Classroom Companion: Economics

Martin Kolmar

Principles of Microeconomics

An Integrative Approach

Second Edition

Springer

Classroom Companion: Economics

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For my daughter,
Carlotta

Preface to the Second Edition

After 4 years, it was time to substantially expand and revise this textbook. In doing so, the three features that make this textbook special, *contextualization*, *critical reflection*, and *application* of the theories, have been further developed.

In particular, the present edition systematically expands the part on decision theory. Traditional decision theory under certainty is joined by a chapter dealing with traditional decision theories under risk and uncertainty. Another chapter is devoted to behavioral economics. One aspect of this chapter is to better understand to what extent people take consequences of their behavior on other people into account (social preferences). A second aspect is to understand and explain deviations from the paradigm of rational choice. In addition, the empirical results and theoretical explanations are methodically scrutinized to strengthen critical thinking and methodological competence. Furthermore, they are compared with the results of classical rational-choice theory and its implications for economic policy. A final chapter on decision theory goes one step further and discusses important theories and results from neuroscience, evolutionary psychology, and narrative psychology to gain an even more fundamental understanding of human perception and behavior. This chapter also explores potential implications of these findings for traditional economics and alternative normative views on how to conceptualize individual well-being and an economy that seeks to promote it.

Regarding those chapters that already existed in the first edition, theoretical additions have been made and case studies and examples have been updated. For example, the chapter on monopoly behavior includes a section on two-sided markets, the chapter on comparative advantage includes case studies on trade wars and long-term changes in comparative advantage, and the chapter on externalities includes models and case studies on pandemics and the climate crisis.

I thank Magnus Hoffmann for co-authoring Chaps. 8 and 10 and for his critical guidance throughout the project. I thank Judith Gamp for her critical comments and careful review of the manuscript. A thank you is also due to Yara Locher, who prepared the graphics, and to Claudia Fichtner, Jürg Furrer, Stefan Legge, and Alfonso Sousa-Poza for their many constructive comments. Last but not least, I would also thank all those students who made inputs big and small that found their way into this book.

St. Gallen, Switzerland Martin Kolmar
February 2021

Preface to the First Edition

One may wonder why I think that it makes sense to add yet another introductory textbook to the overfilled shelf of well-established books on microeconomics. There are three reasons that motivated me to do so.

First, a lot of textbooks in economics want to make one believe that the theories presented are more or less context-free and objective. This is a wrong and dangerous belief. First of all, all theories are embedded in an intellectual milieu from which they borrow and on which they build. No man is an island, and no scientific theory is either. The tendency to shun any contextualizations of the theories comes at the risk of blindness towards the implicit assumptions, value judgements and epistemes on which the theory depends. This makes economics prone to being misused for ideological purposes. Economic literacy does not only mean that one is able to understand the rules and patterns of modern economies, but also that one understands how economic theories relate to other social sciences and the culture from which they emerge. This textbook is an attempt to contextualize modern economics in the hope that students will get a better overview of its strengths and weaknesses. It puts also a specific emphasis on case studies that range widely from the functioning of coffee markets, the logic of overfishing, to price discrimination in the digital age. This approach makes this book also potentially interesting for students who study economics as a minor and who want to understand how economic theories relate to other social sciences and how they can be used to better understand markets as well as phenomena like climate change, among many others.

To make it easier to identify the most important contextualizations in this book, I work with a series of icons that one will find in the margins of this book. $\mathcal{L}$ indicates a legal, $\mathcal{B}$ a business, and Φ a philosophical (broadly speaking) context. Furthermore, one will find the most important definitions and technical terms highlighted with a $\diamond$-sign in the margins of the book.

Second, textbooks that give an introduction to economics have become a million-dollar business over the last decades, with thousands of universities and colleges teaching the same basic principles worldwide. The globalization of this market has led to a commodification of textbooks in the attempt to sell as many copies as possible. As a result, the lion's share of the market is served by textbooks that are very elementary and only scratch the surface of most theories. This strategy makes them commercially successful, because of the appeal to the mass market but, at the same time, denies the students a deeper and more sophisticated understanding of the strengths and weaknesses of the theories. One could argue that such an in-depth understanding of theories is not necessary in an introductory class in economics, because there will be plenty of intermediate and advanced courses that will fill these gaps later on. The reality is, however, that a significant fraction of students gets all of its knowledge from the introductory course. It is never too early to educate independent and critical minds.

Third, most textbooks that I am aware of are not tailored to the needs of a business school where students study economics, business administration and maybe law. Economics is about the functioning of institutions and most institutions have a legal backbone. Bringing this fact to the foreground creates synergies between law and economics. By the same token, economic theory allows one to identify the key parameters that a firm must know in order to be successful in the markets in which they compete. Examining the common ground between management and economics allows one to better understand the implications of different market contexts and industries for managers and it shows one how closely economics and business administration can and should be linked. Economics, law and business administration are really three perspectives on the same phenomenon: the logic of social interaction.

This book took shape over many years during which I have been teaching “Principles of Economics” and “Microeconomics” to undergraduate students. I would like to thank all of my former students for their patience and for their countless discussions that all contributed, in their own ways, to this book. Special thanks are due to my present and former Ph.D. students and research assistants Philipp Denter, Magnus Hoffmann, Hendrik Rommeswinkel and Dana Sisak, all of whom had a major influence on the content and the didactics of this book. This is also true for Thomas Beschorner, Friedrich Breyer, Claudia Fichtner, Jürg Furrer, Michael Heumann, Normann Lorenz, Ingo Pies, Alfonso Sousa-Poza and Andreas Wagener, who gave me me detailed feedback on earlier versions of the book and helped me with valuable suggestions. I would also like to thank Maya G. Davies, Corinne Knöpfel, Leopold Lerach, Jan Riss and Jan Serwart, who supported me in finishing this book and who did a great job in making it more student friendly and accessible. It is definitely not their fault if you find yourself struggling with some of the material.

St. Gallen, Switzerland Martin Kolmar
May 2017

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Part I

Introduction

First Principles

1

This chapter covers ...

- enough philosophy of science to be able to have a qualified opinion about the status and scientific role of economic theories.
- the basic paradigm of economics: to understand the functioning of societies as an adaptation to the underlying principle of scarcity.
- why economics considers itself a methodology, and not a field of application.
- why the opposite of positive is no longer negative but normative.
- the relevance of opportunity costs.
- how to think and make decisions like an economist.

1.1 What Is Economics About?

> Economics is the science that studies human behavior as a relationship between ends and scarce means which have alternative uses.
> (Lionel Robbins 1932)

> The master-economist must possess a rare combination of gifts. He must reach a high standard in several different directions and must combine talents not often found together. He must be mathematician, historian, statesman, philosopher—in some degree. He must contemplate the particular in terms of the general, and touch abstract and concrete in the same flight of thought. He must study the present in the light of the past for the purposes of the future. No part of man's nature or his institutions must lie entirely outside his regard. He must be purposeful and disinterested in a simultaneous mood; as aloof and incorruptible as an artist, yet sometimes as near the earth as a politician.
> (John Maynard Keynes 1924)

If one looks at economics departments all over the world, one may be surprised to see what economists are doing. Of course, economists deal with "the economy," but modern economics is extremely diverse and covers a wide range of fields, which few laymen would intuitively associate with economics. Here is a list of examples:

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economists deal with the “big old” questions about the sources of growth and business cycles, poverty and the effects of unemployment, or the effects of monetary policy on the economy. More generally, they want to find out how markets allocate goods and resources and how markets have to be regulated in order to make sure that they function properly. An important field of research is the economic role of the government: the ways it can levy taxes and provide services. However, economists also deal with problems related to political institutions, like the effects of different voting systems, the causes and consequences of political and military conflicts, or the relationship between different levels of government. They are involved in evolutionary biology, the design of products on financial markets, auctions, and internet market platforms; they work with lawyers to understand the consequences of legal rules and cooperate with philosophers.

The reason for this diversity of fields stems from the evolution of the modern definition of the science of economics. Economics is not the science that studies “the economy”: it is not defined by an object of study. Instead, it defines itself by a particular perspective from which it tries to make sense of the social world: scarcity. Samuelson (1948), one of the most influential economists of the twentieth century, provided what is still the most concise definition of economics: “Economics is the study of how men and society choose, with or without the use of money, to employ scarce productive resources which could have alternative uses, to produce various commodities over time and distribute them for consumption, now and in the future among various people and groups of society.” This definition may not be as elegant as the one by Lionel Robbins, but it has the advantage of larger concreteness: economists try to understand how resources are used to alleviate scarcity. Economics is therefore a scientific method: economists start with the premise that it is possible to understand the logic of individual behavior and collective action as a result of scarcity. This is why the above list of examples covers such a broad array of fields. Whenever one has the conjecture that scarcity plays a role in the functioning of a situation, economists can be brought on board.

But what is scarcity?

Scarcity refers to situations where the wants exceed the means. In economics, the wants are usually restricted to human wants, and means includes the resources and goods that contribute to fulfilling these wants. The reference to wants implies that scarcity has its origin in human physiology as well as psychology. The human metabolism requires a certain intake of energy in order to function and, if food intake falls below a certain threshold, human beings cannot develop and will eventually become sick and die. These physiological wants can be called objective, and their fulfillment is indispensable for life. However, a lot of wants are not of this type. Fast cars, big houses, and fancy clothes are not necessary for healthy survival but are merely pleasant. These wants can be called subjective. Economics is the study of how individuals and societies manage goods and resources, which can be objectively as well as subjectively scarce.

Digression 1.1 (Increasing Means or Increasing Autonomy?)
Economics has no monopoly on scarcity as a starting point for the scientific endeavor. Philosophies like Buddhism start from a similar premise, although phrased in a different terminology. The first two of the so-called Four Noble Truths state that (1) *dukkha* exists and (2) that it arises from one's attachment to desires. Dukkha is often translated as suffering, but this blurs its meaning. It refers to misaligned desires and needs or, in other words, scarcity.

It is interesting to see, however, that the impulse that resulted from this same premise points in opposite directions. Most "Western" economists try to find out how scarcity can be alleviated by *increasing means* (through technological progress, growth, etc.). The intuitive reaction to the phenomenon of scarcity points *outward*: increasing the means to fulfill the given wants. This impulse is even reflected in the idea of individual freedom that is, by and large, conceptualized in the Western tradition as political freedom: as the absence of external compulsion.

On the contrary, the reaction to scarcity in Buddhism points *inwards*: overcoming the wants to make them match the means. To see this, consider the two other noble truths: (3) suffering ceases when attachment to desire ceases and (4) freedom from suffering is possible by practicing the Eightfold Path. Freedom, according to this view, is interior freedom: autonomy from the "dictatorship" of desires. One sees the same starting point, but two completely different conclusions.

Scarcity immediately leads to one of the most powerful tools of economics: the concept of *opportunity cost*. If one makes decisions under the conditions of scarcity, then going one way necessarily implies that one cannot go another way. On the other hand, the other way looks interesting, as well, so deciding to go this way incurs a cost, in this sense. To be a little more specific, assume that one has to choose an alternative a from a set of admissible alternatives A and assume further that one can rank the admissible alternatives according to the joy and fulfillment that one is expecting to experience when one chooses them. If a_1 is the best and a_2 is the second-best alternative, according to this measure, then the opportunity cost of choosing a_1 is the joy and fulfillment that one would have expected to enjoy from alternative a_2.

This sounds rather abstract, but it need not be. The concept of opportunity cost allows one to better understand how one makes decisions and how one should make decisions (this distinction will be discussed in more depth later). If one goes to the movies, one cannot go to a restaurant; if one spends one's money on a new car, one cannot afford an expensive trip to Japan; if one studies economics, one cannot, at the same time, study physics; and so on. In order to make the right decisions, one should be aware of the value one attaches to the other alternatives that one cannot realize. The value one connects to the next-best alternative forgone is the opportunity cost of one's choice.

Digression 1.2 (Generosity for Nerds: Opportunity Costs and Donations) The concept of opportunity costs is helpful when considering the consequences of any kind of behavior. To illustrate this point, I would like to focus on a recent trend called *effective altruism*, sometimes ironically called "generosity for nerds." Effective altruism seeks to maximize the good from one's charitable donations. Here is an example that illustrates the problem. Assume that one graduates and wants to make a great difference in the world by devoting one's career to doing something good. A lot of students with this type of motivation consider careers at Oxfam or some other charity. However, this may not be the smartest idea. Assume that one would earn CHF 50,000 with a job at a charity and that one could be replaced by some other graduate student, who does an equally good job. Now, assume that one considers a career at a major bank, where one would earn CHF 120,000 instead and then gives CHF 70,000 away to charity. This decision creates CHF 70,000 that can be used for doing good. In fact, it finances the position at Oxfam and still leaves CHF 20,000 for other charitable purposes. If the person replacing one at Oxfam does not have this career option, it is better if one works for the bank, even if it seems to contradict one's intention of devoting one's life to doing good. (But please make sure to actually donate the money.)

The importance of this example is not the career advice that it provides, but the principle that can be elicited from it. Consider a simple version of this problem in which one wants to donate a certain amount of money and wants to make sure that it does as much good as possible. Effective altruism makes the point that one should think in terms of opportunity costs when one makes one's decision: what are the alternative uses for one's money and how much good could be done with the different uses? One should then spend one's next Swiss Franc in a way that would maximize the additional good that the money can create.

This idea of donations may look like economics on steroids, but, in fact, it is an important regulative idea to alleviate suffering. There is a lot of evidence, for example, that donations are highly irrational. Disaster relief following earthquakes and tsunamis is a good example. These events are horrible and create a lot of human suffering. However, media attention often creates "superstar effects," where people want to help and thereby crowd out other needs. In the end, earthquake relief programs end up with more money than they can usefully spend to alleviate the suffering from the earthquake. To illustrate, if everyone spends a fixed amount of money on charitable projects, then one additional Swiss Franc for earthquake relief reduces the money that is available for less prominent (but equally urgent) projects. Some charities are aware of this problem and want to use part of the earmarked donations for other projects, but they are often criticized for doing so, because the people want to make sure that their money is spent "in the right way." On the other

(continued)

Digression 1.2 (continued)
hand, what is the right way to spend their money? If saving an additional life in the earthquake region is expected to cost CHF 50,000 and it will likely cost CHF 10,000, if the money is spent on malaria prevention in some low-key project, then it may make sense to apply economic principles to save as many lives as possible. Thinking in terms of opportunity cost allows for a more rational allocation of scarce resources from a utilitarian perspective.

When economists study social phenomena, they usually distinguish between three different levels of analysis:

- **Individual level:** The individual level focuses on the question of how individual people behave under conditions of scarcity. A typical question is, for example, how a person spends his or her income on consumption. Will he/she go to the movies or to dinner? Will he/she spend his/her income on clothes or travel? Decision theory is the field of research that develops theories about individual behavior.
- **Interaction level:** Typically, individual behavior does not take place in isolation. If A decides to go to the movies tonight and B would like to meet A, then B must go to the movies, as well. Equilibrium models of trade and market behavior or game theory are examples of fields of research that investigate how human beings interact with one another.
- **Aggregate level:** Phenomena that are studied at the aggregate level are, for example, inflation, growth, and unemployment. They are a result of individual decisions and the rules that govern individual interactions, but an analysis of a certain phenomenon at the aggregate level usually abstracts from a lot of the details of individual decision-making and interactions in order to still be able to see the forest for the trees.

I have already mentioned that individual human beings ultimately cause all social phenomena at the aggregate or interaction levels. *Methodological individualism* is a scientific position that requires that all social phenomena be explained with reference to individual behavior. According to this view, it is not sufficient to assume that abstract laws exist, which explain, for example, growth and inflation: these laws must be derived from the behavior of individuals in a society. Methodological individualism is a widely recognized position among economists, according to which ultimately all phenomena, which are studied on the aggregate level, need to be traced back to patterns of behavior on the individual and interaction levels.

Digression 1.3 (Homo Oeconomicus)
Economics is infamous for a character that populates most of its tales: the *homo oeconomicus*. Any theory that explains social phenomena as a result of individual behavior needs a *decision theory* that allows for the making of predictions. The term *homo oeconomicus* summarizes a number of assumptions about the way individuals make the decisions that are used in mainstream economics to make predictions about behavior.

Different economists use the term differently, but there is a broad consensus that the minimum requirements are as follows: first, economists usually do not use the concept to explain the motivations that drive behavior in an exclusively descriptive way. This approach goes back to Vilfredo Pareto, John Hicks, Roy Allen, and Paul Samuelson, who eliminated psychological concepts from economics and based economic theory on principles of rational choice. The idea is that all one can observe are individual choices, but not the mental processes that motivate or cause behavior.

All one has to know is that people make decisions in a structured way that allows one to infer a so-called *preference relation* from the observed behavior of the individuals. This is the *revealed-preference approach* in economics, which makes the point that, if behavior follows certain consistency assumptions, then the individual behaves *as if* he/she maximizes his/her preferences or his/her utility function. Note that the formulation says "as if," which implies that the theory does not claim that individuals *have* preferences or utility functions somewhere in their heads. Pareto justified this approach in a letter from Pareto (1897): "It is an empirical fact that the natural sciences have progressed only when they have taken secondary principles as their point of departure, instead of trying to discover the essence of things. [...] Pure political economy has therefore a great interest in relying as little as possible on the domain of psychology."

The consistency assumptions, which guarantee that an individual behaves as if he/she maximizes preferences, are as follows: he/she can rank the alternatives from which he/she can choose according to some relation representing his/her preferences (if I have the choice between broccoli and potato chips, then I prefer broccoli to potato chips). This ranking is unique and stable over a sufficiently long period of time. Furthermore, the ranking is complete (I can rank any two alternatives) and transitive (if I prefer broccoli to potato chips and potato chips to ice cream, then I also prefer broccoli to ice cream). Such preferences are called an *ordering*. Last but not least, it is assumed that individuals always choose the best alternative that is available to them (*maximization*). The maximization of a preference ordering is the core of the *rational-choice paradigm*, which is integral to the concept of homo oeconomicus.

(continued)

Digression 1.3 (continued)

Please note that this view on rationality is purely instrumental: it refers to the consistency of a ranking and the relationship between ranking and behavior. (If preferences are inferred from behavior, then there is no conceptional gap between behavior and preferences; the latter are a workaround to systemize choices.) It can be discussed whether completeness and transitivity capture the idea of rationality and if individuals always choose an alternative that is best for them, but both assumptions are considered indispensable for rational decision-making. The concept has been further refined to be able to cover choice situations under conditions of risk and uncertainty; see Chaps. 7, 8, and 10 for details.

It is a widespread misunderstanding that homo oeconomicus is conceptualized as a selfish actor. Given that the above concept wants to eliminate any deliberations about motives for action from the theory, it cannot, in its purest form, say anything about selfishness, altruism, or fairness concerns, because these concepts refer to the individual's motives for taking action. Admittedly, a lot of scientists added assumptions about the structure of a preference ordering that can be interpreted as selfishness to the theory, but it should be noted that selfishness is not an integral part of what economists conceptualize as rationality.

A detailed discussion of the concept of homo oeconomicus is beyond the scope of an introductory chapter, but some remarks are important. The different aspects of the concept have been subject to critique. Psychologists and behavioral economists have shown that preferences need not be transitive and that individuals do not consistently choose alternatives that are best for them (a statement that cannot even be made within the revealed-preference paradigm). Furthermore, people do not act selfishly in a number of situations; see Chaps. 8 and 10 for details. Despite these empirical anomalies, the concept is popular in economics. From a methodological point of view, it is important as a regulative idea that helps one to better understand the structure of limited rationality and non-selfish behavior, even if everyone agrees that real people often deviate from the ideal of rational decision-making. Boundedly rational behavior follows patterns and it is easier to explore these patterns with reference to the standard of full rationality. In addition, as it will become clear throughout this chapter, good theories do not rely on "realistic" assumptions in a naïve understanding of the word. The predictive power of a theory that, for example, explains the behavior of prices in markets can be high, even if the underlying assumptions abstract from a lot of factors that may be important in reality.

Claiming scarcity as the exclusive paradigm of economics would be imperialistic and wrong without further deliberation. The definitions of economics by Robbins

(1932) and Samuelson are vague about the exact role that human beings play in economic theory. Methodological individualism is what, for the most part, distinguishes mainstream economics from other sciences that are also built on the idea of scarcity.

Evolutionary biology is a good example. Evolution in populations is the result of three basic principles: (1) there are traits that are heritable, (2) there is variability in them, and (3) some traits are more adaptive than others, which implies that the organisms pass more copies of their genes on to the next generation. The crucial point is that a mismatch between means and ends must be underlying the "mechanics" of evolution, because otherwise traits could reproduce indefinitely. Therefore, to get the theory of evolution off the ground, one has to start from scarcity. What distinguishes evolutionary biology from economics is not the underlying paradigm, but the smallest unit of study, genes versus human beings, and it would be preposterous to declare evolutionary biology as part of economics (even though there is a subfield of economics called evolutionary economics that applies the above three principles to study economic phenomena and to lay the foundations for human behavior). Evolutionary biologists distinguish between *ultimate* and *proximate* causes. According to this view, the human brain, with its desires and preferences and, more generally, a human being is a proximate cause of behavior, shaped by forces of evolution. It is an organism that makes its genes more or less well adapted to its environment. The laws of genetic evolution are, therefore, the ultimate causes of human behavior. Economists recognize that human brains are ultimately shaped by evolution but nevertheless take the individual human being as the ultimate cause of behavior and as the starting point of their scientific endeavor. As shown in the next subchapter, this shortcut is neither right nor wrong, good nor bad: it merely simplifies the analysis.

Another common distinction is made between *microeconomics* and *macroeconomics*. Microeconomists study individual decision-making at the individual and interaction levels, whereas macroeconomists study economic phenomena at the aggregate level. The distinction is, however, not as sharp as it may seem. Traditional macroeconomics postulated regularities for aggregates like national savings, which were then used to predict the consequences of, for example, an increase in economic growth. One could find in the data that about 30% of national income Y goes into savings S, which would yield a savings function $S(Y) = 0.3 \cdot Y$. Combined with other regularities of this kind, such a function can be used, for example, for economic forecasting. The problem with this approach is, however, that it remains unexplained why, on average, 30% of national income goes into savings. It is not a theory that fulfills the requirements of methodological individualism. In the end, it is the single individual who makes savings decisions, so the implications of such aggregate models of the economy are more reliable if the behavior of aggregates is linked to individuals. This observation led to the so-called *micro-foundation* of macroeconomics, i.e., the attempt to relate aggregate phenomena, like unemployment or growth, to individual decision-making. Mainstream macroeconomics is micro-founded in this sense, so it is more appropriate to distinguish between micro and macro, as they are colloquially called, by their fields of application.

Macroeconomists usually study phenomena like growth, unemployment, business cycles, and monetary policy, whereas microeconomists focus on the functioning of markets and other institutions or the role and design of incentives in economic decision-making, among other things.

1.2 Some Methodological Remarks

> Everything should be made as simple as possible, but not simpler.
> (Attributed to Albert Einstein, Calaprice 2000)

> Explanations exist; they have existed for all time; there is always a well-known solution to every human problem–neat, plausible, and wrong.
> (H.L. Mencken 1921)

There are cookbooks and scientific theories. In a cookbook, one learns that it takes a hot pan, eggs, flour, milk, baking soda, and a pinch of salt to make pancakes. If one follows the recipe, one ends up with a tasty meal, but one does not really understand why. A scientific theory tells one how heat changes the molecular structure of proteins present in egg white, how baking soda reacts with acids, and how gluten builds elastic networks. This knowledge may not inform one about how to make a pancake, but it can tell one a lot about the deeper reasons why the recipe works. Moreover, one can use this information to develop new innovative recipes. Both cookbooks and scientific theories complement each other: understanding the physical, chemical, and biological mechanisms underlying the transformation of ingredients into meals helps one improve recipes, and the evolved recipes are a source of inspiration for scientific discoveries.

Economics comes in the form of both cookbooks and scientific theories. A stockbroker may just "follow his/her gut" about profitable picks. He/she has no explicit theories about the functioning of capital markets in the back of his/her mind, which informs him/her about the future development of stocks. Like an experienced cook, he/she just "feels" or "sees" which stocks will be profitable. Scientific reasoning would require trying to understand the mechanisms that make one stock successful and the other a failure. Alternatively, take the manager of a firm as an example. When he/she sets up the organization of the firm and the compensation packages for the employees, he/she might follow custom and his/her intuition. The scientific approach to organization and compensation would be to develop theories about the consequences or organizational designs and the incentive effects of different ways to compensate employees. These theories might not be directly applicable to a specific problem, but, over time, they feed into the "culture" of a society and shape the intuitions of decision-makers. John Maynard Keynes made this point quite poignantly: "The ideas of economists and political philosophers, both when they are right and when they are wrong are more powerful than is commonly understood. Indeed, the world is ruled by little else. Practical men, who believe themselves to be quite exempt from any intellectual influences, are usually slaves of some defunct economist."

Economics, as a social science, develops such theories. It is not the primary purpose of these theories to inform decision-makers about the consequences of their decisions, but rather to give one a better understanding of the logic of economic interactions by developing scientific theories. Deepening one's understanding of the functioning of, for example, labor or financial markets will, in the end, allow decision-makers to make better decisions, but this is only a byproduct of the endeavor.

The following subchapters give a short introduction to some philosophical issues that are important for understanding economics as a *social science*. It is very difficult to find the right point in time to discuss these fundamental issues because, if one discusses them before one starts studying economics, then one discusses issues that are still very abstract; one gives answers to questions that the students would not even have asked. If one covers the material at the end of a course, then students will have difficulty in understanding what is going on in economic theories and it is very likely that they will be led astray in their ideas about their relevance and potential. The third option is also suboptimal: integrating the philosophical debate into the presentation of the theories. If one sprinkles economic theories with little bits of the philosophy of science here and there, it is very likely that one will miss the forest for the trees. (The fourth option would, of course, be to skip the material completely and to rely on the methodological and philosophical intuitions of the students.) This is why I have decided to cover some ground at the beginning of this book, with the idea that one need not understand every little detail after the first reading. It is good enough if one gets the basic concept in the beginning and then returns to this subchapter later on when one has a better understanding of economics. All the bits and pieces will fall into place eventually if one perseveres.

1.2.1 True and Reasonable Theories

I used the term *scientific theory* in the last subchapter. For the purposes of this text, a *theory* is defined as a relatively broad conceptual approach that makes reasonable conjectures about causal relationships in the world.

When is a conjecture reasonable and why does one find the word "reasonable" instead of "true" in the above statement? Given the limitations of one's sense organs and one's mind, it is impossible to say that a conjecture is true in the sense that it is in total accordance with reality. A nice way to briefly grasp the epistemic problems that come with a naïve idea of truth is a short elaboration of the so-called Münchhausen trilemma. The basic problem is that scientific reasoning requires that one is prepared to provide proof for any of one's statements. However, such a proof can only be given by means of another statement, which must also be provable. The Münchhausen trilemma makes the point that one has the choice between exactly three unsatisfactory options to deal with this situation:

- **Infinite regress:** Each proof requires a further proof, *ad infinitum*. This process will, of course, never end, such that one never "breaks through" to the truth. It is, understandably, impossible to give an example for an infinite regress.
- **Circularity:** The statement and the proof support each other, maybe in a complex chain of arguments. An example is a flawed interpretation of the theory of evolution that defines the species that fits best in an environment as the one that survives, and then one argues that the species one observes must fit best into its environment.
- **Dogmatism:** One finally reaches a stage in the process of statement and proof, where the underlying assumptions have no further justification. A wonderful example of dogmatism is the second sentence of the US Declaration of Independence, even if it is not a scientific theory: "We hold these truths to be self-evident, that all men are created equal, that they are endowed by their Creator with certain unalienable Rights, that among these are Life, Liberty and the pursuit of Happiness." (Franklin et al. 2015)

For all practical intents and purposes, only dogmatism is an option. That means that truth cannot be achieved by a process of scientific reasoning but necessarily relies on an intuition that must be nurtured by other sources. Dogmatism, for the same reason, also implies that every scientific theory must start from *value judgments* about the basic self-evident principles. Coming back to the discussion about theories, calling a conjecture reasonable bites the trilemma-bullet by requiring the much more moderate standard of being consensual. Wittgenstein (1972)*, 94 and 110* expressed this beautifully: "But I did not get my picture of the world by satisfying myself of its correctness; nor do I have it because I am satisfied of its correctness. No: it is the inherited background against which I distinguish between true and false. [. . .] As if giving grounds did not come to an end sometime. But the end is not an ungrounded presupposition: it is an ungrounded way of acting." In order to reach a consensus among experts, one must at least reach an agreement of the different dogmas that (perhaps subconsciously) taint one's own perspective.

Digression 1.4 (Transcending Reason)
The necessity of a dogmatic starting point of any scientific research project points towards the limits of language in expressing reality. Some spiritual traditions even claim that some truths can and must be assessed by means other than scientific reasoning—for example, an act of revelation—and that reason is not a means of perceiving the truth but an obstacle on the way.

This thought is most clearly expressed in Zen Buddhism, where the practice of meditation leads to a state of pure consciousness in which one sees the world "as it really is." In order to get closer to this state, students are expected to work on *kōans*, which, from the point of view of a Western understanding, are unanswerable questions or meaningless statements. The

(continued)

Digression 1.4 (continued)
goal is the evocation of an existential crisis of rational thinking, which then transcends itself in the moment of *satori*. A distance is created between the conventions of everyday thinking and the immediately perceived world, whereby the convention becomes recognizable as such.

The first dogmatic principles of a theory closely resemble what Thomas Kuhn called a *paradigm*. Paradigms are sets of practices that define a scientific discipline at any particular period of time. Paradigms come in at different levels of abstraction. The most general level of abstraction within the Western paradigm of Enlightenment is the belief that the independent use of *reason* allows one to gain insight into the true nature of this world (see the above digression). Neoclassical economics, for example, has the ideas of rational choice and methodological individualism as important parts of its paradigm.

1.2.2 Theories and Models

In mainstream economics, at least, theories have *models* as their "logical backbones." A model is a collection of assumptions and hypotheses that are linked by the rules of logic and mathematics. A model makes several assumptions about an aspect of reality and derives hypotheses from these assumptions in a logically consistent way. To understand the difference between theories and models, look at the following example.

Assume one wants to develop a theory about the functioning of the price mechanism on markets. In order to do so, one thinks about, for example, the way individuals sell and buy their stuff and how these buying and selling decisions explain the formation of prices. This structured way of thinking is one of the models underlying one's theory.

The crucial function of a model, in the context of theory formation, is to make sure that the key causal mechanisms underlying a theory are made explicit and logically consistent. Look at the following model to understand why:

Model 1
Assumption 1: All human beings are in the streets.
Assumption 2: Peter is a human being.
Hypothesis: Peter is sitting at my home.

"Model 1" is a model because it has a set of *assumptions* and a *hypothesis*, but the hypothesis does not follow logically from the assumptions. In this case, the model is logically inconsistent, even though the hypothesis might be correct empirically (Peter is sitting right next to me). The point is that the assumptions cannot explain my observation, which makes the model useless for any theory. A consistent model is therefore a *necessary* condition for a good theory.

However, is it also *sufficient*? Here is an example of a very simple model:

Model 2
Assumption 1: All the dead are looking over one's shoulder.
Assumption 2: Karl Marx is dead.
Hypothesis: Karl Marx is looking over one's shoulder.

The above set of assumptions and hypotheses fulfills all the requirements of a good model. All the assumptions are spelled out explicitly and the hypothesis follows from the assumptions in a logically consistent way. Would the model be a good ingredient of a *theory of the dead*? It is difficult to imagine that it would get the approval of many experts. Logical consistency is therefore of obvious importance for scientific reasoning, but it is not enough. In order to evaluate the "soundness" of a theory, one needs additional "softer" criteria like adequacy, simplicity, or plausibility.

1.2.3 The Virtue of Thriftiness

An important criterion for good models is simplicity, frugality, or thriftiness. The idea is often referred to as Ockham's razor (named for an English Franciscan Friar in the fourteenth century), which states that, among competing models, the one with the fewest assumptions should be selected. However, this concept is much older. Aristotle (2004), in his *Posterior Analytics*, stated that, "we may assume the superiority ceteris paribus [all things being equal] of the demonstration which derives from fewer postulates or hypotheses." Ockham's razor is widely accepted among economists. (Solow, 1997, p. 43) summarizes the self-image of the profession in a very concise way: "Today, if you ask a mainstream economist a question about almost any aspect of economic life, the response will be: suppose we model that situation and see what happens. [. . .] A model is a deliberately simplified representation of a much more complicated situation. [. . .] The idea is to focus on one or two causal or conditioning factors, exclude everything else, and hope to understand how just these aspects of reality work and interact."

Ockham's razor necessarily implies that the assumptions of a model should not be realistic in the naïve sense that the assumptions shall fit reality. Scientific theory building necessarily reduces complexity to make a situation comprehensible for the human mind. Robinson (1962) found a nice expression for the problems implied by models built on "realistic" assumptions: "[a] model which took account of all the variegation of reality would be of no more use than a map at the scale of one to one." However, the epistemic problem goes even deeper, as illustrated by the novel *Tristram Shandy* by Sterne (2003). The book is the autobiography of the protagonist, which is so detailed that it takes the author 1 year to write down a single day of his life. From this perspective, the map is even more detailed than the territory and the level of detail one considers adequate must be based on a subjective value judgment.

Maps have to simplify in order to be useful. On the other hand, is there a "right" way to simplify? The answer to this question must also be "no," because it depends on what one wants to do with the map. If one is driving a car, contour lines are not essential and may easily distract attention from other more important information. However, if one is planning to hike in the mountains, contour lines are crucial. Therefore, a good simplification depends on its purpose.

1.2.4 Do Assumptions Matter?

If assumptions shall not be realistic, then maybe one can conclude that assumptions do not matter at all. This position has, in fact, been put forward by (Friedman, 1953, p. 14), one of the most influential economists of his time. He proposed that "Truly important and significant hypotheses will be found to have 'assumptions' that are wildly inaccurate descriptive representations of reality, and, in general, the more significant the theory, the more unrealistic the assumptions (in this sense)."

There is some debate as to whether Friedman adheres to the extreme position that assumptions do not matter at all (called *instrumentalism*) or not but, for the sake of argument, consider this position and see where it leads. According to an instrumentalist's view, one should judge a theory according to the validity and usefulness of the *hypotheses*, whereas the assumptions are irrelevant. Does this position make sense? Look at the following model.

Model 3
Assumption: Seatbelts reduce the likelihood of fatal accidents.
Hypothesis: Seatbelts reduce the likelihood of fatal accidents.

Model 3 looks like a pretty nonsensical waste of time and is an example of a circular argument, but why does one find it intuitively unconvincing? The hypothesis can be empirically tested and it has been confirmed by the data. Therefore, according to an instrumentalist's view, a theory that is built on this model passes the test of usefulness. The idea that assumptions are completely irrelevant is, of course, flawed because it prevents one from learning anything about the causal mechanisms that *drive* the hypotheses, if one cannot rule out the trivial model where hypotheses and assumptions coincide. Even if one's mind can never grasp the true causal mechanism, and thus one has to be satisfied with crude narratives and heuristics, declaring the assumptions irrelevant leaves one with only cookbooks.

Instrumentalism is an extreme position and there are reasons to assume that Friedman's own position is more balanced. He argues that the role of a positive science "is the development of a 'theory' or 'hypothesis' that yields valid and meaningful (i.e., not truistic) predictions about phenomena not yet observed." It can be argued that the term "truistic" refers to models of the above type that are only uninteresting tautologies. In the end, scientific theory building has a subjective component, because the balance between, on the one hand, meaningful simplifications of the assumptions and of the supposed causal mechanisms, and, on the other hand, the explanatory power of the hypotheses cannot be precisely nailed down. It is the art and craft of experienced scientists to see if a theory is "in balance" in this sense.

1.2.5 An Example

To illustrate the role assumptions play in models, I will introduce the concept of the *production-possibility frontier* that will reappear in Chap. 2. In a modern, complex economy, there are millions of people, who all go to work, consume goods, enjoy their friends and families, and so on. This maze of interactions would be impossible to analyze without simplifying assumptions that make it comprehensible to the scientist's mind. One question, which is relevant to economists, is about the trade-offs the economy faces when it produces goods and services. Goods and services are produced by all kinds of resources, using tools and skills. The production-possibility frontier abstracts from all these complexities. In the simplest case, one makes the assumption that the economy can produce exactly two goods, 1 and 2, whose quantities are drawn along the axes of Fig. 1.1.

The quantity of good 1 is drawn along the abscissa (horizontal axis) and the quantity of good 2 along the ordinate (vertical axis). The downward-sloping graph in the figure is the production-possibility frontier for goods 1 and 2. The graph shows the various combinations of the two goods that can be produced in the economy, in a given period of time. This illustration of production possibilities relies on drastically simplifying assumptions, but it has two great advantages: it is easy to grasp and it allows for analyzing some of the basic trade-offs a society faces. The graph must be downward sloping, because scarcity implies that an increase in the production of one good must have opportunity costs: an increase in the production of one necessitates a reduction in the production of the other good. The slope of the function is a measure of the opportunity costs, because it measures by how much the production of one good must be reduced, if one produces an additional (small) unit of the other good. It remains to be shown how useful this tool actually is. The purpose of this simple model is to illustrate what the role of simplifying assumptions means.

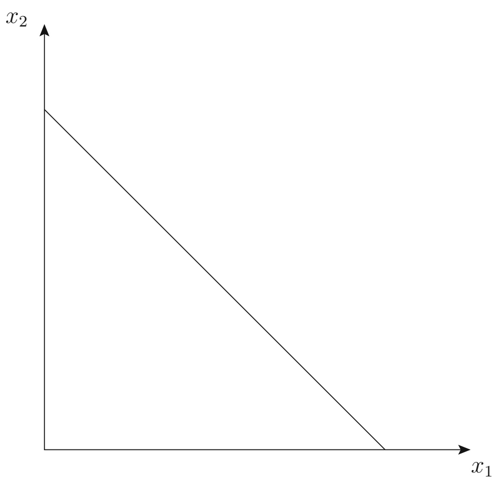

Fig. 1.1 An example for a production-possibility frontier

1.2.6 Critical Rationalism

The workhorse epistemology in economics is *Critical Rationalism*, which has been advocated by Karl Popper, among others. According to this view, scientific theories can never be verified (for reasons that have been discussed before) but can, in principle, be falsified by bringing in empirical evidence that is in conflict with the hypotheses of the theory. Hence, theories should be formulated such that their hypotheses are falsifiable, which means that it has to be possible to give empirically accessible conditions under which the theory is considered incompatible with observations. Good theories are those that have a large empirical content but have not been falsified so far. In addition, Ockham's razor is also an integral part of Critical Rationalism.

Critical Rationalism leads to a back and forth between theoretical and empirical reasoning: the (empirically) falsifiable hypotheses of models must be empirically tested. These tests can either falsify the theory or not. Non-falsified theories are preliminarily accepted, if no other non-falsified theory exists that explains more cases with less restrictive assumptions. If the theory is falsified, the insights from the process of falsification can be used to modify the models.

A weak spot of Critical Rationalism is its unscrutinized belief in empirical falsification. The problem is that one does not have direct proof of facts; that any empirical observation relies on a theory, as well. A lot of statistical data, for example, is collected within a highly complex system of national accounting, and data generated in lab experiments depends on the interpretation of the experiment. Therefore, from an epistemic point of view, falsification is no more or less than the proof of the logical inconsistency of two different theories: a theoretical theory and an empirical theory. Which one will be refuted relies, again, on value judgments or on experts' "gut feelings."

This problem is an example of the much more profound problem known as *underdeterminacy of scientific theory* or the *Duhem–Quine problem*. According to Quine (1951), "[t]he totality of our so-called knowledge or beliefs, from the most casual matters of geography and history to the profoundest laws of atomic physics or even of pure mathematics and logic, is a man-made fabric which impinges on experience only along the edges. Or, to change the figure, total science is like a field of force whose boundary conditions are experience. A conflict with experience at the periphery occasions readjustments in the interior of the field. But the total field is so underdetermined by its boundary conditions, experience, that there is much latitude of choice as to what statements to reevaluate in the light of any single contrary experience. No particular experiences are linked with any particular statements in the interior of the field, except indirectly through considerations of equilibrium affecting the field as a whole."

Some philosophers of science, like Lakatos (1976), draw the conclusion that underdetermination makes scientific "progress" largely a function of the scientist's talent, creativity, resolve, and resources. Even more radical work, by Kuhn (1962), suggests that ultimately the social and political interests determine the conclusions one draws from the inconsistencies within or between theories. In order to take this sting out of the program of scientific reasoning, one must conclude that the best one can hope for is to create a level playing field for scientific debate, where the success of an argument is not influenced by money or power, and a consensus among experts is reached by a "non-hierarchical discourse" (Habermas, 1983).

1.2.7 Positive and Normative Theories

Theories come in two flavors: *positive* theories are used to explain a phenomenon. With the exception of the underlying "dogmatic" first principles, they contain no value judgments. They generate insights into the causal mechanisms linking causes and effects. Positive economics, therefore, tries to explain how people deal with the phenomenon of scarcity. Statements about "what is" are also called *descriptive*.

Normative theories, on the other hand, make *prescriptions* about what people should do under certain circumstances. They, therefore, rely on a value judgment. Statements like "you should lose some weight" and "Switzerland should reduce its corporate income-tax rate" are normative statements. Whether one considers them relevant or not depends on two things. First, one has to share the basic normative principles underlying the advice ("living longer is better than living shorter", or "Switzerland should maximize its national income"). Second, one has to agree with the positive theories bridging normative principles and normative advice ("overweight people live, on average, shorter than lean people because they have a higher risk of cardiovascular diseases", or "lower corporate-income tax rates attract capital investments, which increase national income"). Sen (1970) calls the first class of value judgments *basic* and the second *nonbasic*. Basic value judgments only depend on first ethical principles, whereas nonbasic value judgments are an amalgam of first principles and positive theories.

The distinction between basic and nonbasic value judgments is important for political debates, because it is possible to debate about positive statements. The claim that lower tax rates increase investments, which, in turn, increase national income, can be empirically tested, so people can, in principle, settle disputes about positive statements (in the sense of consensus among experts in a non-hierarchical discourse). The mainstream view, however, claims that this is not the case for basic value judgments. According to David Hume, there is a qualitative difference between descriptive and prescriptive statements. Prescriptive statements, according to this widely accepted view, are not facts of life that can be discovered by scientific reasoning. Here is the famous passage where Hume (1739/2004) makes his point: "In every system of morality, which I have hitherto met with, I have always remarked, that the author proceeds for some time in the ordinary ways of reasoning, and establishes the being of a God, or makes observations concerning human affairs; when all of a sudden I am surprised to find, that instead of the usual copulations of propositions, is, and is not, I meet with no proposition that is not connected with an ought, or an ought not. This change is imperceptible; but is however, of the last consequence. For as this ought, or ought not, expresses some new relation or affirmation, 'tis necessary that it should be observed and explained; and at the same time that a reason should be given, for what seems altogether inconceivable, how this new relation can be a deduction from others, which are entirely different from it. But as authors do not commonly use this precaution, I shall presume to recommend it to the readers; and am persuaded, that this small attention would subvert all the vulgar systems of morality, and let us see, that the distinction of vice and virtue is not founded merely on the relations of objects, nor is perceived by reason."

Likewise, Moore (1903) coined the term *naturalistic fallacy* for the category error someone commits when he defines the "good" (in the sense of intrinsically valuable) by certain properties of things. It could, for example, be that pleasant things are "good" things and that pleasure should therefore be the basis for one's value judgments (a position called hedonism). Others may argue that meaningful things are "good" things, and society should therefore provide the necessary means to promote meaningfulness. The point of the naturalistic fallacy, as Moore describes it, is that, even if one agrees to a certain position, one cannot define the idea of goodness with reference to these properties, because it is no natural property. It is "one of those innumerable objects of thought which are themselves incapable of definition, because they are the ultimate terms by reference to which whatever is capable of definition must be defined." (Principia Ethica, §10)

Scientific reasoning cannot prove the goodness of things or acts; goodness can only reveal itself in, for example, a moment of bliss or awe. The fact that ethical insights lie beyond scientific reasoning is also clearly expressed by Wittgenstein (1998) in that "there can be no ethical propositions. Propositions cannot express anything higher. [...] It is clear that ethics cannot be expressed. Ethics is transcendental. [...] There are, indeed, things that cannot be put into words. They make themselves manifest."

The *fact–value dichotomy* has not remained undisputed, however. As shown, dogmatism is the only practical solution to the Münchhausen trilemma. However, dogmatism implies that the distinction between facts and values is not as clear as was envisioned by Hume. Apparently, value-free facts are tainted by value judgments about first principles Putnam (2002). The opposite point of view is the position that ethical sentences express propositions, which refer to objective features of the world. It is called *moral realism*.

The fact–value dichotomy is widely accepted by economists, which has important consequences for economics as a social science, because it constrains the role of the economist to that of an expert (hopefully) in descriptive statements. Economists can clarify the effects of changes in the tax system, monetary policies, or labor market policies like minimum wages, to name only a few. However, the economist is no expert in the basic normative question, of what the members of society should want. The division of labor between economists and the general public is, according to this view, that the general public articulates what it wants (in terms of first principles) and that the economist uses his/her toolbox to figure what to do.

This restricted role of economists sounds pleasantly humble and innocuous, but, in fact, it is not necessarily so. First of all, and at a very profound level, even positive theories have a normative core that defines the acceptable practices (remember the problem of dogmatism discussed before). However, from a more practical point of view, the division of labor outlined above does not exist in practice. Usually, average people—and even politicians—have very opaque and conflicting ideas about their normative principles. As a result, they mix conflicting emotions and narratives into an amalgam of ideas that Sen (1970) has called nonbasic value judgments. Economic advisors have to somehow fill the resulting gaps, which necessarily grants them authority in normative matters that they should not have. There is not much that one can do about that, but an awareness of this fact can be very helpful. In addition, it should be a unanimously accepted principle of scientific hygiene that economists, who are asked for advice in a situation of unclear normative principles, disclose and actively communicate the normative premises of their work. Otherwise, one crosses the border from scientist to ideologist.

1.2.8 Schools of Economic Thought

The majority of the theories discussed in this book stem from two different schools of thought: *neoclassical economics* and *new institutional economics*. Despite the fact that neoclassical economics is the mainstream school of thought and taught at most universities around the world, the underlying paradigm is far from uncontroversial. The purpose of this subchapter is, therefore, to give a short overview over these, as well as other schools of thought, to better understand the paradigms and to put them into perspective.

Neoclassical economics is not a monolithic theory with undisputed first principles. Despite its heterogeneity and versatility, some underlying unifying principles can be identified: (1) methodological and normative individualism, (2) consequentialism (and, more specifically, welfarism, an ethical theory that we will discuss in Chap. 5), (3) rational or rationality-seeking agents, and (4) society as a network of mutual transactions that follow the logic of opportunity costs. These basal axioms are enriched by other more specific assumptions. Neoclassical economics is especially dominant in microeconomics, but it also developed into macroeconomics where, together with Keynesian economics, it forms the so-called *neoclassical synthesis*. Keynesianism was initially a fundamental critique of some of the implications of neoclassical thinking (like the neutrality of money) but was later integrated into the neoclassical theory (at the price of changing Keynes' initial theory beyond recognition, as some Keynesians would stress).

