the crowding-out phenomenon. The empirical evidence almost exclusively comes from the USA. It focuses on the rapid expansion of Medicaid (for the poor), which is found to depress private saving (this is of interest because in the context of savings deposits, the problems of moral hazard and adverse selection are much less prevalent than in PI). More recently, crowding-out effects have been identified as a cause for the sluggish development of private long-term care insurance.

In view of the evidence on crowding out, there has been a renewed interest in normative prescriptions that take into account moral hazard (on the part of both PI and SI), adverse selection (on the part of PI), and crowding out caused by SI. Indeed, since it turns out that moral hazard can work in favor or against SI, adverse selection remains as the one effect motivating an expansion of SI, while crowding out suggests a reduced amount of SI. Finally, another approach is to view the benefits of SI and PI as assets with stochastic returns in the portfolio of an individual. Deviations from expected value should be negatively correlated both within the lines of PI and of SI—within and between PI and SI. Aggregate data for the USA point to positive correlations in deviations within SI and hence a potential for an improved hedging of risks confronting citizens, possibly by PI.

Even with these insights in hand, it is difficult to answer the two crucial questions for the future, how will the division of labor between PI and SI evolve, and how should this division be changed if at all? As to the first question, the expansion of SI seems to have come to a halt in several industrial countries (see Table 37.1 again). This could be the consequence of several exogenous developments that may challenge SI more than PI. One such challenge is the opening of economies not only to the international flows of goods but of labor and capital as well. Private insurers have the freedom to pursue an investment policy that can benefit from the hedging provided by international capital markets, while institutions of SI are tied to their domestic capital market (provided they dispose of reserve capital at all). In view of their complexity, the theoretical models presented in this chapter invariably neglect PI benefits that can be financed by investment income. When it comes to international movements of labor, SI schemes of rich countries cannot easily follow highly skilled emigrants, whereas PI usually grants full portability of benefits. Conversely, lower-skilled immigrants may even be attracted by the generosity of SI benefits in rich countries while PI benefits reflect risk-based premiums. Emigration and immigration thus threaten to undermine the financial equilibrium of SI but not PI.

Another challenge is demographic change. It affects SI with their pay-as-you-go finance much more directly than PI, which frequently is capital-based. In addition, both theory and (rather spotty) empirical evidence suggest that the individual decisions causing demographic change in the aggregate (length of education, marriage, number of children, age at retirement, and even longevity) are in fact influenced by SI and predominantly in ways exacerbating its financing problems (Zweifel and Eugster 2008). It is conceivable that these changes explain the reversal in the trend towards expanding SI coverage noted above.

Turning to the normative issue of what the division of labor between PI and SI should be, the theory discussed certainly provides a measure of guidance. However, the underlying hypothesis is that

governments implement and adjust SI reflecting reasonably informed self-interest of the voting public. One undisputed characteristic of the implementation is that it should be long-term since volatility in SI disturbs the life-cycle decisions of individuals. However, in a disquieting piece of research, [van Dalen and Swank \(1996\)](#) find clear empirical evidence suggesting that a “solid” government such as the Dutch boosted SI programs around (re)election times, presumably in an attempt to win pivotal votes. Therefore, even if one were to know whether (and in which lines of insurance) the division of labor between PI and SI ought to be changed, the issue of whether the proposed adjustment will be truly efficiency-enhancing remains. The balance between market failures that may beset PI and political failures that may beset SI is far from evident and it may well change over time!

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