As the name suggests, neoclassical economics emerged from *classical economics*, which is also called political economy. The main differences between classical and neoclassical economics represented a shift in attention regarding the most relevant economic problems and in the underlying *theory of value*, that is, a concept of what is valuable and creates value in society.

Classical economics originated at a time when capitalism was gradually replacing feudalism and innovations were fueling the Industrial Revolution that was completely changing society. One of the most pressing problems, in such a period of change, was how society could be organized, if every individual seeks his or her own advantage. This is why the idea that free markets have the ability to regulate themselves was of such profound importance, because it expressed the belief that a decentralized society, built on the principles of self-interest, can work. Important proponents of this school of thought were Adam Smith, Jean-Baptiste Say, David Ricardo, Thomas Malthus, and John Stuart Mill.

In addition, the classical economists had a focus on economic growth and production. This is why they shared the view that the economic value of a product depends on the costs involved in producing that product. This theory of value is one of the key differences between classical and neoclassical thinking, which replaced this comparatively more objective standard of value with a subjective one that is based on utility. The idea is that economic value does not stem from any objective property of a good (like the amount of labor that went into its production), but from the importance, the good has for the achievement of the individuals' goals.

A second distinctive feature of early neoclassical thinking is what is sometimes called the "marginalist revolution" in economics. When individuals make decisions, they think in terms of trade-offs and they think "at the margin," which means that they compare the satisfaction they get from an additional unit of a good with the costs of this additional unit. Market prices then reflect these marginal exchange rates. Thinking "at the margin" allowed neoclassical thinking to resolve puzzles that resulted from objective theories of value, like the fact that water is more important than diamonds, but the price for diamonds is higher than the price for water. While water has greater total utility, diamonds have greater marginal utility, which is relevant for prices.

The neoclassical approach started to replace classical economics in the 1870s. Important early proponents of neoclassical economics were William Stanley Jevons, Carl Menger, John Bates Clark, and Léon Walras. They were followed by Alfred Marshall, Joan Robinson, John Richard Hicks, George Stigler, Kenneth Arrow, Paul Anthony Samuelson, and Milton Friedman, to name only a few.

Institutional economics emphasizes that economic transactions are embedded in a complex network of culture, norms, and institutions. The functioning of, for example, markets, according to this view, cannot be understood in isolation, which brings this school of thought into sharp contrast with neoclassical economics, and it is considered a heterodox school of thought. However, an important variant of this school evolved in the second half of the twentieth century: *new institutional economics*. It has its roots in two articles by Ronald Coase. They made it clear that transaction costs are at the heart of an institutional analysis, which allows for the characterization of the relative merits of markets, firms, or the government in achieving the normative goals of society. New institutional economics is critical of neoclassical economics, because of its focus on markets and rationality, but it uses and builds on elements of this theory. Therefore, it does not contrast with but instead complements neoclassical thinking. Important figures in this field are Armen Alchian, Harold Demsetz, Douglass North, Elinor Ostrom, and Oliver Williamson, among others.

There are, of course, other schools of economic thought, and it would be beyond the scope of this book to do justice to them all and to show their relationships with neoclassical and new institutional economics. Some influential schools of the past have declined in influence, including the *historical school of economics* (for example, Gustav von Schmoller, Etienne Laspeyres, and Werner Sombart), *Marxian economics* (for example, Karl Marx and Antonio Gramsci), *Austrian economics* (for example, Carl Menger, Eugen von Böhm-Bawerk, Ludwig von Mises, and Friedrich von Hayek, some of whom are better classified as neoclassical economists), and *institutional economics* (for example, Thorstein Veblen, John R. Commons, and John Kenneth Galbraith), and are now often considered heterodox approaches. However, there are also more recent developments like *feminist economics* (represented by, for example, Marylin Waring, Marianne Ferber, and Joyce Jacobson) and *ecological economics* (represented, for example, by Herman Edward Daly and Nicholas Georgescu-Roegen). Up until now, however, these schools mostly criticize specific aspects of mainstream economics without developing independent schools.

It is unclear how other more recent developments, like evolutionary economics, behavioral economics, and neuroeconomics, will relate to the neoclassical paradigm. As demonstrated by the neoclassical synthesis, which integrated a specific interpretation of Keynesian with neoclassical thinking, neoclassical economics proved to be extremely versatile in the past, adapting to changes and adopting approaches that started as a critique of the mainstream.

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Gains from Trade

2

This chapter covers ...

- the application of the concept of opportunity costs toward understanding why the process of specialization and trade is potentially beneficial.
- why the principle of comparative advantage is crucial to an understanding of why societies organize economic activities and to the economic role of institutions.
- why institutions matter and what an economic theory of institutions has to explain in order to provide a better understanding of societal phenomena like growth, unemployment, globalization, or anthropogenic climate change.

2.1 Introduction

> What is prudence in the conduct of every private family can scarce be folly in that of a great kingdom. If a foreign country can supply us with a commodity cheaper than we ourselves can make it, better buy it of them with some part of the produce of our own industry, employed in a way in which we have some advantage. The general industry of the country, being always in proportion to the capital which employs it, will not thereby be diminished [...] but only left to find out the way in which it can be employed with the greatest advantage. (Adam Smith, The Wealth of Nations, Book IV: 2, 1776/1991)

> Under a system of perfectly free commerce, each country naturally devotes its capital and labour to such employments as are most beneficial to each. This pursuit of individual advantage is admirably connected with the universal good of the whole. [...] It is this principle which determines that wine shall be made in France and Portugal, that corn shall be grown in America and Poland, and that hardware and other goods shall be manufactured in England. (David Ricardo, 1817/2004)

Economics has always been an underdog among the sciences, with the aspiration to play in the same league as the natural sciences but, at the same time, lacking the general theories and insights that characterize, for example, modern physics. This fact is nicely expressed by an exchange between Paul Samuelson, one of the

M. Kolmar, *Principles of Microeconomics*, Classroom Companion: Economics,
https://doi.org/10.1007/978-3-030-78167-5_2

most influential economists of the twentieth century and Nobel prize winner, and the mathematician Stanislaw Ulam, who once challenged Samuelson to "name me one proposition in all of the social sciences which is both true and non-trivial," obviously expecting the question to be left unanswered. Apparently it took Samuelson several years before he found one: the theory of comparative advantage. "That it is logically true need not be argued before a mathematician; that it is not trivial is attested by the thousands of important and intelligent men who have never been able to grasp the doctrine for themselves or to believe it after it was explained to them" (Samuelson, 1969). It should, therefore, come as no surprise that this theory is still at the heart of economics and it is very useful for understanding how societies cope with the problem of scarcity. Perhaps surprisingly, after all these years, the theory of comparative advantage still gives rise to misunderstandings and ideology-tainted controversies. It is the purpose of this chapter to illustrate the basic insight of this theory, its implications not only for economics but also for business administration and law, and the potential fallacies one is prone to when applying the theory.

Ricardo developed the theory of comparative advantage to explain why it is mutually beneficial for nation states to allow for international trade. His famous example is trade between England and Portugal. This focus on international trade was obvious in the political atmosphere of the days when powerful political forces in England opposed free trade, because they feared that they could not compete with Portugal. At the same time, it planted the seed for potential misunderstandings and misinterpretations, as will be discussed below. This is why I approach the theory from a different angle where individuals rather than states contemplate exchanging goods and services.

A fundamental aspect of societies coping with scarcity is that the acts of individuals are interdependent. If person A eats a sandwich, then B cannot eat the same sandwich; if B wears a red sweater, then A has to look at it; and so on. This interdependency can explain the phenomenon of exchange and specialization. The starting point of this endeavor is a situation where all individuals in a society abstain from trading goods and services, i.e., an individual must produce everything he/she consumes. This situation is called *autarky*.

The theory of comparative advantage is developed here by means of an intuitive example: assume there are two individuals, Ann (A) and Bill (B), and two commodities, pears (P) and tomatoes (T). Ann and Bill are initially in a situation of autarky.

- **Case 1:** Each individual can produce exactly one and wants to consume only this good. This is the trivial benchmark case when autarky is, in fact, a perfectly adequate way to organize economic activities. Interactions between Ann and Bill cannot reduce scarcity because neither person has goods or services to offer that the other person wants. The only challenge imposed by scarcity is self-management: how should Ann and Bill organize their days such that they can consume enough pears and tomatoes? If this situation were an adequate and exhaustive description of reality, the economic journey would end before it really got started, because there would be no need to think about how people organize interactions and develop institutions to alleviate scarcity. Human beings would live happily from the yields of their own gardens. Fortunately for social scientists, this is not what the world is about.

- **Case 2:** Each individual can produce exactly one good but wants to consume both. This case gives a first explanation for *trade* between the individuals. Ann can grow only tomatoes in her garden and Bill only pears, but they prefer to have both for lunch and dinner. In this case, it is obvious that it makes sense for them to establish a "trade agreement" that specifies how many pears and tomatoes shall be exchanged between A and B. If this scenario were to adequately describe the world, one should observe trade.
- **Case 3:** Each individual can produce and wants to consume both goods. However, one individual is better at producing tomatoes (Ann) and the other at producing pears (Bill). In this situation, each individual has an *absolute advantage* in the production of exactly one good. (One can interpret case 2 as a special case of case 3 where the absolute advantage of each individual is pushed to its extreme.) In this situation, Ann and Bill do not necessarily rely on each other, if they want to have tomatoes together with pears for lunch, but cooperation can make life easier. With absolute advantages in the production of goods, it makes sense that individuals *specialize and trade*. The total number of pears and tomatoes that is available, if Ann specializes in the production of tomatoes and Bill in the production of pears, increases. However, specialization and trade are two sides of the same coin. Assume that the production of pears and tomatoes in an autarky reflects Ann's and Bill's "taste" for both goods (economists call these tastes the individuals' *preferences*) such that they are the most preferred bundles they can produce, given their production possibilities. For example, let us assume that both individuals seek to produce and consume both goods (tomatoes and pears) in an equal amount. Deviating from this production plan and specializing, according to the absolute advantage, makes them worse off without trade. Given that specialization increases the total production, it is always possible to guarantee both individuals their autarky consumption and still leave a surplus.
- **Case 4:** Each individual can produce both goods and wants to consume both. One individual is better at producing both goods, tomatoes and pears. This is the critical case, which required Ricardo's ingenuity to understand that both, Ann and Bill, can be better off by specialization and trade. The intuition as to why this is the case is built around the idea of scarcity itself. Assume A has an absolute advantage in the production of pears and tomatoes. With unlimited resources, she could easily outperform B. However, resources are not unlimited. Assume that both individuals spend all of their work time producing either P or T. In this case, the only way for A to produce more T is by reducing the production of P, because she has to devote more of her scarce time to the production of T, which leaves less for P. Assume that the rate of transformation is 2 to 1, i.e., a reduction of one unit of P increases the production of T by two units. Given that her autarky production was optimal for her needs (the quantity of tomatoes produced was equal to the quantity of pears produced), such a change is not advisable. At this

point, B can make his appearance. Assume that A and B team up and arrange that B compensates the loss of P by producing less T. Remember that his rate of transformation is 1 to 1. To compensate for the increase of P by one unit, he therefore has to reduce the production of T by one unit. However, if one does the math, one can see how the apparent magic of comparative advantage works: the change in the total quantity of pears is -1 (by A) +1 (by B) =0, so the total amount of pears remains unchanged. How about tomatoes? The change in total in the quantity of tomatoes is +2 (by A) -1 (by B) $= +1$: the total production goes up, because Bill has a *comparative advantage* in the production of pears.

Even though Ann is twice, or even a hundred times, more productive than Bill in absolute terms, she is still subject to resource (time) constraints. Hence, as long as Ann and Bill differ in their rates of transformation of the two goods at the point where the resource (time) constraints become binding (their opportunity costs), there is room for mutually beneficial specialization and trade.

To illustrate the point, compare a Nobel Laureate in Economics with me. I am doing OK as an economics teacher as well as a researcher. The Nobel Laureate is a brilliant researcher and also a very good teacher. Thus, he/she is better than me in both respects: he/she has an absolute advantage in research as well as teaching. I can sympathize with the position that a student would like to be educated by a very good teacher, not only a decent one, but does it make sense from an overarching perspective? If the Nobel Laureate were to teach economics, he/she would not be able to use the time to develop new theories. Thus, one basically has the choice between two alternatives: learning economics from the best teacher available and missing out on the opportunity to have better theories in the future, or learning economics from an OK teacher but with better theories.

Looking at it from this perspective, the theory of comparative advantage is very comforting for ordinary people like us: Do you think that you are nothing special? Do not worry, even if there are people out there who outperform you in every possible aspect of life, they have only a limited amount of time. That is our chance.

2.2 An Example

The next step is to develop a more precise understanding of the theory of comparative advantage by specifying the production possibilities of Ann and Bill. Assume that both have a total of 100 h that they can spend on the production of either pears or tomatoes. Table 2.1 gives an overview of the productivities of the two and the implied maximum production levels. The table shows that A is, in fact, more productive than B: she needs half the time to produce a kilo of tomatoes and one quarter of the time to produce a kilo of pears. Assume that A and B can divide their time freely between the production of both goods and that productivities are constant. With this assumption, one can analyze the example by means of the concept of the production-possibility frontier that was introduced in Chap. 1.

Table 2.1 Productivities and production possibilities for Ann and Bill

	Time for 1 kg of tomatoes	Time for 1 kg of pears
A	1 h	1 h
B	2 h	4 h
	Maximum quantity of tomatoes	Maximum quantity of pears
A	100 kg	100 kg
B	50 kg	25 kg

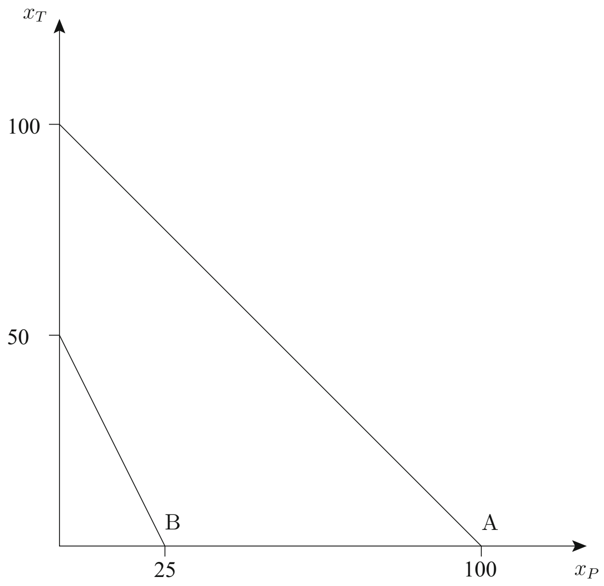

Fig. 2.1 Ann's and Bill's production-possibility frontiers

Figure 2.1 shows the production-possibility frontiers for A and B. $x_T^A, x_P^A, x_T^B, x_P^B$ denote the quantities of T and P for A and B. The functional forms can be defined as

$$x_T^A = 100 - x_P^A, \quad x_T^B = 50 - 2 \cdot x_P^B.$$

The total production of pears (in kilos) is drawn along the abscissa, and the total production of tomatoes (in kilos) is drawn along the ordinate. The *absolute* advantage of A in the production of both goods is reflected in the fact that her production-possibility frontier lies to the northeast of B's. Note, however, that the *slopes* of both frontiers differ, which will be crucial for the identification of a *comparative* advantage.

In order to get there, one starts with the determination of the opportunity costs of production (OC). The opportunity cost of an additional kilo of, for example, tomatoes is the reduction in the production of pears, which is necessary due to the reallocation of time from pear to tomato production. It is equal to the slope of the production-possibility frontier (in absolute terms). Alternatively, one can determine the opportunity cost of pears in terms of tomatoes, which is equal to the inverse slope of the production-possibility frontier (in absolute terms). Table 2.2 summarizes these costs.

A comparison of the opportunity costs allows one to identify the comparative advantage of Ann and Bill. Figure 2.2 shows the opportunity cost of a one-unit increase in the production of tomatoes, measured in units of pears for both individuals. It is one kilo for Ann and half a kilo for Bill. This observation shows that it is *relatively* easier for Bill to increase the production of tomatoes: an additional kilo costs him half a kilo of pears, whereas Ann would have to reduce the production by one kilo. Hence, Bill has a *comparative advantage* in the production of tomatoes.

The concept of comparative advantage is *relational*, because the fact that Bill has a comparative advantage in the production of tomatoes *necessarily* implies that Ann has a comparative advantage in the production of pears: if she reduces the production of tomatoes by one kilo, she gets an additional kilo of pears, whereas Bill only gets 500 grams.

Table 2.2 Opportunity costs for Ann and Bill

	OC tomatoes (in terms of pears)	OC pears (in terms of tomatoes)
A	1	1
B	0.5	2

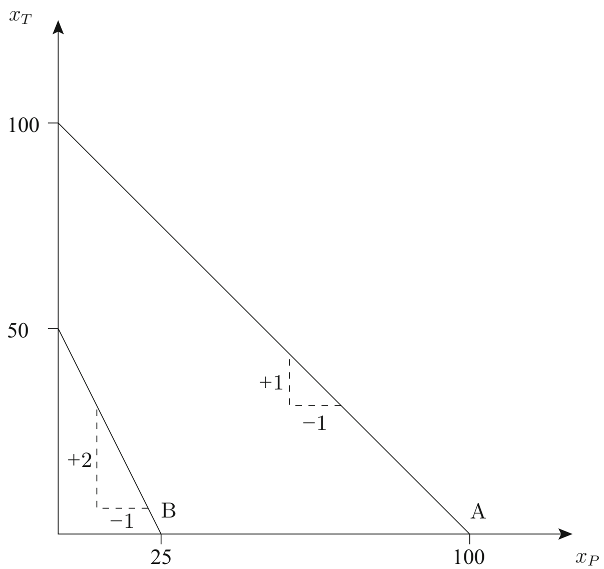

Fig. 2.2 Increase in the production of tomatoes, if the production of pears is reduced by 1 kg

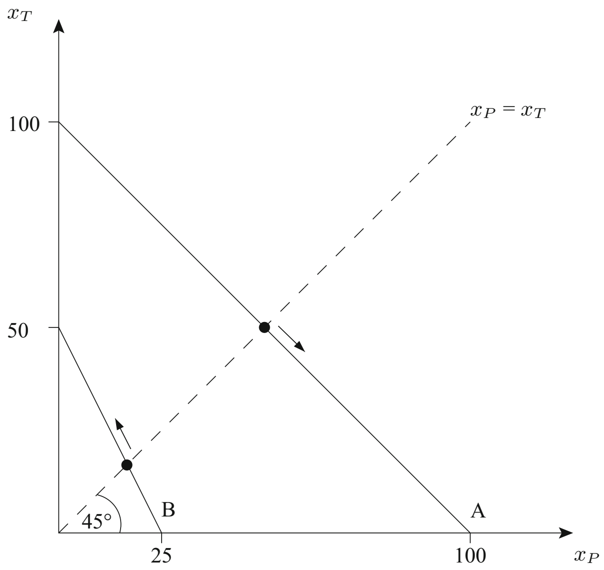

Fig. 2.3 Specialization according to Ann's and Bill's comparative advantage

After identifying the comparative advantages of Ann and Bill, one can set up an example that illustrates how specialization, according to comparative advantage, can increase the total production. In order to do so, assume that both individuals want to consume pears and tomatoes in equal quantities. The 45°-line in Fig. 2.3 denotes the set of most preferred combinations of pears and tomatoes (consumption bundles).

The consumption levels in autarky are given at the intersections of the 45°-line and the production-possibility frontiers. Analytically, they are the solution to the two systems of equations $x_T^A = 100 - x_P^A \wedge x_T^A = x_P^A$ and $x_T^B = 50 - 2 \cdot x_P^B \wedge x_T^B = x_P^B$. The solutions are $x_T^A = x_P^A = 50$ and $x_T^B = x_P^B = 50/3$. The important question is if both Ann and Bill can be made better off, if they specialize according to their comparative advantages and exchange goods. Table 2.3 shows how individual and total production change, if A produces more pears and B more tomatoes. As predicted by the theory of comparative advantage, specialization can increase the total production of both tomatoes and pears. It is completely irrelevant that B is less productive than A in everything he can do. The only thing that matters is that they differ in their opportunity costs.

Table 2.3 The effects of specialization, according to comparative advantages

	Change in tomatoes	Change in pears
A	−3/4kg	+ 3/4 kg
B	+1 kg	−1/2 kg
$A+B$	+1/4 kg	+1/4 kg

The increase in production is called the *material gains from trade*, which one distinguishes from the *subjective gains from trade* or, simply, *gains from trade*. What is the difference? The material gains from trade measure the increase in the total production. The production of material goods is, however, only a means and not the end of economic activities. What ultimately counts is what material goods can do for people, how they contribute to their well-being, and the term "gains from trade" refers to a measure of this increase in subjective well-being.

At this point, one has to ask two different questions.

- First, it is important to understand how comprehensive the result is. Is it an artifact of the above model or does it hold under general conditions?
- Second, if it is a general result, then one has to ask what it implies for an economy. Are gains from trade exploited automatically or must societies organize economic activity in a specific way to ensure that the potential gains from trade will in fact be exploited?

The next two subchapters are dedicated to the discussion of these two topics.

2.3 How General Is the Theory of Comparative Advantage?

A peculiar feature of the above model is the linearity of the production-possibility frontier. In this case, comparative advantage is a well-defined *global* concept and the results are completely general: with the exception of the limiting case of equal opportunity costs, there is always a way to increase production by specialization. There may, however, also be cases where production possibilities are more accurately described by a strictly concave (outward-bending) frontier. Such a frontier is typical if the productivity of production gets lower, the more you produce, like for example mining when it gets more and more difficult to extract the resource over time. In this case, comparative advantage is no longer a global, but rather a local concept, and it depends on the autarky points along the production-possibility frontier. Production-possibility frontiers are concave, if productivity is decreasing in production. Figure 2.4 illustrates such a situation and the possibility for the reversal of comparative advantages.

Points X and Y represent two possible autarky situations. The slopes of the frontiers are a measure for *local* opportunity costs. As one can see, A has a comparative advantage in the production of T in X and a comparative advantage in the production of P in Y. Beyond that, however, there is no difference from the model with constant opportunity costs: if opportunity costs in autarky differ, there is room for mutual improvement by specialization and trade.

If the frontier can be concave, it could also be convex (inward-bending). Such a frontier is typical if the productivity of production gets higher, the more you produce, like for example if you learn over time to be more effective (learning by doing). Production-possibility frontiers are convex, if productivity is increasing in production. Figure 2.5 illustrates this case.

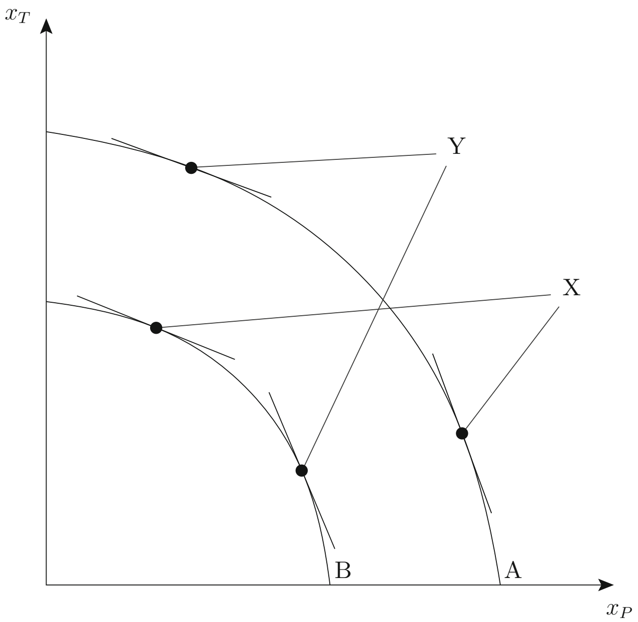

Fig. 2.4 Comparative advantage with a strictly concave production-possibility frontier

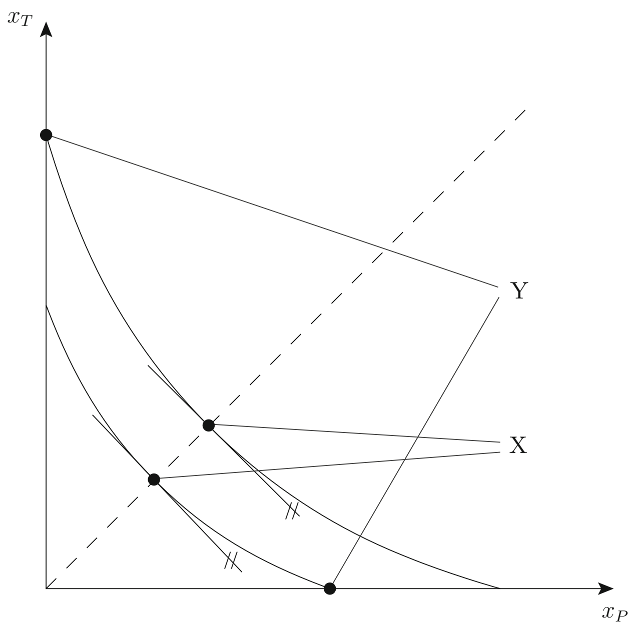

Fig. 2.5 Comparative advantage with a strictly convex production-possibility frontier

Assume that one starts in a situation of autarky *X*, where neither *A* nor *B* has a local comparative advantage. Even in this case, it makes sense to specialize and trade, because specialization allows them to increase productivity. In this case, specialization creates a comparative advantage that was non-existent in autarky. This is shown with point *Y* in Fig. 2.5 in which it is assumed that *A* and *B* completely specialize.

The theory of comparative advantage, therefore, seems to be robust with respect to the laws governing production. In this sense it is, in fact, completely general. If this were the end of the story, however, there should be no resentment towards the process of globalization, which seems to be shared by many people. It can often be read that globalization does create not only winners but also losers and that it is, therefore, wrong to claim that everyone is better off. If, in the words of Adam Smith, "the extent of this division [of labor] must always be limited by the extent [. . .] of the market," and if *division of labor* is a good thing, the process of global market integration must be a good thing, as well. The only explanation as to why skeptics are skeptics is that they do not get it.

However, this may not be the case. I claimed, at the beginning of this chapter, that there is an important difference in whether the theory of comparative advantage is applied to individuals or states and that one of the reasons for the confusion can be traced back to Ricardo's decision to apply it to the England–Portugal case. However, what is the difference?

The key to finding an answer to this question is the realization that the sequence of market integration may matter, and this phenomenon cannot be understood in a two-person example. To illustrate this, I will, therefore, add Charles (*C*) to the picture and assume that he can produce tomatoes and pears as well. One distinguishes between two scenarios.

Simultaneous Integration In this scenario, assume that all the individuals start negotiating about specialization and trade simultaneously, starting from autarky. In this case, the theory of comparative advantage readily applies in the modified situation: *A*, *B*, and *C* will specialize according to their comparative advantages, and the surplus of production can be distributed in a way that makes at least one individual better off, without making any other individual worse off, since each individual can at least ensure itself the autarky level of consumption. Therefore, with simultaneous integration, the benchmark is autarky consumption and, given this benchmark, there can be no loser from integration.

Sequential Integration In this scenario, assume that *A* and *B* have already negotiated a trade agreement when *C* enters the picture. Thus, the benchmark for comparisons for *A* and *B* is no longer the autarky consumption, but the consumption with "partial" integration. Compared to this situation, including *C* into the trade agreement need no longer be mutually beneficial. It could, for example, be that the availability of *C* as a potential trading partner for *A* motivates *A* to drop *B* as a trading partner and to replace him with *C*. In this case, *B* falls back to autarky, which worsens his position. This is, in a nutshell, exactly the situation a lot of manufacturing industries in Europe were facing when China entered the world markets. Its rise as the "workbench of the world" induced deep structural changes in Europe, which lost the better part of its manufacturing jobs to China. The crucial fact one has to understand, in order to square this fact with the theory of comparative advantage, is that the theory can be correct, and yet, at the same time, market integration creates losers. It is a problem of the adequate benchmark that is used for welfare comparisons.

The fact that a process of sequential integration can create losers on the way to a fully globalized world economy also gives a hint as to why Ricardo's example is potentially misleading. Ricardo's original example had cloth and wine as goods and England and Portugal as countries, with Portugal having an absolute advantage in the production of both. Market integration between countries is a special form of sequential integration in the above sense: the starting point is not autarky, but a situation where the English and the Portuguese have partially integrated markets. Starting from this benchmark, any further integration of markets can produce losers.

The decisive difference between Portugal and Ann and England and Bill is that countries are no unitary actors. Saying that "England" can profit from trading with "Portugal" is not the same as saying that Bill can profit from trading with Ann. If, in the process of specialization, the necessary restructuring of the two economies leads to a loss of jobs in the winemaking industry in England, it is hardly comforting for the now unemployed to learn that the total size of the cake for the English has increased. On the contrary, knowing that the total size of the cake is larger, but one's own piece is smaller, may even foster social tensions. The restructuring processes in the economies create winners and losers and, even if the winners could, in principle, compensate the losers because goods become more abundant, this is rarely done in practice. The problem does not exist in the Ann and Bill example because it is a single individual who has to reorganize her or his day. Treating countries like individuals blurs the underlying distributional conflicts that necessarily exist when new players enter a market. Forcing one to think all the way back to the level of the individual is one of the strengths of methodological individualism.

Digression 2.1 (Heckscher–Ohlin and the Losers of Globalization)
The above example illustrates the possible distributional effects of sequential integration. To get a deeper understanding, we need to look "behind" the production-possibility frontier to see how resources, production technologies, and goods are interconnected and how the conditions for production differ between countries. A full formal analysis is beyond the scope of this chapter, but we can at least develop some basic ideas. The standard model for analyzing distributional effects of globalization is the *Heckscher–Ohlin model*, which assumes that two countries produce two goods using two factors (such as capital and labor). The model abstracts from factor mobility between

(continued)

Digression 2.1 (continued)
countries, i.e., foreign direct investment and migration. Specialization and trade do not take place in a vacuum in this model, but by means of markets with perfect competition (see Chaps. 3, 4, and 12 for a definition and analysis of this type of market). The main implication of perfect competition for our purposes is that market prices before and after a trade agreement determine the distribution of income and thus access to goods.

Comparing autarky with trade reveals the comparative advantage of countries: "Countries tend to export goods whose production is intensive in factors with which the countries are richly endowed." (Krugman et al. 2018). Moreover, trade tends to equalize prices, leading to the following conclusions regarding the distributional effects of integration: "Owners of a country's abundant factors gain from trade, but owners of a country's scarce factors lose." (Krugman et al 2018). Thus, factors of production that are specific to the industry facing new competition from foreign imports, being it capital or labor, are negatively affected.

What are the conclusions of this general finding? Compared to the rest of the world, Western Europe and the United States have a relative abundance of high-skilled labor and a relative shortage of low-skilled labor. Therefore, trade tends to hurt low-skilled workers in these countries. Part of the problem may be temporary because, while skills may not change in the short run, incentives exist to acquire better skills in the long run. But part of the problem is also structural if not all people can acquire the skills necessary to be employed in the (high-skilled) export sector. This is one of the reasons for the domestic problems that are a consequence of globalization. Theoretically, these problems could be addressed because trade expands the two countries' joint production (and thus consumption) possibilities. The redistributive effects are, thus, a result of the specific institutions, competitive markets in this case, that guide integration in the Heckscher–Ohlin model. The art and craft of good distributional policy, then, would be to intervene in market processes in such a way that (a) incentives to specialize remain unchanged and (b) potential gains from trade are distributed in a way that makes everyone better off. In practice, however, this is rarely done.

Do we find effects like these in reality? The research service for the US Congress found in a report on the development of the US income distribution from 2016 a sharp shift in the above mentioned trend (Donovan et al. 2016). From the mid-1970 to 2000, income inequality increased significantly. However, incomes grew for households in all income quintiles (you cut the income distribution in five parts). This pattern changed between 2000 and 2015 when incomes rose modestly for the two top quintiles and fell for the three bottom quintiles, with a positive net effect. The authors identify technological change, decline in unionization, and globalization as the three

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(interdependent und mutually reinforcing) most important causes for this trend.

These insights shed light on some of the political conflict lines in Western Europe and the United States of the last couple of years (you find qualitatively similar trends in other Western countries as well). If one restricts attention to labor, high-skilled and typically urban workers are profiting and consequentially have a rather positive view about globalization and the awesome opportunities that come with it. On the other hand, somewhere: low skilled workers from and oftentimes rural workers feel like being left behind.

This opposition played a role in the British ("*Brexit*"-) EU referendum, and David Goodhart in his book *The Road to Somewhere: The Populist Revolt and the Future of Politics* (2017) coined the names *anywheres* and *somewheres* to describe these two groups. Anywheres are well educated, urban elites who feel more like citizens of the global network of urban centers and who feel comfortable with diversity and immigration, whereas somewheres often live far from the metropolitan centers, feel left out and left behind, and are oftentimes more reluctant towards immigration as the most visible aspect of globalization in their lives (whether immigration contributes to their relative economic decline or not). And this decline is not only economical but also cultural and symbolic: Goodhart argues that the self-absorbed lack of interest of the typical anywhere in the destiny of their fellow citizens and the search for self-respect of the typical somewhere make them tribes, not only groups, and these tribal us-versus-them identities are the seed for the "culture wars" that we can observe in many Western countries at the moment.

Meanwhile, on the other side of the Atlantic, one of the reasons for the election of Donald Trump in the 2016 election was the voting behavior of the US equivalent of the British somewhere: workers from rural and formerly industrialized areas (like the *rust belt*) of the United States. Interestingly, the Trump administration started to roll back globalization by starting to impose tariffs on foreign imports, at least initially.

The Heckscher–Ohlin model has been used to simulate the effects of a US–Chinese trade war on US-American wages. It turns out that one has to distinguish between two scenarios to understand the implications. In a hypothetical scenario where the US unilaterally imposes tariffs on Chinese imports, aggregate US consumption rises by a standard *terms-of-trade effect*. Fajgelbaum et al. (2019) quantify this effect to be about (a modest) $ 0.5 billion. The simulation shows that this overall gain is, however, unevenly distributed: workers in the exporting sector lose and workers in the importing sector gain. Hence, high- and low-skilled workers have opposing interests.

However, China retaliated by imposing tariffs on US imports ("trade war"), the aggregate picture changes because overall consumption falls as the

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economies move closer to autarky. Fajgelbaum et al. (2019) assess that the loss to US consumers and firms who buy imports was $51 billion, and the overall income loss for the US economy (accounting for tariff revenue and gains to domestic producers) was $7.2 billion.

The distributional consequences are, however, still qualitatively the same: It is no surprise that high-skilled labor is negatively affected. However, low-skilled labor can still profit in the short run and is more or less unaffected in the long run. This explains why protectionism can find political support irrespective of the threat of a trade war, even though the overall effects on the economy are negative. Yet, this is not what empirically happened according to Fajgelbaum et al. (2019). They conclude: "Import tariffs favored sectors concentrated in politically competitive counties, and the model implies that tradable-sector workers in heavily Republican counties were the most negatively affected due to the retaliatory tariffs." This is in part a result of the fact that Chinese retaliations mainly targeted agricultural sectors, which tend to be concentrated in Republican-leaning counties.

There are two additional aspects of the theory of comparative advantage that should, at least briefly, be discussed: the vulnerability towards exploitation and the phenomenon of alienation.

- **Exploitation:** An economy that opens up for international trade will undergo restructurings when the industries adapt, according to the comparative advantages of the economy, which is usually not in the short-run interests of the workforce of the declining industries. An often-heard argument in the preceding political debates is that relinquishing autarky makes a country more vulnerable, because of the increasing dependence on exports and imports. Switzerland, for example, sees the security of vital goods like food as sufficiently important to give it the rank of constitutional law. Article 102 of the federal constitution specifies two principles. "(1) The Federation ensures the supply of the country with vital goods and services for the case of power-politics or martial threats, or of severe shortages which the economy cannot counteract by itself. It takes precautionary measures. (2) The Federation may, if necessary, deviate from the principle of economic freedom." By and large, agriculture is not a sector where Switzerland has a comparative advantage by international standards, which implies a tension between economic freedom, market integration, and food security. These enacted policies to protect domestic agriculture lead to higher domestic food prices and subsidies of the agrarian sector.

Digression 2.2 (Exploitation and Lock-Ins in Unproductive Technologies) The traditional mathematical theories of comparative advantage are static in nature, which means that they take resource endowments, qualifications, and technologies as given. This assumption paints a picture of globalization that neglects the inter-temporal evolution of comparative advantages that can be a result of changes in technology or education. The short-run comparative advantage of a country may in fact be given at any time, be it because of differences in resource endowments, be it because of differences in skills, and specialization in this direction will in fact increase income in this country. However, the long-run comparative advantage of a country can be determined and influenced by the investment in specific technologies and skills of the workforce.

These dynamic changes in comparative advantages can be nicely illustrated by the development of China over the last decades. In the early stages of China's opening up to the world economy, the country had a comparative advantage in low-skilled production. Take furniture as an example. The US and Western Europe had an absolute advantage in the production of furniture, which were reflected in huge differences in real wages between the countries. These differences resulted mainly from a better trained work force, a higher quantity of capital used to make things, and better infrastructure. From this point of view, lower wages in China were a result of disadvantages that can be transformed into an advantage by specializing in making, for example, furniture. Over time, however, qualifications, capital stock, and infrastructure improved, and the rapid growth of the Chinese economy changed its comparative advantage into the direction of high-tech sectors.

If specialization creates some kind of path dependence (for example, because it is costly to switch from specialization in one sector to specialization in another sector), letting short-run market forces guide you towards a technological and skill structure that reflects your short-run comparative advantage may be dangerous: If the sector will fall back in time in its relative economic performance, for example, because the potential for long-run technology-induced increases in productivity is limited, one may get stuck in a technology that is a dead end with respect to its potential to increase productivity.

Whether this view is correct or not depends on the existence of the above-mentioned substantial path dependencies and the realistic alternatives of a country in this dynamic competition for productivity growth. A country that decides to not specialize according to its short-term comparative advantage but to invest in a way to change it needs the means to do so. The question whether one should leave the evolution of comparative advantages and the accompanying transformation processes to market forces is subject of intensive debate among economists. Believers in the efficiency of markets

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tend to argue that government interference in this process tends to harm long-term efficient development, whereas believers in what is called market failures see room for government interventions to shape this process efficiently. Market failures are a special case of externalities that we will cover in Chap. 6. As we will see in Chaps. 14 and 15, they can also exist because of market power, i.e., because of oligopolistic or monopolistic concentration.

It is not easy to understand whether ensuring food security in times of political crises is a welcome narrative for the farmers to support protectionism or not. What can be said, however, is that vulnerability due to specialization cuts both ways, because different economies become more dependent on each other. In order to get the right perspective on the problem, one therefore has to distinguish between two scenarios. The first can be called the *ceteris paribus* scenario: *if* a crisis occurs, it is important that one does not have to give in to the unjustified demands of an aggressor. Food security is, potentially, a way to achieve this goal. The second can be called the *General equilibrium* scenario, which tries to understand the effect of specialization on the *likelihood* of political crises. Here, the basic idea is that mutual interdependencies make crises less likely, because international interdependencies also increase the risks for potential aggressors.

However, there are conditions under which countries are vulnerable towards exploitation. Such a scenario exists, if a relatively small country is highly dependent on a relatively large powerful country, and the restructuring of the local economy is not easily reversible. Economists have coined the term *hold-up problem* for a situation where specialization creates power asymmetries that can be exploited by the relatively more powerful partner.

It is, ultimately, an empirical question whether the pacifying effects of specialization or the potential exploitability dominate in a specific context.

Digression 2.3 ("Taming the Passions": How Early Theorists of Capitalism Looked at Trade and Competition)
Early theorists of capitalism, like Charles Montesquieu, James Steuart, and Adam Smith, had a complex understanding of the interplay between individuals and society. Hirschmann (1977), for example, pointed out that it was a widely shared conjecture among these philosophers that a major merit of an economic system, based on specialization and trade, is its ability to "tame" the passions of men: "Money making [was seen] as an 'innocent' pastime and outlet for men's energies, as an institution that diverts men from the antagonistic competition for power to the somewhat ridiculous and distasteful,

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but essentially harmless accumulation of wealth." This view on markets (as institutions) is fundamentally different from the later view, held by twentieth century mainstream economics, which has almost exclusively focused on the ability of competitive markets to achieve efficiency. It was reanimated in the twentieth century by Keynes (1936, p. 374), who argued that "[. . .] dangerous human proclivities can be canalized into comparatively harmless channels by the existence of opportunities for money-making and private wealth, which, if they cannot be satisfied in this way, may find their outlet in cruelty, the reckless pursuit of personal power and authority, and other forms of self-aggrandisement. It is better that a man should tyrannise over his bank balance than over his fellow-citizens; and whilst the former is sometimes denounced as being but a means to the latter, sometimes at least it is an alternative."

Profit-seeking behavior and competition defined a vision of a better society where the darker passions of human beings are kept under control by the pursuit of profit. With free trade, according to this view, one need not see an enemy in a stranger, but instead a potential trading partner. Free trade and competition present a form of moral education that brings about relatively harmless bourgeois virtues and that suppresses the darker aspects of human nature. Competition, within the context of free markets, has an explicitly *moral* quality, because the alternatives are so much worse. This view found its expression in Milton Friedman's famous example of discrimination in a competitive economy (Friedman, 1962, Ch. 7): "It is a striking historical fact that the development of capitalism has been accompanied by a major reduction in the extent to which particular religious, racial, or social groups have operated under special handicaps in respect of their economic activities; have, as the saying goes, been discriminated against. The substitution of contract arrangements for status arrangements was the first step toward the freeing of the serfs in the Middle Ages. The preservation of Jews through the Middle Ages was possible because of the existence of a market sector in which they could operate and maintain themselves despite official persecution." McCloskey (2006) goes even further and makes the case that markets and capitalism lead to the development of a set of distinctively *burgeois virtues*. As a consequence, markets and capitalism breed their own capitalist personalities.

- **Alienation:** Specialization implies the division of labor. As soon as one gives up autarky, one devotes one's professional life to a specialized task. The limit of this process is, according to Adam Smith, only defined by the number of potential trading partners: "As it is the power of exchanging that gives occasion to the division of labour, so the extent of this division must always be limited by the extent of that power, or, in other words, by the extent of the market." (Smith, 1776/1991, p. 21). Thus, the larger the number of potential trading partners is, the more specialized the individual activities can be. The only additional limits come from coordination and transportation costs, which are inevitable when production is partitioned into specialized tasks.

This view focuses exclusively on the material side: the production of “stuff,” material goods, and services. However, this ignores the psychological consequences for the people. Karl Marx (1988/1844) was, perhaps, the most prominent thinker, who stressed the implications of the division of labor on the ability of human beings to experience a happy, autonomous, and meaningful life. He described the concept of *Entfremdung*, or *alienation*, as the costs of living in a socially stratified and specialized society where each individual is just a little cog in a big wheel, without autonomy of his time and the products he contributes to, and his managers merely value him as a factor of production.

However, the idea of alienation goes back, at least, to Adam Smith. He expresses the idea very poignantly in *The Wealth of Nations*: “In the progress of the division of labour, the employment of the far greater part of those who live by labour [. . .] comes to be confined to a few very simple operations; frequently to one or two. But the understandings of the greater part of men are necessarily formed by their ordinary employments. The man whose whole life is spent in performing a few simple operations, of which the effects too are, perhaps, always the same, or very nearly the same, has no occasion to exert his understanding, or to exercise his invention in finding out expedients for removing difficulties which never occur. He naturally loses, therefore, the habit of such exertion, and generally becomes as stupid and ignorant as it is possible for human creature to become.” He follows up on these ideas in his *Lectures*: “Where the division of labour is brought to perfection, every man has only a simple operation to perform; to this his whole attention is confined, and few ideas pass in his mind but what have an immediate connection with it. [. . .] These are the disadvantages of a commercial spirit. The minds of men are contracted and rendered incapable of elevation. Education is despised, or at least neglected, and heroic spirit is almost utterly extinguished. To remedy these defects would be an object worthy of serious attention.”

In order to be able to understand if specialization leads to alienation, in this sense, one has to understand the meaning work has for human beings, which is to a certain extent culture specific. Thus, the concept is inherently a cultural and psychological one. What one can say, without digging deeper into this matter, is that the production of goods and services is a means for some underlying end: call it happiness, meaningful life, or whatever. A focus on the materialistic side of production can, therefore, be too narrow to understand the implications of the division of labor on individual well-being.

2.4 Comparative Advantage and the Organization of Economic Activity

> When will we realise that the fact that we can become accustomed to anything [. . .] makes it necessary to examine carefully everything we have become accustomed to? (George Bernard Shaw 1930)

I committed a major scientific crime in the last subchapter, because I was very sloppy with respect to the terminology I used. I repeatedly referred to markets, although the theory of comparative advantage is formulated as a *technological* property, without any reference to specific institutions like markets. However, Smith (1776/1991) [1991] and Ricardo (1817/2004) are brothers in arms, which makes this crime, hopefully, forgivable. Examples of the effects of specialization and trade are easier to find in market contexts and the political tensions and debates are also results of market integration. For David Ricardo, it was reasonable to think of comparative advantages in market contexts, because he was thinking of opening up the English economy to competition. What he found, however, was much more general than a property of markets.

- Consider the theory of comparative advantage within the organizational context of a firm. The divisional structure of the firm (like accounting, marketing, strategy, production, etc.) reflects a specific form of division of labor. Employees specialize as engineers, workers, or accountants with the expectation that the whole is bigger than the sum of its parts. The within-firm exchange of goods, services, and resources is, in general, not organized like a market but follows hierarchical rules that may, but need not, simulate market mechanisms (as, for example, in the case of profit centers that exchange goods and resources on the basis of a firm's internal transfer prices).
- Alternatively, looking at organizations like public research institutes or universities, scientists are extremely specialized, but their exchange of ideas is not governed by market forces. Instead, to a large extent, this takes place in conferences and in research seminars where scientists give away their ideas "for free." Competition for public research funds more closely resembles a contest where the relatively best or most promising proposals get the funding.

The examples show that one can have a division of labor and an exchange of goods, services, and resources without markets. A more fruitful perspective on the relationship between the theory of comparative advantage and markets is to ask whether markets are a good *means* to enable specialization and trade. Theory states that people can alleviate scarcity by a process of specialization and exchange. The next question then must be: do people have to organize economic activities in a specific way to make sure that the potential become actual gains from trade? This is a question about *institutions*, which is at the heart of economics.

According to North (1991), "[i]nstitutions are the humanly devised constraints that structure political, economic and social interaction. They consist of both informal constraints (sanctions, taboos, customs, traditions, and codes of conduct), and formal rules (constitutions, laws, property rights). Throughout history, human beings devised institutions to create order and reduce uncertainty in exchange, either consciously or by cultural evolution. Together with the standard constraints of economics they define the choice set and therefore determine transaction and production costs and hence the profitability and feasibility of engaging in economic activity. They evolve incrementally, connecting the past with the present and the future; history in consequence is largely a story of institutional evolution in which the historical performance of economies can only be understood as a part of a sequential story. Institutions provide the incentive structure of an economy; as that structure evolves, it shapes the direction of economic change towards growth, stagnation, or decline."

Economics, as the study of how men and society choose to employ scarce productive resources, is therefore primarily the study of institutions. A market is one example for an institution, a firm is a second, and centralized government planning is a third. The study of the properties of different institutions will help develop an understanding of how they function (positive science), to what extent they alleviate scarcity, and how they distribute goods, services, and resources (positive as well as normative science).

From a philosophical point of view, institutions are very peculiar. Searle (2010) reconstructs the ontology of institutions as a specific class of speech acts called "declarations." Humans possess "the capacity to impose functions on objects and people where the objects and the people cannot perform the functions solely in virtue of their physical structure. The performance of the function requires that there be a collectively recognized status that the person or object has, and it is only in virtue of that status that the person or object can perform the function in question." Institutions come into being by the repeated application of specific linguistic representations (declarations), and they cease to exist as soon as people no longer collectively recognize their status. They are, at the same time, epistemologically objective and ontologically subjective: there can be no doubt that an institution exists within a given convention, but the convention itself is, to a certain extent, arbitrary.

Take the convention or institution "Switzerland" as an example. There is a mutually recognized consensus that Switzerland exists, as a legal entity and as an institution; thus, it makes no sense for a single human being to deny its existence and act on its territory according to, for example, Russian law. In this sense, the institution "Switzerland" objectively exists. However, as soon as the people in Switzerland (and the rest of the world) deny that Switzerland exists, it actually ceases to exist, which makes it ontologically subjective. Its existence relies on a convention. This is different, for example, from the Matterhorn, which continues to exist even if seven billion people deny its existence; it is ontologically objective. The hybrid nature of institutions distinguishes them from most phenomena studied in the natural sciences: they are products of "shared fantasies." Property rights, as an integral requirement for markets, do not exist independently of human beings: their existence relies on a mutual consensus. The same is true for money, the state, firms, and so on. The most fundamental declarative speech act is language itself: there is nothing inherent in the ontological object "chair" that requires one to call it a chair: it could just as well be called a "Stuhl." The partition of phenomena, according to the rules of a language, has far-reaching implications for one's perception of reality.

Digression 2.4 (What Is Ontology and Epistemology?)
In philosophy, ontology is the study of "what there is," of the nature of being and reality. It studies problems concerning the entities that do exist and their properties. Examples of ontological questions include the following: *What is existence?*, *What is the nature of existence?*, and *What principles govern the properties of matter?*

Epistemology is the study of knowledge and justified belief. Questions that it addresses may include the following: *What are the necessary and sufficient conditions of knowledge?*, *How does one separate true ideas from false ideas?*, and *How does one know what is true?*

The specific ontology of institutions makes economics special among the sciences. In the words of Rosenberg (2013), "[u]nlike the physical world, the domain of economics includes a wide range of social 'constructions'—institutions like markets and objects like currency and stock shares—that even when idealized don't behave uniformly. They are made up of unrecognized but artificial conventions that people persistently change and even destroy in ways that no social scientist can really anticipate. We can exploit gravity, but we can't change it or destroy it. No one can say the same for the socially constructed causes and effects of our choices that economics deals with." This potential fluidity of institutions makes them inherently difficult to study. Here is an example: money relies on the social convention that people are willing to accept it as a medium of exchange, because it cannot directly be consumed. As soon as this convention starts to unravel, money loses its value; it is ontologically subjective. In order to have a reliable theory of money, economists cannot simply assume its existence; they have to identify the individual and group processes that determine its emergence and sustainability.

To summarize, the theory of comparative advantage can explain why people organize economic activities. They are organized by means of institutions, which is why economics is the study of such institutions. The major part of this book will be devoted to the analysis of markets as—together with democracy—the most prominent institution in bourgeois societies. However, it should be clear by now that markets are only one way to organize economic activities, among many others.

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Part II

A Primer in Markets and Institutions

Introduction

3

This chapter covers…

- the importance of property rights,
- the different forms of markets,
- the importance of "money" as a barter good,
- basic terminology that is useful in analyzing markets, and
- where economics and law meet.

3.1 General Remarks

The chapter on the theory of comparative advantage has revealed that the problem of scarcity can be alleviated, if individuals are willing to specialize according to their comparative advantages and then find a way to allocate goods and services that is mutually beneficial. I have further argued that this process cannot be expected to unfold without an adequate institutional "frame" within which specialization and exchange can take place. A *market* is one such institution; it is the most important institution that fosters specialization and exchange and is the foundation on which modern capitalist societies are built. Informally speaking, a market is a framework that allows potential buyers and sellers to exchange goods, services, and information.

In order to make these transactions possible, a market relies on *private property rights* and *contract law*. Property rights define individual spheres of control over objects and they allow individuals to determine in which ways these objects shall be used and thus create a distinction between "mine" and "yours." Without such a distinction, it would be impossible to establish markets and trade, because it would be unclear who has the right to control and use these objects. Property rights can be absolute, giving the owner of an object the freedom to use it in any way he/she wants, but in most societies there are socially agreed-upon restrictions on the use

M. Kolmar, *Principles of Microeconomics*, Classroom Companion: Economics,
https://doi.org/10.1007/978-3-030-78167-5_3

of one's property. Restrictions may occur, if some uses impede on the well-being of others or are in conflict with moral values.

An important example of objects for which many countries have constrained the rights of the owner is the ownership of land, which is called real estate or immovable property. Land development, types of uses and the architecture of buildings are subject to constraints and regulations, and some countries limit individual rights even further by preventing them from using real estate in the way most preferred by the owner (for example, by construing the right to abandon one's buildings). Therefore, it is more adequate to think of property rights as those user rights that society leaves to the formal owner. The technical term for these rights is *residual control rights*.

Digression 3.1 (Property-Rights Enforcement)
It is vital to distinguish between the mutual recognition and the enforcement of property rights. People are used to thinking of property-rights enforcement as a centralized activity delegated to "the state." An important proponent of this view was Weber (1988/1919), who observed that the modern state has monopolized the legitimate use of force. According to this point of view, the state provides for public enforcement and, with a few exceptions like self-help, limits private enforcement of property rights. This has not always been the case. The private enforcement of rights has been of considerable importance historically, for example, in late medieval Europe. The development of the code of conduct called "Lex Mercatoria," in the eleventh and twelfth century, is seen as one of the key factors for the economic success of Europe, which arched over into the Renaissance. This helped to overcome the limited possibilities of centralized law enforcement in a politically fragmented Europe. According to Berman (1983), "[t]his legal system's rules were privately produced, privately adjudicated, and privately enforced." The system became effective exactly because medieval Europe was plagued by a maze of fragmented states, whose rulers more closely resembled self-interested elites. In certain respects, the situation in medieval Europe looks similar to the situation of the globalized economy of today, where multinational firms are confronted with nation states that lack a centralized agency, which enforces contracts.

The fact that markets rely on property rights implies that every transaction on a market has a "physical" and a "legal" side. The physical side of a transaction is the exchange of goods, services, or information (I will henceforth speak of goods and services, implicitly assuming that information can be interpreted as a specific kind of service), whereas, from a legal perspective, a transaction is an exchange of rights. In order to be able to exchange rights, it is necessary to specify the conditions under which such a transaction is binding. An exchange of rights is specified in a *contract* and the rules that apply to the establishment of such contracts are specified in a society's *contract law*.

Digression 3.2 (Self-Ownership)
An often bypassed constituent element of private property is *self-ownership*, which is an important virtue and achievement of modern bourgeois society. Self-ownership excludes serfdom and slavery and is a necessary prerequisite for ownership rights over objects in the outside world. It is also important for the establishment of transactions of services like, for example, the time and expertise a person offers on labor markets. Usually, a labor contract specifies the duties of the employer as well as of the employee. Self-ownership makes these contracts possible and, at the same time, defines limits to contractual freedom, because it, for example, prohibits a person from voluntarily selling himself/herself into slavery.

The very brief discussion of the institutional prerequisites for a market economy—private property as residual control rights plus contract law—reveals that there is a close relationship between the legal and economic aspects of the study of markets. The civil law of a society implicitly defines the extent to which markets can develop and what they can achieve, while the economic analysis of the functioning of markets can inform the legal scholar about the likely consequences of legal rules. The importance of the interaction between a legal and an economic perspective is reflected in the fact that a whole field of analysis called "Law and Economics" has emerged, which is devoted to the analysis of the relationship between legal rules, individual behavior, and societal outcomes.

Assume that a society has established a system of private property rights, which assigns residual rights of control over objects to individuals and contract laws, which specify the conditions under which the ownership of rights can be transferred. The individuals can now start to exchange these rights, given the rules specified in contract law. The rights-based approach to markets is straightforward but, at the same time, may be a little bit too abstract to define a good or service as any (bundle of) right(s) an individual may be interested in buying or selling. These rights can be anything from the right to eat an apple to the right to acquire a share in a company 12 months from now, if the share price is above a certain threshold.

Basically, there are two ways to establish trade. In a *barter economy*, goods and services are exchanged for other goods and services, like two apples for a loaf of bread. Most modern societies, however, rely on an abstract medium of exchange: money. At this point, it is not necessary to explicitly distinguish between economies that barter and economies that use money as a medium of exchange. It makes sense, however, to discuss the "nature" of money in the following digression.

Digression 3.3 (Money)
One of humanity's major achievements has been the invention of an abstract medium of exchange for facilitating the exchange of goods or trade. This medium of exchange is called money. Money is traditionally regarded as having three functions: it acts as a medium of exchange, a unit of accounting, and a means of storing value.

Given that most people grew up in societies where money is almost as pervasive as the air we breathe, it is easy to oversee three really peculiar aspects of money. First, compared to a barter economy where transactions can only take place if the supply and demand of two individuals perfectly align (which is called the "double coincidence of want"), the use of money dramatically facilitates this exchange, because it no longer depends on this coincidence.

Second, given that money has no intrinsic value and merely represents an abstract promise to be convertible into directly useful goods and services in the future, it is a convention in the sense of Searle, see Chap. 2. Thus, its invention relies on abstract thinking and trust (it most likely evolved from debt certificates) and the historic development of money shows people's increasing ability of thinking in abstract ways about the use and nature of money. The step from gold and silver coins (used by Lydians around 500–600 BCE) to paper money (from the seventh century CE in China to the thirteenth century CE in Europe), and then from Banknotes backed by Gold (Bretton–Woods System) to unbacked money, and finally to a perfectly abstract unit of exchange in the digital age shows an increasingly abstract way of thinking.

Third, in opposition to directly useful goods and services, the value of money results from a social convention. Money has value only insofar as people are willing to accept it as a medium of exchange. This explains why the value of money, and of currencies, is inherently fragile, because the value of banknotes and coins (and, even worse, of purely abstract forms of money) drops to almost zero (which is an extreme form of inflation) as soon as people lose faith in its future value and start rejecting it as a medium of exchange, despite the fact that everyone would be better off, if money was accepted.

Assume that an exchange rate between goods and services, or a monetary price, exists. In the case of money, a person who is willing to give away (some of) his/her residual rights of control in exchange for the given price is called a *seller* of these rights (and the associated goods and services), while a person who is willing to acquire (some) residual rights of control from another person, in exchange for the given price, is called a *buyer*. The example of a barter economy, where one good is necessarily exchanged for another, makes it clear that a person is necessarily a buyer and a seller at the same time, because he/she has to give up apples for potatoes or *vice versa*. This reciprocity of supply and demand carries over to monetary economies, if one reminds oneself that money is an abstract promise to acquire goods and services in the future and, therefore, a bundle of rights. Thus, buying apples for money means that one person acquires control rights over apples (buyer) and the other gives up control rights over future consumption (seller). Hence, one should bear in mind that any transaction in a market is necessarily complemented by a transaction on some other market.

3.2 Taxonomy of Markets

The remainder of this book will take the existence of property rights and contract law as given and develop a taxonomy of different markets. Table 3.1 gives an overview of the most important market structures. It is common to distinguish supply and demand according to the number of buyers and sellers on a market. It is also customary to distinguish between one buyer or seller, a few buyers or sellers, and many buyers or sellers. This taxonomy defines nine prototypical market structures, each one with its own distinctive, functional logic. First of all, one should focus on the three market structures that will be analyzed in greater detail in the following chapters: polypoly, oligopoly, and monopoly.

A polypoly has many buyers and sellers of a homogenous good or service. Goods or services from different suppliers are called *homogenous*, if the potential buyers are not willing or able to distinguish between them and, therefore, consider them as perfectly interchangeable. The term "many" has a specific meaning in this context, as well. It refers to a situation where each buyer or seller considers his/her influence in the market so negligible that he/she does not have any influence on the market price. The buyers and sellers are therefore *price takers*, and the market is also called *perfectly competitive*. A market with perfect competition is the workhorse model for a lot of problems analyzed by economists, ranging from the determination of market prices to the effects of taxes and to the determinants of international trade. In addition, this market is relatively easy to analyze, which is why our analysis of market economies starts with this case. Examples for markets that approximate perfect competition are:

- Some agrarian resources, like wheat, approximate perfect competition, because an international commodities market exists for these approximately homogenous resources, which implies a large number of producers (farmers) and buyers.

Table 3.1 Taxonomy of market structures

	Buyers		
Sellers	One	Few	Many
One	Bilateral monopoly	Restricted monopoly	Monopoly
Few	Restricted monopsony	Bilateral oligopoly	Oligopoly
Many	Monopsony	Oligopsony	Polypoly

- The stock exchange is, in principle, also a good example for a competitive market, but one has to be cautious, because of institutional investors who can, generally, influence prices.

However, for reasons that will become apparent later on, not many markets can be adequately described as polypolistic. The reason why economics textbooks still focus on a market structure that is apparently unrealistic or not very common is because its simplicity allows one to understand fundamental properties of market transactions. Furthermore, it also acts as a reference point for more complicated markets. More realistic markets, like monopolies or oligopolies, are more complex to analyze but, fortunately, the additional complexity is relatively easy to digest because it is, in a sense, additive: the functioning of the most basal monopolistic market can be analyzed using the understanding derived from competitive markets, plus additional layers of complexity.

These additional layers of complexity exist because the seller on a monopolistic market understands that he/she is the only seller of a specific good or service, which gives him/her a certain leverage to influence prices. Hence, the assumption of price-taking behavior is no longer adequate and one has to understand how this additional factor influences supply and demand. The first known mention of a monopoly goes all the way back to Aristotle who, in his "Politics," describes the market for olive presses as a monopoly. More recently, De Beers had a monopoly in raw diamonds before countries like Russia, Canada, and Australia emerged as alternative distributers of diamonds. Public utilities that maintain infrastructures like electricity, water, sewage, etc. usually also have regional monopolies.

On the same note, the functioning of the most basic oligopolistic market can be analyzed using the understanding derived from monopolistic markets, plus yet another layer of complexity. With only a few suppliers, each of them has, in principle, some control over prices, but they have to take their competitors' likely behavior into consideration. Such strategic considerations are not necessary in monopolistic markets, because there are no competitors. They are also obsolete in perfectly competitive markets, because no supplier is able to influence the market. This is no longer the case with a limited number of competitors, because the optimal behavior of one supplier, in general, depends on the behavior of his/her competitors. This situation is defined as *strategically interdependent* and an analysis of markets with strategically interdependent decisions will be the capstone of this introductory textbook. Formally, an oligopoly is a market where a limited number of suppliers sell homogenous goods. Here are some examples:

- The grocery market in Switzerland is dominated by Coop and Migros.
- The market for wireless telephone services in Switzerland is dominated by Swisscom, Sunrise, and Salt.
- The worldwide accountancy market is dominated by PriceWaterhouseCoopers, KPMG, Deloitte Touche Tohmatsu, and Ernst & Young.
- The worldwide aircraft market is dominated by Boeing and Airbus.

Bearing the increasing complexity of different market structures in mind, the structure of the following chapters is straightforward: they start with a relatively simple market structure that is easy to understand, continue with a market structure that better describes a lot of markets that one is confronted with on an almost daily basis and that is of moderate complexity, and finish with the most complex market structure.

The taxonomy in Table 3.1 encompasses not only three, but nine market structures. Even if I only explicitly cover the above-mentioned three in this introductory textbook, I will discuss the other structures' peculiarities briefly.

Monopsonistic and oligopsonistic markets are mirror images of monopolistic and oligopolistic markets and the main insights that can be derived from the latter can also be applied to the former.

A bilateral monopoly, however, confronts one with a totally different situation, because both sides of the market possess some market power, which derives from the fact that the trading partner cannot fall back on some other identical alternative, if trade does not take place. Such a situation arises because manufacturers and suppliers often customize their production processes and products to the needs of their trading partners, with the result that the manufacturer cannot sell the tailored products at the same price to other trading partners and the trading partner has difficulties in finding adequate substitutes on the market. Here are some additional examples:

- Collective bargaining agreements (CBAs) between labor unions and (especially large) companies or employers' associations,
- highly specialized scientists and their employers (e.g., pharmaceutical companies and their lead scientists; both would have difficulties finding adequate alternatives, at least in the short run),
- governments and some of their defense contractors (an extreme example is the market for nuclear-powered aircraft carriers, where the US government is the only buyer and Huntington Ingalls Industries is the only seller), and
- marriage (think about it: dissolving a partnership is costly, so, even if one thinks that one has found an even better match, one may decide not to dissolve it).

Analytically, the challenge lies in understanding the factors that influence the success of the resulting bilateral negotiations and the distribution of the potential gains from trade between the buyer and the seller. The field of research that analyzes these questions is called *bargaining theory*.

The three remaining market structures, bilateral oligopoly, restricted monopoly and restricted monopsony, are far less studied. The basic challenge in understanding the functioning of these markets, and the corresponding optimal strategies, is how varying degrees of competitiveness influence the bargaining power of a single buyer or seller. An example is the retail industry in Germany: historically, the supply side was concentrated and the demand side was rather competitive in the corresponding markets, but demand-side concentration greatly increased over the last 40 years or so. This trend towards concentration was reinforced by the formation of buyer groups.

Another commonly analyzed market form, which does not appear in Table 3.1, is called *monopolistic competition*. The model of monopolistic competition blends elements from the monopoly with elements from the polypoly model. Basically, it is assumed that firms behave like monopolists and that firms can produce similar, but not identical, products. A good example is the market for sports utility vehicles (SUVs), where each major car company sells its own variant of SUV. All of them are similar, but a lot of customers have their favorite brands. The model of monopolistic competition is very useful, if one is interested in determining the number of competitors that a market can sustain.

The above line of argumentation assumes that the number of buyers or sellers has an important influence on the functioning of a market and one will get a deeper understanding of this conjecture throughout the following chapters. However, there are two questions that should come to mind at the present stage. First, it is unclear what determines the market structure. Is it possible to organize markets for arbitrary goods and services at will, or are there underlying explanatory factors that determine whether a specific good or service is traded on a perfectly competitive or on a monopolistic market, or on a completely different one? Second, how many are "few" and how many are "many?" If the dividing line between few and many is important for the functioning of a market, it would be helpful if one could attach a number to this question.

An exhaustive answer to these questions is beyond the scope of an introductory textbook, but the following chapters will shed a little light on the subject. Regarding question one, economists usually distinguish between markets and industries. An industry is a sector of the economy that produces a specific type of good; it is better characterized by the technological way of production that summarizes the physical, biological, and chemical laws that convert the resources needed for production (inputs) into products (outputs). This relationship between inputs and outputs is also called the *technology of production*.

As Chap. 12 illustrates, industries differ with respect to the laws linking inputs with outputs and these laws have an important influence on the possible market structures. Furthermore, the perception of goods and services by the "buyers" (customers) has a direct impact on the market structure. If they can, or are willing to, distinguish between, for example, red wine and white wine, all producers of red wine are in the same market for "red wine." If the customers, however, distinguish between different types of grapes, region of origin, producer, or even characteristics of the vineyard, the market for red wine explodes into a plethora of differentiated markets, where even small local producers may have the market power to influence prices. I will discuss this phenomenon further in Chap. 14. Last, but not least, the legal framework determines market structures. Most countries have, for example, a competition law, the purpose of which is to guarantee a minimum degree of competitiveness on each market, thereby excluding monopolies. However, the opposite can be true as well: patent law, for example, grants the patent holder a temporarily restricted monopoly for those products that can be developed from his patent. In summary, market structure is not completely arbitrary, but it depends, in a complex way, on the technology of production, the perception of goods and services by customers, and the legal framework.

With respect to the second question, the answer is even more difficult. Remember that the dividing line between "few" and "many" is the perception of one side of the market that the price is *de facto* given. There are industries for which two sellers or two buyers are "many" (there is an example in Chap. 15), and other industries, where a much larger number of competitors is necessary to more closely approach price-taking behavior. Experiments for the so-called Cournot markets have shown that the magic number seems to be between two and four.

With these prerequisites, it is now time to analyze the functioning of the first type of market: a market with perfect competition.

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Supply and Demand Under Perfect Competition

4

This chapter covers …

- the functioning of competitive markets as one way of organizing economic activities.
- how supply and demand can be determined, how they can be used to predict market behavior and the effect changes have in the economic environment on economic outcomes.
- how to apply the theory of competitive markets in order to better understand the economy.

4.1 Introduction

> From the time of Adam Smith's Wealth of Nations in 1776, one recurrent theme of economic analysis has been the remarkable degree of coherence among the vast numbers of individual and seemingly separate decisions about the buying and selling of commodities. In everyday, normal experience, there is something of a balance between the amounts of goods and services that some individuals want to supply and the amounts that other, different individuals want to sell. Would-be buyers ordinarily count correctly on being able to carry out their intentions, and would-be sellers do not ordinarily find themselves producing great amounts of goods that they cannot sell. This experience of balance is indeed so widespread that it raises no intellectual disquiet among laymen; they take it so much for granted that they are not disposed to understand the mechanism by which it occurs. (Kenneth Arrow, 1974)

This chapter will start with a basic initial analysis on the functioning of competitive markets. One may remember, from the last chapter, that everyone acts as a buyer and a seller simultaneously. I buy groceries and other consumer goods in the local stores or on the Internet and, in turn, sell my time and expertise to my employer. In order to have a lean terminology, it is therefore necessary to interpret buyers and sellers as artificial roles, both of which one adopts, depending on the good or service one

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is considering. For the purposes of this book, the terms seller, firm, and company as well as buyer, consumer, and customer will be used interchangeably, keeping in mind that not only firms sell and that not only (end-) consumers buy goods and services.

The two most fundamental concepts in the analysis of markets are supply and demand. These measure the quantity of a given good or service, which customers are willing to buy and firms are willing to sell at a given market price, as well as other explanatory factors like income, expectations about the future, prices of resources, and so on. In order to be able to study the functioning of perfectly competitive markets, one has to develop theories that explain the market's demand-side and its supply-side, as well as the interaction between the two sides.

4.2 Determinants of Supply and Demand

In order to be able to create these theories, one has to distinguish between the demand of a single individual (one's demand of apricots) and market demand (the demand of all individuals, who buy apricots in Switzerland). On that note, one also has to distinguish between the supply of a single firm (the supply of apricots in one's local grocery store) and market supply (the supply of all firms selling apricots in Switzerland).

Given that this chapter is a primer in competitive markets, it will motivate supply and demand heuristically by means of plausibility considerations. A full-sized microeconomic theory of markets replaces these plausibility considerations by a decision-theoretic foundation, which traditionally assumes that individuals can rank alternatives according to their preferences and determine demand and supply by choosing the most highly ranked alternative available. This kind of decision-theoretic foundation of supply and demand is, from a scientific point of view, preferable. However, it comes at the cost of added complexity, so it makes sense to skip it during our first passage through the logic of competitive markets. We will develop the underlying decision theory in Chaps. 7, 8 and 10 and 11.

Demand One can start this endeavor with the analysis a single customer's demand for a given good. Assume that there are n goods in total among which a customer, j, can choose. n is a natural number larger than 1, and the goods are numbered $1, 2, \ldots, n$.

- It is reasonable to assume that the quantity of the good i (kilos of apricots), x_i^j, demanded by customer j most likely depends on the price of the good, p_i (CHF per kilo), as well as on the prices of other goods $p_1, p_2, \ldots, p_{i-1}, p_{i+1}, \ldots, p_n$ (for example, the price for a kilo of pears, as well as the price for a kilo of bread).
- In addition to prices, other factors will also likely influence demand. A prominent candidate is the customer's income or wealth, b^j (for budget, which is the amount of money the customer can spend on purchases).

- On a more profound level, the demand is also influenced by the customer's tastes, which are called the customer's preferences. Different customers may have different preferences and they, of course, have an influence on the demand for goods. A vegetarian will spend nothing on meat, an outdoorsy person will spend part of her budget on hiking boots and other outdoor equipment, etc.
- The last factor, which is likely to influence the customer's demand for some good i, is her expectations for the future. They include expectations about general economic development, life expectancy, career perspectives, and so forth. For example, expectations about the impact of climate change may influence a person's consumption pattern, leading to more environment-friendly choices. Alternatively, the expectations about the future innovative drive of different companies may influence her investment strategy.

This list is not meant to be exhaustive, but it summarizes some of the key explanatory factors for individual demand. Hence, this is a formulation of the first causal hypothesis that will play an important role in the model of the competitive markets that are going to be developed: prices, budget, preferences, and expectations are the *explanatory* or *exogenous* variables, whereas individual demand is the *explained* or *endogenous* variable. Neglecting preferences and expectations for the rest of this chapter, one can write this causal hypothesis of the demand of customer j for good i in the form of a mathematical function $x_i^j(p_1, \ldots, p_n, b^j)$. This complicated piece of notation has the following interpretation: the quantity of the good that is demanded by the customer, x_i^j, is explained by all the prices, $p_1, \ldots, p_n$, and income, b^j. A function of several variables is, therefore, a straightforward extension of a function with one variable, which a college student should know from high-school. The premise of competitive markets, in which all buyers are too small to influence prices, is reflected in the fact that prices are explanatory variables and, therefore, independent of the behavior of the customer.

Table 4.1 shows the demand of customer A, Ann, for apricots based on different prices of apricots. Ann would buy two kilos, if the price were CHF 6 per kilo, and her demand would increase to 6 kilos, if the price were to sink to CHF 2 per kilo. Why should the demand go up, if the price goes down? It could, for example, be that

Table 4.1 Ann's demand schedule

p_i	x_i^A
0	8
1	7
2	6
3	5
4	4
5	3
6	2
7	1
8	0

a reduction in the price of apricots induces a change in behavior, because Ann likes different types of fruit equally well and, therefore, decides to save some money by going for the, now, relatively cheaper ones, and substituting, for example, cherries with apricots.

This table is called an *individual demand schedule* and it is a perfectly sound way of representing demand. However, this kind of a table places a heavy load on one's cognitive resources, which is why economists usually analyze demand through the use of a graph.

Figure 4.1 is a graphical representation of the demand schedule in Table 4.1. This figure has the good's price on the ordinate and the quantity demanded on the abscissa. It is easy to verify that the *individual demand function*, $x_i^A(p_i)$, summarizes the same information as the demand schedule.

One will have noticed by now that economists have an apparently odd convention regarding the axes of the diagram. Most students learned in school that the explanatory variable is drawn along the horizontal axis, and the explained variable is drawn along the vertical axis. If this is the case, the opposite convention used by economists will likely drive one crazy during the first few weeks. However, economists have a good reason for this deviating convention: from the point of view of a customer, the price is given. However, what one is ultimately interested in is the determination of prices by the interplay of supply and demand. Thus, the determination of supply and demand is only an intermediate step on one's way towards understanding the market. In the end, the "old" convention will hold again.

In order to determine prices, however, one needs an additional intermediate step that brings one from individual to market demand. Table 4.2 shows A's as well as

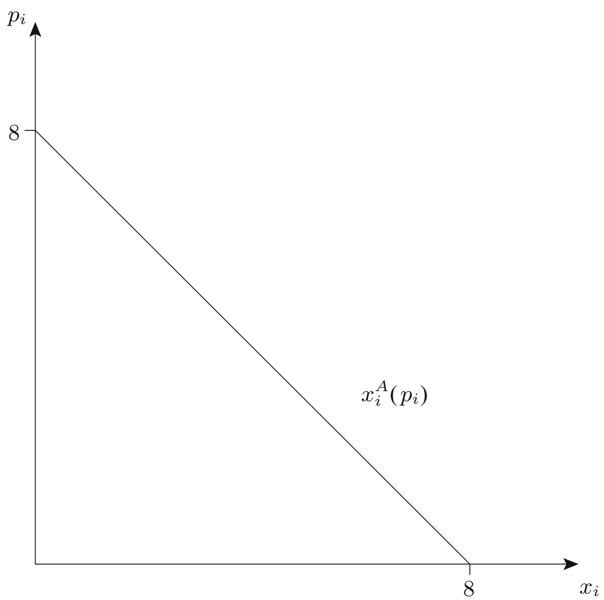

Fig. 4.1 Ann's demand curve

Table 4.2 Ann's and Bill's demand schedules

p_i	x_i^A	x_i^B	x_i
0	8	10	18
1	7	8	15
2	6	6	12
3	5	4	9
4	4	2	6
5	3	0	3
6	2	0	2
7	1	0	1
8	0	0	0

B's (Bill's) demand for apricots. Assuming that A and B are the only customers, one can get from the individual demand schedules to the *market demand schedule* by adding up the individual demands for each price. Market demand is shown in column four.

It is, of course, also possible to analyze market demand by the use of demand functions, as one can see in Fig. 4.2. In this figure, $x_i^A(p_i)$ and $x_i^B(p_i)$ denote Ann's and Bill's demand functions. In order to get from there to the *market demand function* one has to add both demand functions horizontally (i.e., look for the total demand for every possible price). The market demand function is the bold kinked line denoted by $x_i(p_i)$. The kink results from the fact that only Ann is willing to buy apricots, if the price is between CHF 8 and CHF 5.

One can express the same relationship formally. Denote A's and B's demand for good i (apricots, in this example) by $x_i^A(p_1, \ldots, p_n, b^A)$ and $x_i^B(p_1, \ldots, p_n, b^B)$. Then the market demand function for good i can be denoted as:

$$x_i(p_1, \ldots, p_n, b^A, b^B) = x_i^A(p_1, \ldots, p_n, b^A) + x_i^B(p_1, \ldots, p_n, b^B).$$

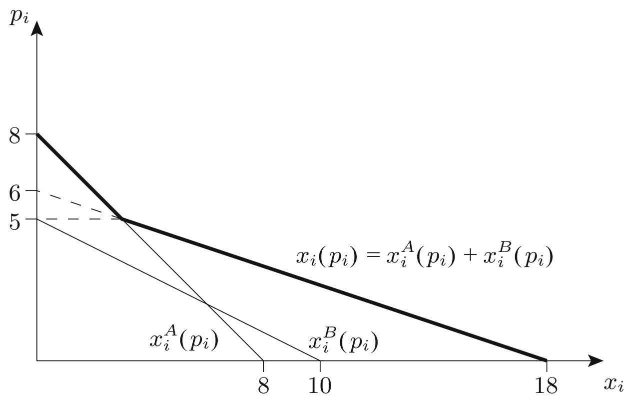

Fig. 4.2 Ann's and Bill's demand curves and market demand

Realistically, there are more than two customers for a good in the economy, but the same logic applies to the general case. Assume that there are m customers in total, where m is a natural number, and that j is a generic customer with demand function $x_i^j(p_1, \ldots, p_n, b^j)$. In this case, market demand for good i is

$$x_i(p_1, \ldots, p_n, b^1, \ldots, b^m) = \sum_{j=1}^{m} x_i^j(p_1, \ldots, p_n, b^j).$$

Now that one has defined individual and market demand, one can introduce some terminology, which will allow one to describe the different causal mechanisms that link explanatory and explained variables that can be formulated for individual, as well as market, demand. One defines them for an individual j. These mechanisms are described with respect to the induced *changes* in demand, which are caused by changes in the explanatory variables. This kind of exercise is called *comparative statics* and lies at the heart of economics as a positive science. The reason why it is so important, is because most of the testable predictions of economic theory are predictions about *changes* in empirically identifiable endogenous variables, caused by changes in empirically identifiable exogenous variables. The *absolute* value of a variable, like demand, is often irrelevant and the models can usually be tailored to meet the empirical patterns. However, *changes* in variables are often more robust and are, therefore, the only means to falsify a theory. The ability to produce falsifiable hypotheses is crucial for Critical Rationalism, which is the mainstream philosophy of science in economics, and is why comparative statics plays such an important role. However, even more than that, most economic-policy questions are also about the effects of changes in taxes, regulations, and so on; or on changes in employment, production, and so forth.

▶ **Definition 4.1 Ordinary Goods** A good, i, is called ordinary, at given prices and budget, if the demand for that good, x_i^j, decreases with its price, p_i.

Note that this property is defined as a local one, if it holds for a given combination of explanatory variables. A good can be ordinary at some prices and incomes, and not ordinary at others. The basic idea behind Definition 4.1 is that, if the price increases, the demand decreases; this is the most common type of good. However, this need not be the case and there are a lot of empirical examples showing that the demand for a good can be increasing with its price. Examples for goods that are not ordinary are those that are primarily purchased to signal status, but are otherwise of limited intrinsic value (they have to be expensive to function as a status symbol) or goods whose prices are interpreted as a quality signal by the customers. These goods are called Giffen goods, named after Robert Giffen, who studied this phenomenon.

▶ **Definition 4.2 Giffen Goods** A good, i, is called a Giffen good, at given prices and budget, if its demand, x_i^j, increases with its price, p_i.

▶ **Definition 4.3 Normal Goods** A good, i, is called normal, at given prices and budgets, if the demand for that good, x_i^j, increases with an increasing budget, b^j.

The name "normal good" is also suggestive, because it seems intuitive that individuals will buy more of a good, if they get richer. However, there are important exceptions from this rule, especially cheaper goods of perceived low quality that will be substituted by higher-quality goods (as perceived by the customer), if she gets richer. Examples are cheap food that is replaced by high-quality food, or cheap used cars that are replaced by more expensive new ones. These goods are covered by the next definition.

▶ **Definition 4.4 Inferior Goods** A good, i, is called inferior, at given prices and budgets, if the demand for that good, x_i^j, decreases with an increasing budget, b^j.

The next definitions describe the relationship *between* different goods:

▶ **Definition 4.5 Substitutes** A good, i, is called a substitute for good k, at given prices and budgets, if the demand for that good, x_i^j, increases with an increase in price p_k.

An intuitive example for two goods that are substitutes is two different, but similar, types of wine. If the price of, for example, Chianti goes up, the customer substitutes it with Barolo. (Bear in mind, however, that the example may or may not be correct for a given customer: it is ultimately an empirical question whether she is willing to substitute one type of wine for another.) However, a different relationship is also possible:

▶ **Definition 4.6 Complements** A good, i, is called a complement for good k, at given prices and budgets, if the demand for that good, x_i^j, decreases with an increase in price p_k.

If one has ever wondered why shoes are sold in pairs, the concept of complementarity gives one a clue: for most people, left and right shoes are perfect complements: they always need a pair of them. If they were sold separately, an increase in the price of left shoes would reduce the demand for right shoes and *vice versa*. Another example for two goods that are complementary is printers and toner, because one can only print, if one has both.

Table 4.3 summarizes the comparative-static effects.

With these definitions, one can now analyze the demand-side of the market. This is done graphically and, in order to do, one sticks to the convention that the price of a good is drawn along the ordinate and its quantity along the abscissa. In order

Table 4.3 Overview over the comparative-static effects of an increase in explanatory variables

	Demand goes up	Demand goes down
Increase in income	Normal	Inferior
Increase in own price	Giffen	Ordinary
Increase in other price	Substitute	Complement

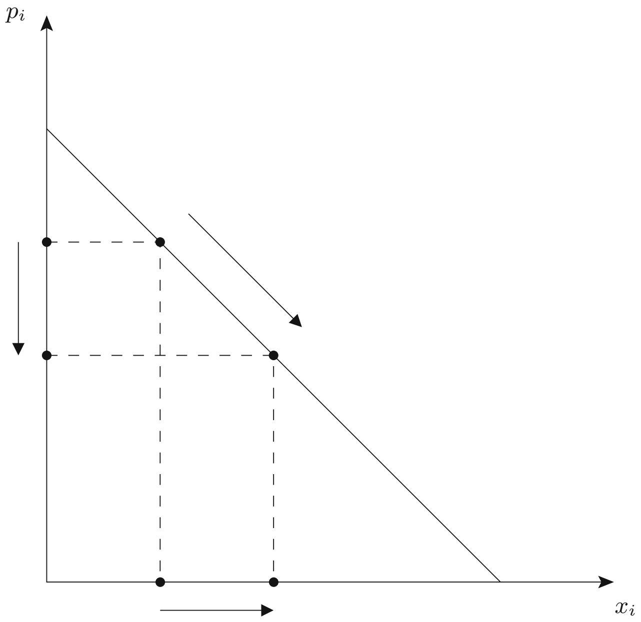

Fig. 4.3 A movement along the demand curve: a change in the explanatory variable, which is displayed in the figure, leads to a movement along the curve

to be able to isolate the effects of a single explanatory variable on an explained variable, economists decompose complex changes in the explanatory variables into simple ones, where the effect of each explanatory variable on the explained variable is analyzed separately (*comparative statics*), and the possible, comparative-static experiments for our model are changes in the price of the good, changes in the price of other goods and changes in income. A change in the price of the good can be analyzed by a movement *along* the demand curve, as illustrated in Fig. 4.3.

Changes in the prices of other goods or income have an influence on the *location* of the demand function. There are two potential effects: a rightward or a leftward shift of the demand function. Both are illustrated in Fig. 4.4.

Please verify that the demand for the good shifts outwards (inwards), if

- the good is normal and income goes up (down),
- the good is inferior and income goes down (up),
- the price of a substitute good goes up (down), or

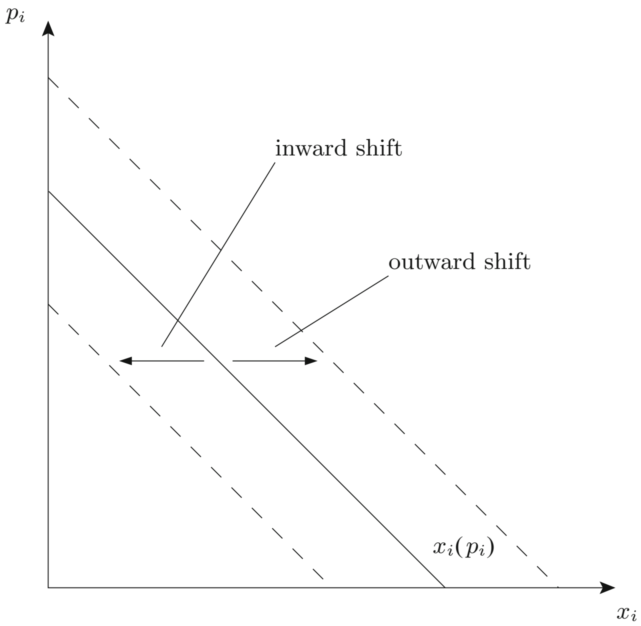

Fig. 4.4 A shift of the demand curve: a change in an explanatory variable, which is not displayed in the figure, leads to a rightward or leftward shift of the curve

- the price of a complementary good goes down (up).

Given the comparative-static effects covered by the definitions, this list gives one a comprehensive overview of the possible effects. The art and craft of economics is to identify situations that can be analyzed as price or income changes. An increase in income taxes, for example, decreases the disposable income of the individual. The economic effects on the goods markets can, therefore, be analyzed as if the individual's income had decreased. Alternatively, rising immigration to a region might increase the market value of real estate, which implies that the landlords' incomes go up.

Before one can start to see how perfectly competitive markets work, the supply side has to be introduced, as well.

Supply The derivation of the individual and market supply functions follows the same steps as before, assuming that some good, i, is produced by a firm, j, of a total of h firms. What are the likely determinants of firm j's supply decision, y_i^j, (for example, kilos of apricots)?

- The price of the good p_i (CHF per kilo of apricots) is likely to have an influence on the quantity supplied.

- Furthermore, the good must be produced by the use of some resources (for the apricot example, land, labor, fertilizer, etc.). Hence, the price of these resources determines the profitability of the firm. These resources are also called *inputs*, whereas the quantity produced is called an *output*. Physical, chemical or biological laws causally link inputs and outputs. The production of goods requires all kinds of inputs, resources, and intermediate products. Economists customarily restrict attention to two generic inputs called capital and labor, whose quantities are denoted by k and l and whose prices (per unit) are denoted by r (which is the interest rate the firm has to pay per unit of capital for borrowing it on the capital market) and w (which is the wage rate the firm has to pay a worker per unit of labor).
- Given that the conversion of inputs into outputs follows the laws of physics, chemistry, and biology, the technology of production is also relevant for the supply decisions of the firm. For example, assume that a technological innovation makes labor more productive, thus increasing the output per unit of labor by 20%. In that case, production becomes more profitable, implying that the firm, *ceteris paribus*, is likely to produce more.
- Again, similar to the determination of demand, the supply of some good, i, is likely dependent on the firm's expectations for the future. If, for example, a firm determines the medium- to long-run production capacity of its plants, then it has to form expectations about future output and input prices, exchange rates (if part of the production shall be exported), and so on. The more optimistic the firm's expectations are, the more likely it is to invest in its capacity.

This heuristic allows one to formulate the second causal hypothesis for one's model of competitive markets: output and factor prices, technology of production, and expectations are the explanatory or exogenous variables, whereas firm supply is the explained or endogenous variable. As before, I will neglect all non-price variables for the rest of this chapter, such that one can write this causal hypothesis for the supply of firm j of good i in the form of a mathematical function, $y_i^j(p_i, w, r)$, which reads as: the supply of good i by firm j, y_i^j, is a function of (is explained by) the price of the good, p_i, and the prices of labor and capital, w, r.

Digression 4.1 (What Is Capital?)
Capital is a key concept in economics and the eponym of the economic system of *capitalism*. It, therefore, deserves some extra attention. The term goes back to the Latin word *caput*, "head," which is also the origin of *cattle*. This is important, because it casts light on two basic properties a resource must have in order to count as capital: the stock of cattle is moveable (which distinguishes it from land) and reproduces. Therefore, capital is any resource that is potentially mobile and bears an interest, if it is not immediately

(continued)

Digression 4.1 (continued)
consumed. Adam Smith defined capital as "[t]hat part of a man's stock which he expects to afford him revenue [. . .]."

The first resources economists had in mind when they used the term capital were livestock, machines, and other tools. However, over time, the concept got more abstract, covering other "interest-bearing" phenomena, as well. On a very abstract level, capital consists of resources that enhance a person's power when she uses her time to achieve her goals (Pierre Bourdieu, 1983). This idea is nicely exemplified by the closely related German words "Kapital" (capital) and "Vermögen" (capability, which stems from the Latin word *capabilis*, "being able to grasp or hold", but is translated as "assets" in the system of national accounts). One could say that capital is a resource that makes one capable of achieving a goal. (This idea is also reflected by the fact that wealth is counted as an asset, whereas capital is a liability, in the system of national accounts.)

Consequently, contemporary economists distinguish between three or four different types of capital: *physical, human, social, and symbolic*.

Physical capital corresponds to the traditional concept, including machines, tools, and so on.

Human capital refers to the skills of a human being that make him or her more productive in manipulating physical capital. It is the stock of knowledge that allows an individual to use his or her labor in a productive way.

Social capital refers to the network of friends that allows one to achieve one's goals. It is the stock of social bonds and relationships that helps one succeeding with one's plans and insures one against adverse events. For example, information disseminated in a network of friends may allow one to make better decisions, or one may profit from cooperative and altruistic behavior among friends. This has its roots in the preferential treatment group members can expect from each other.

Symbolic capital is a controversial concept, which is better established in sociology than in economics. It refers to the ability of an individual to achieve her goals because of honor, prestige, or recognition and it depends on the cultural norms and language games of a society. The concept allows one to better understand the role of cultural conventions and ideologies within societies and it, therefore, became important in gender studies. Here is an example why: cultural norms and language games impose categories of thought and perception upon individual social agents who, if they accept these categories unscrutinized, perceive the social order as legitimate. If women, for example, do not consider it appropriate to become CEOs of firms, they do not strive for these careers and, thereby, leave them to their male counterparts.

Sometimes, human, social, and symbolic capital are difficult to differentiate, and some definitions have social and symbolic capital, as in special cases of human capital.

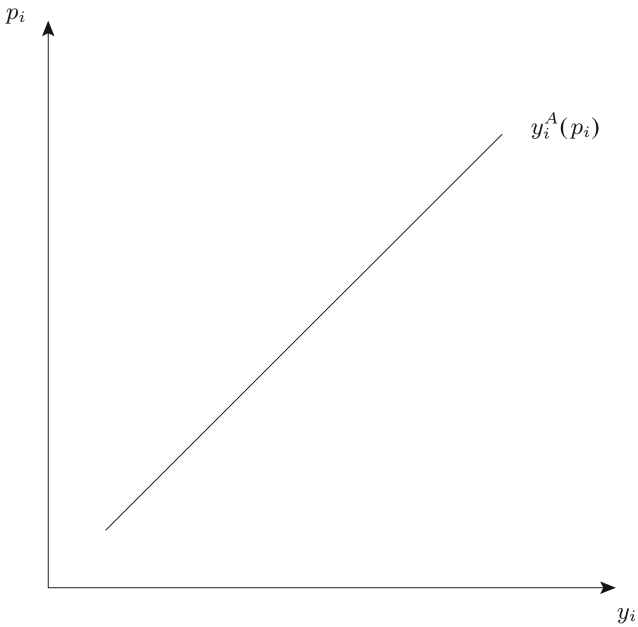

Fig. 4.5 Firm *A*'s supply curve

One can, in principle, analyze individual and market supply using supply schedules that are constructed analogously to the demand schedules introduced in the previous subchapter. Given that a demand or supply schedule is a rather cumbersome instrument for the analysis of markets and, given that this chapter has only introduced demand schedules as an intermediate step to motivate demand curves, one can immediately jump to individual and market supply functions.

Figure 4.5 is a graphical representation of the supply of firm *A* ("Alpha Limited") of some good *i*. As before, the figure has the price of the good on the ordinate and the quantity supplied on the abscissa.

The graph assumes that supply is increasing in the price of the good, which is a very intuitive assumption, because a higher price—holding all other factors constant—makes the good more profitable and encourages the firm to try to expand production. However, there may be situations where supply is not upward sloping, for example, in the short run, if a capacity constraint is binding. In the apricot case, farming company Alpha limited may not be able to buy or rent additional land to plant and harvest additional apricots, in the short run.

The final step that one has to take is to move from individual to market supply. Figure 4.6 shows *A*'s, as well as *B*'s (Beta Limited's), supply curves for apricots. Assuming that *A* and *B* are the only producers, one can get from individual to market supply curves in the following way: $y_i^A(p_i)$ and $y_i^B(p_i)$ denote Alpha's and Beta's supply functions. In order to get from there to the *market supply function*, one has

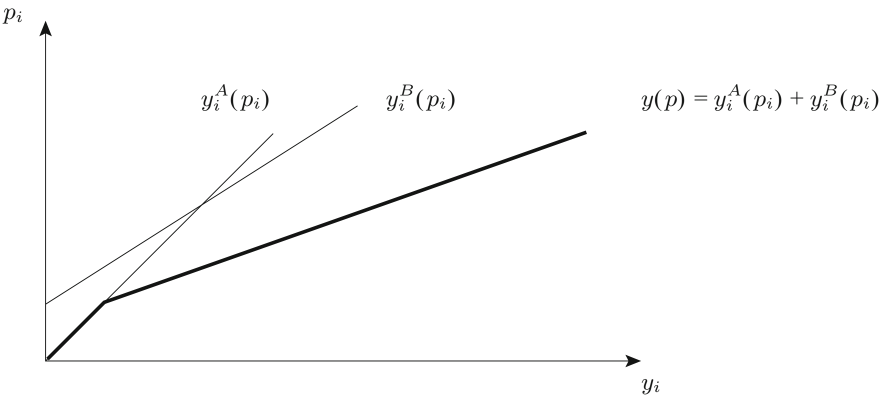

Fig. 4.6 Firm *A*'s and firm *B*'s supply curves and the market supply curve

to add both supply functions horizontally (i.e., look for the total supply for every possible price). The market supply function is the bold kinked line, denoted by $y_i(p_i)$. The kink results from the fact that only Alpha is willing to sell apricots, if the price is below a certain threshold.

Again, one can express the same relationship formally. Denote *A*'s and *B*'s supplies of good *i* by $y_i^A(p_i, r, w)$ and $y_i^B(p_i, r, w)$, then the market supply function for good *i* is

$$y_i(p_i, r, w) = y_i^A(p_i, r, w) + y_i^B(p_i, r, w).$$

This formulation implicitly assumes that both firms have access to capital and labor at the same input prices. If both firms hire on different capital and labor markets, they would likely face different interest rates and wages, which would then have to be reflected by firm-specific indices r^j and w^j. This situation is likely to be relevant, if the firms produce in different countries, like apricot farmers who produce in Switzerland and apricot farmers who produce in Italy and export to Switzerland.

If there are more than two firms producing a good, then market supply is the sum of all firms' supplies at a given market price. Thus, with a total of *l* firms, and *j* being a generic firm with a supply of $y_i^j(p_i, r, w)$, market supply for good *i* is given as:

$$y_i(p_i, r, w) = \sum_{j=1}^{l} y_i^j(p_i, r, w).$$

How do changes in input and output prices affect supply? In order to answer this question one follows the same steps as before and graphically analyzes this question in a figure where the price of a good is drawn along the ordinate and its quantity along the abscissa. A change in the price of the good can be analyzed by a movement *along* the supply curve (see Fig. 4.7).

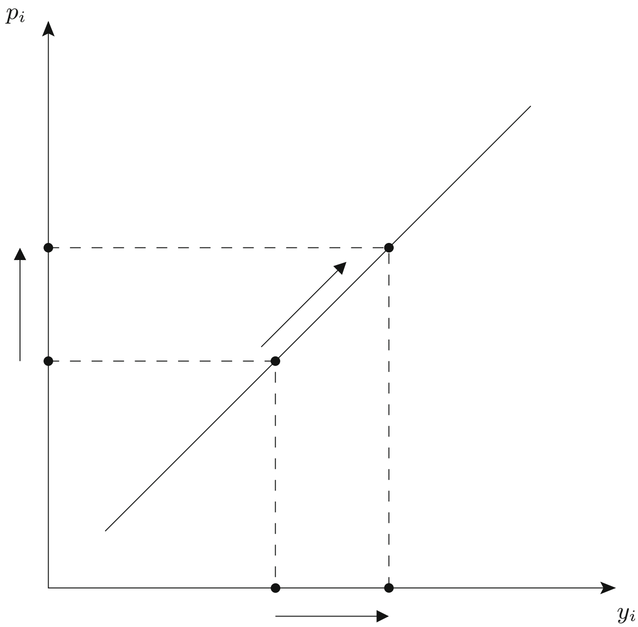

Fig. 4.7 A movement along the supply curve: a change in the explanatory variable, which is displayed in the figure, leads to a movement along the curve

Changes in input prices have an influence on the *location* of the supply curve and, again, it can either shift leftward or rightward, as illustrated in Fig. 4.8.

What are plausible conjectures about the effect of changing input prices? If production gets cheaper (more expensive), it is plausible to assume that firms will increase (reduce) production. If this is the case, one can summarize the potential effects as follows: the supply of the good shifts outwards, if wages or interest rates go down, and *vice versa*. As before, the tricky thing is to identify real-life situations that can adequately be described as changes in input prices.

The fact that this textbook has thus far included only output and input prices as explanatory variables in the formal definition of supply functions is a matter of convenience. There are, of course, other causal mechanisms that are likely to influence individual and, therefore, market supply. Expectations, as already discussed, are one example, but there are other influences as well. For example, a natural disaster may destroy part of the production capacity, which cannot be offset in the short run (supply shifts leftward), good weather conditions may increase the crop (supply shifts rightward), or technological progress may lead to an increase in output per unit of input (supply shifts rightward).

The same arguments can, of course, also be made for the demand side, which implies that a complete analytical description of demand and supply functions should include all those other factors. Call these explanatory variables

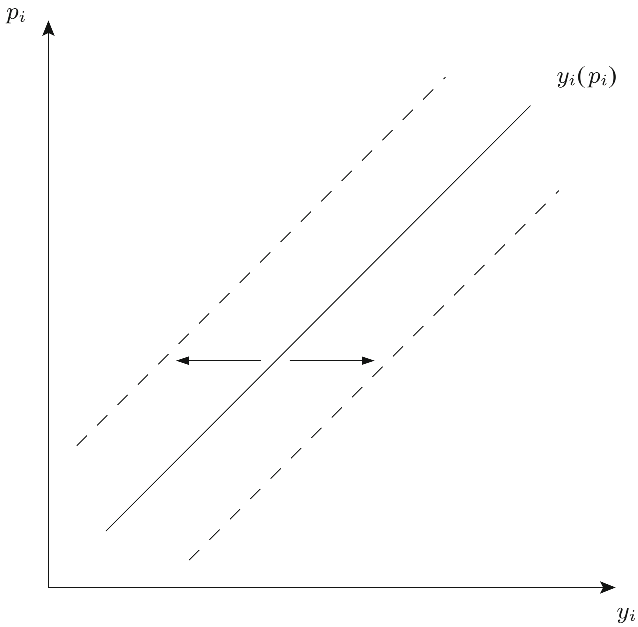

Fig. 4.8 A shift of the supply curve: a change in an explanatory variable that is not displayed in the figure leads to a right- or leftward shift of the curve

$\alpha, \beta, \gamma, \ldots$ and suppose that all customers have identical budgets b. Market supply and demand for good i could then be written as $y_i(p_i, r, w, \alpha, \beta, \gamma, \ldots)$ and $x_i(p_1, \ldots, p_n, b, \alpha, \beta, \gamma, \ldots)$. Specifying the most interesting causal mechanisms, therefore, depends on the specific problem.

With these concepts in the back of one's mind, one is now ready to move on and see how demand and supply are coordinated on a competitive market.

4.3 Equilibrium

Have you ever thought about how it is possible that the baker knows that you will buy a bagel when you go to the city? When you enter his store, the bagel is just there, ready for you to buy and eat it. How come? How could the baker have known, even though you never ordered the bagel in advance? If this example seems a little bit underwhelming, to put it mildly, then you better think twice. The great miracle of the market mechanism is that millions and billions of people are making decisions in an apparently uncoordinated, decentralized way and, despite this fact, there is a great deal of order in market outcomes. How is this possible?

Well, the first hint is that decisions are, of course, not uncoordinated. They are coordinated by market prices that shape individual incentives to buy and sell (and, more generally, to act), so decisions in a market economy are decentralized, but not uncoordinated. The question then becomes: to what extent are prices able to coordinate individual behavior and what does this imply for the functioning of markets?

Economists put a lot of emphasis on the idea of *equilibrium*. To motivate a formal definition, look at the following example: assume that, at a given market price, demand exceeds supply, i.e., customers want to buy more than suppliers are willing to sell. A situation like this has an in-built tension, because some customers have to go home unsatisfied: the decentralized plans of the economic agents are mutually inconsistent. (One reaches the same conclusion in the opposite case of excessive supply.) Therefore, the only situation where all the plans of the economic agents are compatible is at a price where supply equals demand. This situation is called an *equilibrium*. It can be defined for the whole economy with n different goods and associated markets (general equilibrium), or for a single market for good i, leaving the rest of the economy out of the picture (partial equilibrium). For simplicity, and without significance for the results, suppose that all customers have identical budgets, b.

▶ **Definition 4.7 General Equilibrium** Assume there are n goods with n market prices. A general equilibrium (in goods markets) is a set of prices $p_1^*, p_2^*, \ldots, p_n^*$, such that supply equals demand, i.e., for all $i = 1, \ldots, n$ one has $y_i(p_i^*, r, w) = x_i(p_1^*, \ldots, p_n^*, b)$.

▶ **Definition 4.8 Partial Equilibrium** Assume there are n goods with n market prices. A partial equilibrium on market i is a price, p_i^*, such that supply equals demand on market i: $y_i(p_i^*, r, w) = x_i(p_1, \ldots, p_{i-1}, p_i^*, p_{i+1}, \ldots, p_n, b)$.

Graphically speaking, a partial or general equilibrium is reached at the point where the supply curve intersects the demand curve, as represented in Fig. 4.9.

As this chapter has explained, equilibrium implies mutual consistency of plans and has, therefore, the status of a local property. However, the question is whether it is a good requirement from an empirical point of view. In other words, the question is whether or not "real" markets tend to be in equilibrium. This is a question about the dynamic forces that would act on the variables, if the system were not in equilibrium. Economists usually have two epistemic views on that problem.

Some would argue that equilibrium is nothing more than the requirement of logical consistency, which implies that markets cannot be out of equilibrium, by definition. When one empirically tests these theories, one can only observe equilibrium points. The rest of supply and demand curves are empirically non-accessible. Others have an epistemically less rigid approach and interpret the idea of equilibrium more metaphorically, admitting that markets can be out of equilibrium in the above sense. Equilibrium analysis, in this case, must be complemented by a model that explains the adjustment of prices out of equilibrium. Otherwise, the

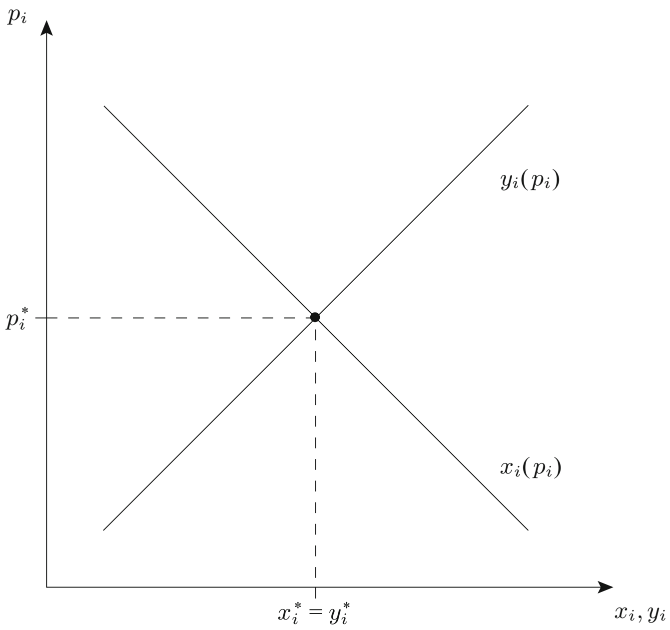

Fig. 4.9 Supply, demand, and equilibrium

concept would be analytically arbitrary. This is usually done by the formulation of the following conjecture:

► **Definition 4.9 "Law" of Supply and Demand** The prices of goods adjust in a way that supply becomes equal to demand.

One may have noticed that there is a tension in the way the "law" of supply and demand is introduced. It has the status of an assumption but, at the same time, it looks like a property of markets that can either be true or false and that could, in principle, be empirically tested. Intuitively, it makes perfect sense that excess demand will have the tendency to drive prices up and excess supply will have the tendency to drive prices down, but mainstream economics is still lacking a full-sized theory that explains out-of-equilibrium behavior in this sense and, at the same time, it unambiguously supports the "law." The conceptual problem is nicely summarized by the following quote from Kirman (1992): "Economists have no adequate model of how individuals and firms adjust prices in a competitive model. If all participants are price-takers by definition, then the actor who adjusts prices to eliminate excess demand is not specified." In other words, the invisible hand of the market has to belong to someone and this someone is absent in standard theory. Therefore, the standard theory is static in nature, and the epistemically most convincing position is to bite the bullet and interpret equilibrium as a logical constraint of the model.

Why are economists interested in a general equilibrium? There are at least five reasons that one should briefly discuss.

- As mentioned before, economists are concerned about the *existence* of an equilibrium, because its existence implies that "the invisible hand of the market" can guide individual decisions in a way that makes them mutually consistent. The modern treatment of the existence problem and general-equilibrium theory, in general, goes back to Léon Walras, a French economist from the nineteenth century. His idea, from today's perspective, was of striking simplicity: the equilibrium condition for each market, i, is characterized by the equation $y_i(p_i^*, r, w) = x_i(p_1^*, \ldots, p_n^*, b)$, or $x_i(p_1^*, \ldots, p_n^*, b) - y_i(p_i^*, r, w) = 0$, for every good or service $i = 1, \ldots .n$. Thus, the problem of the existence of a general (partial) equilibrium boils down to characterizing the conditions under which a system of n (1) equation(s) with n unknown variables—the prices—has a solution. Nearly a hundred years later, in the beginning of the twentieth century, there were still uncertainties as to whether or not such an equilibrium exists under circumstances that are sufficiently general to be representative of real-world supply and demand decision. One of the major achievements of the so-called *general-equilibrium theory* is the clarification of these conditions. Digging deeper into the problem would be far beyond the scope of an introductory textbook, but the general consensus is that the conditions that are sufficient to guarantee its existence are relatively mild. Thus, I give a statement of this property without proof:

► **Result 4.1 Existence Theorem** A general (partial) equilibrium exists under quite general assumptions.

This statement, of one of the most fundamental results of general-equilibrium theory that has been used, is rather loose, so it makes sense to work on understanding this result by means of an example: assume there is only one market with one price, so that the equilibrium condition boils down to $z(p^*, b, r, w) = x(p^*, b) - y(p^*, r, w) = 0$. This function is called the *excess-demand function* and the equilibrium is the root of this function. Intuition dictates that this function would tend to be positive, if the price approaches zero, because a lot of people would like to buy, but only few are willing to sell. By the same token, this function tends to be negative, if the price approaches infinity, because no one can afford to buy the good, but it is very attractive to sell. (Making this conjecture precise requires a lot of work, but this is the insight of intuition in a nutshell.) If one knows the properties of the excess-demand function for very low and very high prices, the intermediate-value theorem tells one that the function has at least one root, if it is continuous, because continuity makes sure that it cannot "jump" above or below zero. Does it make sense to assume that the excess-demand function is continuous? Continuity implies that demand and supply change only a little bit for small price changes. One's demand for apricots does not "jump," if apricots become a little bit more expensive. This assumption also seems pretty reasonable, but whether it holds true or not is ultimately a question of preferences and production technologies. The art and craft of general-equilibrium theory is to work out conditions based on preferences and technologies that make sure that demand and supply are continuous. If they are, a generalization of the intermediate-value theorem confirms that an equilibrium exists. Interested readers can find more details in graduate-level textbooks on advanced Microeconomics.

- A related question is the *uniqueness* of an equilibrium. It is an important property of any positive theory to make unique and testable predictions. If there are *Multiple equilibria*, then the predictive power of the theory is rather limited. Unfortunately, it turns out that the assumptions that are necessary to guarantee uniqueness are much stronger than the assumptions that are necessary to guarantee existence.
- Coming back to the epistemic question of the "correct" interpretation of the existence property, a lot of economists consider stability a desirable property of an equilibrium. *Stability* refers to the property of a system to return to its initial state after a shock has occurred. Assume, for example, that an economy is not in equilibrium initially. Are there forces at work that will lead the economy towards the equilibrium? The answer is similar to the case of uniqueness: only under strong assumptions.
- The problems of uniqueness and stability are also relevant for the predictive power of the model. Assume, for a moment, that the model of competitive markets is a good description of the "real" economy and that it is used to inform oneself and political decision makers about the likely effects of policy reforms like changes in taxes, integration of markets, and so on. As covered before, comparative-static analysis is the analysis and comparison of equilibria for different states of the explanatory variables like, for example, the equilibrium with high and low income taxes. In order to be able to learn something meaningful about real-world policies, uniqueness, and stability are, in fact, crucial. Without uniqueness, it would be very hard to predict the outcome of policy reforms and, without stability, one could not be sure that the "new" equilibrium would ever be reached.
- The basic normative question that results from the theory of comparative advantage is how to design institutions (like competitive markets) to make sure that the gains from trade that are, in principle, possible from specialization and trade can actually be realized. This is the question about economic efficiency: are competitive markets capable of inducing incentives such that the problem of scarcity is alleviated to the largest extent possible, given technological and resource constraints? Chapter 5 will be devoted to an in-depth analysis of this question.
- Last, but not least, one could be interested in questions of economic justice, in the following sense: assume that there are two individuals, Ann and Bill, who can specialize and trade according to the theory of comparative advantage. Let the monetary value of the gains from trade that is made possible by this process be CHF 100 (which will henceforth be called *rents*). The fact that markets are, in

principle, able to make sure that these gains from trade can, in fact, materialize does not tell one anything about their distribution. They could, in principle, go exclusively to Ann, exclusively to Bill or could be shared. This raises the question of distributive justice and if society has strong opinions about the distribution of these rents, there might be a tension between economic efficiency and distributive justice.

4.4 Equilibrium Analysis

As one says, the proof of the pudding is in the eating so, the next step is to see how useful the model of perfect competition is for gaining better understanding of the economy. The most important comparative-static exercises for the supply and demand side have already been covered. This subchapter will now put them together to show how they can be used to develop one's intuition for the effects of external shocks or economic policy. The case studies below are intended to give one a basic idea of how to analyze economic problems by means of models. The purpose is not to develop a complete picture, which would be a very demanding task. Even the very simple model of demand and supply gives one a lot of mileage in understanding complex social phenomena.

Case Study: How Bad Weather in Brazil Affects the Swiss Coffee Market
Coffee is an important agricultural product worldwide, and Brazil is the world's largest coffee producer. In the days before the so-called second and third waves of coffee culture, coffee was essentially run down to a commodity of moderate quality and low prices. Low quality implied that the customers had low willingness to pay, and a low willingness to pay implied that farmers would have a low willingness to invest in quality. Assume that there is a world market for green coffee and that the situation in this market can be summarized by Fig. 4.10.

The supply of green coffee is shown by the upward-sloping supply function $y(p)$, which is determined by the coffee farmers from the different growing regions. On that note, the downward-sloping function, $x(p)$, is the demand for green coffee, which is determined by the coffee roasters, who buy green coffee, roast and package it, and sell it directly to the consumer or to national retailers. Assume that these supply and demand functions reflect the situation in an average year with average harvests. The equilibrium in this market is given by the intersection of the supply and demand curves, which implies a market price of p^* and a trade volume of x^*.

Now, examine the effects of adverse weather conditions in a country, like Brazil, that is responsible for about one third of the world supply of green coffee. These weather conditions reduce the crop by a substantial amount compared to an average year. The effect of this reduction in supply is illustrated in Fig. 4.11: the world supply function for green coffee shifts leftward, because the quantity available at any given price is now smaller than in an average year. The demand function is unaffected by this change, because it is mainly determined by the demand function of the final customers, which leverages onto the demand function of the roasters.

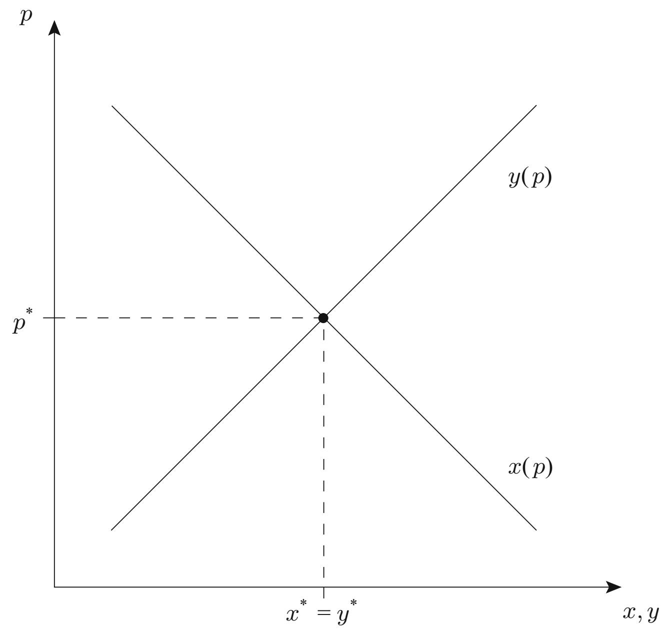

Fig. 4.10 Equilibrium in the market for green coffee

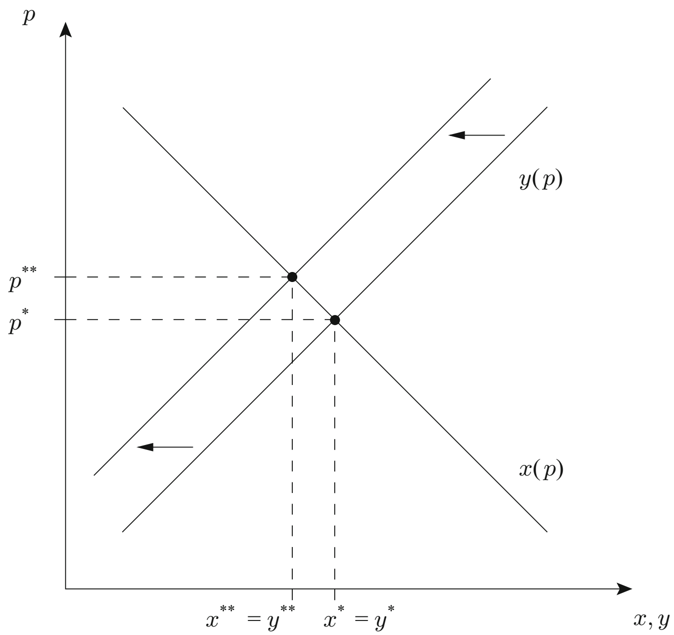

Fig. 4.11 The effect of a reduction in the crop on the equilibrium

Therefore, the total effect of the shift in the supply function is that the market price for green coffee increases to p^{**}, and the volume of trade drops to x^{**}. What are the implications of this change? At first glance, Brazilian coffee farmers are, of course, negatively affected by the adverse weather conditions, because they suffer a loss in their crop. However, they are at least partly compensated for this loss by the increase in the market price which can even lead to higher revenues of the Brazilian farmers.

The following example illustrates this point: assume the demand for green coffee is given by $x(p) = 1 - p$, and supply by $y(p) = a + p$. a is a scaling parameter that can be used to analyze the effect of changes on the crop. Smaller values of a shift the supply function leftwards. These demand and supply functions lead to a market equilibrium of $p^* = (1 - a)/2$, $x^* = (1 + a)/2$. In addition, the total revenues R of the coffee farmers are given by the total quantity of green coffee times the market price, $R = p^* \cdot x^* = (1 - a^2)/4$. Assume that supply in an average year is given by $a = 1/2$, which implies that $p^* = 1/4$, $x^* = 3/4$, and $R = 3/16$. The loss in crop can be analyzed by a change in a from 1/2 to, say, 0. In this case, $p^* = 1/2$, $x^* = 1/2$, and $R = 1/4 = 4/16 > 3/16$: total revenues go up, despite the fact that farmers sell less coffee.

It should be noted that the positive effect of the adverse weather conditions on the farmers' revenues depends on the parameters of the model (please check for different values of a). It may also be the case that revenues go down, so it is ultimately an empirical question as to whether a shortage in supply has positive or negative effects on revenues. However, assume for a moment that the effects are positive, because this nicely illustrates the nature of perfect competition. If revenues go up and production costs do not overcompensate this effect, then profits should go up, as well (I will come back to this point in Chap. 12, when we will be in a position to determine profits explicitly). In that case, why do coffee farmers have to rely on bad weather conditions to reduce their crop when they could reduce it voluntarily? Are they irrational, too stupid to understand what is good for them, or is there something more profound going on? The reason why every single farmer has no incentive to reduce his crop is that he is too small to be able to influence the market price by a reduction in crop size. Bad weather conditions, on the other hand, influence approximately one third of the farmers, which has a substantial effect on the market. This explains why prices go up. Therefore, even though each single coffee farmer acts rationally, the total effect is that prices and revenues are low. This is an illustration of the idea of *unintended consequences*, first brought forward by John Locke and Adam Smith.

Other coffee farmers, of course, profit from the increase in price, because their crops are unaffected, so they are able to sell them at higher prices. The effect on roasters is unclear at the moment, because it depends on whether they can pass on the price increase to the retailers or final customers or not. On that note, one can have a look at the downstream market for coffee and, for simplicity's sake, assume that roasters sell directly to customers, bypassing retailers (this simplifying assumption has no qualitative effect on our analysis). The market for roasted coffee looks similar

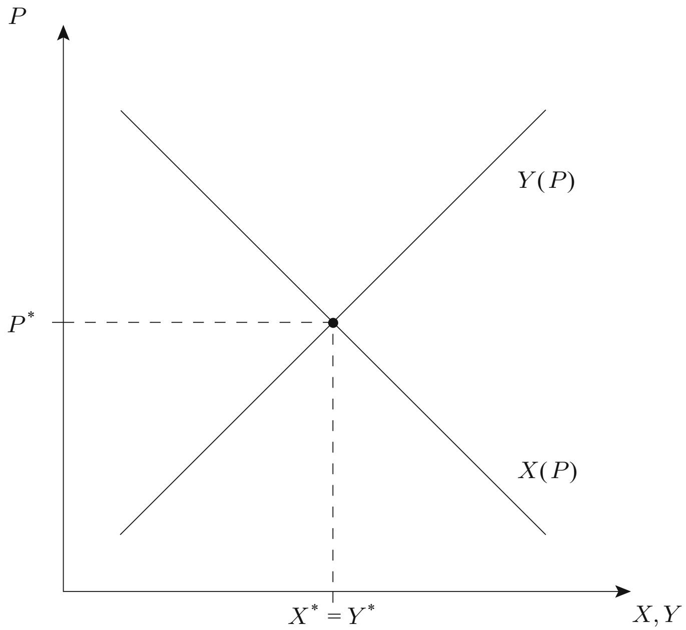

Fig. 4.12 Equilibrium in the market for roasted coffee

to the market for green coffee, but has a different interpretation. Figure 4.12 shows this market.

The demand function, $X(P)$ (I use capital letters to distinguish this downstream market from the upstream market for green coffee), represents the demand for roasted coffee by customers like students and professors. The supply function, $Y(P)$, for coffee is determined by the coffee roasters. They buy green coffee on the downstream market, which was analyzed before, and use it as an input to produce the different varieties of coffee that customers can find on the shelves. The equilibrium in an average year is given by X^* and P^*. What is the effect of the shortage of green coffee due to the Brazilian crop failure? The increase in the price for green coffee raises the costs of the coffee roasters, which implies that their supply functions also move leftward. Thus, the situation is qualitatively similar to the market for green coffee and is illustrated in Fig. 4.13.

As before, the price for roasted coffee tends to go up to P^{**} and the quantity sold tends to go down to X^{**}. In a situation like this, the roasters are able to pass on part of the increase in input prices to the customers, but only part of it, because customers react to an increase in prices by a reduction in the quantity of coffee consumed (the demand function is downward sloping). In summary, bad weather in Brazil will ultimately affect Swiss coffee drinkers, because of the tight relationship between the different markets.

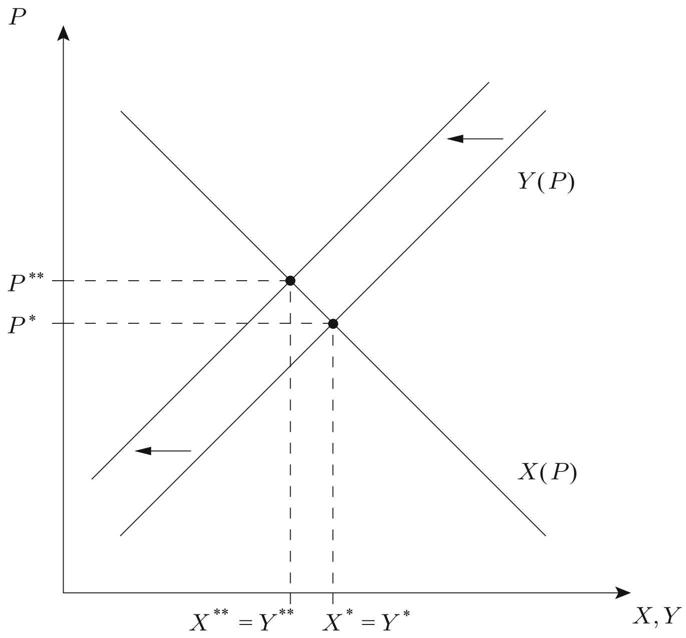

Fig. 4.13 The induced effect of a reduction in the supply of green coffee on the market for roasted coffee

Case Study: What Makes Financial Markets Special? In principle, it is possible to use the same techniques to analyze the functioning of financial markets. There are, however, a few peculiarities of the traded goods that make these markets special and that create an inherent instability. For simplicity's sake, one can restrict one's attention to equity markets, where shares of firms are traded and then start with a representative, potential buyer of stocks. How does she determine her willingness to pay? Contrary to consumer goods, like apples or shoes, shares are not directly useful; people buy them because they want to make money and there are two ways to make money with shares: the first source of income results from the future flow of profits the share will bring to the shareholder, and the second results from a difference between the future selling and the present buying price.

If the flow of future profits were known, the price of a share should be equal to the discounted cash flow (DCF). For example, assume that a share brings a profit of CHF 100 a year from now, CHF 100 two years from now, and nothing from then on. Assume further that she could invest her money in safe government bonds that give her an annual return of 10%. In that case, she should use this interest rate to discount the future profits, which leads to a DCF of $1/(1+0.1)^1 \cdot 100 + 1/(1+0.1)^2 \cdot 100 \approx 173.5$. With uncertainty about future returns, the price would be reduced by a risk premium. In such a world and with rational expectations, there could only be a difference between discounted selling and buying prices, if unanticipated surprises regarding the future value of the shares take place (for example, because of an unanticipated invention).

The problem with the DCF method is, of course, that no one in the market knows the discounted cash flow for sure, which implies that no one knows if a share is overvalued or undervalued at any given point in time. Take Apple Inc. as an example: its DCF depends on the perceived ability to create “the next big thing.” This ability depends on a large number of factors, from the current personnel, to the ability to attract creative employees in the future, and to the general corporate culture and technological constraints and opportunities (the usefulness of devices, like the Apple Watch, depends on the reliability of sensors that allow one to track certain parameters of one’s health, and it is unclear *ex ante* if and when the technology will be marketable).

The plethora of different factors that determine future profits make any assessment of DCF risky. If all market participants had equal information, then trade should only occur because of differences in attitudes towards risk. If all market participants also had equal attitudes towards risk, the transactions should only take place between those individuals with more optimistic and those with less optimistic expectations.

The market becomes inherently unstable, because expectations about future profits may become self-fulfilling, if they can spread through the market and influence buyers and sellers. Similarly to viruses that infect a population, rumors can spread and influence the willingness to pay for shares. If market participants, for example, lose their faith in the ability of Apple Inc. to deliver the next big thing, they will reduce their DCF, which can cause a downward price spiral. If share prices go down, however, the ability of a company to finance investments and research and development can be severely impeded, which creates a situation where its ability to create profits in the future is, in fact, reduced: the negative expectations become self-fulfilling, even if there was initially no reason for the more pessimistic view. This is the key difference between the share price for Apple Inc. and the price for apples.

Case Study: Markets as Production Technologies The theory of comparative advantage was covered in Chap. 2 and it is now time to come back to those basic ideas to see how they relate to competitive markets. To recapitulate, the sequential integration of ever more trading partners increases the size of the cake, but may, at the same time, produce losers who would be better off with a system of partial integration. The identity of winners and losers is determined by the institutional structure of the economy. I will elaborate on this idea by focussing on policy interventions on competitive markets. There is a striking formulation of the central thought underlying the idea of comparative advantage that goes back to David Friedman. In the words of Steven Landsburg (1995): “There are two technologies for producing automobiles in America. One is to manufacture them in Detroit, and the other is to grow them in Iowa. Everybody knows about the first technology; let me tell you about the second. First, you plant seeds, which are the raw material from which automobiles are constructed. You wait a few months until wheat appears.

Then you harvest the wheat, load it onto ships, and send the ships eastward into the Pacific Ocean. After a few months, the ships reappear with Toyotas on them. International trade is nothing but a form of technology. The fact that there is a place called Japan, with people and factories, is quite irrelevant to Americans' well-being. To analyze trade policies, we might as well assume that Japan is a giant machine with mysterious inner workings that convert wheat into cars. Any policy designed to favor the first American technology over the second is a policy designed to favor American auto producers in Detroit over American auto producers in Iowa. A tax or a ban on 'imported' automobiles is a tax or a ban on Iowa-grown automobiles. If you protect Detroit carmakers from competition, then you must damage Iowa farmers, because Iowa farmers are the competition."

This way of thinking allows one to focus on the key aspects of policy interventions in globalized markets. Markets for wheat and markets for cars are connected, because individuals spend the money that they make with wheat for buying cars and *vice versa*. The connection does not have to be direct, but may follow from a complicated maze of interactions that, in the end, make both markets interdependent. Wheat farmers may, for example, sell their harvests to bakeries, which produce and sell bread and pay wages to their workers. The bakeries sell the bread to retailers, who pay their workers, as well. Farmers and bakers use part of their wage income to buy cars and thereby transform, via a complicated chain of events, wheat into Toyotas. The really fascinating insight from this example is that policy interventions in one industry may have—for the layperson—completely unanticipated side effects on other industries. The above example shows that, at the end of the day, the complicated interplay between different markets makes Detroit-built cars and Iowa-grown wheat substitutes. Economists, who are used to think in terms of market interdependencies, can play a very important role in society by carving out these effects.

Here is another example that this chapter does not fully work out, but that can serve as food for thought. Switzerland is currently an immigration country and most people are motivated to move to Switzerland, because of high wages. A couple of years ago, some politicians and economists discussed the idea to skim off part of the 'immigration rent' by the introduction of an immigration tax that has to be paid by the immigrant workers. This may sound like a good idea, however, are we aiming at the right target? In order to understand this question, assume that the labor market for internationally mobile workers is competitive. In this case, immigration will take place up until the point at which workers are indifferent between working in different countries, in the long run. This is called an *arbitrage condition*. The introduction of an immigration tax does not change this logic: arbitrage between labor markets makes sure that the tax-induced reduction of net incomes of mobile workers will be compensated by an increase in gross income, up until the point where the marginal immigrant is again indifferent between working in Switzerland and working abroad. Therefore, the immigration tax cannot skim off rents from mobile workers, because the market reacts in such a way as to compensate them for the tax. Then again, all immigrant workers pay the tax and the state generates revenues.

Hence, there seems to be a puzzle: who pays the immigration tax, in the end? To answer this question one has to analyze the connections between different markets and the most promising candidate is the housing market: immigrants have to live somewhere, so one can expect that immigration would tend to increase rents and the overall price level on the housing market. (A side effect is that immigration triggers a redistribution from Swiss renters to landlords, because rents tend to increase for both Swiss and foreign renters.) What one can conclude is that at least part of the immigration tax is passed on to property owners. Given that an arbitrage condition holds in labor markets for internationally mobile workers, in the long run, it is the group of property owners who profit from immigration, because of the increased values of their property, and it is the same group that, in the end, has to bear the better part of the immigration tax. The phenomenon that the groups that are legally responsible for paying taxes and the groups that, in fact, pay it do not have to coincide is called *tax incidence* in economics and it is, again, one of the most important duties of an economist to create an awareness of the real effects of policy decisions.

Case Study: The Likely Consequences of Autonomous Vehicles A more speculative example is to tinker with the likely effects of self-driving cars, which is no longer exclusively Google's hobby horse. Companies like Mercedes Benz or Volvo have invested a lot of resources into this new technology, and an economic analysis reveals why this is the case. This case study will combine the insights gained from the concepts of both opportunity costs and competitive markets in order to speculate about the economic and social implications of this technological innovation.

It is tempting to think about autonomous vehicles (AVs) in terms of increased convenience, creating the appearance that it is just another innovation. The reality will, however, be quite different, because the new technology will have massive ramifications for cities, insurance markets, labor markets and the way one thinks about mobility.

To begin with, if cars can move around autonomously, then why should they be idle most of the day? It may make much more sense to let a car pick one up and drop one off at work before it continues on to transport someone else. The reason why this option opens up with AVs is a change in opportunity costs. With the current technology, mobility is bound to a human driver, so the opportunity costs of letting one's car transport other people during one's office hours is the wage rate of the car driver (this is the Taxi or Uber model). These opportunity costs drop to essentially zero as soon as the new technology takes over, which makes it more costly (in terms of opportunity costs) to leave a car idle.

These changes will have four likely major consequences:

- They will likely cause a change in ownership structures, because it becomes more and more attractive for an individual user to borrow usership rights than to own a vehicle, because the transaction costs of organizing vehicle sharing are likely smaller with large, specialized sharing companies (that may but do not have to be the car manufacturers themselves; Zipcar, Car2Go and Mobility are good examples). Additionally, one may observe the emergence of new sharing models that do not exist today. People will not stop buying cars altogether, because they might still enjoy the act of driving or the flexibility of owning a car, but the opportunity costs of these aspects of individual ownership will increase, implying that fewer cars will be owned.

More fundamentally, with AVs forming a large part of transportation, commuting could be thought of as an interlinked system of complementary transport carriers that, together, form a seamless network of mobility opportunities. AVs will be moving through the streets and people will hop on and off as needed. For long-distance rides, AVs will pick one up at home, drop one off at the train station or airport, and another AV will pick one up at the final destination. As a result, the divide between private and public transportation will get blurred.

- If total mobility remains stable, a better utilization of the existing fleet frees up parking space in cities (AVs can park more consistently and closer together than humans do now and they can park outside of the city center), which changes the appearance and functioning of cities, leaving more room for pedestrians, but also freeing up valuable properties for better uses than parking space.
- However, if consumers develop from owners of cars to users of mobility services, the functioning of the insurance industry will change, as well. Today, it is mostly a highly regulated business-to-customer market where each individual car driver or car owner is required to insure against accidents. In the future, it will transform into a business-to-business market where insurance companies insure the providers of mobility services. This move is also inevitable, because the main sources for accidents will change from human error to technology failures.

  In addition, experts assess that the new technology will be safer than the existing one. McKinsey predicts a 90% drop in accidents, implying annual savings on repair and health-care bills of up to $190 billion in the US alone. This will save lives and drastically reduce insurance premiums.
- The incentives to rethink ownership structures will also likely change the way individuals think about cars and mobility. Cars have been a very important status symbol for the better part of the twentieth century. Changes in opportunity costs make this status symbol increasingly costly and maybe even ridiculous in the eyes of a majority of people.

However, AVs will also influence productivity and labor markets. They will, for example, fundamentally reform the logistics industry. The current complementarity between vehicles and human drivers will be replaced by substitution competition between man and machine. The short-run consequence will be downward pressure on wages in these sectors and the long-run consequence will be massive job losses.

Regarding productivity and leisure time, the time spent commuting might not go down but people, freed from the need to drive, can spend their commute working, consuming media or being in contact with friends. These changes will provide opportunities for other industries, for example, by creating an in-car media market.

The above examples illustrate the usefulness of the model of perfect competition for an understanding of the functioning and interdependence of markets. They have been exercises in what has been called *positive* economics. A natural question at this point may be if markets are able to coordinate economic activities in a way that is desirable from a *normative* point of view. The next chapter is devoted to answering this question.

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Normative Economics

5

This chapter covers . . .

- what consequentialist and deontological theories of justice are and how they relate to virtue ethics.
- how mainstream economics is based on a consequentialist idea of justice.
- the concept of Pareto efficiency and why competitive markets are efficient.
- how there could be tensions between efficiency and distributional objectives.
- how individuals can fail to do what is good for them.

5.1 Introduction

> 'It is demonstrable,' said he, 'that things cannot be otherwise than as they are; for as all things have been created for some end, they must necessarily be created for the best end. [. . .] [A]nd they, who assert that everything is right, do not express themselves correctly; they should say that everything is best.'
> 'If this is the best of possible worlds, what then are the others?' (Voltaire, 1984, Candide)

> If one is a utilitarian in philosophy, one has the perfect right to be a utilitarian in one's economics. But if one is not [. . .] one also has the right to an economics free from utilitarian assumptions. (John Hicks)

The analysis of the coffee market in the last chapter showed how the model of perfect competition can be used to better understand economic phenomena. This has been an exercise in what economists call positive economics, which is a very important aspect of economics, as a social science. However, most people are interested not only in the logic of social interaction but also in normative questions about desirable properties of institutions like markets. Economists, like other social scientists, are not experts in justifying specific, normative criteria, but what they can do is to analyze if or to what extent certain institutions make one's ideas about justice and fairness a reality. There is a division of labor between economists,

M. Kolmar, *Principles of Microeconomics*, Classroom Companion: Economics,
https://doi.org/10.1007/978-3-030-78167-5_5

practical philosophers, and the general public in the discourse about the “right” way to organize society. The general public has certain (culturally influenced) viewpoints and gut feelings about justice that are scrutinized and systematically analyzed by practical philosophers, and some of these theories are put to the test by economists, who try to figure out how institutions have to be designed to help promote the normative goals of the individual members of society. Under ideal circumstances, this process can lead to a fruitful discourse between philosophers, economists, and the general public, because the coherence of one’s ethical gut feelings with the implied institutional consequences can thereby become visible and may lead to a process of adjustments in one’s ethical views as well as one’s ideas of just institutions. John Rawls (1971), a philosopher, called such a state of balance among ethical intuitions and institutions, which is reached through a process of deliberative mutual adjustment among general principles and particular judgments, a *reflective equilibrium*.

The outlined picture of the division of labor is, maybe, a little bit too optimistic, in the sense that mainstream economics is overwhelmingly concerned with a specific class of normative theories, which are called *welfarism*. Welfaristic theories of just institutions start from the normative premise that individual welfare, and only individual welfare, should matter for an evaluation of institutions. Individual welfare is measured in terms of the (subjective) well-being (often called *utility*) the individuals experience (or are supposed to experience) in a specific institutional context. Welfarism is a subclass of a larger class of normative theories that is called *consequentialism*. All consequentialist theories of justice share the view that the consequences of acts are all that matters for normative evaluations. This property has far-reaching implications for the way one perceives the role of institutions: they are basically incentive mechanisms that have to guarantee that individual behavior leads to the socially most desired outcomes. Institutions are like irrigation systems: the flow of water follows the laws of gravity so, to make sure that a garden flourishes, one has to dig the channels in the right way. The same is true for society: individuals follow their interests so, to make sure that individual and social interests are aligned, one has to make sure that individual interests are “channeled” in the right way, by means of adequately designed institutions.

In looking at the big picture, consequentialism itself is only one of three major classes of normative theories that are debated in practical philosophy, the other two being *deontology* and *virtue ethics*. Deontological theories assert that consequences are irrelevant for the normative evaluation of acts, but rather the focus belongs on certain properties of the procedure, which lead to decisions. A prominent representative of this way of thinking is Immanuel Kant, who famously claimed that good will is the only analysis that counts for the normative evaluation of acts, though there are many more. This view puts much more emphasis on individual moral responsibility and less on institutions. It states that the primary entity that makes sure that individuals behave morally is the law of reason, not the law of the state. The role of formal institutions is, therefore, secondary.

Another classical proponent for a completely different deontological concept of justice is John Locke, who argued that humans have absolute natural rights. Rights are not assigned because they serve a higher purpose (they are means) but because they are an integral part of what it means to be human (they are ends). According to this view, natural rights are not contingent upon the laws, customs, or beliefs of any particular culture or government and therefore are universal and inalienable. They are life, liberty, and property. However, if property is a natural right of every human being, then markets get a direct, normative underpinning, because liberty, private property, and markets go hand in hand. Disciples of the natural-rights tradition do not support markets because they have desirable consequences but because they respect property and liberty.

Virtue ethics goes all the way back to at least Aristotle and is a theory that sees the main challenge a human being faces in the quest to perfect his or her virtues. Very similar ideas can be found, in, for example, Confucianism and Buddhism. The virtuous moral person, like the virtuosic violin player, acts morally effortlessly, because she trained herself to make it her "second nature." The virtuous person does not act morally in the sense of Kant, because she does not act out of a sense of duty. If a person performs an act, it is because she is inclined to act this way, due to it "feeling natural" to the virtuous person, Kant calls this act *beautiful*, not moral.

The virtuous person acts in accordance with his or her moral duties, which again changes the view one has on the role of institutions. Contrary to Kant, who puts a lot of trust in the ability of reason to control individuals, institutions play an important role in virtue ethics, because good institutions help individuals to become (morally) virtuous. The good state, according to this view, is the state that helps its citizens become virtuous: "We become just by the practice of just actions, self-controlled by exercising self-control, and courageous by performing acts of courage. [...] Lawgivers make the citizens good by inculcating [good] habits in them, and this is the aim of every lawgiver; if he does not succeed in doing that, his legislation is a failure. It is in this that a good constitution differs from a bad one." (Aristotle, Ethics 1103a30)

There is also a decisive difference between virtue ethics and consequentialism regarding the role of institutions, which can be traced back to Machiavelli. He wrote that "anyone who would order the laws [...] must assume that all men are wicked [...] it is said that hunger and poverty make them industrious, laws make them good." (Machiavelli, 1984, 69–70). The task of government for Machiavelli was not to make citizens moral but to make them act *as if* they were (Adam Smith's invisible hand that leverages self-interest onto social welfare lurks in the door). Institutions, in this sense, are *incentive mechanisms* and this view made its way via Mandeville and Hobbes into modern consequentialism, with far-reaching consequences for people's ideas about the role of institutions and the balance between individual responsibility, autonomy, and the state. A state, whose main purpose is to make selfish people behave as if they were not selfish, is a different state from the one that helps people to develop, for example, the virtue of justice. Both ideas about the role of institutions start from different anthropologies and it is unclear which one describes a human being more adequately.

Mainstream economics has mostly, if not exclusively, focused on welfaristic theories of just institutions and is, in this respect, normative. Insofar as it is not tailored to the specificities of consequentialism, the toolbox could, in principle, be used to analyze the implications of other ethical views, but this is not done in practice.

Economists' self-perception is that they are no experts in normative theories and that they, therefore, focus on what could be seen as a minimum criterion for a just society: the criterion of *Pareto efficiency*. The idea goes back to the Italian economist Vilfredo Pareto. He wanted to understand under which conditions institutions are able to cope with the problem of scarcity in order to avoid waste. Waste, in this sense, is not the peel of a carrot but a specific property of the allocation of goods, services, and resources. An *allocation* is a technical term for the distribution of resources, goods, and services among the individuals in a society. The basic idea is that this allocation would be wasteful, if it were possible to redistribute the available goods and resources in a way that makes at least one individual better off without making any other individual worse off. This type of wastefulness will henceforth be called *inefficiency*, and an allocation that avoids waste will be called *efficient*.

The idea of efficiency sounds rather intuitive: an allocation cannot be just in the welfaristic sense, if it is possible to make some people better off without harming others. Therefore, efficiency is, in a sense, a necessary condition for a just allocation of goods and resources. The question as to whether this is sufficient or not will be the topic of later discussion.

In order to make this idea more precise, one can split the production and consumption of goods and services into two classes of activities: production, given resource constraints, and consumption, given constraints on the available goods and services (scarcity).

► **Definition 5.1 Efficiency in Production** An allocation of given quantities of resources is efficient in production, if it is not possible to reallocate the resources among the producers in such a way as to increase the production of at least one good without reducing the production of some other good.

► **Definition 5.2 Efficiency in Consumption** An allocation of given quantities of goods and services is efficient in consumption, if it is not possible to reallocate the goods and services among the consumers in such a way as to increase the well-being of at least one consumer without reducing the well-being of another consumer.

► **Definition 5.3 Pareto Efficiency** An allocation of given quantities of resources, goods, and services is Pareto-efficient, if it is efficient in production and consumption.

It is straightforward to extend the above definitions to the concept of a *Pareto improvement*: comparing allocations A and B, if no one is worse off and at least one person is strictly better off in A than in B, then A is said to Pareto-improve B. (Note that two Pareto-efficient allocations can never Pareto-improve each other, but it is not true that a move from an allocation that is not Pareto-efficient to an allocation that is Pareto-efficient is always a Pareto improvement. Assume, for example, that allocation *A* gives 30 apples to individual *i* and 30 apples to individual *j*, allocation *B* gives 80 apples to individual *i* and 20 apples to individual *j*, and allocation *C* gives 40 apples to individual *i* and 40 apples to individual *j*. The individuals prefer more apples to fewer apples. *A* is not Pareto-efficient, because it is dominated by *C*, but both, *B* and *C* are Pareto-efficient. Moving from *A* to *B* implies a change from a Pareto inefficient to a Pareto-efficient allocation, but it is no Pareto improvement, because *j* is worse off.)

The concept of Pareto efficiency has some intuitive appeal as a normative principle but has nevertheless been criticized even by adherents of welfarism. The reason is that Pareto efficiency is "blind" with respect to the distribution of economic rents. Assume that Ann and Bill prefer more money to less money and try to distribute CHF 100 in a Pareto-efficient way. It is straightforward to see that *any* distribution of the money among the two is Pareto-efficient: the only way to make one person better off is by taking money away from the other person, which makes this person worse off. Thus, Pareto-efficient allocations may easily be at odds with one's ethical intuitions about just or fair distributions of goods and services.

On the other hand, it is hard to deny that a plausible normative theory (among the welfaristic ones) would not qualify a Pareto improvement as a general improvement in the well-being of society: if it is possible to improve the lot of at least one person without harming any other, why should one not move in this direction? As long as one is not malevolent, it is hard to justify arguments against Pareto improvements. To summarize, if one considers welfarism to be a convincing class of normative theories, then seeking Pareto improvements is necessary but may not be sufficient for justice.

5.2 Normative Properties of Competitive Markets

The definition of Pareto efficiency is very general and relies on a concept of individual well-being that this textbook has not formally introduced so far. While motivating individual and market demand, Chap. 4 made a vague point that it has something to do with individual preferences that we will formally introduce in Chap. 7. In order to see if one can say anything about the efficiency of equilibria on competitive markets, one has to derive a proximate measure for efficiency. Fortunately, this can be done.

In order to see how to do this, it makes sense to focus on a special example of a market, a market for some good in which the demand of a single customer is typically either zero or one, like refrigerators. The analysis is completely general, though, and extends to all products. Figure 5.1 shows the demand function on the market for fridges.

Each point along the demand function can be associated with a specific individual in society and the individuals are ranked according to their willingness to pay for a fridge. This interpretation allows for a very powerful interpretation of the points

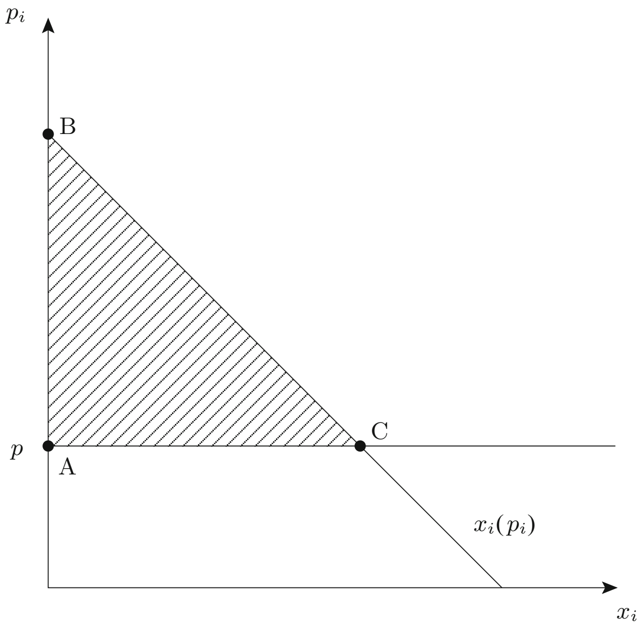

Fig. 5.1 Consumer surplus in the market for refrigerators

along the demand function: they give us the customers' maximum willingness to pay. Look at the individual who is "behind" the first unit of the good. The market-demand function at this point signals a willingness to pay that is equal to CHF 2000. How does one know? By analyzing the response of this customer to different prices. If the market price is below CHF 2000, the customer is willing to buy, if it is above, she prefers to not buy. Thus, CHF 2000 is the critical price of the good where the customer is indifferent between buying and not buying, hence it is her willingness to pay.

Assume that the price of the good is equal to CHF 1200. In that case, the customer will buy one unit of the product. Is it possible to infer anything about the customer's increase in well-being? Under a certain condition that will have to be scrutinized below, yes, because her willingness to pay would have been CHF 2000 and she pays only CHF 1200, so a monetary measure for her increase in well-being is CHF 2000 − CHF 1200 = CHF 800. The same logic can be applied to all customers, whose willingness to pay exceeds the market price. (All other customers are neither better nor worse off, because they do not buy the good.) Therefore, the aggregate monetary surplus is given by the added differences between one's maximum willingness to pay and one's actual payment. It is equal to the triangular area ABC in Fig. 5.1. This area is called the *consumer surplus*.

In order to define this measure formally, one has to make use of the concept of an *inverse function*. Remember that a function, f, is a mapping from one set A to

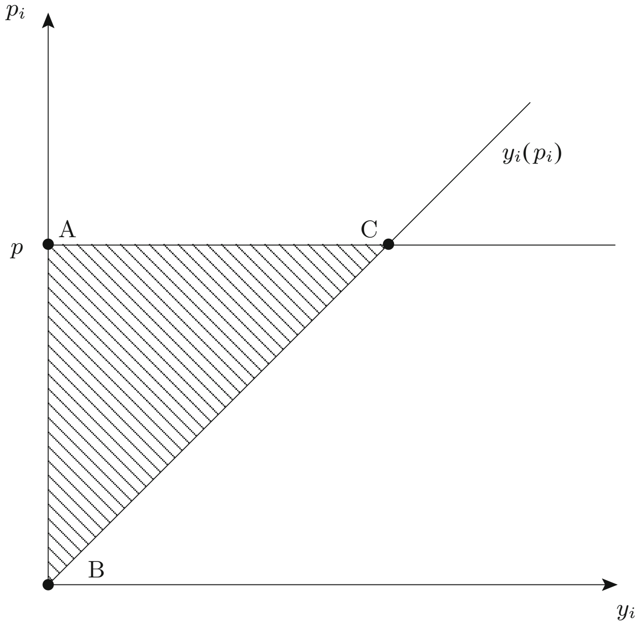

Fig. 5.2 Producer surplus in the market for refrigerators

some other set B that links elements from A with elements from B, so $f : A \to B$. Assume that the mapping is one-to-one such that, for every element a in A there is exactly one element b in B that is connected with the element in A by f, $b = f(a)$ and *vice versa*. The function, f, answers the question as to which elements in B are associated with the elements in A. One can also ask the opposite question: take an arbitrary element of B; which element of A is associated with it? Given that the mapping is on-to-one, the answer is given by the inverse function that is usually denoted by f^{-1} and which is a mapping from B to A.

▶ **Definition 5.4 Consumer Surplus** Given a market demand function for some good i, $x_i(p_i)$, and a market price p_i, let $P_i(x)$ be the inverse demand function and define as $x(p_i)$ the demand where the price equals the willingness to pay. The consumer surplus is the aggregate difference between the customers' willingness to pay and their actual payment,

$$CS(x(p_i)) = \int_{x=0}^{x(p_i)} (P_i(x) - p_i)dx.$$

One can develop a similar argument for the supply side. Figure 5.2 gives one the supply function for refrigerators.

Assume, for simplicity, that each seller sells either one or no fridge. Then, each point along the supply function can be associated with a specific seller in society and the sellers are ordered according to the minimum price they want to receive in order to be willing to sell the fridge. In order to understand why, look again at the firm that is "behind" the first unit of the good. The market supply function at this point signals a minimum price that is equal to CHF 100. How does one know? Again, by analyzing the response of this firm to different prices. If the market price is below CHF 100, the firm prefers not to sell the good; if the price exceeds CHF 100, it is willing to sell. CHF 100 is the critical price where the firm is indifferent between selling and keeping the good, hence it is its willingness to sell (which is also sometimes called the reservation price). Formally, this price is equal to a point on the inverse of the supply function. Assume that the price of the good is equal to CHF 1000. In this case, the firm will sell one unit of the product. This increases its (monetary measure of) well-being by CHF 1000 − CHF 100 = CHF 900.

Again, the aggregate monetary surplus of all firms that sell at a given market price is given by the added differences between market price and willingness to sell. It is equal to the triangular area ABC in Fig. 5.2. This area is called *producer surplus*.

▶ **Definition 5.5 Producer Surplus** Given a market supply function for some good i, $y_i(p_i)$, and a market price p_i, let $Q_i(y)$ be the inverse supply function and define as $y(p_i)$ the supply where the price equals the willingness to sell. The producer surplus is the aggregate difference between the market price and the firms' willingness to sell,

$$PS(y(p_i)) = \int_{y=0}^{y(p_i)} (p_i - Q_i(y))dy.$$

Combining supply and demand in the same figure, one can now calculate a measure for the aggregate rent on this market, see Fig. 5.3.

What one can see in this figure is the sum of consumer and producer surpluses as the total area between the supply and demand function up to the equilibrium quantity x^*. This sum of consumer and producer surpluses is a measure for the gains from trade that are made possible by this market.

How do the concepts of consumer and producer surplus relate to the concept of Pareto efficiency? If one identifies the willingness to pay and the willingness to sell as expressed on the market with the individual's "true" willingness to pay and sell, then one can identify the allocation that maximizes the sum of consumer and producer surplus with a Pareto-efficient allocation: the only way to make sellers better off is by increasing prices, which makes customers worse off, and *vice versa*. By the same token, selling more than the equilibrium quantity requires both a price below the market price, to induce a buyer to buy, *and* a price above the market price, to induce a seller to sell, which boils down to saying that one would destroy rents.

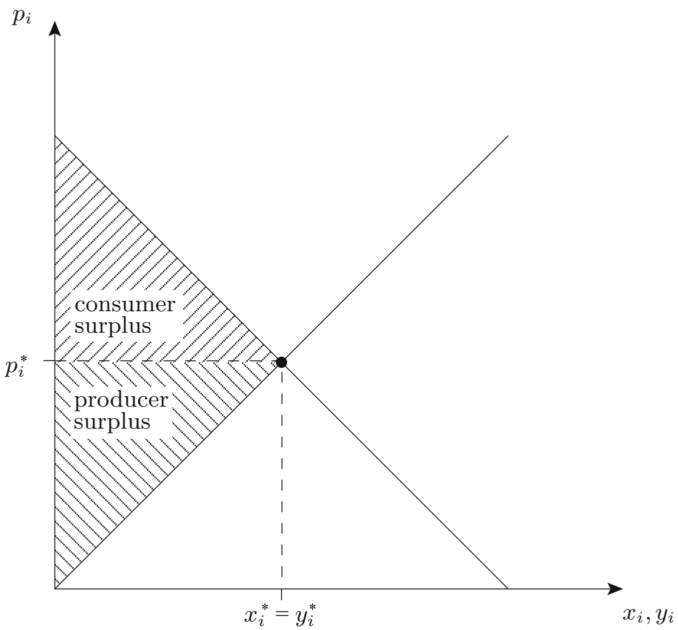

Fig. 5.3 Consumer and producer surplus in the market for refrigerators

This observation is one of the most profound findings of the theory of competitive markets and, therefore, has a very prominent name.

▶ **Result 5.1 First Theorem of Welfare Economics** Every equilibrium on competitive markets is Pareto-efficient.

The First Theorem of Welfare Economics is a strong result in support of competitive markets, because it implies that markets have a tendency to avoid socially wasteful activities. Under conditions of scarcity, when people would always prefer a larger slice of the cake, competitive markets make sure that the cake is as large as it can be, given the available resources. This is why many economists have a lot of confidence in market economies and competition.

It gets even better. The previous subchapter explained that Pareto efficiency is only a necessary but, for many people, not a sufficient criterion for distributive justice, because the resulting allocation may be highly unequal. Can one say anything about the distribution of welfare? The so-called Second Theorem of Welfare Economics gives a clue.

▶ **Result 5.2 Second Theorem of Welfare Economics** Assume there are endowments of goods and resources, and that demand and supply fulfill certain conditions of regularity. Then, every Pareto-efficient allocation can be reached as a competitive equilibrium by means of reallocating the endowments.

Again, the statement of this result is not very precise, but it is sufficient for working on the economic reasoning underlying the theorem. Building this reasoning is important, because the theorem became very influential for the way economists think about redistribution. For simplicity, assume that one looks at an economy without production, where individuals are endowed with certain goods. They can decide to consume their endowments (autarky), or they may enter the market and trade their endowment for some other goods. For example, Ann and Bill are endowed with apples and pears and can try to do better than what they can expect from their endowments, by trading apples for pears with each other. The total endowment of apples and pears is 10 and 10, and both want to consume as many apples as pears. Assume that Ann has all the apples and pears in her endowment and Bill has nothing, so the endowments are $e^A = (10, 10)$ and $e^B = (0, 0)$. In this case, there is nothing to trade and the allocation is Pareto-efficient, but highly unequal. Next, assume that the endowments are $e^A = (2, 8)$ and $e^B = (8, 2)$. In this case, it makes sense to trade and a plausible candidate would be to trade three apples for three pears, allowing Ann and Bill a consumption of five apples and five pears each. This trade would lead to a market price of apples in terms of pears that is equal to 1 (one gets one apple for one pear), and the resulting allocation is the egalitarian one.

Now, assume that one is a social planner or politician, who is leaning towards egalitarian outcomes, and one is confronted with initial endowments $e^A = (10, 10)$ and $e^B = (0, 0)$. The Second Theorem of Welfare Economics tells one what to do: in order to reach a more egalitarian outcome, one should redistribute the endowments of the individuals in roughly the desired direction and let the market do the rest. Therefore, if a social planner, "the state", or politicians have sufficient coercive power to administer this type of redistribution, then there is no tension between efficiency and equity.

One should devote some more effort to deeply understanding the meaning of the welfare theorems. A modern economy is an unbelievably complex social arrangement, where millions and billions of decisions are made every day. Each decision has a tiny influence on the way goods and resources are distributed among individuals. If I decide to spend CHF 150 for a new pair of sneakers, I am revealing that the pair of sneakers are worth more to me than their price and, at the same time, they must be worth less to the producer, because the purchase is voluntary. Thus, trading the sneakers is efficiency-enhancing. On that note, if there are people who are willing to sell sneakers at the given market price, they will enter the market. Given that this process only stops when the willingness to pay of the "last" buyer equals the willingness to sell of the "last" seller, markets are Pareto-efficient and goods and resources are directed towards their most efficient uses. There is no centralized planner with information about the willingness to buy and sell of billions of individuals to get to this point: the only thing that is needed is that individuals have information about the prices that are relevant for them.

At the same time, I am revealing that CHF 150 for a pair of sneakers is worth more to me than any other alternative use of the money, including saving the money for my future (concept of opportunity costs). This creates a link between the market for sneakers and *all other* markets. This complicated network of markets makes sure that signals about relative scarcity are transmitted in a way that guides resources towards their most efficient uses. If, for example, a technological innovation in the IT sector (for example, a new accounting software) creates a substitute for a traditional job, like an accountant, which has capital costs lower than the wage rate, then firms will start replacing accountants with software. If software is cheaper to use, it reduces the costs of production, which reduces the firm's willingness to sell. For given market prices, profits increase, but the firm will ultimately be pressured on market prices, because high profits will encourage market entry. Hence, the technological innovation influences the price of the goods that are produced with this technology and makes them relatively cheaper compared to other goods. This effect, again, redirects consumer behavior: if the good is ordinary, consumers will buy more of the cheaper goods, increase consumption of their complements, and reduce consumption of their substitutes, which has effects on these markets, as well. Therefore, the effect of a relatively local technological change will ultimately be spread over the whole economy, leading to adjustments in all kinds of markets.

How about the accountant? The technological innovation created a substitute for his job, making him compete with a new technology. The only way for the accountant to keep his job is to be willing to reduce his wage to the point where the employer is indifferent between using the new computer software and human labor. In this sense, wage rates also signal relative scarcity: the emergence of new technologies makes this specific type of labor less scarce, leading to lower prices (wages). In the long run, this reduction in wages is an important signal, because it discourages people from becoming accountants, making labor available for more valuable uses. Thus, wage rates are also an important signal of scarcity that support individuals in their decisions to qualify for certain jobs. However, this knowledge may be of little help for a fifty-year old accountant with two young kids and a mortgage to pay, who becomes unemployed.

Should one trust the theorems of welfare economics? There are three points that should be mentioned before one can reach a conclusion:

- The reason why there is no tension between efficiency and equality in the example is that redistributing exogenous endowments has no adverse incentives for the individuals. The amount of ingredients that are available for baking the cake do not depend on the initial property rights of the ingredients. If this were the case, redistribution might have adverse incentive effects. For example, if the state levies an income tax, people are likely to be discouraged from working. In this case, there is a tension between efficiency and equity, because moving into the direction of more egalitarian outcomes shrinks the pie. Therefore, the policy advice that follows from the Second Theorem of Welfare Economics is to look for "tax bases" that do not react to redistributive policies. However, such tax bases are rather limited. The only ones that come to mind are land plus the natural resources in the ground (but, even in this case, the willingness to extract them may depend on the tax system), potential ability of the people, like IQ (but there is a lot of evidence that IQ is, to a certain extent, a function of effort), or the individual himself (which is called a *head tax*). All other tax bases may react to changes in redistributive policies. Hence, the range of applicability of the theorem, in its pure form, is rather narrow, but the general insight is very important: if one wants to minimize the efficiency costs of egalitarian policies, one should try to identify tax bases that are as independent as possible from the redistributive policies.

- In order to be able to impose and enforce redistributive policies that are in line with the Second Theorem of Welfare Economics, the agency that is in charge needs sufficient independence and sufficient coercive power to be able to enforce the policies. *Independence:* coming back to the apple-pear example, it is likely that the endowment-rich Ann will oppose redistributive policies and she has at least two channels to be effective in this respect. First, she can try to influence the agency's decisions, for example, by lobbying. Putting politicians on the payroll of the rich is a very effective way to prevent even worse redistributive policies (from the point of view of the rich). Therefore, the quality of political institutions becomes important in determining whether redistributive policies can be implemented or not, if one cannot rely on the intrinsic motivation of the politicians and bureaucrats to execute them. *Coercive power:* a second problem, which has to do with the quality of political institutions, is the ability of the agency that is responsible for redistributive policies to actually enforce them. Ann, for example, could try to shield her fortune by complicated tax-avoidance strategies, trusts, etc. If the agency has only limited means to enforce its policies, then it has to rely on the voluntary cooperation of the "rich."
- The third point worth mentioning is more methodological. In the apple-pear example, the "state" would like to enforce the egalitarian solution (5, 5), (5, 5). However, if this is the case, why do they choose the detour (2, 8), (8, 2) and rely on markets, instead of choosing the desired allocation directly? Looking at the problem from this angle shows that the second theorem is, of course, correct, but it does not provide us with a strong argument in favor of competitive markets, because it is unclear why markets are needed in the first place.

5.3 Willingness to Pay and Preferences

The argument about the efficiency of market equilibria relies heavily on a rather innocuous-looking, implicit assumption about the relationship between the willingness to pay and the "true" willingness to pay of individuals. Research, which has been primarily conducted behavioral economists, neuroscientists, and psychologists has increasingly scrutinized whether one can always identify the expressed willingness to pay or sell with the "true" willingness to pay or sell. We will introduce and discuss these fields in Chap. 10 and 11 in detail.

The identification of both is an example of what economists call the *theory of revealed preference*, which makes the point that the true, normatively relevant preferences of a person can be elicited from his or her (market) behavior. This conjecture has strong implications for the normative evaluation of individual choices, because it implies that individuals make no mistakes when they choose among different alternatives. This does not mean that they never regret their choices, but that any regret is a necessary consequence of resolved uncertainty: I caught a virus during my trip to a foreign country so, *ex-post*, I would have preferred to have stayed at home. However, *ex-ante*, before the trip, and given my subjective assessment of the risks, it was still the right decision.

Whether or not the observed willingness to pay is a reliable measure for the actual preferences of the individuals is a highly controversial and disputed question, because much is potentially at stake. If one assumes that people sometimes do not know what is best for them, then the door is wide open for paternalistic interventions that undermine individual freedoms. However, at the same time, not interfering with individual freedoms implies that those who understand those weaknesses and design products and pricing strategies to their advantage can exploit systematic weaknesses in the ability to make correct decisions. Chapter 10 on behavioral economics and Chap. 11 on the psychology and neuroscience of decision processes will address these issues in detail. The picture that will emerge is that people act rationally only to a limited extent. Especially when confronted with new and complex situations, they make predictable and systematic mistakes, but even in situations they are familiar with, irrational behavior is often observed.

What are the areas where it is very likely that individuals do not consistently act according to their true interests? Loewenstein et al., (2008) give an overview: "There are areas of life [. . .] in which people seem to display less than perfect rationality. For example, although the United States is one of the most prosperous nations in the world, with a large fraction of its population closing in on retirement, the net savings rate is close to zero and the average household has $8400 worth of credit card debt. Fifty percent of U.S. households do not own any equities, but the average man, woman, and child in the U.S. lost $284 gambling in 2004, close to $85 billion in total. Many workers don't max out' on 401k plans despite company matches (effectively leaving free money 'on the table') and what they do invest often goes undiversified into their own company's stocks or into fixed income investments with low long-term yields. At lower levels of income, many individuals and families sacrifice 10–15% of their paycheck each month to payday loans, acquire goods through rent-to-own establishments that charge effective interests rates in the hundreds of percent, or spend large sums on lottery tickets that return less than fifty cents on the dollar. Worldwide, obesity rates are high and rising rapidly, and along with them levels of diabetes and other diseases, and people with, or at risk for, life-threatening health conditions often fail to take the most rudimentary steps to protect themselves."

If one takes this list at face value, a pattern becomes visible: the decisions that require a minimum degree of financial literacy, far-sightedness and commitment seem to be the ones where people struggle the most. Maybe our evolutionary past did not shape our brains in a way that makes it easy for us to handle these problems, because they have not been very relevant for the better part of the history of our species.

If one agrees that there are economic decisions where it is uncertain whether an individual is acting according to his or her well-understood interests, then the revealed-preference paradigm is hard to defend and, if one cannot defend it, then one can no longer be certain that consumer and producer surplus are an adequate measure of welfare, which—finally—leaves the relevance of the welfare theorems up in the air. This assessment does not imply that competitive markets are not efficient, if the revealed-preference paradigm cannot be defended in a substantial number of market contexts. What it implies, however, is that one cannot build one's understanding of Pareto efficiency on the welfare theorems.

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Externalities and the Limits of Markets

6

This chapter covers . . .

- the implicit assumptions underlying the assertion that competitive markets are efficient.
- the concepts of interdependency and externality and how they contribute towards understanding the problem of how to organize economic activities and the role of markets.
- the concept of transaction cost and why it is important to not only understand limitations of markets but also the firms and the state as alternative means to organizing economic activities.
- how to apply the concept of transaction costs to understanding how specific markets have to be regulated.
- the relationship between externalities, common goods and public goods, and why these types of goods may justify state interventions beyond property-rights enforcement, contract law, and market regulation.
- a lot about climate change, why status concerns make one unhappy, and the social responsibilities of firms.

6.1 Introduction

> It is not possible to add pesticides to water anywhere without threatening the purity of water everywhere. Seldom if ever does Nature operate in closed and separate compartments, and she has not done so in distributing the earth's water supply. (Rachel Carson, 1962)

The last chapter showed that competitive markets are a very effective way to organize economic activity, because they are able to coordinate the behavior of economic actors in a Pareto-efficient manner, as long as one sticks to the assumption implicit in mainstream economics that true and revealed preferences coincide (see Sect. 5.3). This finding has potentially far-reaching consequences

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for one's perception of the economic role of institutions and, especially, of the state: if competitive markets can alleviate scarcity efficiently, and if efficiency is a convincing normative ideal, then the role of the state is restricted to that of a night watchman. The *night-watchman state* is a metaphor from libertarian political philosophy that refers to a state whose only legitimate function is the enforcement of property rights and contracts and whose only legitimate institutions are, therefore, the military, police, and courts.

This concept of a state, whose monopoly on violence is restricted to the enforcement of property rights and contracts, is sometimes also called a *minimum state*. According to this view, a state that extends its functions beyond this role needs a different normative legitimization by, for example, including distributive objectives. However, even in this case, the Second Theorem of Welfare Economics guides directions of government intervention: distributive objectives can best be achieved by redistributing exogenous endowments and, if they are not subject to redistribution, one should look for the closest substitutes.

The purpose of this chapter is to scrutinize this narrative by extracting the implicit assumptions underlying the claims about competitive markets. The idea is to put the conclusions into perspective in order to allow one to better understand the reasons for the efficiency of competitive markets, as well as their potential and their limitations in the organization of economic activities. In summary, there are three qualitatively different lines of reasoning suggesting that the First Theorem of Welfare Economics cannot be the final say in the debate about the best way to organize economic activities:

- The first line of reasoning has already been mentioned in the last chapter: irrespective of the functioning of the price mechanism, it is unclear whether the revealed-preference paradigm is adequate for all types of goods and services.
- The second point that one has been able to tackle is the relationship between the mode of production in a given industry, summarized by the production technology, and the viable market structures. Not all market structures are compatible with all technological modes of production, but there is a close link between the two. For example, perfect competition requires a specific production technology to be sustainable. In the absence of such production technologies, other market forms might emerge. I only briefly mention this point in this chapter, for completeness, but will dive into the details in Chap. 12.
- Last, but not least, there can be contractual limits to the establishment of markets, and these limits will be the focus for now. As I argued in the last chapter, any exchange of goods and services has two dimensions: a goods- or service-oriented one that focuses on the physical aspects and a legal one that focuses on the transfer of rights. This is why the majority of arguments, which will be developed below, are also relevant in legal contexts and, in fact, *law and economics* as an interdisciplinary field of research evolved along some of the lines demonstrated here.

I will start with some observations that should puzzle one if one looks at them from the perspective of the First Theorem of Welfare Economics.

First, the welfare theorems provide only necessary, but not sufficient, arguments for a night-watchman state, because one has not looked for the efficiency properties of alternate solutions yet. It may be that, under the conditions of the welfare theorems, other organizational structures would also turn out to be efficient. As I will show in later chapters, both monopolistic and oligopolistic markets can turn out to be Pareto-efficient as well, and one does not have any *a priori* reason to assume that centralized planning is not efficient, even though the big historical experiment in centralized planning called socialism can, in all fairness, be called a failure. However, maybe a comparison between "capitalism" and "socialism" is too bold and ideologically charged to allow for a constructive view on institutions. A strong and complete argument in favor of markets has to close this gap.

Second, there is a big theory-reality gap that one has to approach. Assume that the First Theorem of Welfare Economics is a correct characterization of competitive markets, for all types of goods and services. What one should expect, in this case, is a strong tendency of real economies to evolve into the direction of perfect competition, because such an organization would outcompete others. What would such an economy look like? Every transaction would take place in markets and, for example, corporations and other institutional entities would not exist. The assembly of, for example, cars would be organized by a complex chain of bilateral contracts between all the persons who contribute to the manufacturing of the car and the customers. Everyone would act as "You Inc.'s" on atomistic markets without any firms as hierarchical organizations, which replace the market place by a system of hierarchical command and control mechanisms. However, this is not what we observe.

A lot of economic activities are revoked from markets and are, instead, organized according to the different logic of corporations. Basically, what happens if a firm hires a worker is that the worker accepts, within a certain scope, to comply with the instructions of one's principal, which is a hierarchical and not a market interaction. The first step into the corporation is of course a market transaction (signing the job contract), but it is exactly with this contract that one agrees to simply follow the orders of one's boss without further negotiations about prices and so on. A firm can be interpreted as an institution that replaces markets with hierarchies. Yet how could this ever be beneficial, if a market is a reliable instrument for achieving Pareto efficiency? Taking the First Theorem of Welfare Economics at face value, firms should not exist. But they do. Here are two potential reasons why: first, because people are not sufficiently smart to figure out how efficient markets are, so they make mistakes by withdrawing so many transactions from the market place; second, there is something missing in the theory.

One can also turn the question on its head: if one infers, from the existence of firms, that there must be good reasons (in efficiency terms) for their existence, why does one not organize all economic activities within a firm? Why does one organize some transactions with the use of markets? This question has been baptized the "Williamson puzzle" after one of the founding fathers of contract theory and the theory of the firm, Oliver Williamson. Here is the idea: if one has a set of transactions that are organized on markets, one could just as well organize them under the roof of one big firm. If markets are efficient, the manager leaves everything as it is, so the performance of the firm must be equal to the performance of the market. However, if the market is, for some reason, inefficient, then the manager can correct this inefficiency by a centralized, selective intervention. Hence, the firm should be able to outperform the market. However, if one thinks about it, this one big firm, which is organizing all economic activities under its roof, comes close to a system of centralized planning. Again, this is not what we observe in reality. Thus, again, the puzzle shows that there must be something missing in the theory thus far.

Additionally, to further increase the confusion, why do some firms replace the market mechanism for a set of transactions and then hurry to imitate its functioning in mimicking its mechanisms internally by, for example, the introduction of cost and profit centers, where the inter-center transfer of goods and services is organized by centrally administered transfer prices? The reason for the this is the topic of the next chapter.

6.2 Transaction Costs

There is a plethora of different institutions in modern economies: markets, profit-oriented firms, non-profit organizations, and government agencies. These are all responsible for the mediation of the production and distribution of goods and services, all with their own distinctive logic for providing and distributing goods and services. Any economic theory that aims to understand the reasons for the existence and boundaries of these different ways to organize economic activity must go beyond the First and Second Theorem of Welfare Economics.

Therefore, the challenge is to identify the missing concept that explains institutional diversity. In order to do so, it makes sense to look at the logic of the First Theorem of Welfare Economics from a different perspective. This allows one to reach a deeper understanding of the reasons why markets can be efficient, but also points towards possible explanations for the limitations of markets.

On a very basic level, scarcity implies that individual acts and consequences are interdependent. My decision to drink this glass of wine implies that no one else can drink it. My decision to wear a blue sweater implies (a) that no one else can wear this sweater at the same time and (b) that everyone passing along my way has to see me wearing it. In a world without scarcity, acts would be independent from each other and, therefore, individual goals would not compete with each other. Therefore, what scarcity does is to make individual acts interdependent. As a result, my decisions have repercussions on some other peoples' well-being, and the question is whether I take these consequences into consideration when I make a decision. Efficiency, from this perspective, requires exactly this: that each and every person takes the effects of his or her decisions on others into consideration and behaves accordingly. The technical term is that the person *internalizes* the effects of his or her behavior on others.

However, if I am selfish or ignorant, or both, then I do not care about the effects of my behavior on others. This is the point where markets step in: if I own a car and I consider driving it myself, I am in principle also aware of the fact that I could alternatively sell it on the market. What I am doing in this situation is comparing the monetary value of using the car myself with the market price. If the market price is higher, I want to sell my car; otherwise, I prefer to use it myself.

What does this almost trivial observation have to do with other people? Remember what one has found out about equilibrium prices thus far. The market price in a competitive market is equal to the willingness to pay of the consumer, who is just indifferent between buying and not buying. Thus, prices reflect the willingness to pay of other market participants: my ability to sell the good makes me implicitly internalize the effects that my choices have on others, with the consequence that I only use the good if my willingness to pay exceeds the willingness to pay of other potential users. This is the deeper meaning behind Adam Smith's famous remark on self-interest mediated by the market: "It is not from the benevolence of the butcher, the brewer, or the baker that we expect our dinner, but from their regard to their own interest. We address ourselves, not to their humanity but to their self-love, and never talk to them of our own necessities but of their advantages." The self-love of the baker leverages into one's well-being, because one pays him to do so. Prices, in this respect, have two very powerful functions in an economy: they motivate the selfish to care about the effects of their actions upon others, and they also help the benevolent, because prices considerably reduce complexity. The question remains: why does this mechanism of internalization not always prevail?

6.2.1 An Example

Assume a firm produces some good (bread) by means of capital and labor. The capital (oven) is debt-financed and labor (the baker's time) is employed. This economic activity has three effects. First, the bread makes those people eating it better off (it is crispy, tasty, nourishing bread). Second, it ties capital to the specific use, which has opportunity costs in the sense that it cannot be used elsewhere. Third, the baker spends some time baking bread, which also has opportunity costs either in the form of forgone alternative earnings or in the form of forgone leisure time. With competitive markets for capital, labor, and goods, there will be market prices for both inputs and the output. The owner of the bakery has to decide how much bread to bake, how much capital to invest in, and how much labor to hire. The price for bread indicates the social value of an additional loaf of bread, which implies that one correctly internalizes the additional effect on well-being that one creates with the bread. The price for capital (the interest rate) signals the opportunity costs of the next-best use of capital, which implies that the owner correctly internalizes the "damage" that one creates by detracting capital from alternative uses. Additionally, the price for labor (wage) signals the opportunity costs of labor, i.e., the loss in welfare that results because the baker cannot do anything else during the time of bread baking. This example illustrates not only that decisions are interdependent but also that markets make sure that they are made in an efficiency-enhancing way.

So far, so good, but one still is not at the point where it becomes apparent how markets are *not* efficient. In order to reach this point, I will modify the above example. In the first modification, the production of the product now has sewage as a necessary byproduct, which is dumped into a nearby lake. This solely reduces the profit of a local fisherman. Can one still count on markets doing their magic and leading the economy towards efficiency? The answer is that it depends, and this is where the legal side of the problem enters the picture. There are three possible scenarios:

1. The firm has the legal right to dump sewage.
2. The fisherman has the legal right to prohibit the dumping of sewage.
3. The existence and allocation of rights is unclear.

The first and second scenarios are qualitatively identical to the example before the modification: property rights are completely assigned, which is a prerequisite for bilateral negotiations between the firm and the fisherman. Assume that the reduction of sewage by 10,000 liters reduces the profit of the firm by CHF 1000 and increases the profit of the fisherman by CHF 1500. In this case, there are gains from trade between the fisherman and the firm, and the fisherman can buy "sewage-abatement rights" from the firm, in case the firm owns the rights (scenario 1). Any price for a 10,000-liter reduction between CHF 1000 and CHF 1500 increases the profit of both, the firm and the fisherman, and it is *a priori* not clear why negotiations should not be successful. However, the same holds true if the fisherman is the initial owner of the rights (scenario 2). In this case, the firm can buy "sewage rights" from the fisherman. Assume that an initial increase of sewage from 0 to 10,000 liters increases the profit of the firm by CHF 1500 and decreases the profits of the fisherman by CHF 1000. Again, there are gains from trade between the fisherman and the firm. In the next chapter, we will show that from, the point of view of efficiency, there is no assignment of rights that is more preferable than the other. However, both scenarios lead to different distributions of economic rents, because the owner of the right gets paid. This is no different from the case of, for example, apples: ownership rights, of course, have a value, but they are irrelevant with respect to the efficiency of the resulting allocation.

It is only case three where markets cannot do their magic. If there is no "owner" of the lake, the fisherman and the firm can haggle until eternity without ever reaching a legally binding agreement. Therefore, what one can learn from the example is that markets can only be established if property rights are well defined. These findings motivate the following definition:

▶ **Definition 6.1 Externality** An institution is inefficient if not all interdependencies caused by the individuals are internalized. These non-internalized interdependencies are called *externalities* or *external effects*.

This definition is sufficiently general to include non-market as well as market institutions. In a market context, the institution is, for example, a system of competitive markets and the internalization takes place by means of market prices. A situation where externalities exist in a system of markets is sometimes also called a *market failure*. If the institution is a firm, the internalization could take place by means of internal transfer prices between divisions or by means of wage contracts for employees. It is important to stress that the concept of external effects refers to the institutional framework in which transactions take place; in general, externalities are not properties of goods and services *per se*. However, sometimes specific goods have properties which are likely to produce external effects. We will come back to this later.

The above example has shown that incompletely specified property rights are likely to lead to externalities, because markets cannot emerge. This is an example of what is called *incomplete markets*, and the key question is whether markets are necessarily incomplete, because it is impossible to assign property rights, or if the problem can be fixed by "closing the gaps" and assigning previously unassigned property rights.

The narrative of the example has purposefully been developed around an environmental problem, because many people think that there is something inherent in environmental goods that prevents markets from being efficient. This is a profound misunderstanding, as the example shows. The fact that the interdependency between the fisherman and the baker is caused by sewage is inconsequential for the ability of markets to steer incentives efficiently; what is relevant is the existence and enforcement of property rights and contracts. The same type of problem, as in case 3, would occur if the property rights for bread were not assigned or unclear. If everyone were to enter the bakery and take as much bread as he or she could, the allocation of bread would likely be inefficient since the owner of the shop would lose any incentive to continue production. Thus, why is it that, especially environmental goods are prone to market inefficiencies? There are several reasons, but none of them is causally linked to the "environmental quality" of a good or service. One reason is that, for a long time in human history, a lot of environmental goods have not been scarce. Fresh air and water became only scarce in a lot of areas over the last century. However, without scarcity, it is not necessary to think about efficient uses and there is, therefore, no need to assign property rights to these goods. Thus, part of the problem is a lagging behind of the assignment of property rights when scarcity finally kicks in. For the better part of human history, humans simply did not have the technology to completely deplete fishing grounds, so there was no need to regulate access, and the same goes for other natural resources. However, these problems are relatively easy to solve because, in principle, one can assign rights.

In addition to incompletely assigned property rights, there is another reason why markets may fail. Assume, in the above example, that property rights are completely assigned, so that either the firm or the fisherman have the user rights for the lake. Therefore, in principle, it should be possible to set up a contract that specifies the quantity of sewage the firm is allowed to emit into the lake. The problem may then be that the contracting parties are not able to verify if the other party sticks to the terms of the contract. There may be emissions by the firm that cause a reduction in the population of fish that is not easily detectable or even impossible to detect. In a situation like this, setting up a contract that specifies emissions may be insufficient to reaching efficiency because the contract cannot be enforced if neither party can verify a potential breach of it (in front of a court, for example).

However, there are other reasons why markets may fail. In order to get to this point, consider a further variation of the example. In this case, the firm no longer produces sewage as a byproduct that impedes with a single fisherman, but pollutes the air with negative consequences for all the residents in the nearby city. Now, one can look into what property rights and markets can do in this example.

1. The firm has the right to emit.
2. The residents have the right to prohibit emissions.

In the first case all the residents have to find an agreement with the firm. However, given that there are a lot of them, reaching such an agreement is likely to be very costly (think of the opportunity costs of time the residents and firm representatives have in reaching an agreement). Thus, it is very likely that negotiations will break down. The same is also true, if the residents hold the rights. Here is a numerical example: assume, as before, that the reduction of pollution by 10,000 liters reduces the profit of the firm by CHF 1000 and has a monetary value for each of the 10,000 residents of CHF 2. So there are huge gains from trade (CHF 20,000 − CHF 1000 = CHF 19,000), but each resident is only willing to negotiate up to the point where his or her opportunity costs of time are smaller than CHF 2, which is if they take no longer than, say, five minutes.

These opportunity costs are an example for a type of costs that turned out to be the key for understanding the economic role of institutions:

▶ **Definition 6.2 Transaction Costs** Transaction costs are the costs of economic activity that are caused by the institutional framework.

Transaction costs are, therefore, the costs of organizing economic activities, of measuring and policing property rights, of lobbying, or of monitoring performance, to mention a few potential sources.

One can check if the above-mentioned type of opportunity costs prevents successful negotiations. Assume that mutual negotiations take longer than five minutes for each resident. In this case, the potential gains from trade are more than consumed by the transaction costs of negotiations (the transaction costs of five minutes of negotiations are CHF 2 times 10,000 residents = CHF 20,000), so it is very unlikely that negotiations will be successful and, even if they are, they create a negative net value.

The fact that markets will likely lead to inefficient outcomes is not an argument against markets *per se*. The question is if alternative institutions exist that economize on transaction costs. In the above case, the residents could, for example, delegate the authority to negotiate with the firm to a single representative. Even if some residents have to accept a compromise in the negotiations because of their very specific preferences, this compromise may be better than the externalities that would result from decentralized negotiations. To be more specific, assume that the opportunity costs of reaching an agreement to delegate authority to a representative are CHF 1 per resident, and that the subsequent negotiations between the representative incurs additional opportunity costs of CHF 1000 but reach an efficient agreement. In order to calculate the "net" gains from trade one has to subtract the sum of transaction costs from the gains from trade, i.e., CHF 20,000 − CHF 1000 − CHF 10,000 = CHF 9000. In this case, delegating authority consumes part of the gains from trade, but dominates the decentralized market outcome in terms of welfare, because it reduces the transaction costs. Note that the resulting arrangement can no longer be described as a decentralized market mechanism, but more closely resembles what might be called "representative democracy."

Digression 6.1 (Class Action)
A class action is an element of the U.S. legal system that allows a group to sue another party. It is a way to overcome the collective-action problem that exists, if many people are harmed by the actions of one party. The problem, in cases like these, is often that the small recoveries that can be expected by any individual do not provide an incentive to sue individually, despite the fact that the aggregate recoveries may be very high. Such a situation creates an incentive for parties to take disproportionately high risks, because the likelihood that they will be brought to court in case of harm is inefficiently small without class action. This problem leads to externalities.

Class action is a means to internalize these externalities. This argument has been explicitly used by the United States Court of Appeals. In Mace v. Van Ru Credit Corporation (1997), the court argued that "[t]he policy at the very core of the class action mechanism is to overcome the problem that small recoveries do not provide the incentive for any individual to bring a solo action prosecuting his or her rights. A class action solves this problem by aggregating the relatively paltry potential recoveries into something worth someone's (usually an attorney's) labor."

This point is also stated in the preamble to the Class Action Fairness Act of 2005: "Class-action lawsuits are an important and valuable part of the legal system when they permit the fair and efficient resolution of legitimate claims of numerous parties by allowing the claims to be aggregated into a single action against a defendant that has allegedly caused harm."

Swiss law, on the contrary, does not allow for class action. When the government proposed a new Federal Code of Civil Procedure in 2006, replacing the cantonal codes of civil procedure, it rejected the introduction of class actions. In the message to Parliament on the Swiss Code of Civil

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Digression 6.1 (continued)
Procedure (Federal Journal 2006, p. 7221) it has been argued that "[it] is alien to European legal thought to allow somebody to exercise rights on the behalf of a large number of people if these do not participate as parties in the action."

6.2.2 Analysis of Externalities on Markets

Externalities in markets can be analyzed using the supply and demand diagram that was introduced in Chap. 4. We have seen that the demand function can be reinterpreted as a function that measures the customers' marginal willingness to pay, and the supply function as a function that measures the producers' marginal willingness to sell. If interdependencies between individuals remain uninternalized, there is a gap between the individual and the social valuations of economic transactions, implying that individual demand and supply do not adequately reflect the social value of the transaction. Take the emissions problem from above as an example and assume that the residents do not figure out ways to organize collective action. In this case, markets are incomplete, because a market for emissions does not come into existence. If one wants to analyze this problem using standard supply and demand diagrams one, therefore, has to focus on the existing market for bread, which is given in Fig. 6.1.

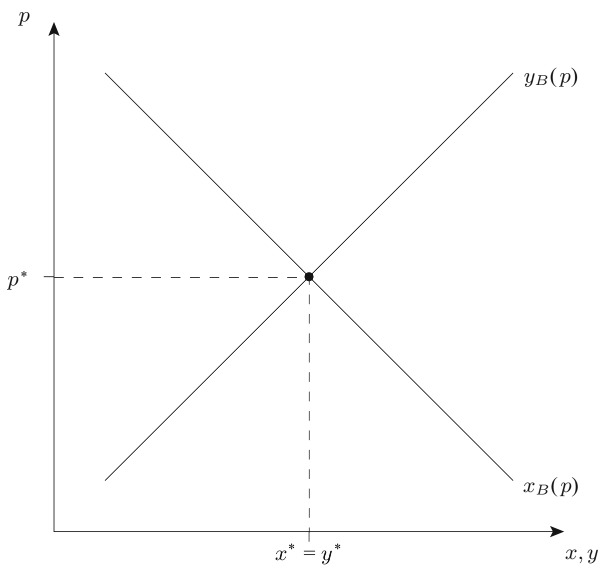

Fig. 6.1 Supply and demand in the bread market

The figure shows the demand function $x_B(p)$ which represents the marginal willingness to pay of the consumers, and the supply function $y_B(p)$ which represents the marginal willingness to sell of the producer. Note, that $y_B(p)$ only represents the *private* costs of production, i.e., it does not reflect the additional costs which emerge due to the sewage that accompanies the production of bread. In this case, the equilibrium quantity is x^* and equilibrium price is p^*. Next, we focus on the case where the baker pays for pollution, i.e., the case where the residents are the owner of the rights. One knows, from the above reasoning, that there must be a difference between the baker's marginal willingness to sell if he does not have to pay for pollution, and the marginal willingness to sell in case he has to pay. If pollution is proportional to the quantity of bread, the supply curve with internalized interdependencies must be *above* the supply curve with uninternalized interdependencies. The former thus represents the *social* costs of production: Making the baker pay for pollution increases his opportunity costs of production, which should influence his marginal willingness to sell any given quantity of bread. Production becomes more expensive, so his marginal willingness to sell should be higher than with uninternalized interdependencies. This situation is given in Fig. 6.2.

Assume that the upward-shifted supply curve has been derived for the hypothetical case of complete markets, where the baker has to pay for pollution. The

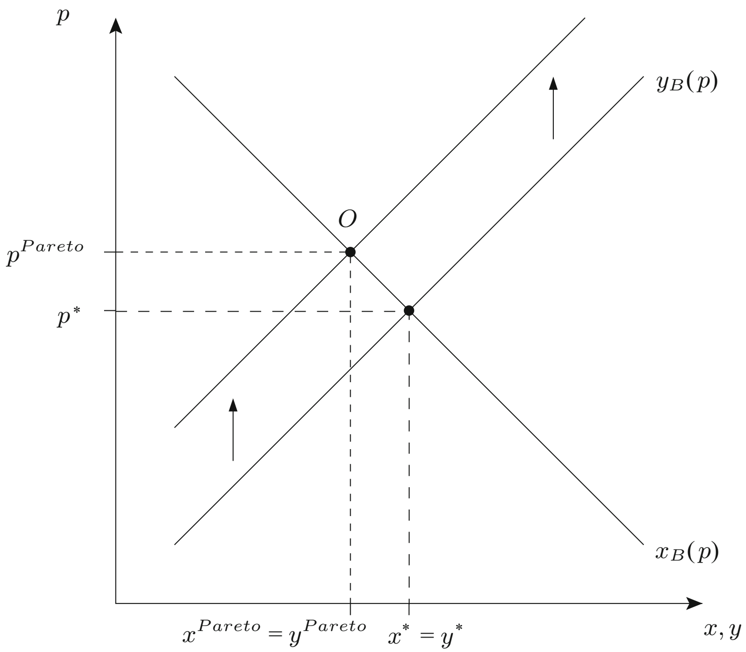

Fig. 6.2 Bread market, if the baker has to pay for pollution or if the fisher has to pay for the omission of pollution

intersection between the demand curve $x_B(p)$ and the "truncated" supply curve $\tilde{y}_B(p)$ (point O in Fig. 6.2) then represents the Pareto-efficient solution. Apparently, uninternalized interdependencies lead to inefficiently high levels of production ($x^* > x^{Pareto}$) at disproportionately cheap prices ($p^* < p^{Pareto}$): too much for too little. A situation like this is also called a *negative externality in production*. But we can do even more than this. By means of Fig. 6.2 we can now quantify the loss in welfare due to the uninternalized interdependencies: for $x \leq x^{Pareto}$ we find that the marginal willingness to pay (represented by $x_B(p)$) is at least as large as the marginal willingness to sell in case of internalized interdependencies (represented by $\tilde{y}_B(p)$), so that gains from trade exists. This no longer holds true for $x > x^{Pareto}$. Here, we find that $\tilde{y}_B(p) > x_B(p)$, i.e., the marginal willingness to sell exceeds the marginal willingness to pay, which in turn destroys welfare. Thus, the grey triangle above the demand function and between x^{Pareto} and x^* represents the loss in welfare due to the uninternalized interdependencies.

Digression 6.2 (Externalities, "Polluter-Pays Principle", and the "Principle of Minimum Harm")
In environmental law, the "polluter-pays principle" makes the party that produces pollution responsible for paying for the damage. It has support from the Organization for Economic Co-operation and Development (OECD) and the European Union, and it seems to make a lot of sense intuitively: in the above example, the baker is responsible for the pollution of the lake, so why not making him pay for cleaning up his mess?

Before one rushes to this conclusion, however, it makes sense to hold on for a second. It is correct to say that the baker causes the pollution, but this does not mean that he also causes the externality. This claim seems odd at first and it is one of the many counterintuitive insights from Ronald Coase to stress that externalities, necessarily, involve more than a single party. The externality exists only because both, the baker and the fisherman, are located on the same lake. If one of them would move away, the externality would cease to exist. In other words, externalities must be treated as a *reciprocal* problem. The polluter-pays principle ignores the fact that externalities are jointly caused by all involved parties: to avoid harm to a pollutee necessarily inflicts harm on the polluter.

If one is still not convinced, because it *is* the baker who *pollutes* the lake, think about a situation where a dynasty of bakers has been living at the lake for generations. Then, from one day to the other, a fisher decides to settle and set up his business. A few days later, he starts complaining about the pollution. Is it still so obvious that the baker causes the *externality*?

The polluter-pays principle is one way to assign rights, because it implies that one party, and not the other has to pay and, with adequately set payments, the externality gets internalized. One has, however, also seen that the same

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Digression 6.2 (continued)
type of solution can be reached if the baker has the right to pollute and the fisherman pays for reductions in pollution. Such a "pollutee-pays principle" may be at odds with one's intuitions of fairness but, from an efficiency point of view, one has no reason to assume that it is better or worse than the polluter-pays principle. If one sticks with efficiency as a normative principle, it makes sense to replace the principle with a "cheapest cost avoider principle". The idea behind this principle is that it cannot be assumed, in general, that both assignments of rights are equally efficient. With differences in transaction costs, however, it makes sense to assign the rights in a transaction-costs minimizing way.

The above discussion was exclusively concerned with the normative criterion of efficiency, which is an example of an anthropocentric ethic. The reason why the normative problem of externalities vanishes, if the fisherman moves away, is because there is no human being left to be harmed. Environmental ethics like "deep ecology" make the point that such an ethic is too narrow, because the lake, as an ecosystem, still gets harmed and the only way to solve this problem is to reduce pollution. If one includes considerations like this, the polluter-pays principle requires a different interpretation, because it is the only one that respects the integrity of nature. From this perspective, it can be seen as a special case of the more general *principle of minimal harm* or *ahimsa* that is a fundamental moral position of Jainism, Hinduism, and Buddhism. A very popular proponent of the principle of ahimsa was Mahatma Gandhi, and it also shaped Albert Schweitzer's principle of "reverence for life".

Case Study: Fossil Fuels The above analysis was despite its importance rather abstract. So it makes sense to practice a little bit by focussing on an example. The use of fossil fuels creates two main effects: It creates value within the present generation (mobility, power to produce stuff, stuff itself, etc.), and it contributes to the climate crisis which harms our and future generations. We may therefore ask the question if we can expect markets for fossil fuels to be efficient, and in case there is evidence that they are not, what can be done about it.

To tackle this problem we go back to the *willingness to buy* and *willingness to sell* interpretations of the demand and supply functions that we have introduced in Chapter 5. Formally, the marginal willingness to buy function is the inverse of the demand function $x(p)$, and we call it $P(x)$. By the same token, the marginal willingness to sell function is the inverse of the supply function $y(p)$, which is called $Q(y)$.

The potential economic value that can be created for the present generation is summarized by the market demand function for fossil fuels $x(p) = 1100 - p$, $p \geq 0$. We further assume that the market supply function for fossil fuels is equal to $y(p) = -100 + p$, $p \geq 100$. According to scientific consensus, there is an expected damage that is caused by each unit of fossil fuel used in the present on the well-being of future generations. We denote it by q and assume for illustrative purposes that it is equal to $q = 400$.

The first thing that we have to discuss is whether the intergenerational interdependency measured by q is an externality or not. The answer to this question is straightforward: Future generations cannot participate in today's markets. Therefore, their interests cannot be reflected in today's market prices. The only exception to this rule would be if present generations were perfectly altruistic with respect to the future and take their effects on future well-being into consideration. This may partly be the case, but it seems safe to say that in a large number of cases, this is not what motivates supply and demand decisions. Hence, q is an externality. However, the problem is tricky from a philosophical point of view because future generations do not exist yet, and their existence depends at least partly on today's decisions. We neglect this problem that has spurred discussion in philosophy and simply assume that the mere existence of future generations suffices to argue that they can be harmed by today's decisions. So, a market without further interventions is inefficient.

Next, let us calculate the equilibrium on the market for fossil fuels. As we have seen in Chap. 4, an equilibrium is a price p^* such that $x(p^*) = y(p^*)$. If we insert the given demand and supply functions, we get $1100 - p^* = -100 + p^*$, and the resulting equilibrium price is $p^* = 600$. We can then insert the price into either the supply or the demand function to get $x(600) = y(600) = 500$. We call it *night-watchman equilibrium* because it results without further interventions by the state.

What would happen to either supply of demand if one would internalize the harm imposed on future generations? In order to answer this question we have to determine the Pareto-efficient equilibrium. There are two ways to do so, and we will look at both of them to show that they are in fact equally effective to internalize externalities.

- The first one is to let consumers pay for the externality $q = 400$ per unit of fossil fuel. In this case, the new demand function (from the point of view of the producers) can be determined as follows: First, we have to determine the inverse function, $x = 1100 - p(x) \Leftrightarrow P(x) = 1100 - x$, subtract the additional costs, $p^{EX}(x) = 700 - x$, and get back to the initial function: $x^{EX}(p) = 700 - p$. This demand function internalizes the externality imposed on future generations. We can use it to calculate the new equilibrium $p^{EX} : x^{EX}(p^{EX}) = y(p^{EX}) \Leftrightarrow 700 - p^{EX} = -100 + p^{EX}$. If we solve for p^{EX}, we end up with $p^{EX} = 400$ and $x^{EX}(400) = y^{EX}(400) = 300$.
- The second one is to let producers pay for the externality $q = 400$ per unit of fossil fuel. In this case, the new supply function (from the point of view of consumers) can be determined as follows: First, we need the inverse function, $y = -100 + p(y) \Leftrightarrow p(y) = y + 100$, add the additional costs, $p^{EX}(y) = y + 500$, and get back to the initial function: $y^{EX}(p) = -500 + p$. This supply function internalizes the externality imposed on future generations. We can use it

to calculate the new equilibrium in the same way as before, and we end up with $p^{EX} = 800$ and $x^{EX} = y^{EX} = 300$.

If we compare the night-watchman equilibrium with the equilibria that internalize externalities, we see that the use of fossil fuels is inefficiently large, $dx = 500 - 300$, and this is exactly at the heart of the problem with most of the activities that contribute to the climate crisis. So the natural next question is, what kinds of interventions into the night-watchman market would allow it to move closer to the Pareto-efficient solution? We will discuss four potential solutions.

- The first solution is not an option here. One could argue that at the heart of the problem is a missing market. But of course we cannot create such a market because future generations cannot participate by definition.
- So, the second solution could be to impose a tax on fossil fuels. This is in principle possible and is also done in practice. A disadvantage of taxes in a situation with a lot of heterogeneity between firms and users is, however, that it does not take these differences into consideration. Therefore, in practice a tax cannot be expected to be fully efficient. In general, taxes have another disadvantage. Taxes that are levied to finance public projects like schools, roads, etc., are a source of inefficiency in themselves because they usually distort individual decisions. This is where taxes that are used to internalize externalities come into play. They do not only reduce an externality, but they can also be used to reduce other, distortionary taxes if total tax revenues are constant. This is called a *double dividend*.
- The third solution is the creation of an artificial market, for example, for the right to emit the pollutants that are responsible for climate change (like CO_2 or methane). In this case, a government agency makes these permits mandatory and sets a total supply for these permits. Firms then have to buy permits if they use resources that issue the respective pollutant. This solution is in principle possible, and a lot of economists see it as the best available alternative because it allows firms to adjust according to their specific circumstances. This flexibility avoids some of the inefficiencies that come with taxes.
- A fourth solution is price regulation or quantity control. In this case, the government intervenes with the existing markets by either setting maximum or minimum prices or restricts the quantities that are allowed to be traded on markets that strongly correlate with the emissions. This instrument is rather bold and usually comes with efficiency costs because it is practice usually not tailored to the individual characteristics of the pollutant. In addition, there is no double dividend that counterbalances these losses in efficiency.

From a purely theoretical point of view it is impossible to rank the different solutions according to their efficiency. The best solution in practice depends on a number of things like the information available to the regulating authority, the strengths of the institutions to credibly implement the measures, the sensitivity of the environmental problem, etc. This ends the case study.

As previously stated, there are always two ways (that may differ in transaction costs) of internalizing interdependencies, depending on which side of the market holds the property rights. Therefore, the alternative in the example above would be to analyze the effects on the bread market, if the residents pay the baker. Is the effect on the bread market identical to the example above or can one expect something different? If the previous analysis is correct, then the assignment of property rights should not influence the efficiency of the solution (without transaction costs), so both scenarios had better yield the same effects on the bread market. In order to check this, assume that the baker gets paid for the reduction in emissions and emissions are again proportional to bread production. For simplicity, assume that one loaf of bread produces one unit of emissions. Let the price of bread be p^b and the price for each unit of omitted emissions be p^e. In this case, an additional loaf of bread has two effects on the baker: it increases his revenues by the market price for bread, p^b, and he reduces his revenues because of the additional emissions by p^e. The total effect on the baker's revenues is therefore $p^b - p^e$, whereas it had been p^b with uninternalized interdependencies. The effect of this change is that the supply curve moves *upwards* as in Fig. 6.2: the only way to convince the baker to sell as much bread as with uninternalized interdependencies is to pay him *more*. This finding verifies the conjecture that, in the absence of transaction costs, it is irrelevant which side of the market pays for the interdependency: it is only relevant that one side does. This insight plays an important role in the literature on law and economics that tries to understand the behavioral consequences of different legal rules.

If there are negative externalities in production, it should not be too surprising that there can also be positive externalities in production, negative externalities in consumption, and positive externalities in consumption:

- **Negative externality in production:** The behavior of an individual causes non-internalized interdependencies, the internalization of which would increase the opportunity costs of production. An example is the above-mentioned problem of uninternalized environmental interdependencies.
- **Positive externality in production:** The behavior of a firm causes uninternalized interdependencies, the internalization of which would reduce the opportunity costs of production. An example is the pollination of fruit trees by bees. The presence of a beekeeper in proximity of a fruit farmer increases the crop of the farmer, because more blossoms get pollinated. If there is no market for "pollination services," the resulting equilibrium is inefficient with too few bees, honey, and fruits. Such a situation can, for example, be analyzed in the market for honey, where the individual's marginal willingness to pay falls short of the social value of honey, because the quantity of honey is positively correlated with the pollination services provided, for which the beekeeper is not paid. (This is an assumption to illustrate how this type of interdependency can be analyzed using supply and demand diagrams if, in fact, the interdependency causes an externality. In practice, farmers and beekeepers are likely to figure out ways to pay for the services). Alternatively, one can focus on the fruit market, in

which the individual's marginal willingness to sell is higher than the efficient one, because the same quantity of fruit is more costly to produce, if there are not enough bees around.

Digression 6.3 (Pollination Services)
The first reaction of a lot of people when they first hear about pollination services is to discard them as a slightly idiosyncratic curiosity, without much economic relevance. The truth is that pollination services are the backbone of agriculture and are also a very important economic factor.

Pollination makes a very significant contribution to the agricultural production of fruits, vegetables, fiber crops, and nuts. Estimates show that pollination services contribute between US $6 and US $14 billion to the US economy per year (Southwick & Southwick, 1992; Morse & Calderone, 2000). The United Nations Environment Programme (UNEP, 2016) estimated that pollination services are worth between US $235 billion and $577 billion globally.

Given the economic importance of pollination services, it should not come as a surprise that commercial pollination services have emerged, mostly provided by honeybees through a long-standing and well-organized market. Californian Almonds are a good example to study the functioning of this market. Almonds are one of the most profitable agricultural products. Recently, honeybee pests and other problems have reduced available bee supplies. At the same time, the high profit margins led to an expansion of almond acreage. Standard supply and demand analysis predicts that this trend—shortage in supply and increase in demand for pollination services—leads to an increase in the price. Figure 6.3 shows that this has, in fact, been the case: the average price per colony almost tripled between 1995 and 2006.

Pollination services are an example of what is called an *ecosystem function*, which is defined as "the capacity of the ecosystem to provide goods and services that satisfy human needs, directly or indirectly" (De Groot, 1992). These services are not only provided by bees, but by a wide variety of insects, birds, and mammals (like bats). A study for the UK found that insect-pollinated crops have become increasingly important in UK crop agriculture and, as of 2007, accounted for 20% of UK cropland value. Bees account for only about 34% of pollination services, down from 70% in 1984 (Breeze et al., 2011). Unlike with bees, it is very difficult to create markets for pollination services provided by other species, which leads to externalities. One of the consequences is that the conservation status of pollinating bird and mammal species is deteriorating.

- **Positive externality in consumption:** The behavior of an individual causes non-internalized interdependencies with other individuals, which increases the value of their consumption. An example is the decision to buy a product that

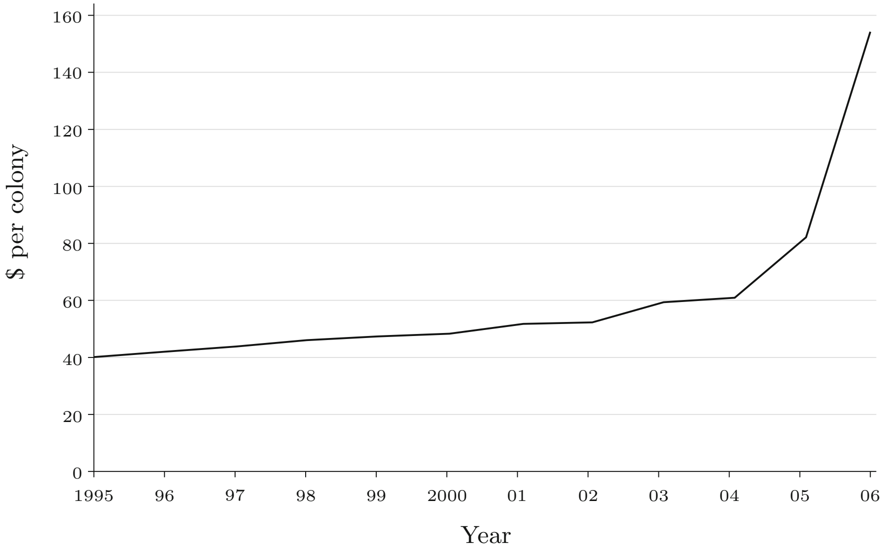

Fig. 6.3 Price level for pollination services (source: Sumner & Boriss, 2006, p. 9)

is interconnected in a network, like a specific type of software or cellphone. The more users coordinate on a given standard, the more valuable the standard becomes for others. For example, the more people use the same text editor, the easier it becomes to exchange text documents. This means that the social value of consumption exceeds the individual value. In other words, the Pareto-efficient demand function lies above the market demand with uninternalized interdependencies. Other examples are individual education decisions that raise individuals' qualifications, but also have an effect on the average literacy of a community, or maintenance of housing that not only increases the value of the individual property but also the attractiveness of the neighborhood.

- **Negative externality in consumption:** The behavior of an individual causes uninternalized interdependencies with other individuals, which reduces the value of their consumption. An example is noise from gardening that annoys the neighbors. In this case, the Pareto-efficient demand function for gardening activities lies below the market demand with uninternalized interdependencies. Another example is vaccination. The World Health Organization (WHO) estimates that vaccination averts 2–3 million deaths per year (in all age groups) and that up to 1.5 million children die each year due to diseases that could have been prevented by vaccination. The individual decision to vaccinate against a pathogen creates a positive interdependency, because it makes the spreading of pathogens more difficult, reducing the risk of other people getting infected. By the same token, the individual decision not to vaccinate creates a negative interdependency. The transaction costs of internalizing these interdependencies on markets are prohibitive, leading to negative externalities in consumption.

Case Study: Vaccination The Corona pandemic is an ideal example that allows to illustrate the concept of interdependencies, transaction costs, and externalities. Among the different aspects, we take vaccinations as an example. The following model can, however, be easily reinterpreted to allow insights into another important phenomenon of a pandemic: that people behave in a way that is inefficiently risky from a societal point of view. We come back to this reinterpretation at the end.

Assume the following simplified model that provides the flavor of the problem. In a society with $n > 1$ individuals, each one can evaluate utilities and costs of their health status as well as their costs of getting vaccinated, and they are all identical in these respects.

- $u_h > 0$: utility (in monetary terms) of being healthy,
- $u_s \geq 0$: utility (in monetary terms) of getting sick with a virus ($u_h > u_s$),
- $c \geq 0$: costs (in monetary terms) of vaccination (direct plus health),
- $1 \geq p \geq 0$: probability of catching the virus without vaccination (probability in case of vaccination is assumed to be 0),
- $r \geq 0$: effective reproduction number (average number of persons that get infected by a person infected with the virus).

We neglect problems that stem from the heterogeneity of individuals (in reality they differ with respect to all of the above variables) and the long-run endogeneity of probabilities (r and p influence but also depend on individual behavior). You can make the model more complicated later; the basic message would stay the same.

We assume that the only choices that the individuals can make is to either vaccinate themselves or not. We will come back to this assumption when we discuss the results. With this information, we can calculate the expected utilities of the individuals for the two options they face, vaccination or no vaccination:

- expected utility (in monetary terms) of an individual without vaccination: $(1 - p)u_h + pu_s$,
- expected utility (in monetary terms) of an individual with vaccination: $u_h - c$.

If people make their decisions in terms of opportunity costs, they get vaccinated if and only if $u_h - c > (1 - p)u_h + pu_s$, and you can simplify this inequality to get $p(u_h - u_s) > c$.

Is this decision rule rational from a societal perspective? In order to be able to answer this question, we have to determine the expected societal utility of an individual without vaccination, which is $(1 - p(1 + r))u_h + p(1 + r)u_s$, and compare it with the expected societal utility of an individual with vaccination, which is $u_h - c$. The difference is the interdependency caused by the individual decision. It results from the additional expected infections that are a consequence of a lack of vaccination.

If you compare both terms, you come to the conclusion that an individual should get a vaccination if and only if $u_h - c > (1 - p(1 + r))u_h + p(1 + r)u_s$, which again can be simplified to get $p(1+r)(u_h - u_s) > c$. We can now compare the individual with the societal decision rule:

- Observation 1: If it is optimal for the individual to vaccinate, it is also optimal for society: $p(u_h - u_s) > c \rightarrow p(1+r)(u_h - u_s) > c$.
- Observation 2: If it is not optimal for society to vaccinate, it is also not optimal for the individual: $p(1+r)(u_h - u_s) < c \rightarrow p(u_h - u_s) < c$.
- Observation 3: It is possible that it is not optimal for the individual to vaccinate despite the fact that it is optimal for society: $p(u_h - u_s) < c \wedge p(1+r)(u_h - u_s) > c$.

Observation 3 shows that there are parameter values that lead to a negative externality. If one would follow the optimal societal decision rule, every person would profit by $EX = p(1+r)(u_h - u_s) - p(u_h - u_s) = rp(u_h - u_s)$ if an individual gets vaccinated. The negative externality of not getting vaccinated is equal to the non-internalized effect of individual behavior on society which is equal to the weighted (by the expected utility difference between being healthy and sick) effective reproduction number. This externality occurs in cases where the loss of utility from an infection compared to the costs of vaccination is neither very high nor very low.

Why does the underlying interdependency (individual decisions have an impact on the health of other people) turn out to be a negative externality in this case? We did not model transaction costs explicitly, but it is not difficult to see why decentralized solutions cannot be expected to be effective if n is sufficiently large. We have assumed that individuals have only two choices, to get vaccinated or not. It is not surprising that this restriction leads to an inefficiency if people feel no direct, moral obligation to care for others, because with selfish individuals, an internalization of the interdependency requires inter-individual payments that make them internalize the effects of their behavior on others and to nudge them to act efficiently. Hence, up to this point the externality is a result of the modeling strategy not to allow these payments. How realistic and convincing is this strategy? If n would be very small (for example, 2), not very, because it would be relatively straightforward to negotiate between only two individuals. However, if n gets large, the network of required decentralized payments will likely be ineffective because the transaction costs of negotiating them would be too high.

What are the alternatives to internalize the externality? We discuss two policies that require a centralized agency (the state) whose ability to act in a unified and coordinated way reduced transaction costs.

- The agency could subsidize each vaccination by an amount of EX. The advantage is that such a subsidy is sufficient to induce optimal behavior while at the same time making the decision to participate voluntary. The disadvantage is that the agency needs sufficient financial resources to finance the subsidies, which in practice means either higher taxes and/or more public debt.

There is a second disadvantage that is not apparent in this simplified model but that should be discussed to illustrate the limits of simplifying assumptions. If all individuals are identical, one needs exactly one type of subsidy. With heterogenous individuals, the subsidies that are necessary to induce the right type of behavior have to vary between different individuals. If individualized subsidies are not feasible in practice (for example, because the agency has incomplete information), an effective policy of subsidization has to make sure that a sufficient fraction of the population gets vaccinated. Hence, the subsidy is higher than necessary for those individuals who would get vaccinated anyway in order to induce the right kind of behavior in those who are more reluctant. This is called a *windfall gain*, and it makes this policy even more expensive.

- If the agency has sufficient coercive power, it could make vaccinations mandatory. The main advantage of this policy is that it implements the efficient behavior relatively easily without expensive subsidies (however, enforcement costs can be high if people resist). The disadvantage is also easy to identify: people do not like to be forced by the state to do something.

  This reduction in individual freedom does not show up as a direct cost in most economic models, which is why mainstream economics is sometimes criticized. However, it is important in practice not only because people do not like it but also for more systematic reasons. In a society that is built on liberal democratic principles, there is a qualitative difference between incentives (which leaves the ultimate decision with the individual) and compulsion, even if the final result is the same. This is not the place to get more deeply into these legal and political territories. But it should serve as a reminder that economic analysis has to be put into a broader context.

We conclude with the reinterpretation of the formal model that we have mentioned in the beginning. In a time without effective vaccination, the only two major means to prevent the spread of a virus is (1) controlling the spread of the virus by means of masks or social distancing and (1) reducing interactions with other people. (2) can be easily analyzed by a simple reinterpretation of the model, (1) requires a slightly more complicated model.

- Precautionary measures that reduce the spread of a virus are uncomfortable in general. Take masks as an example. In this case, the two options are to either wear one or not, and c measure the disutility from wearing a mask. The one major difference between vaccination and mask wearing is that the latter does not give the same protection as the former, which is why one has to modify probabilities. So, the expected utility of not wearing a mask would be $(1-p)u_h + pu_s$, and the expected utility of wearing a mask would be $(1-p^M)u_h + p^M u_s - c$. $p^M > p$ is the individual probability of staying healthy if one wears a mask. This extension makes the analysis more complicated, but as long as $p^M > p$, the qualitative results stay the same (you can do this as an exercise).
- Social contacts are an important part of what is means to have a good life. Hence, reducing social contacts is costly. In this case, the two options are to reduce

contacts (to zero for simplicity) or not, and c measure the disutility from isolation (in terms of opportunity costs). If contacts are reduced to zero, this measure is as effective as a perfect vaccine, so everything else stays the same.

We can get an important methodological insight from the reinterpretations of the model: The mathematical model is a structure that focusses on certain abstract properties of a problem. The specific interpretation of this abstract structure depends on the specific situation that one wants to analyze. The same mathematical model can fit several different scenarios. This ends the case study.

The literature on externalities is very inconsistent in its terminology, mixing the physical properties of activities, which we call interdependencies, together with the institutional properties, which either lead to an internalization of these interdependencies or do not. It should therefore be stressed again that, in a market context, the term externality relates to missing or imperfect markets. An analysis that makes the *assumption* that an externality exists does not ask for the deeper reasons for the externality and, therefore, risks that one will draw the wrong policy conclusions, which could have been derived from a more thorough analysis. The baker-fisherman problem is a good example. If one starts the analysis with the premise that there is a negative externality between the two, one *assumes* that the two gentlemen cannot figure out ways to fix the problem. However, it would be in their best interest to find a solution, because there are gains from trade. Therefore, one must explore the deeper reasons for this failure and the institutional alternatives. This points one towards a detailed analysis of transaction costs.

Economists can sometimes be blinded by their own theories. It was, for example, a staple in the profession that lighthouse services are a good example for positive externalities in production, because ships cannot be excluded from the insurance provided by the lighthouses. The obvious policy implication from this analysis would be that the state has to step in to provide these services, because markets must fail. However, a more detailed empirical analysis revealed that there are numerous examples for the provision of lighthouse services without government interventions and the key to understanding this "curiosity" was the realization that port owners have an incentive to provide these services to make their ports more attractive. The situation is similar to today's free TV or free services on the Internet. Content providers give away content for free because users allow those firms to make money on other markets, like advertising or data collection.

6.2.3 The Bigger Picture

It is now time to use these examples to develop a more comprehensive view on institutions and transaction costs. The idea that something may be missing in standard theory, which helps explain institutions, goes back to a paper by Ronald Coase that he wrote as early as Coase (1937). Standard theory models firms simply as technological phenomena transforming inputs into outputs, and makes a behavioral assumption that they seek to maximize profits. This "black-box approach" to the firm had the advantage of simplicity and it allowed for generating a lot of deep insights into the functioning of markets, some of which the last chapter covered. However, the standard approach turned out to be ill-suited to answering the question of why firms exist in the first place, given the apparent efficiency of markets. Ronald Coase's major insight was that transaction costs are at the heart of the problem of optimal institutional design. Unfortunately, transaction costs are a vexed concept, because they turned out to be very difficult to define in a precise and useful way.

Much effort has been devoted to understand the exact conditions under which the invisible hand can leverage self-interest into social welfare and the most useful insight, for this purpose, goes back to another paper by Ronald Coase (1960). If society is interested in promoting efficiency, then every institution that is compatible with this goal must share the same structure: it has to make sure that individuals fully internalize the effects of their behavior on others.

As suggested above, internalization of interdependencies can be achieved by a complete set of competitive markets. The completeness of the markets implies the absence of an important category of market-related transaction costs. The term "transaction costs" is closely related to institutions, since transaction costs can be used to assess the relative "imperfectness" of different institutions (see Definition 6.2). This understanding allows it to put the First Theorem of Welfare Economics into perspective. It was clear from the work of theorists of socialist planning like Oskar Lange (1936; 1937) that, under the conditions of the First Theorem of Welfare Economics, a central planning mechanism is efficient as well. In order to find the equilibrium price, "the market" needs information that, in the hands of a central planner, would be sufficient to implement the efficient allocation directly without the detour of market transactions. This implies that, under ideal circumstances, the institutional structure does not matter for the efficiency of the resulting allocation.

Coase (1960) generalized this idea by creating the awareness that it is neither the complete set of markets nor the idealized planner mechanism that is responsible for the result, but two other, implicit assumptions, namely the rationality of economic actors and the absence of transaction costs.

▶ **Result 6.1 Coase Theorem** In the absence of transaction costs, rational actors will find an agreement that is both Pareto-efficient and independent of the initial allocation of property rights.

The insight is of striking simplicity: if individuals are rational and no transaction costs exist, they should always end up in a situation where gains from trade are completely exhausted; it would simply not be rational to leave them unexploited. In an ideal world, without transaction costs, potential externalities would be fully internalized by rational individuals, whether through market prices, centralized planning in either the form of centrally determined transfer prices or direct quantity control, or other institutional arrangements.

What is the importance of this result? Contrary to what is sometimes argued in the literature, the Coase Theorem is not a result about the efficiency of markets or the advantages of decentralized negotiations. It is rather a methodological critique of models and theories that either im- or explicitly compare the efficiency of different institutions or organizations without making the underlying assumptions regarding transaction costs explicit (or even better explain the specific transaction costs). It is like comparing different architectural designs that have been derived without incorporating gravity. The houses may look beautiful, but it is not clear what will happen if one actually builds them. Transaction costs, in this sense, are like gravity.

The First Theorem of Welfare Economics is a case in point. At the time the underlying theory had been developed, economists have not been aware of the key importance of transaction costs in explaining the comparative efficiency of different institutions. So, the underlying market mechanism is modeled as if transactions were zero. The implication is that from a transaction-cost perspective, the result cannot be used to argue that markets are superior to other institutions as long as the relevant transactions costs are not understood and compared to the transaction costs of alternative institutions. Without transaction costs, rationality alone makes any institution efficient. (This finding does not imply that the market model is useless. On the contrary, it can be extremely valuable in making predictions about all kinds of effects on market prices, the allocation of goods, etc. It can, however, not be used to infer anything useful regarding the comparative efficiency of market- compared to other institutions.)

The implication of this finding is, of course, not that institutions do not matter in reality, but that one has to identify the institution-specific transaction costs, if one wants to understand the relative efficiency of, for example, markets, firms, and government agencies. The transaction-costs-free economy plays the role of the frictionless pendulum in physics: it is not a good description of reality, but a benchmark that allows one to understand the role of friction (or, for that matter, transaction costs) better.

A number of important research areas emerged from this benchmark over the last decades, all of them unified by their attempt to understand transaction costs and their implications for efficiency and the organization of economic activity. The following are some of the most important types of transaction costs:

1. Transaction costs due to the formation of contracts: as shown in the above example, contracts are not just "there" but have to be negotiated, which requires investment of scarce time and effort. Thus, contracts will only be written (and market transactions will only be performed), if the gains from trade exceed the (opportunity) costs of negotiations. Even buying a smoothie requires that one enters the shop, checks the price and pays.

   A very dramatic example of market failure, due to the impossibility to cope with interdependencies by means of contracts, is the interdependencies between generations. Most of one's present decisions are likely to have long-term consequences far beyond one's own planning horizon. However, they will likely affect the well-being of future generations. The most prominent examples are anthropogenic climate change and nuclear power. In both cases, there surely are intergenerational interdependencies and they cannot be internalized by the use of markets, because one side of the contracting table has not yet been born when the relevant decisions have to be made. Markets must create externalities almost by definition. On the other hand, if markets must fail, what other means does one have to include the interests of future generations? Given that unborn people cannot be part of *any* decision procedure, be it market-based or political, there is only one alternative left: the literal internalization of interdependencies by means of moral concerns of contemporaries. If the present generations are willing to think and act according to the legitimate claims of future generations, then and only then is it possible to internalize the otherwise existing externalities. Even if political decisions to, for example, raise the price of fossil fuels constrain individual behavior, the decision to implement these regulations is not a result of some kind of bargaining between all the affected parties. It is a commitment mechanism by contemporaries that makes it easier for them to follow their moral standards.

Digression 6.4 (Is There Someone to be Harmed? The Non-Identity Problem of Intergenerational Justice)
There is an aspect of the problem of intergenerational justice that makes it different from standard allocation problems between contemporaries. There is a debate in practical philosophy about the normative status of unborn people that focuses on the question, of whether unborn people have the same rights as contemporaries and whether and in what sense contemporaries can harm unborn human beings (Parfit, 1984). One of the key obstacles is the so-called *non-identity problem*, which argues that apparently trivial changes in one's plans are likely to change the identity of the future people (for example, because the egg is fertilized by a different sperm).

Thus, changes in the political environment are likely to have some influence on the identity of future generations but, if this is the case, it cannot be argued that anybody is worse off in the future because one is comparing different people. A pragmatic view would accept this problem as it is and declare the specific identity of a future human being to be morally irrelevant. The only fact that counts, one could argue, is that future generations will come into existence and that they can profit or can be harmed by present generations' choices. Plausible as this approach may sound, it implies a major deviation from standard welfarism, which builds on the idea that the welfare of actual people is normatively relevant.

1. Transaction costs due to the enforcement of contracts: even in a night-watchman state, property rights and contractual arrangements have to be backed by the police and courts. The capital and labor costs of maintaining these agencies must

be considered part of the transaction costs of markets. From an efficiency point of view, the police are only indirectly productive, because its presence creates the necessary environment in which people feel save to invest and trade but, if police were obsolete (for example, because individuals behave cooperatively out of an intrinsic motivation), capital and labor would be freed for other directly productive purposes.

2. Transaction costs due to the incompleteness of contracts: An extensively studied problem is the role that information plays in contract design and in the performance of institutions. There are several strands of literature that I will briefly discuss in turn.
   (a) Asymmetric information: Asymmetric information refers to a situation where one of the contracting parties is aware of information that is relevant for the contract and that of which the other contracting party is not aware. This situation is, of course, the rule rather than the exception, because the parties, in almost any buyer-seller relationship, are unaware of the other party's marginal willingness to pay or sell. Here is an example that highlights the specific problems that may be caused by asymmetric information. Assume a market for used cars, where the sellers are better informed about the quality of the cars than the buyers are. The representative buyer's marginal willingness to pay depends on her assessment of the *average* quality of the car, which implies that the price is not attractive for high-quality sellers. These sellers will withdraw from the market. If the buyers anticipate this incentive, they will further reduce their expectations about average quality and, therefore, their marginal willingness to pay. In the end, the market can completely unravel, leaving only cars of poor quality for sale. George Akerlof (1970), one of the pioneers of information economics, called this type of market a *market for lemons* (a lemon is an American slang term for a car that is found to be defective only after its purchase).

       It turns out that this informational incompleteness is especially relevant on insurance markets and explains why unregulated insurance markets are likely to be inefficient. Specific forms of regulation, like mandatory insurance and obligation to contract (plus some form of price regulation that is necessary to prevent insurance companies from levering out the obligation to contract by charging high prices), reduce these inefficiencies. This kind of regulation works on insurance markets, but not generally on other markets because the standard for efficiency is easy to set. If individuals want to avoid risk (they are *risk averse*), an efficient solution is one where everybody gets full insurance. Such a standard is relatively easy for a government to regulate.
   (b) Non-verifiable contracts: Some contractual arrangements may refer to properties of the good or service that are observable for both contracting parties, but are not verifiable, for example, in front of a court. An example would be a labor contract, where both parties know that the employee is cheating, but the employer is unable to prove it.
   (c) Imperfect foresight: Many contracts expand into the future, which makes the anticipation of future consequences of the contractual arrangement crucial.

> However, in a number of cases, the future cannot be foreseen with sufficient precision to allow for efficient contracts. An example is a different labor contract where a person is hired to conduct research for a company. By definition, the terms of the contract cannot be specified contingent on the outcome of the research project, because it would contradict the nature of research and development. Something completely and qualitatively new may come out of a research project, which makes contracts necessarily incomplete.

From the perspective of transaction-cost economics, climate change is maybe the worst problem someone could have invented to challenge humanity, because it combines a lot of elements that human beings are ill-prepared to solve. First of all, the very nature of intergenerational interdependencies makes it impossible for everyone who is influenced by a decision to participate in a market or any other form of negotiation. Therefore, the only way to incorporate the interests of future generations into today's decision-making is by means of the morality of the present generations. Second, even if one is sufficiently morally motivated to care for future generations, one has imperfect foresight about the future consequences of one's behavior. Third, humanity evolved as a species that had to solve small-group problems for the better part of its history. One's "hard wired" moral instincts are restricted to one's kin and tribe. Problems on a global scale require going beyond one's moral intuitions and caring for the lot of all human beings, not only one's relatives and fellow tribe members. However, reason is a lazy and easily exhausted companion. The executive summary of the so-called Stern Review (2007) makes this point in all clarity: "The scientific evidence is now overwhelming: climate change presents very serious global risks, and it demands an urgent global response. [...] Climate change presents a unique challenge for economics: it is the greatest and widest-ranging market failure ever seen. The economic analysis must therefore be global, deal with long time horizons, have the economics of risk and uncertainty at center stage, and examine the possibility of major, non-marginal change. [...] The effects of our actions now on future changes in the climate have long lead times. What we do now can have only a limited effect on the climate over the next 40 or 50 years. On the other hand what we do in the next 10 or 20 years can have a profound effect on the climate in the second half of this century and in the next. No one can predict the consequences of climate change with complete certainty; but we now know enough to understand the risks. [...] For this to work well, policy must promote sound market signals, overcome market failures and have equity and risk mitigation at its core."

The following subchapter will cover the examples of traffic congestion and environmental problems in order to illustrate how the concept of transaction costs can be used to understand the organization of economic activity better and to design solutions for externality problems.

6.2.3.1 Externalities in Traffic

> A society sufficiently sophisticated to produce the internal combustion engine has not had the sophistication to develop cheap and efficient public transport?
> Yes, boss . . . it's true. There's hardly any buses, the trains are hopelessly underfunded, and hence the entire population is stuck in traffic. (Ben Elton, 1991, Gridlock)

The most common feeling of car drivers who are locked in a traffic jam is anger, but these psychological costs are only the tip of the iceberg regarding economic costs caused by crowded streets and overburdened infrastructure. The main causes of traffic jams are accidents, poor infrastructure, peak-hour traffic, and variable traffic speeds on congested roads. The Centre for Economics and Business Research and INRIX (a company providing Internet services pertaining to road traffic) has estimated the impact of such delays on the British, French, German, and American economies. Here are some of the main findings (US data):

- The costs of congestion summed up to $124 billion in 2013. This cost is (ceteris paribus) expected to increase 50% to $186 billion by 2030. The cumulative cost over the 17-year period is projected to be $2.8 trillion.
- The annual cost of traffic for each American household is $1700 today. This cost is expected to rise to $2300 in 2030, with huge regional variations (the cost is $6000 in the Los Angeles area). To put these numbers into perspective, the median household income was $51,939 in 2013.
- The monetary value of carbon emissions caused by congestion was $300 million in 2013. By 2030, this is expected to rise to $538 million, totaling $7.6 billion over the 17-year period.

Congestion costs of traffic can legitimately count as an externality, because the main causes of these costs are (a) opportunity costs of time, (b) costs of carbon and other emissions, and (c) price effects of higher transportation costs. In order to understand this conjecture, it makes sense to look at a car driver's decision problem. When deciding if, when or where to use streets, she takes individual costs and benefits into consideration. However, the lion's share of costs and benefits spills over onto other traffic participants and the general public. Emissions cause either regional or global effects, which are not included in the individual's decision problem, and other drivers' wasted time is also neglected. The reason is that decentralized negotiations about when and where to use the streets would lead to prohibitive transaction costs.

What else can one do to make traffic more efficient? What are the institutional alternatives? Solving congestion is not easy. Building more roads, or widening existing ones, can encourage people to drive even more. Charging road users for travelling at busy periods can help to solve the efficiency problem, but it may cause other problems. To highlight them, one can focus on the *London Congestion Charge*. The standard charge in 2016 was £11.50 on most motor vehicles operating within the Congestion Charge Zone (Central London) between 07:00 a.m. and 08:00 p.m., Monday through Friday. In theory, the charge should be set such that the individual driver pays a price that is equal to the costs caused by his decision to use a specific network of streets during a given time period. Hence, if the charge is calculated correctly, one can infer that the externality caused by a single driver is approximately £11.50. If the price of going to central London goes up, demand should go down and one gets the desired increase in efficiency, because congestion is reduced. What makes this instrument problematic is that it has distributional consequences, because the fee is especially burdensome for the relatively poor, who are disproportionately deterred from coming to the city center by car.

Digression 6.5 (The Role of Public Space in Democracy)
Congestion charges or road prices not only have distributive consequences, which one might find objectionable, but also have more profound effects on how one thinks about the societal role of public space. In a democracy, public spaces have an important role in the expression of political opinions, as locations for spontaneous gatherings and, more generally, places where a representative profile of people comes together and has the right to do so. A public space is a site where democracy becomes possible. Henri Lefebvre (1974) made this point quite poignantly: "(Social) space is a (social) product [...] the space thus produced also serves as a tool of thought and of action [...] in addition to being a means of production it is also a means of control, and hence of domination, of power." Charging high prices for the access to public space, which makes it more difficult for specific groups to access them is, therefore, politically questionable. A narrow economic view, which focuses on efficiency gains, easily loses sight of the bigger context in which the instruments are embedded.

A good example for the relationship between democracy and public space is the *Landsgemeinde* (cantonal assembly). This is a Swiss institution where eligible citizens of the canton meet on a certain day in a public space and debate and decide on laws and public expenditures. Another example is the *Speakers' Corner*, an area for unrestricted public speaking, debate and discussion, which became a symbol for the importance of unrestricted access to public space in a democracy. An interesting, yet unresolved, question is whether virtual public space on the internet can take over the role of physical public space, thereby overcoming physical and legal boundaries.

6.2.3.2 Environmental Externalities

> Climate change is a result of the greatest market failure the world has seen. (Nicholas Stern, 2007)

> The metaphor is so obvious. Easter Island isolated in the Pacific Ocean—once the island got into trouble, there was no way they could get free. There was no other people from whom they could get help. In the same way that we on Planet Earth, if we ruin our own [world], we won't be able to get help. (Jared Diamond, 2005)

Oil spills that waste beautiful beaches and wilderness areas are only the tip of the iceberg of environmental externalities. The following are some examples of environmental externalities in production that lead to social costs that are not internalized by market prices. Unregulated air pollution from burning fossil fuels becomes a problem, if no market for pollutants exists. Anthropogenic climate change, as a consequence of greenhouse gas emissions, involves future generations. Negative effects of industrial animal farming include, for example, the overuse of antibiotics that results in bacterial resistance and the contamination of the environment with animal waste. Another problem is the cost of storing nuclear waste from nuclear plants for very long periods of time.

There is a broad consensus among scientists that the rate of species loss is greater now than at any time in human history. In 2007, the German Federal Environment Minister acknowledged that up to 30% of all species would be extinct by 2010. The Living Planet Report (World Wildlife Fund, 2014) comes to the conclusion that "the number of mammals, birds, reptiles, amphibians and fish across the globe is, on average, about half the size it was 40 years ago." If one follows the scientific consensus and assumes that part of the loss in biodiversity is a consequence of the economic system, the question is whether this loss is a result of externalities. Is it possible that mass extinction of species can be Pareto-efficient? This is a tough question, because it requires information about the role of biodiversity in supporting human life on this planet and it relies on assumption about the way humans value biodiversity *per se*. If one starts with the conservative assumption that biodiversity has only instrumental value in supporting human life and if one admits that intergenerational externalities exist, because current generations do not adequately take the interests of future ones into consideration, then one can make a case for the existence of an externality. This is if one assumes that a more diverse biosphere is more likely to support human life than an impoverished one. This latter conjecture, however, is built on deep uncertainty of the complex role of the biosphere in supporting human life. The deeper problem is that the concept of Pareto efficiency, as seen before, is blind with respect to the distribution of gains from trade, and, more generally, economic welfare. A policy where the present generation has a big "party" and uses up most of the natural resources, leaving a devastated planet where future generations scrap along at the subsistence level, is Pareto-efficient as long as there is no alternative policy to make future generations better off without harming the present ones.

The concept of Pareto efficiency has a lot of shortcomings when it comes to long-term problems, which is why is has been supplemented, and even replaced, by the concept of *sustainability* in the normative social and natural sciences and in politics. The most popular definition of the concept of sustainable development goes back to the so-called Brundtland Commission of the United Nations (1987): "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This concept implicitly acknowledges the right of future generations to live a decent life and is, therefore, stronger than the Pareto criterion. However, it still suffers from the need to understand the complex role of ecosystems and it is anthropocentric in nature. I will come back to this latter point at the end of this subchapter.

Returning to a less complex externality, the example of an oil spill illustrates the basic problems and solutions. Assume that a company operates a fleet of oil tankers, which move large quantities of crude oil from its point of extraction to the refineries. The environmental risk of this business model is that oil spills, due to accidents, affect the (marine) environment and may also affect the fishing industry. One can divide the discussion into two parts. Part one assumes that it is possible to attach a meaningful monetary value to the damage caused by oil spills and to ask for institutional arrangements that lead to efficient outcomes. Part two scrutinizes this assumption and takes a closer look at the normative issues that are involved when attaching price tags to oil spills.

The risk of an accident can be influenced by the shipping companies' investment in safety technology. A profit-oriented company faces a tradeoff between the costs and benefits of such investments and the question is whether it adequately reflects the social costs and benefits when it makes its decisions. In an unregulated market, with only property rights and contract law, this is very unlikely, because many people are potentially influenced by an oil spill, so decentralized negotiations cannot solve the problem efficiently. Therefore, safety standards are presumably inefficiently low in an unregulated market. How can one internalize these externalities? I will discuss three different instruments:

- A very direct and crude way of enforcing safety standards is by setting and enforcing mandatory standards. This instrument is effective, if enforcement is guaranteed, but not necessarily efficient. It becomes the more efficient, the more homogeneous the global fleet is because, in this case, the costs and benefits of a reduction in the risk of accidents are the same for all tankers. Unfortunately this is not the case and, the more heterogeneous the ships are, the less efficient a homogenous regulation will be. One could argue that this is not a problem, as long as regulation can be fine-tuned to the specific characteristics of the tanker, but regulations that are more complicated are more difficult to enact and enforce. Therefore, it is very likely that, in practice, standards would lead to some efficiency losses.
- It is also possible to tax activities that are positively correlated with risks and to offer subsidies for activities that are negatively correlated with risks. Taxes and subsidies change the perceived prices, either making risky activities more costly or making risk-avoiding activities cheaper. The effect is that one creates incentives to influence investments into safety in a socially desirable way. The major advantage of this solution is that, unlike with standardization, this instrument works selectively for different types of tankers and it is, in principle, able to avoid inefficiencies that result from the one-size-fits-all approach of standards. However, a tax-subsidy system has to be administered, which causes transaction costs of its own.
- Last, but not least, one can react with the introduction of liability law. Liability law makes shipping companies pay in case of damage. Liability law increases

the costs of the firms in case of an accident and is, therefore, a theoretically promising instrument for internalizing externalities. When it becomes more costly to have an accident, the company will be more prudent and invest in higher safety standards. However, this legal instrument can conflict with other legal instruments, which have legitimizations of their own. For example, most countries have an insolvency law that restricts the risks of firms and individuals. If such a law is in place, the worst that can happen to a firm is for it to become insolvent, which effectively restricts its monetary risks. Since oil spills are usually big events, liability law can, therefore, be a toothless tiger, if the owners of the company are protected by insolvency regulations.

The above discussion has shown that there are several tools for coping with environmental externalities in the economist's toolbox and it depends on the case at hand which tool (or combination of tools) will work best.

The second aspect of the problem, which one should at least briefly consider, is the question of whether it is possible to attach a price tag to environmental damages. It is relatively uncontroversial that it is possible to get reasonable estimates of damages to the local fishing or tourism industries, because the goods and services they provide have market prices and past experience gives a good proxy for the loss in revenues and profits that result from environmental damages. The question becomes more involved, if one tries to estimate the non-economic costs to human beings that result from the depletion of resources such as air, water, and soil, the destruction of ecosystems and the extinction of wildlife. What is the value of a species of beetle to humankind, which is threatened to become extinct?

However, a radical position would even go beyond the evaluation of non-economic (in a narrow sense) damages and scrutinize the implied anthropocentrism implicit in the normative values underlying Pareto efficiency (or more generally welfarism) and also in the idea of sustainability in the sense of the Brundtland report. According to, for example, the *deep ecology movement*, heavily influenced by the Norwegian philosopher Arne Næs, animals, wildlife, and biosystems have intrinsic value, whereas the mainstream approach is to see them exclusively as means for human ends. The latter approach would deny wildlife a right to existence, if it does not serve any needs of human beings. The deep ecology movement would reject the characterization of non-human life as a means to an end. The core principle is the belief that the living environment, as a whole, should be respected and regarded as having certain inalienable legal rights to live and flourish, independent of its utilitarian instrumental benefits for human use. This has far-reaching consequences for normative economics, which are based on welfaristic ideas about ends and means, good and bad, right and wrong. From the perspective of deep ecology, classifying a meat market as being efficient is completely off the mark, because animals are ends and not means to human needs. A comparison to slave markets is illuminating: trading slaves on markets can be classified as Pareto-efficient, as long as one denies slaves human and civil rights and does not see them as ends, but rather as means for the needs of the class of "non-slaves." Hence, it is a meaningful problem to discuss the efficiency properties of slave markets in such a society. As soon as one extends basic human and civil rights to all human beings and declares them unalienable, however, there is no meaningful way to discuss the efficiency of such a market, because the traded "resources" are no longer means, but rather ends in themselves. One gets the same fundamental transformation if one grants rights to non-human species.

It would be far beyond the scope of an introductory textbook to dig deeper into the thorny issues of environmental ethics and the consequences for one's perception of economic systems. What the above discussion should have made clear, however, is that our perception of markets relies on normative principles that are—despite their widespread acceptance—far from obvious and innocuous.

There are other, less obvious, ways to cope with externalities and also other, less obvious, sources of externalities in markets. The next two examples focus on business ethics and, especially, the concept of *corporate social responsibility* (CSR), status concerns, and relative-performance measurement as illustrations.

6.2.3.3 Morality and Corporate Social Responsibility

> Globalization makes it clear that social responsibility is required not only of governments, but of companies and individuals. (Attributed to Anna Lindh, 2002)

In the realistic case that the institutional structure of a state is imperfect, in the sense that it does not always provide incentives for (Pareto-)efficient behavior, the question is how the people within society do or should deal with these inefficiencies. An example of this is when property rights are imperfectly enforced because of high transaction costs. The better part of everyday transactions is, for example, formally but not materially protected by property rights, because it would be too costly to enforce them. If a customer buys a bottle of orange juice at a kiosk and the retail clerk refuses to give back the change, the opportunity costs of calling the police, verifying the tort (which is difficult, if the retail clerk refuses to confess), etc. are likely prohibitive. Alternatively, on that subject, it is equally unlikely that the retail clerk can do much to prevent the customer from saying thank you and walking away with the bottle of juice without paying for it. Property rights cannot explain the fact that the overwhelming number of these transactions take place smoothly and efficiently.

There must be other mechanisms at work, and I will briefly discuss two of them. First, the interaction may not be singular but rather repeated and, if there is always a probability that the customer and the retail clerk will meet again in the future, it would be rather shortsighted to sacrifice future trades for the (relatively small) present gain. Repeated interactions can, therefore, be used to build up a reputation as a reliable trading partner, which can stabilize transactions, even in situations where formal property rights cannot be protected by the state. Second, the trading partner may have an intrinsic motivation to play fair. There is broad, scientific consensus by now that individuals are, for good evolutionary reasons, not always selfish, but have the ability and also (sometimes) the desire to act morally. The marginal willingness to keep one's promises, to pay one's bills, etc., however, depends very much on the perception of the situational context. If people have the feeling that—by and large—society gives everyone his or her fair share, their willingness to cooperate, to act fairly and to voluntarily follow certain moral standards of behavior is much larger than in a situation that is considered unfair from the beginning. Social norms and the intrinsic desire to act morally are then substitutes for formal property-rights enforcement. The more porous the system of property-rights enforcement is, the more important moral behavior becomes.

How relevant is the above observation? Is moral behavior, as the example suggests, only necessary for small-scale transactions, like buying soft drinks at kiosks, or is there more to the story? Here is an example. As one has seen, imperfect and asymmetric information is potentially a major cause of transaction costs. Therefore, in all cases where the better-informed party can exploit the other party, moral behavior can reduce transaction costs and facilitate trade. This view has been nicely expressed by Kenneth Arrow (1971): "In the absence of trust [. . .] opportunities for mutually beneficial cooperation would have to be forgone [. . .] norms of social behavior, including ethical and moral codes (may be) [. . .] reactions of society to compensate for market failures." What could be scrutinized in this quote is the implied supremacy of markets. It is too narrow of a view to see morality only as a repair shop for market failures. However, the general point is irrespectively valid: if specialization, exchange, and trust go hand in hand, it is much easier for a society to flourish.

As one will see below, the existence of public goods, like infrastructure, basic research or defense, is a reason why the state can improve efficiency by playing a role beyond the enforcement of property rights. In order to be able to do so, the state needs to have access to finances, which are primarily collected as taxes. The process of globalization has, however, created opportunities for (multinational) firms and (mainly) wealthy individuals to minimize their tax burden by ever more complicated financial constructions. It may be a good deal for small countries to attract big companies by low tax rates, but the result is a global tax structure and provision of public goods that is inefficient. The point is that the international system of sovereign national states and international tax treaties creates loopholes and leads to discretionary power for firms and wealthy individuals and, despite the OECD initiatives, it is unrealistic to close those loopholes by means of enforceable treaties. As a consequence, one can either accept the resulting inefficiencies or appeal to the moral responsibilities of these firms or people. This is what the former Swedish politician Anna Lindh had in mind in the quote from the beginning of this section and international tax evasion strategies, of course, do not exhaust the number of challenges imposed by globalization.

In the field of Business Ethics, corporate social responsibility (CSR) emerged as a separate field of research, exactly because current trends in international markets led to a redistribution of power from the institutions of the traditional state into the hands of corporations. One of the key questions, in this literature, is whether this increase in power goes hand in hand with the moral responsibilities of the managers and the corporation as an institutional actor.

6.2.3.4 Status

> From whence, then, arises that emulation which runs through all the different ranks of men, and what are the advantages which we propose by that great purpose of human life which we call bettering our condition? To be observed, to be attended to, to be taken notice of with sympathy, complacency, and approbation, are all the advantages which we can propose to derive from it. It is the vanity, not the ease, or the pleasure, which interests us. (Adam Smith, The Theory of Moral Sentiments, Chapter II.)

> Comparison brings about frustration and merely encourages envy, which is called competition. (Jiddu Krishnamurti, 2005)

Social comparisons and the urge to outperform others seem to be deep motivational factors for human beings. Humans are, sometimes, not only a cooperative but also a competitive species and there are good evolutionary reasons for why relative performance is an important factor in mate selection. The human metabolism also requires that some absolute standards are met to stay healthy (for example, daily caloric intake) but, apart from that, relative (status) concerns are an important factor for the explanation of human behavior across cultures and times.

However, this powerful drive has a dark side to it and almost all spiritual traditions from Christianity to Buddhism warn people that the concern for relative status is the road to unhappiness and suffering and that the way towards a fulfilling live is to free oneself from social comparisons. Mark Twain has the, perhaps, shortest account of this fact: “Comparison is the death of joy.”

May this be as it is; is there anything that one can say, as an economist, about the functioning of markets, if demand is driven by status concerns? The first observation that one can make is that scarcity works differently for status than for other goods. Say one is eating apples for nourishment. An additional apple makes one better off, irrespective of what the other people are doing. Thus, if everybody in society eats twice as many apples, everybody is better off. This is not true for status goods. If cars are acting as a status symbol (or for that matter, smartphones or Prada shoes) and one buys a bigger car, while no one else in one’s neighborhood does the same, then one gains in status and prestige. However, if everyone buys a bigger car, the effects neutralize and one ends up in the same status position as before, when everyone had the smaller car. It is like running a race: if everyone trains harder and runs faster, the odds of winning remain the same but, if one is the only one who “goes the extra mile,” then one can tip the balance in one’s direction.

What this example shows is that technological progress or an increase in material well-being can alleviate scarcity for ordinary goods (people live healthier, longer lives, are better nourished, etc.), but not for social status. This is why status is called a *positional good*. It is the relative ranking in the pecking order that determines one’s position and, if everyone works twice as hard to improve, then no one will be better off in the end. It might even be the case that a point is reached when everybody is worse off, when people start paying tribute for working longer hours. However, do status concerns create externalities in market economies? To understand this, one can use the extended supply and demand analysis introduced in Sect. 6.2.2. Assume that x measures supply and demand for a status good (mechanical watches), which means that part of the reason for buying this good is to impress the neighbors. Assume further that this interdependency between one and one's neighbor cannot be internalized directly (think about it: "how much would you pay me to not buy that Rolex?"). In that case, the individual value of the status good is, in general, higher than the social value.

One may wonder if *positional externalities* are a mere theoretical curiosity, or if anything more significant is going on. One way to approach this problem is to look for empirical evidence that is anomalous, given the predictions of standard theory (without status concerns), but that can consistently be explained if one accounts for status. In fact, such evidence exists and it became famous as the "happiness paradox." However, it is still highly contested whether the empirical findings are valid.

The happiness paradox refers to patterns in empirical research on happiness. Two findings are key for it. The first relates to the relationship between average subjective happiness and average income. The findings are summarized in Fig. 6.4.

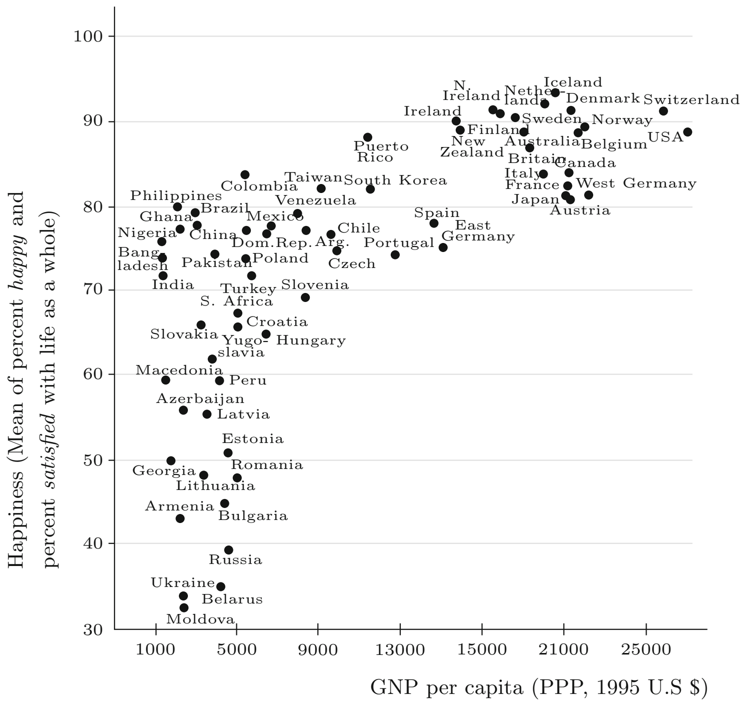

Fig. 6.4 Average subjective happiness and average income (source: Inglehart & Klingemann, 2000, p. 168)

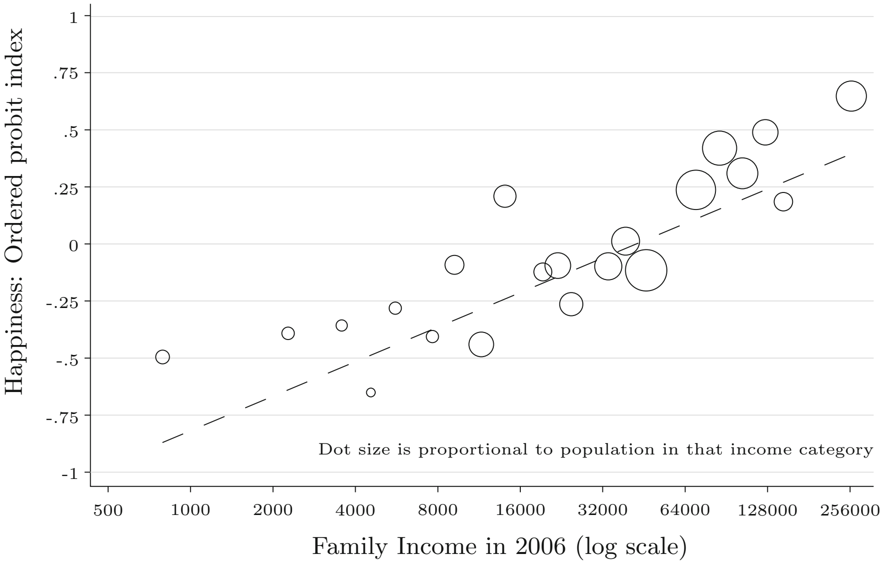

Fig. 6.5 Individual happiness as a function of individual income (source: Stevenson & Wolfers, 2008; General Social Survey, 2006)

The figure depicts *average* happiness levels and *average* income levels in different countries. It shows that there is a positive association between average happiness and average income up to an annual income of about $12,000. However, there is no positive association between average happiness and average income for higher income levels. This "flatness" is sometimes also referred to as the "hedonic treadmill" where one runs faster and faster without moving forward. This finding is difficult to square with the idea that individuals are mutually unconcerned or selfish, because this assumption would imply that increases in material well-being (and average income should be a proxy for this) increase subjective well-being (i.e., happiness). This is apparently not the case. Here is a nice summary of this aspect of the paradox: "People in the West have got no happier in the last 50 years. They have become much richer, they work much less, they have longer holidays, they travel more, they live longer, and they are healthier. But they are no happier." (Layard, 2005)

The second finding refers to *individual* happiness levels as a function of *individual* income within countries, see Fig. 6.5.

The figure reveals that richer individuals are happier than poorer individuals, in a given society, and this is the puzzle: how is it possible that individual income is a good proxy for individual happiness while, at the same time, these effects net out for the whole society as soon as the average income exceeds a certain minimum?

Status preferences provide a missing link for resolving this puzzle: in poor countries, where individuals have to fight for subsistence, the relative importance of non-status-related compared to status-related consumption and production is high.

However, the richer a society gets, the more important status concerns become. Thus, in these societies, there is no longer a positive association between *average* income and *average* happiness, because status effects "net out." If one climbs up on the status ladder, someone else necessarily has to climb it down. However, increases in *individual* income make a difference, because one climbs higher on the status ladder, and the negative happiness effects on others that result from this improvement are irrelevant for one's individual happiness.

As mentioned before, the findings and the interpretation of the happiness paradox are contested. This results from the fact that the exact meaning of the paradox is sometimes misinterpreted. Critics usually start from the premise that the paradox claims that the initially positive correlation between income and subjective happiness disappears above a certain income (often estimated at around $75,000) *at the individual level*. The existence of such an individual kink has been re-examined by Killingsworth in 2021 on the basis of a very large data set and new methods, and he finds no evidence for such a kink. But this finding is without relevance for the paradox, as we have seen.

To attribute the existence of the paradox to a status effect based on relative positioning is in line with a lot of evidence from other fields, like evolutionary biology, where *relative* fitness is key for survival and mating and therefore evolutionary success of ones' genes. Additionally, it comes as no surprise that all the major spiritual traditions humans have created attach large warning signs to individual comparisons. However, even if one takes the interpretation at face value, the policy implications are complicated. Should one infer from the hedonic treadmill that the state has an active role in the internalization of status externalities that is similar to its role in the internalization of, for example, environmental externalities (taxation of status goods, etc.), or should one leave it to the individual to overcome the attachment to status? These are deep questions and they are even more pressing because, as long as social norms declare that social status is a function of material well-being, one straps oneself to the wheel of consumerism and materialism, which is, at least partly, responsible for the environmental externalities mentioned above.

6.3 Four Boundary Cases

> [T]hey devote a very small fraction of time to the consideration of any public object, most of it to the prosecution of their own objects. Meanwhile each fancies that no harm will come to his neglect, that it is the business of somebody else to look after this or that for him; and so, by the same notion being entertained by all separately, the common cause imperceptibly decays. (Thucydides, 2013, The Peloponnesian War, Book 1, Section 141)

Coming back to the variations of the bakery example from the last subchapter, the distinctive difference between the two types of environmental interdependencies (sewage and air pollution) was the physical "reach" of the interdependency-causing activity. In the sewage-case, there was only one person, the fisherman, who was affected by the interdependency with the bakery whereas, in the air-pollution case, the bakery influenced all the residents. These differences in the number of people, who are influenced by economic activities, are an important element in the classification of goods and services and in developing an understanding of the functioning of markets.

The implicit assumption behind the model of competitive markets discussed in Chap. 4 was that the interdependency is *bilateral*. A typical example for a bilateral interdependency is an apple. Either one or the other person can eat an apple (one cannot eat the same apple twice), so Ann's decision to sell an apple to Bill has no direct physical consequences for third parties. The same was true in the sewage example. However, the bilateralism of the interdependency was a result of the fact that only one fisherman made his living from the lake. If two fishermen had have cast their nets into the lake, the interdependency would have been trilateral, because the emissions by the factory would have reduced the catches of both fishermen. In the air-pollution example, the reach of the interdependency was even larger, covering all residents of the area. This observation motivates the following definition.

▶ **Definition 6.3 Reach** The reach of an economic activity is the set of people directly influenced by the activity.

It is important at this point to say a little bit more about individual motives for consumption. Let us therefore come back to the apple from above. Most people see an apple as food. In this case, it causes a binary interdependency. However, it cannot be excluded that people like apples for aesthetic reasons and simply like to look at them. In this case, the interdependency is no longer necessarily binary, more than two people can profit from the apple. The reason why this example may sound rather awkward is because it is. But it makes an important point: economists usually do not care about motives to act because these motives are hard to measure. However, the motive to act may have an impact on the reach of the act, as one can see from the example, with important economic consequences . So, the reach of an act depends on the specific mental context of the act, not on the physical activity itself.

The two meaningful boundary cases are the minimum and the maximum reach. The use of a good with minimum reach has an effect on only one person, and the use of a good with maximum reach has an effect on all individuals in an economy. A good with minimum reach is called *rival in consumption*, and a good with maximum reach is called *non-rival in consumption*. Combined with scarcity, goods with minimum reach create a bilateral interdependency. One has already seen that an apple is an example for a rival good and it is either person A or B who gets nourished by the apple. An example for a global non-rival good is a fossil fuel combustion increasing CO_2 levels which, in turn, contribute to anthropogenic climate change, which has an impact on all individuals on the planet. Finally, an example for a national, non-rival good is the protection against foreign aggressors due to national defense.

A good part of the goods and services fall in-between these extremes. The reach of national defense, for example, is the boundaries of the nation-state. A live sports event or a music concert has a reach that is limited to the visitors of the stadium or concert hall. Additionally, a piece of music uploaded on YouTube has everyone with internet access within its potential reach. Even though reach can vary widely in range, it is customary to start with a discussion of the two extreme forms of rival and non-rival goods and this book will stick to this custom here, keeping in mind that the understanding that one can develop from these cases must be somewhat modified, when applied to intermediate cases.

What one has also seen from the air-pollution example is that different types of transaction costs exist that have an impact on the functioning of markets, as well as on other institutions. In order to be able to use markets to allocate goods and services, one relies on the ability of the owner of the good to exclude others from its use. Without excludability, people would freely use the goods and services provided by others with the consequence that market transactions would never take place. Excludability of goods and services is, therefore, a necessary condition for the establishment of markets and the (opportunity) costs of exclusion are a major source of transaction costs in the market mechanism. This motivates the following definition:

▶ **Definition 6.4 Exclusion Costs** The transaction costs that are necessary to exclude third parties from the appropriation and use of goods and services owned by a person are called exclusion costs.

The reach of an economic activity and the exclusion costs span a two-dimensional map where goods can be pinned down according to their specific characteristics. Figure 6.6 illustrates this point.

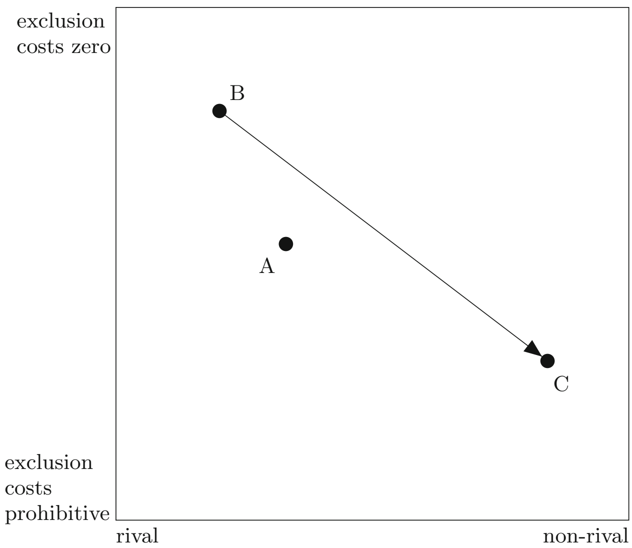

Fig. 6.6 Types of goods according to reach and exclusion costs

Table 6.1 A taxonomy of goods

	Rivalrous	Non-rivalrous
Excludable	Private goods	Club goods
Non-excludable	Common goods	Public goods

The four corners of this "map" define the boundary cases of minimum and maximum reach and zero and prohibitive exclusion costs. In reality, all goods are located somewhere in between. A point like *A* could, for example, be a car. Its reach is to carry up to five persons and exclusion costs are given by the price for locks and the alarm system.

Exclusion costs can vary over time. Take music as an example. In the good old days of the phonograph record, excluding third parties from the illegal consumption of music was relatively easy: in the absence of technologies for copying, exclusion required investments to prevent the theft of the physical record. The piece of music, as such, was non-rival in consumption, but the specific physical "carrier", the record, made it *de facto* rival (a point like *B* in the figure). With the invention of music cassettes, copying music became easier, which had an impact on the way property rights had to be protected. However, the big change came, of course, with the digitalization and distribution of music via the internet. This technological change essentially transformed music from a rival to a non-rival good and had a huge impact on the ability of the owner to exclude people from the illegal use of music (a shift from point *B* to point *C* in the figure). It took the music industry years to cope with this problem and to develop new business models. Technological inventions like copy and data-storage devices can, therefore, cause externalities for other products, like music or software.

Again, custom has it that one focuses on the two most extreme manifestations of exclusion costs. If exclusion causes zero transaction costs, then the good or service is called *(perfectly) excludable*. If exclusion causes prohibitive transaction costs, then the good or service is called *(perfectly) non-excludable*. Perfect excludability is, obviously, a simplifying assumption. To quote James Madison in the Federalist Papers No. 51 (p. 377), "If men were angels, no government would be necessary," because mankind would never steal, which is the only way perfect exclusion is possible without any costs. Otherwise, shop owners protect their shops by locks, security systems, and guards, all of which contribute to transaction costs. The same is true for the general public that protects its flats, houses, and cars against theft. However, some goods come relatively close to the ideal of perfect excludability, for example, the above-mentioned apple. An essential good that is non-excludable is oxygen in the air. Just try to enforce any property rights on a specific molecule.

The extreme cases of rivalry and excludability give rise to a two-by-two matrix of goods that is useful for a first discussion of the different types of challenges that have to be overcome, if one wants to organize economic activities. Table 6.1 gives an overview. The four boundary cases are called private goods, common goods, club goods, and public goods, and I will discuss them in turn.

Private Goods One does not have to devote much time and attention to private goods, because they are the ones whose efficient production and distribution can be organized relatively easily, at least in principle. They are also the type of good that is implicitly assumed in the theory of competitive markets, which is analyzed in Chap. 4. Their minimum reach makes the interdependence bilateral under conditions of scarcity, and market prices induce efficient incentives to produce and exchange these goods. If it is, furthermore, costless to exclude others from the use of these goods, without consent from the owners, there is nothing standing in the way of establishing markets.

Common Goods Things are getting much more involved when it comes to common goods, in the literature sometimes also referred to as Common-pool goods. These goods share the minimum-reach property, but it is not possible to allocate them using market mechanisms, because the owner of these goods cannot prevent others from their use, which is a prerequisite for the functioning of market transactions. The ability to exclude others from the use of resources, goods, and services depends very much on the state's ability to function properly. Even the night-watchman state needs laws and law enforcement to support the development of markets and, with weak state institutions (insufficient funding of the police, corrupt officials, etc.), excludability is far from guaranteed, which prevents markets from functioning efficiently. Irrespective of the quality of institutions, though, there are some goods and resources, whose inherent qualities make exclusion very costly. Examples are migratory species, like fish and birds, or oxygen. In comparison to cattle, where the assignment of property rights to specific animals is possible and effectively enforceable in principle, it is very hard to assign and enforce property rights to individual fish. This need not be an impediment to effective exclusion, as long as close substitutes to property rights for fish exist, and a close substitute could be property rights over the part of the sea where a shoal of fish lives. For example, the United Nations Convention on the Law of the Sea assigns exclusive economic zones (EEZ) to states. These zones grant special rights regarding the exploration and use of marine resources to nation states. They stretch from the baseline out to 200 nautical miles from its coast (as long as there are no overlaps between different countries). Territories beyond this stretch are international waters without exclusively assigned user rights.

Exclusion is, therefore, possible for all fish that migrate only within the boundaries of a given EEZ. However, for fish that migrate beyond or across the EEZs or in international waters, property rights over the sea are no effective substitutes for property rights over the fish themselves. The result is often overexploitation, because sustainable shoal management is not in the interest of the states or the fishery fleets: they have to bear the (opportunity) costs of sustainable management, but part of the revenues spill over to other nations or fleets. In order to understand this problem better, it makes sense to dig a little deeper into the economics of renewable resource management.

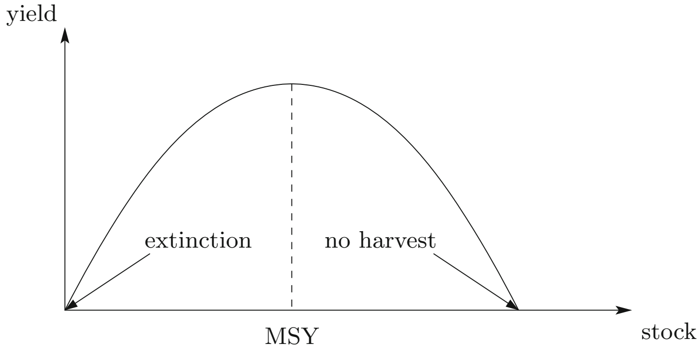

Fig. 6.7 Maximum sustainable yield

For all renewable resources, there is a causal relationship between the size of the stock and the yield. If the stock size is zero, obviously, the yield is zero, as well. Increasing stock size makes positive yields possible and the yield increases with stock size up to a certain point, where larger stocks require smaller yields again, up to the point of maximum stock size, which can only be sustained if the yield is zero. Figure 6.7 shows this relationship.

The *maximum sustainable yield* (MSY) is the largest yield (or catch for the fishery example) that can be taken from a species' stock over an indefinite period. It is given by point *MSY* in Fig. 6.7. Given this biological law, it is in the interest of a long-term business to adjust the yield around *MSY*. Underexploitation would leave money on the table and overexploitation would trade long-term for short-term profits. However, if the stock is not excludable, the incentives to act according to the long-run interests are diminished, because no user of the stock can be sure that the stock will still be there tomorrow. There is a tension between the logic of individual and the logic of collective action. I will come back to this point in Chap. 9.

Digression 6.6 (Cod)
One of the most "famous" examples for the overexploitation of marine resources is *gadus morhua*, or cod. Cod has been a very important commodity for about 600 years and dried cod (also called stockfish or clipfish) was an essential food for mariners. During the Middle Ages and the Age of Discovery, it was one of the most important commodities that made seafaring possible, because dried cod was one of the world's first non-perishable foods. It also became a popular food in Europe and, for about 250 years, 60% of all the fish eaten in Europe was cod. As early as 1620, cod fishing was at the center of international conflict, because various nations attempted to monopolize rich fishing grounds. Even the King of Spain married off his son

(continued)

Digression 6.6 (continued)
to the royal house of Portugal, because of fishing rights. By the late 1700s, codfish made New England an international commercial power.

For a very long time, it was beyond imagination that human activity could negatively impact the species, because it was famous for its reproduction rates. In the words of Alexandre Dumas (1873), “It has been calculated that if no accident prevented the hatching of the eggs and each egg reached maturity, it would take only three years to fill the sea so that you could walk across the Atlantic dryshod on the backs of cod.” Human imagination proved to be too limited. Since the late 1950ies, technological advances, which have made fishing more effective, have heralded the start of a period of overfishing, which led to a first partial collapse of Atlantic northwest cod fishery in the 1970ies and a complete collapse in the 1990ies. In the summer of 1992, the Northern Cod biomass fell to 1% of its earlier level, see Fig. 6.8.

Cod is only a very prominent example of the problem of overfishing: the Peruvian coastal anchovy fisheries crashed in the 1970s after overfishing, the sole fisheries in the Irish Sea and the west English Channel have become hopelessly overfished and many deep-sea fish are at risk, as well as a number of species of tuna. A 2008 UN report asserts that the world’s fishing fleet could be halved with no change in catch. Even more fundamental is the impact on the whole marine biosystem. Scientific evidence regarding the impact of humans on marine life is nicely summarized in a recent paper by McCauley et al. (2015): “Three lessons emerge when comparing the marine and terrestrial defaunation experiences: (i) today’s low rates of marine extinction may be the prelude to a major extinction pulse, similar to that observed on land during the industrial revolution, as the footprint of human ocean use widens; (ii) effectively slowing ocean defaunation requires both protected areas and careful management of the intervening ocean matrix; and (iii) the terrestrial experience and current trends in ocean use suggest that habitat destruction is likely to become an increasingly dominant threat to ocean wildlife over the next 150 years. [...] Human dependency on marine wildlife and the linked fate of marine and terrestrial fauna necessitate that we act quickly to slow the advance of marine defaunation.”

Unresolved commons problems even led to the collapse of whole societies throughout human history. As far as we know today, examples are the Greenland Norse, Easter Island, the Polynesians of Pitcairn Island, the Anasazi of southwestern North America and the Maya of Central America (Diamond 2005). There are, of course, always several factors that contribute to the collapse of a society, but overexploitation of natural resources plays a very prominent role.

Markets are only sufficient, not necessary, to reach efficiency. Humans have developed other effective means to cope with commons problems and property

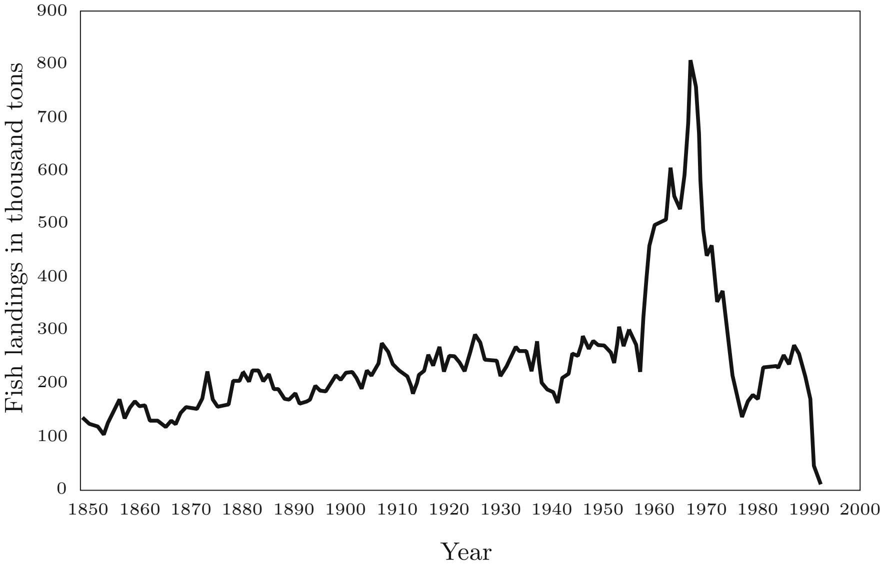

Fig. 6.8 Collapse of the North Atlantic cod fishery (source: Millennium Ecosystem Assessment, 2005, p. 12)

rights plus trade, interestingly, is not one of the most common forms of resource management, as is stressed by Elinor Ostrom who systematically analyzed solutions to the commons problem in different societies. She came to the conclusion that the absence of private property and markets need not be an impediment to the efficient and sustainable use of common goods. On the contrary, evidence suggests that well-maintained systems of resource and ecosystem management can, in fact, yield better results than markets can. These findings are of considerable importance for the way one should think about institutions, because they point towards the blind spots of the standard model in economics, which puts (too?) much emphasis on markets. What makes Ostrom's findings difficult to integrate into this discussion about common goods is, however, a tension between the microeconomic definition of common goods and the one she uses. This book defines them by the "technological" property of non-excludability, which excludes certain institutions *by definition*. Ostrom (2005) starts from a different perspective, focusing on goods and resources for which common property exists *de facto*. The set of admissible institutions, therefore, remains unclear and some of her criteria for successful institutional principles show that they rely on excludability. With this caveat, one can briefly discuss the basic principles of successful management of common goods that have been identified.

- Pretty much in line with the standard model, precise delineations of the resources and effective exclusion of externals are important. Hence, even if exclusion is not practiced within the group, it is important to exclude outsiders.

- One needs rules regarding the appropriation and provision of the common goods and these rules have to be adapted to local conditions. This property shows that institutional diversity is key, because there are close ties between the norms and cultures of groups and the environment.
- Rules for collective decision-making play an important role by giving voice to as many users of the common resource as possible and allowing the management system to adapt to changing environmental and social conditions.
- Monitors maintain compliance effective and are part of or are accountable to the users.
- One needs a scale of graduated sanctions for resource appropriators, who violate community rules.
- One needs mechanisms of conflict resolution that are cheap and are easily accessible for the conflicting parties.
- The self-determination of the community is recognized by higher-level authorities.

This list shows that institutions, which can effectively manage common goods, are diverse, but share common patterns. One-size-fits-all solutions that rely on property rights and markets should, therefore, be considered with caution, because they are only one means to cope with commons problems and may even be maladapted to local norms and traditions. However, given that the above principles have been identified in mostly stable and small communities, it remains an unresolved question whether they can be "scaled up" to cope with large or even global commons problems. Trust and sanctions are relatively easy to establish in small and stable communities and small-scale communities are also the environments in which human beings evolved and developed their intuitions about fairness and justice. A suggestion about how to deal with larger common-goods problems, which comes out of this line of research, is to organize them in the form of multiple layers of nested organizational units.

Club Goods If exclusion is possible and the good is non-rival, then it is a club good. The name sounds strange at first, but it will become clear as I discuss the implications of this combination of factors. Think of a live music concert or sports event. In order to be able to enjoy it, one has to enter a stadium or concert hall and this physical barrier can be used to exercise exclusion and to force one to buy an entrance ticket. Further examples for club goods are Pay TV, lectures, music and software or—to a certain extent—roads. I will briefly discuss them, to see if there are interesting patterns to be found.

Lectures at universities, for example, are pretty much like live music and sports events club goods, because one can, in principle, exclude people from attending and thereby enforce the payment of prices. These prices are sometimes also called entrance or user fees. Moreover, if the primary motive for attending lectures is a grade certificate, one can enforce the payment of user fees by withholding the certificate. Given that exclusion is possible in principle, it is mainly a political decision of whether access should be regulated by the price mechanism and whether it shall be complemented by other mechanisms (like making a high-school degree a mandatory prerequisite for applications). A lot of public universities in Europe charge only moderate or no tuition fees, whereas private universities and also public universities in countries like the USA charge substantial amounts. MIT, for example, charged its students an annual fee of approximately $44,525, (academic year 2019/20), which is pretty much in line with other top US universities. The University of Cambridge discriminates tuition fees between UK and international students. Students from the UK pay £9250 for the academic year 2021, and international students pay £22,227 (for their economics programs).

Another aspect of lectures, music and sports is that the "live event" has a limited reach defined by the capacity of the lecture room, concert hall or stadium. Therefore, the maximum supply is defined by this capacity. To make sure that supply meets demand, one can rely on the price mechanism, adjusting user fees accordingly or one can use alternative rationing schemes. Universities, for example, screen students by means of entrance tests, and so on.

Why is there a difference in the way demand is rationed between, for example, music events and university programs? Profit-oriented universities face a tradeoff between short- and long-term profits. Assume that, at given tuition fees, demand exceeds supply, such that entrance tests must be used to ration. In the short run, the university could increase its revenues by increasing tuition fees, but this may have a negative impact on the selection of the student body, which may have a negative effect on the future reputation of the university, which—as the last step in a complex causal chain—has a negative effect on future entrance fees. This is not the case with other commercial events, like concerts and sports, because the talents and motivation of the audience has only a very limited effect on the quality of the event.

One has already seen that live events face certain capacity constraints, which limits the reach of a club good. These limitations can, in principle, be overcome by "going digital." Broadcasting sports events or live music and selling studio music via, for example, Spotify markedly extended the reach of these goods such that, at the maximum, everyone with access to the internet can get access to the product, which creates huge profit potentials for firms. However, every distribution channel has its own enforcement costs and the music industry had to learn this the hard way during the early days of the internet, when it was almost impossible to prevent illegal downloads. Thus, digital products somehow oscillate between the characteristics of a club good and a public good.

Last, but not least, roads are an example of a good for which regulating access via price mechanisms is becoming increasingly popular, partly because of changes in the available technologies of exclusion, and partly because of other trends. Access to most roads in the majority of countries is free, and traffic infrastructure is financed by taxes. One of the reasons is that road pricing and the investments in the setup and maintenance of the necessary exclusion technology is very costly in general. Furthermore, there is a lot of evidence that, as long as congestion is not an issue, a region's traffic infrastructure creates huge positive externalities, because it facilitates trade. For example, Paris experienced a boost in its economic development after the abolishment of bridge tolls by Baron Haussmann in the nineteenth century. However, positive externalities caused by traffic infrastructure can easily be compensated by negative externalities, if traffic gets congested. The current trend to (re-)introduce tolls on highways, bridges, and other major roads is, to a certain extent, a reaction to the increasing economic costs of a congested traffic infrastructure, combined with more efficient technologies for the enforcement and collection of tolls that bring down the transaction costs of enforcing fees.

If one looks at club goods from a slightly different angle, one observes an interesting property because, as long as no capacity constraints are binding (there are still empty seats in the lecture room), an additional user of the good causes no additional costs. This property has two interesting implications.

First, from an efficiency perspective, it makes sense to increase the number of users to the largest extent possible, because each additional user increases the gains from trade (no additional costs, but additional consumer surplus). It follows that actually excluding people from using the club good can never be efficient. Exclusion is a mechanism that can be used to establish a market and, therefore, has to be distinguished from the act of actually excluding people. The threat of exclusion makes the enforcement of prices (like tolls or tuition fees) possible, but it depends on the actual prices whether potential users will be excluded or not.

Second, the fact that firms can serve additional customers at approximately zero additional costs creates a tendency towards the monopolization of markets for club goods. Take software as an example. From the point of view of a software developer, the lion's share of the costs she has to invest is caused by the development of the product. As soon as the product is on the market, each additional user causes approximately zero additional costs. Hence, the more users there are the better, for the software developer. The fact that the minimum price that is necessary to break even falls as the number of users increases creates an inherent tendency for market concentration: firms with larger market shares can outcompete their smaller competitors, because they can charge lower prices without running a deficit. This is the reason why club goods are sometimes also called *natural monopolies*. I will come back to this point when I discuss production costs in Chap. 12 and monopoly pricing in Chap. 14.

Public Goods The last type of good is non-rival in consumption and exclusion is impossible. If exclusion is impossible, markets cannot be used to incentivize the production and allocation of these goods, so one has to look for alternative ways to organize economic activity.

Examples for public goods are fireworks, basic research, national defense, avoidance of climate change and legal systems, and the following paragraphs will discuss all five examples in turn.

Fireworks are an example for a (local or regional) public good, because no one in a city can be effectively excluded from the spectacle and it is also non-rival. Arguably, the other examples are more important than fireworks.

Basic research is non-rival, because the fact that I understand a mathematical theorem does not make it impossible for another person to understand it at the same time. All knowledge, in this sense, is non-rival. The difference between basic and applied research is, therefore, not the degree to which goods are rival, but the ability to exclude. Applied research usually builds on basic research and "brings it to the market." A good example is quantum physics. Without quantum mechanics, there would be no transistor and hence no personal computer and no laser. Therefore, the development of quantum mechanics made the development of a large number of products possible, without which today's world would be impossible. Products or components thereof, like transistors or computers, can be effectively protected by patent law. However, the protection of property rights for the mathematical formulation of quantum physics, like the Schrödinger equation or the uncertainty principle, is not as easy to do. Even if a formal property right exists, one cannot sell the Schrödinger equation directly and it is, in general, very hard to establish a causal link between abstract physical principles and marketable goods, such that potential property-rights infringements would be hard to detect.

The public-goods character of basic research requires alternatives to the market mechanism and one can find essentially two different ways to organize the production process. One is public financing. Major resources for basic research at universities and research institutions are provided by the state and financed by taxes, and career incentives for scientists have the form of a contest, where the relatively most successful qualify for professorships and research money. The alternative is to interpret education and research as complementary bundles where basic research is, at least partly, financed by tuition fees and students profit indirectly from the direct access to a research-intensive environment, because new ideas disseminate earlier, which gives them a competitive edge in developing new, marketable products. A good example is the synergistic relationship between Stanford University and Silicon Valley startups and companies.

A staple example for public goods is national defense. It is relatively obvious that, within certain geographic limits, a military of a given size provides a non-rival service to its citizens. By its very nature, the reach of national defense is the people living within the territory of a nation state (protecting people living abroad is much more difficult). The non-excludability of national defense becomes apparent, if one distinguishes between an actual military conflict and the insurance against attacks provided by the military. In case of an act of aggression, exclusion of specific citizens is, in principle, possible. One could escort them to the border and hand them over to the enemy. However, it is virtually impossible to exclude people within the territory from the insurance provided by the existence of the military, which results from the fact that one is not attacked at first place.

Last, but not least, the avoidance of climate change has important properties of a truly global public good: CO_2 emissions have global effects on the climate, so measures to slow down climate change cause non-rival effects. Similarly, no one can be excluded from the effects of climate change (or the effects from slowing it down). The global nature of climate change is what makes the problem so difficult to solve. The expected costs and benefits of climate change are unevenly distributed between countries and regions and international negotiations take place within the holey network of international law. International agreements are difficult to reach and they are even more difficult to enforce. If one would ask a group of social scientists and psychologists to design a problem that is hard to solve for human beings, I am pretty sure that it would look very much like climate change.

The last example for a public good that I will discuss is the legal system of a country, because it allows one to focus one's attention on the fact that excludability need not be a physical characteristic of a good. The legal system of a country is clearly non-rival. If A uses contract law to set up contracts, it does not impede B from using the contract law herself. Things get more complex when it comes to excludability. Technically, it is no problem to exclude people from contract law because the courts could decide not to apply it to contracts signed by specific people. However, contract law is embedded within the rest of the legal system, which makes such restrictions illegal. It can (and, in practice, usually does) specify that all laws apply equally to all citizens of a country. Such a norm creates a legal non-excludability and the system depends on levels of analysis to determine whether such constraints are taken as a given or if they are subject to scrutiny.

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Part III

Foundations of Behavior and Interaction

7 Decisions and Consumer Behavior

This chapter covers . . .

- the concepts of preferences and utility functions and how these are related.
- how the assumption that individuals maximize preferences can be used to determine the individual demand functions on a competitive market.
- the strengths and weaknesses of this approach as a foundation of choice and decision-making in general and the structure of demand functions specifically.

7.1 Basic Concepts

> The theory of Economics must begin with a correct theory of consumption.
> (William Stanley Jevons, 1905/1965)

Individual and market demand are the consequences of decisions made by individuals. Until now I have taken a shortcut and skipped a more detailed analysis of the way individuals make decisions, because I wanted to keep the focus on the functioning of markets. For that purpose, it was sufficient to heuristically explain how prices, income, and other factors influence demand. However, this shortcut's cost is preventing one from developing a deeper understanding of the structure of individual and market demand. Additionally, the way I related the idea of Pareto efficiency and the demand function was also pretty clumsy.

Reduced to its essential core, economic decision theory is very simple: One assumes that individuals choose the best alternative from a set of admissible alternatives. In a market context, the admissible alternatives are the goods and services a consumer can afford, given prices and income. It is more difficult to model what it means that individuals choose the best alternative, though. This chapter is devoted to making these ideas precise and to seeing how they can help us to gain a better understanding of market behavior and of behavior in general.

M. Kolmar, *Principles of Microeconomics*, Classroom Companion: Economics,
https://doi.org/10.1007/978-3-030-78167-5_7

7.1.1 Choice Sets and Preferences

In order to develop a decision theory, one needs two conceptual ingredients. First, a set of alternatives from which an individual can choose. Call it a *choice set* and denote it by $X = \{x^1, x^2, \ldots, x^n\}$, in which $x^i, i = 1, \ldots, n$ is one of the possible alternatives and assume, for simplicity, that the total number of alternatives n is finite. The idea of a choice set is very general. If one goes to a café, one's choice set is a subset of all of the items on the menu. This implies that an alternative can be a list of individual items, like "one cup of tea, two scones, and one portion of orange jam." Mathematically speaking, this type of list is called a tuple. If x^i is the above-mentioned alternative, it could be denoted as $x^i = \{$quantity of tea, number of scones, quantity of orange jam$\} = \{1, 2, 1\}$. If one goes to vote, one's choice set is the set of all admissible parties or candidates, and if one is deciding what to do after high school, one's choice set is the set of all potential professions.

Second, the individual may prefer some alternatives to others, which is an expression of her taste or preferences. Assume that she is able to make pairwise comparisons of all the alternatives in X to make statements like, "I prefer alternative x^i to alternative x^j," or "I am indifferent between alternative x^i and alternative x^j." In order to have a lean notation, economists use the following symbols for these statements: "I prefer alternative x^i to alternative x^j" is denoted by "$x^i \succ x^j$" and "I am indifferent between alternative x^i and alternative x^j" by "$x^i \sim x^j$."

It is important to understand the exact meaning of the terminology. Mathematically speaking, one takes two arbitrary elements of X, x^i and x^j, and compares them to each other. This comparison is called a *binary relation* on X. The *strict preference relation* , "$\succ$," and the *indifference relation*, "$\sim$," can therefore be denoted as a subset of the Cartesian product of X, $X \times X$. (I am slightly abusing the notation by using the symbols as names for both the relation and for indicating the binary comparison of alternatives.)

Here is an example: Assume that Ann can choose between an apple, x^1, an orange, x^2, and a cherry, x^3. In this case, the choice set is equal to $X = \{x^1, x^2, x^3\}$ and the Cartesian product is the set of all ordered pairs $X \times X = \{(x^1, x^1), (x^1, x^2), (x^1, x^3), (x^2, x^1), (x^2, x^2), (x^2, x^3), (x^3, x^1), (x^3, x^2), (x^3, x^3)\}$. Assume that Ann prefers apples to oranges and is indifferent between oranges and cherries, $x^1 \succ x^2$, $x^2 \sim x^3$. If one reads a pair (x^i, x^j) as "x^i stands in relation R to x^j," one can represent her preferences, "$\succ$," by the subset of pairs $\{(x^1, x^2)\}$ and her preferences, "$\sim$," by the subset of pairs $\{(x^1, x^1), (x^2, x^2), (x^2, x^3), (x^3, x^3)\}$. Note that the pairs (x^i, x^i) are elements of the subset, because Ann is indifferent between an alternative and itself. This property is not self-evident from a purely mathematical point of view and, therefore, sometimes stated as an assumption of the preference relation that is known as *reflexivity*.

As stated, relation "$\succ$" is called the *strict preference relation* and relation $\sim$ the *indifference relation*. It turns out that it is easier to work with a third type of relation that is called the *weak preference relation*, which is denoted by "$\succsim$." It contains all of the pairs from $X \times X$ that either belong to the strict preference or the indifference relation. In this example, it is the set $\{(x^1, x^1), (x^1, x^2), (x^2, x^2), (x^2, x^3), (x^3, x^3)\}$. The strict preference and indifference relations can easily be reconstructed from the weak preference relation by the following operations:

- $(x^i \succ x^j) \Leftrightarrow (x^i \succsim x^j) \wedge \neg(x^j \succsim x^i)$,
- $(x^i \sim x^j) \Leftrightarrow (x^i \succsim x^j) \wedge (x^j \succsim x^i)$,

in which $\wedge$ and $\neg$ stand for the logical operations "and" and "not."

In order for the concepts to have predictive power, one has to make additional assumptions on the structure of the weak preference relation.

▶ **Definition 7.1 Completeness** For every $x^i, x^j \in X$, either $x^i \succsim x^j$, or $x^j \succsim x^i$, or both are true.

The assumption implies that the individual can compare any two pairs of alternatives. This assumption may sound innocuous, because it seems obvious that one should either be better off with one alternative or the other. However, critiques point out that, depending on the context, alternatives can exist that cannot be compared in a meaningful way. Think, for example, of the alternative "destruction of human life by means of nuclear weapons" and "destruction of human life by means of a lethal virus." It is argued that there is a meaningful difference between being indifferent between two alternatives and not being able to compare them. If one has to choose between alternatives whose consequences are beyond our imagination, it is not clear that an inability to compare and indifference are the same.

▶ **Definition 7.2 Transitivity** For every $x^i, x^j, x^k \in X$, if $x^i \succsim x^j$ and $x^j \succsim x^k$, then $x^i \succsim x^k$.

Transitivity implies that there are no "cycles" in the relation. The main justification for this assumption stems from the so-called money-pump argument, which rests on the idea that a person with intransitive preferences can be exploited by some other person. In order to understand this, assume that there is a "cycle" $x^i \succ x^j \succ x^k \succ x^i$ and that the individual is willing to pay at least one cent for the next-best alternative. In that case, she would be willing to give up x_i plus a small amount of money in exchange for x_k, x_k plus a small amount of money in exchange for x_j and—attention: money pump—x_j plus a small amount of money in exchange for x_i. Now she is back where she started, with the exception that the individual has lost three cents. Continuing this process would, in the end, separate the individual from all her money.

However, a lot of empirical experiments have shown that transitivity cannot be taken for granted. Here is an example. Procrastination describes the tendency to delay uncomfortable duties until later. A tendency to procrastinate may have very adverse consequences and the intransitivity of inter-temporal preferences seems to be playing an important role. This is why: assume that it is Monday and you have a report due on Thursday. Overall, you would like to hand in a high-quality report. However, starting to work on Monday is less preferable to starting to work on Tuesday ("you know, I had a stressful day anyway"). However, when Tuesday comes, it is preferable to delay and start working on Wednesday ("I need the pressure to get things done"). However, from Wednesday's perspective it seems better to delay another day ("well, I simply cannot do it"). However, on Thursday it is too late to prepare and hand in a report of decent quality.

A weak preference relation that is complete and transitive is called a *preference ordering*. What do they imply in this little example? One already knows that Ann's preferences are $x^1 \succsim x^2$ (because $x^1 \succ x^2$ and $\succsim$ is a weaker condition than $\succ$) and $x^2 \succsim x^3$ (because $x^2 \sim x^3$ and $\succsim$ is weaker than $\sim$). Completeness is guaranteed by assumption (there are only three alternatives in the example) and transitivity implies that one can infer $x^1 \succsim x^3$ from $x^1 \succsim x^2 \succsim x^3$. Hence, the completed preference ordering is given by $\{(x^1, x^1), (x^1, x^2), (x^1, x^3), (x^2, x^2), (x^2, x^3), (x^3, x^3)\}$.

Completeness and transitivity are usually taken for granted in almost all economic applications. However, depending on the specific context that is analyzed additional assumptions have to be imposed.

▶ **Definition 7.3 Continuity** For any $x^i \in X$ the set of all $x^j \in X$ is such that $x^i \succsim x^j$ and the set of all $x^k \in X$ is such that $x^k \succsim x^i$ are closed sets in X.

Continuity is less obvious from an economic point of view, but it still has some intuitive plausibility. It implies that the preference relation does not "jump" in the following sense. Assume that an individual is comparing two alternatives, x^1 and x^2, and she weakly prefers x^1 to x^2, $x^1 \succsim x^2$. For example, if one modifies x^1 a tiny bit to $x^1 + \epsilon$, in which ϵ is a very small quantity, then the preference ordering does not suddenly reverse, $x^1 \succsim x^2 \Rightarrow x^1 + \epsilon \succsim x^2$.

▶ **Definition 7.4 Monotonicity** For any $x^i, x^j \in X$, $x^i \geq x^j$ and $x^i \neq x^j$ imply that $x^i \succ x^j$.

Monotonicity needs a few words of clarification. The specification of X is completely general: Elements can be arbitrarily complex or very simple alternatives. However, in some cases the alternatives can be quantitatively measured and compared, for example the quantity of a good like milk. In that case, x^i could be two liters of milk and x^j one liter. In all of these cases, an expression like "$x^i \geq x^j \wedge x^i \neq x^j$" makes sense. It makes no sense, however, to compare smartphones with ice cream. Monotonicity is, therefore, only applicable for those alternatives that can be measured and quantified on an absolute scale. It then implies that the individual prefers larger quantities to smaller quantities.

▶ **Definition 7.5 Convexity** For any $x^i, x^j \in X$, such that $x^i \succsim x^j$ and for all t : $0 \leq t \leq 1$, it follows that $t \cdot x^i + (1 - t) \cdot x^j \succsim x^j$.

▶ **Definition 7.6 Strict Convexity** For any $x^i, x^j \in X$, such that $x^i \sim x^j$ and for all $t : 0 < t < 1$, it follows that $t \cdot x^i + (1 - t) \cdot x^j \succ x^i$.

Convexity and strict convexity are similar in spirit. What they imply is that individuals prefer balanced over extreme alternatives. However, in order to illustrate this idea, one has to restrict one's attention to the alternatives that are quantifiable and measurable in the same way as one has assumed to make sense of monotonicity.

Convexity and strict convexity will play an important role in the theory of consumer choice on competitive markets, which is why it makes sense to discuss them in greater detail. Assume that the alternatives from which the individual can choose are quantities of two different goods, like bread and water. Denote two alternatives by $x^1 = \{10, 0\}$ and $x^2 = \{0, 10\}$. In alternative 1 the individual gets 10 units of water and no bread, while in alternative 2 she gets no water and 10 units of bread. In this example, convexity and strict convexity imply that an individual would, for example, prefer the more balanced alternative $x^3 = 0.5 \cdot x^1 + 0.5 \cdot x^2 = (5, 5)$ to the extreme ones.

In the example, convexity and strict convexity seem to make perfect sense. However, there are situations where it is not convincing: If the first good is Miso soup and the second is vanilla ice cream, few people would like to eat them together at the same time.

The above assumptions are usually not all imposed simultaneously. As the theory of consumer choice on competitive markets will show, economists try to establish properties of choice behavior with minimal assumptions about preferences, because every additional assumption constrains the admissible behavior of individuals, thus making the theory less general. Generality of the theory can be seen as a virtue in itself, but it is even more important in the present context because preferences cannot be directly observed and therefore not directly empirically tested. Only behavior is observable and therefore testable. Hence, one would like to abstain from very specific assumptions regarding unobservable elements of a theory.

One can now define the concept of rationality as used in economics. It has two different aspects. First, if individuals have a preference ordering, a well-defined subset of alternatives $X^o \subset X$ exists that defines the best or optimal alternatives given the preferences. Such a set would not necessarily exist, if preferences were not complete and transitive. Hence, a preference relation is called *rational*, if it is complete and transitive. Second, it is not sufficient that individuals are able to consistently order the alternatives according to their preferences; they must also *act* according to them. Hence, individual *behavior* is rational, if the individual *chooses* a best alternative given the choice set and the preference ordering. This idea of rationality is at the heart of the concept of *homo oeconomicus*.

▶ **Definition 7.7 Homo Oeconomicus** An individual behaves as homo oeconomicus, if (i) she perceives a choice situation as a choice set X, (ii) has a preference ordering over this choice set, and (iii) chooses one of the best alternatives from this choice set, given her preferences.

Two statements are helpful to understand this. First, the concept of rationality is purely instrumental. It only requires that the preferences are structured in a manner that makes it possible to talk about better and worse alternatives in a meaningful way and that individuals act according to their preferences. It does not scrutinize the individual's taste or value judgements that cause her preferences. A debate that allows one to distinguish between better and worse preference orderings would build on a different concept of rationality, which is called value-based rationality. Mainstream economists accept a philosophical position called *subjectivism*, a value judgement that leads to an acceptance of all types of preference orderings. Second, note that no such thing such as selfishness enters this definition of homo oeconomicus. Selfishness is not an integral part of what economists consider rational behavior, even though selfish behavior is added as an *additional* assumption in a lot of analyses. The reason is that concepts such as selfish, altruistic, sadistic, etc. preferences refer to *motives of action* and, as I have just said, mainstream economists do not scrutinize such motives but take them as given. It would, therefore, be alien to the idea of instrumental rationality, if it required any specific motive to act.

In order to get started with an analysis of decision-making, one needs a few more concepts.

▶ **Definition 7.8 Not-Worse-Than-x Set** The Not-Worse-Than-x Set, for an alternative $x \in X$, $NW(x)$, is given by the set of all $x^i \in X$, such that $x^i \succsim x$.

▶ **Definition 7.9 Not-Better-Than-x Set** The Not-Better-Than-x Set, for an alternative $x \in X$, $NB(x)$, is given by the set of all $x^i \in X$, such that $x \succsim x^i$.

▶ **Definition 7.10 Indifferent-To-x Set** The Indifferent-To-x Set, for an alternative $x \in X$, $I(x)$, is given by the intersection $NW(x) \cap NB(x)$.

7.1.2 Indifference Curves

Thus far, I have introduced the concept of a preference ordering in the simplistic case of a finite set of alternatives X. However, the concepts can be readily generalized to allow for infinitely many different alternatives, which is usually done if the theory is applied to market contexts. In this case, if there are n different goods, then the choice set is a subset of the n-dimensional set of positive real numbers, $X \subset \mathbb{R}_+$. In this case, one can illustrate the indifferent-to-x set by a graph. Assume that there are two goods whose quantities are represented by the two axes of Fig. 7.1.

The downward-sloping graph represents the indifferent-to-x set for an alternative that one calls a consumption bundle $\bar{x} = (\bar{x}_1, \bar{x}_2)$. It is called *indifference curve*. Hence, Ann is indifferent between this consumption bundle and any other consumption bundle on the indifference curve ($\tilde{x} = (\tilde{x}_1, \tilde{x}_2)$ and $\hat{x} = (\hat{x}_1, \hat{x}_2)$ are two examples for such bundles in the figure), $\bar{x} \sim \tilde{x} \sim \hat{x}$. Please note that if the curvature of this curve is representative for the whole preference ordering, "$\succsim$," then the ordering is both convex and strictly convex. The continuity of the curve reveals that preferences are continuous.

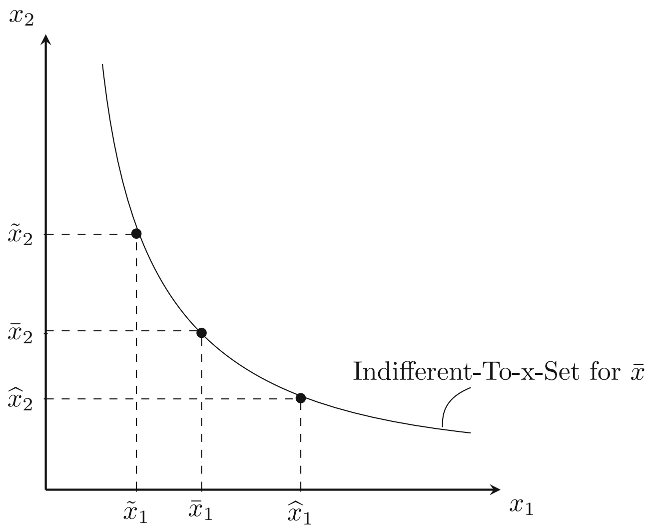

Fig. 7.1 Ann's Indifferent-To-x-Set

The indifference curve in Fig. 7.1, of course, only partially represents the individual's preference ordering. There exists an indifferent-to-x set for every consumption bundle x that can in principle be represented by an indifference curve.

The slope of an indifference curve has an important economic interpretation. Suppose that one not only wants to reallocate the consumption goods but also wants to ensure that the individual is neither better nor worse off. This is only possible if one chooses consumption bundles that lie on the same indifference curve. Now, suppose that at some point x one takes $dx^2 < 0$ away from the individual. Given that the indifference curve is downward sloping, one has to compensate the individual by some extra quantity, $dx^1 > 0$, to ensure that one stays on the indifference curve. See Fig. 7.2 for an illustration of this.

If one looks at infinitesimal changes, $dx^2 \to 0$, then the exchange rate between the two goods is given by the slope of the tangent to the indifference curve at the point $\bar{x}$. The absolute value of this exchange rate, dx^2/dx^1, is called the *marginal rate of substitution* (*MRS*) between good 2 and good 1. It is an expression of the idea of opportunity costs in the context of the individual's decision problem: If one takes a little bit of one good away, how much of the other good does one have to give the individual to make her indifferent?

Figure 7.3a–d illustrates the shape of indifference curves for different types of preference orderings.

Figure 7.3a illustrates so-called *perfect substitutes*. Indifference curves are straight, parallel lines. The outward-pointing arrow indicates that the individual prefers larger quantities to smaller ones (monotonicity). If indifference curves are straight lines, then the *MRS* is independent of the consumption bundle. This means

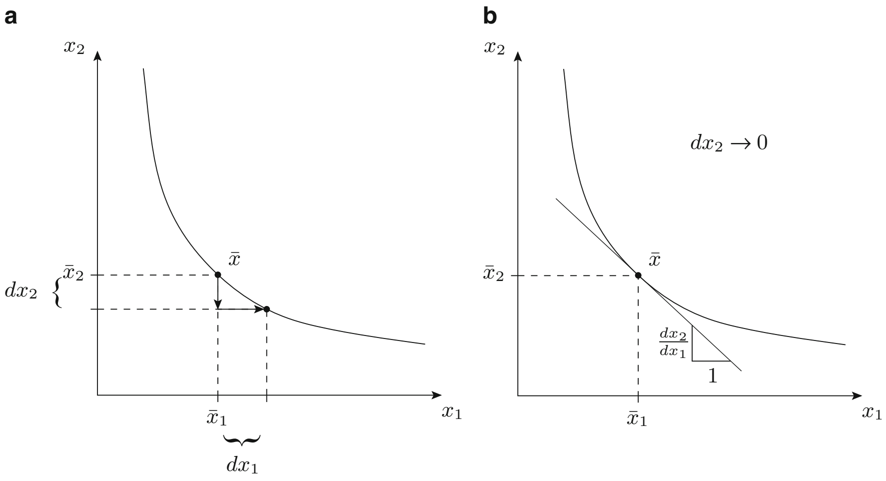

Fig. 7.2 Marginal rate of substitution

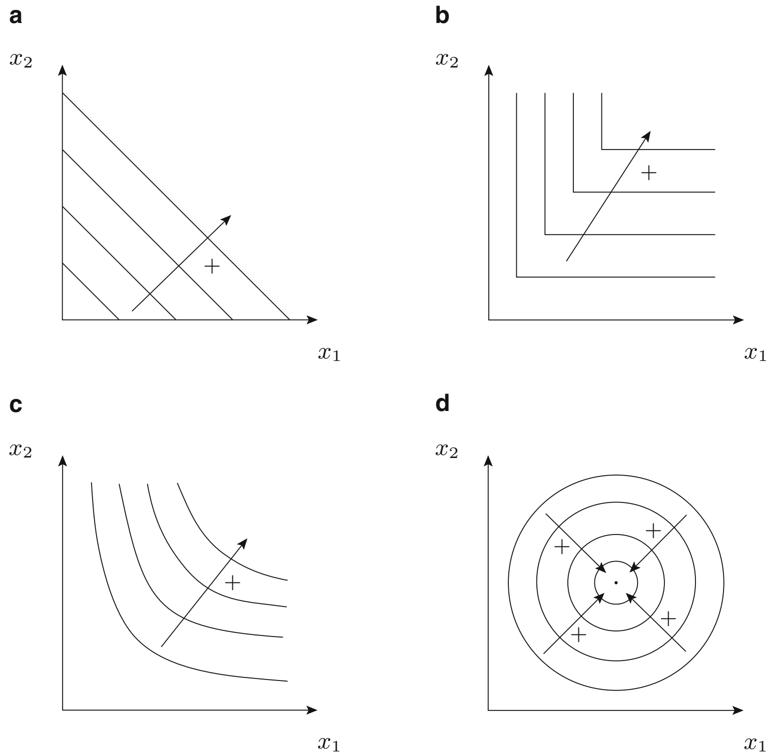

Fig. 7.3 Indifference curves for different preference orderings. (**a**) Perfect substitutes, (**b**) perfect complements, (**c**) strictly convex, and (**d**) strictly convex preferences with a point of satiation

that the individual is always willing to substitute one good for the same quantity of the other good, hence the name perfect substitutes. Whether two goods are perfect substitutes to each other or not ultimately depends on the perception of the individual, but plausible examples are different brands of toothpaste, yoghurt, shoes, etc. Perfect substitutes are preference orderings that fulfill continuity, monotony, and convexity, but not strict convexity.

Figure 7.3b illustrates so-called *perfect complements*. Indifference curves are L-shaped with a kink. L-shaped indifference curves imply that the individual wants to consume the two goods in a fixed ratio. This fixed ratio is given by the slope of the straight line through the origin that connects the kinks. Examples could be left and right shoes (which is why they are sold as pairs), computer hard- and software, coffee and cream, etc. Perfect complements are preference orderings that fulfill continuity, monotony, and convexity, but not strict convexity.

Figure 7.3c illustrates strictly convex preferences. Indifference curves bend inwards, but not as extremely as it does for perfect complements. Perfectly convex preferences are somewhere in between perfect substitutes and perfect complements. An individual with such preferences is willing to substitute one good for the other, but has a *ceteris paribus* preference for more balanced bundles.

Finally, Fig. 7.3d illustrates another type of strictly convex preferences, however, with a point of saturation. As the arrows indicate, such preferences are not monotonic, because a globally optimal consumption bundle exists. If consumption falls short of this point, then increasing it makes the individual better off. If consumption exceeds this point, then the individual is better off if she can reduce consumption. Preferences like these are plausible in situations in which goods are not storable and there are physical limits to consumption. Think of ice cream as an example: The first scoop is very good, the second still good, the third is ok, but a fourth, fifth, or sixth scoop makes you sick. It is important to note, however, that if it were possible to produce goods in quantities such that individuals are on or beyond their points of satiation (and the excess can be freely disposed of), society would have overcome scarcity. Hence, the assumption that economics is the science that studies the allocation of scare goods and services implies that one implicitly assumes that one is *not* beyond these points of satiation, either because no such points exist (monotonicity), or because our technological means to production are insufficient to reach these points for all goods in X. In this latter case, however, the indifference curves in Fig. 7.3d look qualitatively similar to the indifference curves in Fig. 7.3c.

7.1.3 Utility Functions

The decision problem of an individual can be completely analyzed by the use of the concept of preference orderings. However, it has turned out that it is sometimes more convenient to represent an ordering by a function, because it allows one to use different and more standard tools from mathematics. This kind of a functional representation of a preference ordering is called a *utility function*. This subchapter will first introduce the concept and then describe some of the potential pitfalls and misunderstandings that come with it.

Economists use the following convention when they represent preference orderings by a function $u(x)$, in which x refers to an arbitrary alternative that can itself be a tuple. They assume that the function assigns a larger number to strictly preferred alternatives, $x^i \succ x^j \Leftrightarrow u(x^i) > u(x^j)$, and the same number to indifferent alternatives, $x^i \sim x^j \Leftrightarrow u(x^i) = u(x^j)$. Any function that meets these requirements qualifies as a utility representation, $u(x)$, of a preference ordering "$\succsim$." More formally, this means:

▶ **Definition 7.11 Utility Function** A function $u : X \rightarrow \mathbb{R}$ is called a utility function for a preference ordering "$\succsim$" if and only if $x^i \succ x^j \Leftrightarrow u(x^i) > u(x^j)$ and $x^i \sim x^j \Leftrightarrow u(x^i) = u(x^j)$ for all $x^i, x^j \in X$.

This definition of a utility representation or function leaves a lot of freedom when assigning numbers to alternatives or, to put it differently, a given preference ordering has not only one utility representation but many. Here is an example: Assume that an individual must choose from a choice set $X = \{x^1, x^2, x^3\}$ and has preferences $x^1 \succ x^2 \succ x^3$. In this case, the following three assignments of numbers to alternatives u_A, u_B, u_C are all utility representations of this preference ordering: u_A:$u_A(x^1)$=3, $u_A(x^2)$=2, $u_A(x^3)$=1, u_B:$u_B(x^1)$=354, $u_B(x^2) = 7.65$, $u_B(x^3)$= 0, u_C:$u_C(x^1)$=−1, $u_C(x^2)$=−2, $u_C(x^3)$=−3. However, Function D does not represent the preference ordering: u_D:$u_D(x^1) = 3$, $u_D(x^2) = 1$, $u_D(x^3) = 2$, because it assigns a larger number to the worst alternative x^3 rather than to the second-best alternative x^2 (2 compared to 1).

An implication of this definition of a utility function is that the absolute values that it assigns to alternatives are meaningless. By the same token, the differences in utility levels for different alternatives are meaningless, as well. The only thing that counts is that preferred alternatives are assigned larger numbers. This is why it is called an *ordinal* concept (absolute values and cardinal differences have no economic meaning).

An immediate implication of this concept is summarized with the following result: assume that $u : X \rightarrow \mathbb{R}$ is a utility representation of preference ordering "$\succsim$" and assume that $f : \mathbb{R} \rightarrow \mathbb{R}$ is a monotonic and increasing function. In that case, the composite function $v = f \circ u$ is also a utility representation of "$\succsim$." In order to show this, I assume that $u : X \rightarrow \mathbb{R}$ is a utility representation of "$\succsim$," which implies, by the definition of a utility function, that

$$u(x^i) > u(x^j) \Leftrightarrow x^i \succ x^j \quad \wedge \quad u(x^i) = u(x^j) \Leftrightarrow x^i \sim x^j.$$

If $f(x)$ is a monotonic increasing function, then one knows that

$$f(u(x^i)) > f(u(x^j)) \Leftrightarrow u(x^i) > u(x^j) \quad \wedge$$
$$f(u(x^i)) = f(u(x^j)) \Leftrightarrow u(x^i) = u(x^j).$$

However, this implies that

$$f(u(x^i)) > f(u(x^j)) \Leftrightarrow x^i \succ x^j \quad \wedge \quad f(u(x^i)) = f(u(x^j)) \Leftrightarrow x^i \sim x^j,$$

and, thereby, that

$$v(x^i) > v(x^j) \Leftrightarrow x^i \succ x^j \quad \wedge \quad v(x^i) = v(x^j) \Leftrightarrow x^i \sim x^j.$$

The transfer from preference orderings to utility functions bears some risk of misinterpretation. Because utility functions assign numbers to alternatives, it is tempting to use these numbers and perform all types of operations with them, like calculating differences ($u(x^i) = 10$, $u(x^j) = 7$, hence $u(x^i) - u(x^j) = 10 - 7 = 3$ and thus the individual must be three units better off) and comparing them between different individuals (individual A has 8 units of utility, whereas individual B only has 3 units, which makes individual A 5 units better off than individual B). These calculations are mathematically well defined, but economically meaningless, because absolute values of utility or differences in utilities have no meaning if the underlying, primary concept is a preference ordering. What remains as a meaningful concept is the *marginal rate of substitution MRS*, because it is independent of the exact utility representation used. To see this, return to the two representations used above, $u(x)$ and $v(x) = f(u(x))$, and use the following notation: Alternative x^i consists of the quantities x_1^i and x_2^i of the two goods 1 and 2. One can express the marginal rate of substitution dx_2^i/dx_1^i by the total differential of the utility function. One can start with the representation $u(x)$ to get the total differential

$$du = \frac{\partial u}{\partial x_1^i} \cdot dx_1^i + \frac{\partial u}{\partial x_2^i} \cdot dx_2^i.$$

If one wants to stay on the same indifference curve, one has to set $du = 0$, which implies that

$$\frac{dx_2^i}{dx_1^i} = -\frac{\partial u/\partial x_1^i}{\partial u/\partial x_2^i}.$$

For infinitesimal changes in the quantities of the goods, the marginal rate of substitution is equal to the inverse ratio of marginal utilities $\partial u/\partial x_i^k, k = 1, 2$. If one does the same exercise with the representation $v(.)$ instead of $u(.)$, one gets

$$\frac{dx_2^i}{dx_1^i} = -\frac{\partial v/\partial x_1^i}{\partial v/\partial x_2^i} = -\frac{(\partial f/\partial u)(\partial u/\partial x_1^i)}{(\partial f/\partial u)(\partial u/\partial x_2^i)} = -\frac{\partial u/\partial x_1^i}{\partial u/\partial x_2^i}.$$

The *MRS* is independent of the utility representation that is used. It is the same, irrespective of the exact utility function used, as long as it represents the underlying preference ordering. Hence, the *MRS* is an economically meaningful concept, because it is a property of the preference ordering, which itself is an explanatory element of the theory.

Digression 7.1 (What Do Preferences and Utility Functions Stand for? The Development of the Modern Concept of Preference Orderings)
The view on the concept of utility has gone through substantial changes over the past 100 years or so. What unifies all interpretations is the assumption that individual behavior is somehow related to individual well-being. Initially, economists used the term utility as a proxy for what is called *hedonic* well-being. This position was put forward by *utilitarian* philosophers, like Jeremy Bentham or John Stuart Mill. Mill wrote: "The creed which accepts as the foundation of morals, Utility, or the Greatest-Happiness Principle, holds that actions are right in proportion as they tend to promote happiness, wrong as they tend to produce the reverse of happiness. By happiness is intended pleasure, and the absence of pain; by unhappiness, pain, and the privation of pleasure." Therefore, these philosophers had a specific understanding of what is now called the *theory of mind* and a substantive claim as to what promotes happiness: feeling good. Both the brain and the mind were conceptualized as pleasure- and pain-generating machines and these feelings were considered to be the exclusive motivators for behavior. According to this view, a utility function is a measure for hedonic pleasure (higher utility = more (pleasure minus pain), lower utility = less (pleasure minus pain)) and—together with the assumption that pleasure motivates behavior—is therefore a highly stylized theory of mind. This view of utility was pretty much in line with the leading paradigm of psychology of the time. Psychologists like Gustav Theodor Fechner or Wilhelm Wundt were convinced that mental processes could be measured and compared.

At the turn of the century, however, this view was increasingly scrutinized. The idea that mental phenomena could be measured was mocked as "metaphysical *hocus pocus*," the paradigm in psychology shifted towards what is today called behaviorism and economics followed swiftly. One of the main proponents was Vilfredo Pareto, who wrote in a letter in 1897: "It is an empirical fact that the natural sciences have progressed only when they have taken secondary principles as their point of departure, instead of trying to discover the essence of things. [. . .] Pure political economy has therefore a great interest in relying as little as possible on the domain of psychology." He replaced the concept of measurable and comparable utility with the concept of an ordinal preference ordering and even went a step further by suggesting that one should not think of a preference ordering as something that summarizes what is going on in the mind or brain, but as a mere *as-if*-device that allows one to explain behavior without giving it a deeper meaning.

However, Pareto kept a minimal theory of mind by assuming that alternatives that individuals rank higher in their preference ordering are better for them (given their own subjective standard). This assumption led to the idea of

(continued)

Digression 7.1 (continued)
what is today called *Pareto efficiency* as a normative criterion (see Chap. 5 for the definition).

This concept of preferences and the associated idea that utility functions have no deeper ontological meaning beyond representing preferences led to the development of economic analysis of individual behavior on the basis of indifference curves by Edgeworth and it was perceived as liberating at the time. The enthusiasm can still be sensed in the following quote (Eugen Slutsky, 1915/1952): "[I]f we wish to place economic science upon a solid basis, we must make it completely independent of psychological assumptions [...]." In the wake of this enthusiasm, economics also developed from a rather narrow science of market behavior to a one-size-fits-all tool in an attempt to understand society at large (John Hicks & Douglas Allen, 1934): "The methodological implications of [the new] conception of utility [...] are far reaching indeed. By transforming the subjective theory of value into a general logic of choice, they extent its applicability over wide fields of human conduct."

There is one issue remaining before I can move on to applying the theory of preference orderings in order to better understand the market behavior of consumers. Up until this point the assumption has been that preference orderings can be represented by a utility function, but this is far from obvious. In fact, there is a counterexample that is not too far off the mark when it comes to human behavior. Assume that a consumer who has the choice between two goods, x_1 and x_2, has the following preferences: She prefers more of good 1 to less of good 1 and the same for good 2, but for every quantity of good 1 and, irrespective of the quantity of good 2 that she could consume, she prefers more of good 1. These preferences are called *lexicographic*, because the individual orders the quantities of the goods in the same way as a lexicon orders entries: It defines a hierarchy that gives priority of the first letter over the second, the second letter over the third. Only in the event of a tie in the first letter, the second letter becomes relevant and so on. Figure 7.4 illustrates this case.

Here is an example: Assume the consumer has the choice between three alternatives $x^1 = (1, 1), x^2 = (1,100), x^3 = (2, 1)$. With lexicographic preferences, the consumer prefers x^2 to x^1 (more of good 2) and x^3 to x^2 (more of good 1, in which good 2 does not matter as soon as there is more of 1).

Lexicographic preferences may seem rather special and they probably are, but one cannot exclude them from consideration without knowing what people really want. However, the problem with these preferences is that they cannot be represented by a utility function. Understanding the deeper reason for this odd result requires some knowledge in measure theory. (Here is a sketch of the argument: Assume that $u_L : X \to \mathbb{R}$ is a utility representation of the lexicographic ordering

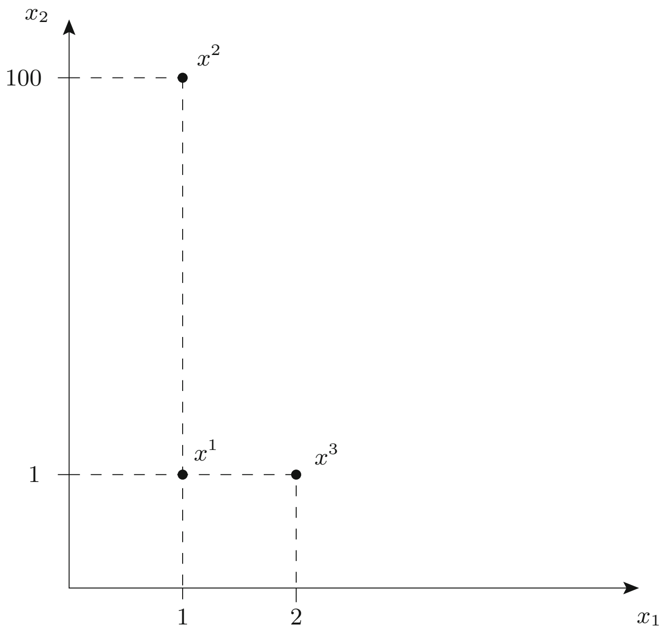

Fig. 7.4 Lexicographic preferences

$\succ_L$. For every $x, y \in \mathbb{R}$ with $x > y$ we must have $(x, 1) \succ_L (x, 0) \succ_L (y, 1)$, which implies that the intervals $\{[u_L(x, 0), u_L(x, 1)] | x \in \mathbb{R}\}$ are disjoint, $[u_L(x, 0), u_L(x, 1)] \cap [u_L(y, 0), u_L(y, 1)] = \emptyset$ for $x \neq y$. Furthermore, each set $[u_L(x, 0), u_L(x, 1)]$ contains at least one rational number. But this implies that we have constructed a one-to-one mapping from the set of real numbers to the set of rational numbers, which is not possible because the set of rational numbers is countable.) One way to fix the problem is to assume a continuity of preferences, which gives one an explanation for this assumption, and I will henceforth assume that preference orderings are continuous.

7.2 Demand on Competitive Markets

Chapter 4 described several causal factors that explain both individual and market demand on a competitive market. It was argued that demand will most likely depend on the price of the good as well as the prices of other goods, the income of an individual, the individual's tastes, and expectations of the future. I am now in a position to replace these intuitive arguments with a sound decision-theoretical analysis using the model of preference or utility maximization introduced before. Remember that economic decision theory comes in two parts: the specification of a choice set and the determination of individual choices from this set for given preferences.

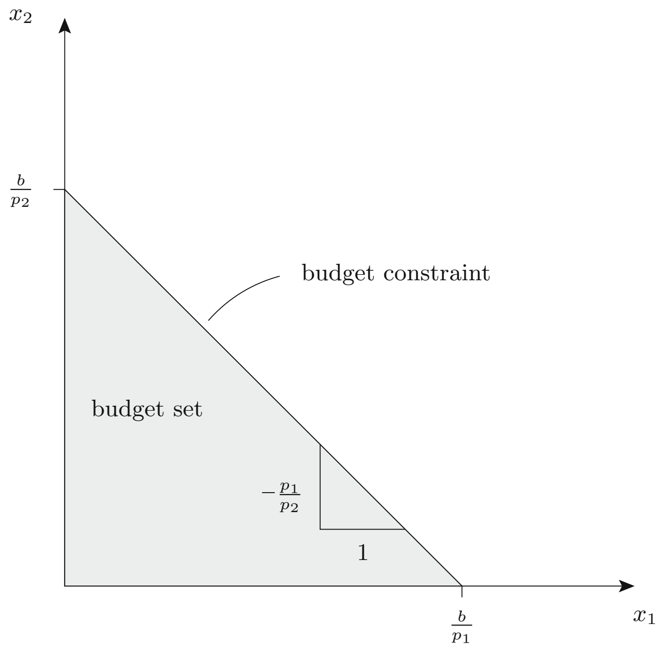

Fig. 7.5 The budget set and the budget constraint on a competitive market

Assume that an individual (Ann) has the choice between two consumption goods, 1 and 2, whose quantities are denoted by x_1 and x_2, both from the set of positive real numbers (including 0). The individual behaves as a price taker and has a budget or income b that she completely spends on the two goods. (The model is very versatile, if one assumes, for example, that x_1 is the consumption today and that x_2 is the consumption tomorrow, it can be interpreted in an inter-temporal way to analyze savings behavior.) The prices of the two goods are p_1 and p_2, respectively.

This information can be used to specify Ann's choice set: We know that Ann can spend at most b units of money for the two goods. Expenditures for them are equal to $p_1 \cdot x_1 + p_2 \cdot x_2$. Hence, if expenditures cannot exceed the budget, it must be that

$$p_1 \cdot x_1 + p_2 \cdot x_2 \leq b.$$

This inequality defines all the pairs x_1, x_2 that Ann can afford to buy, given her income b and prices p_1, p_2. It is her *choice set* that will henceforth also be called her *budget set* and denoted by $B(p_1, p_2, b)$. If Ann completely spends her budget, one will reach a point along the boundary of this set, $p_1 \cdot x_1 + p_2 \cdot x_2 = b$. This equality implicitly defines a function that is called the *budget constraint* or the *budget line*. Figure 7.5 illustrates the budget set.

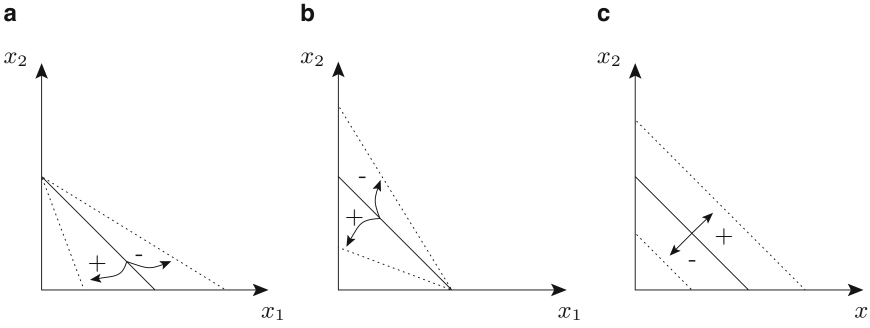

Fig. 7.6 The effects of price and income changes on the budget constraint, (**a**) Change in p_1, (**b**) Change in p_2, (**c**) Change in b

In this figure, x_1 is drawn along the abscissa and x_2 along the ordinate. Using this convention, one can use the budget constraint to solve for x_2,

$$x_2 = \frac{b}{p_2} - \frac{p_1}{p_2} \cdot x_1 .$$

This equation reveals that the budget constraint is a downward-sloping straight line that intersects the abscissa at b/p_2, the ordinate at b/p_1 and has a slope $-p_1/p_2$. The set below and to the left of this line is the budget set. It defines the set of all consumption bundles that Ann can afford to buy.

The budget constraint changes with changes in prices or income, as indicated in Fig. 7.6. Note that it shifts outwards (inwards) in a parallel way if the income goes up (down). It rotates outwards (inwards) through the intersection with the ordinate $(0, b/p_2)$ if p_1 goes down (up) and it rotates outwards (inwards) through the intersection with the abscissa $(b/p_1, 0)$ if p_2 goes down (up).

The slope of the budget constraint $-p_1/p_2$ has an important economic interpretation; it measures the rate at which the two goods can be exchanged against each other. Assume that $b = 100$, that $p_1 = 8$ and that $p_2 = 4$. In this example, $-p_1/p_2 = -2$: If one spends one's whole income on the two goods, one has to forfeit two units of good 1 if one wants to consume an additional unit of good 2, because good 2 is twice as expensive as good 1. The slope $-p_1/p_2$ is, therefore, the *relative price* of good 1 in units of good 2 and measures the opportunity costs of an additional unit of good 2 as defined by market prices.

7.2.1 Graphical Solution

Now one can apply the concept of preference orderings or utility functions in order to analyze choice. The hypotheses that can be derived depend on the assumptions that one makes regarding the structure of the preference ordering. Most of the

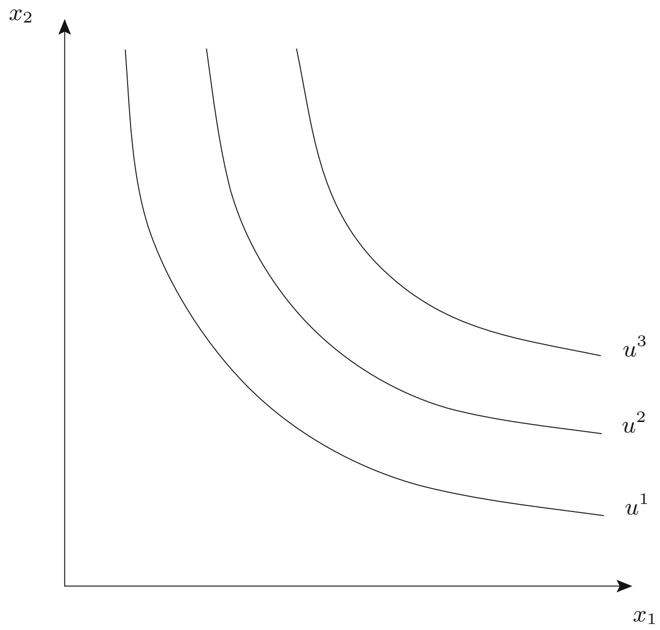

Fig. 7.7 Indifference curves in the context of a competitive market

literature assumes that individual behavior in markets can be described as if individuals would like to maximize a continuous, monotonic and convex or strictly convex preference ordering based on their respective budget sets $B(p_1, p_2, b)$. In order to have an easier diagrammatic representation of the choice problem, it is also assumed that preferences are not only defined on $B(p_1, p_2, b)$ but also on all possible consumption bundles (x_1, x_2), irrespective of whether the individual can afford them or not.

Continuity implies that a preference ordering can be represented by a (utility) function, $u(x_1, x_2)$, and I will henceforth work with this convention. In order to illustrate the choice problem of an individual (Ann) I will assume in the remainder of this subchapter that her preferences are strictly convex and that they can be represented by a continuously differentiable utility function. In that case, her indifference curves for different levels of utility u^j must be inwards bending, as illustrated in Fig. 7.7, where I have drawn three indifference curves for utility levels $u^1 < u^2 < u^3$. In order to keep the language simple I will refer to indifference curves that have larger utility indices as "higher" and indifference curves that have smaller utility indices as "lower."

Monotonicity implies that indifference curves that correspond to higher utility levels lie to the upper right of indifference curves that correspond to lower levels of utility. As one can see, the indifference curves provide an ordering of the set of potential consumption bundles. Starting from a given indifference curve,

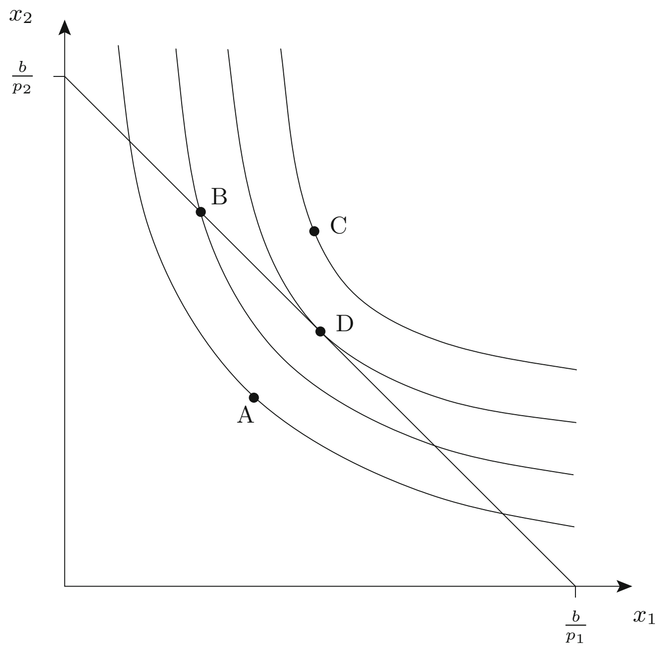

Fig. 7.8 Structure of optimal choices

consumption bundles that lie on indifference curves with a larger utility index are preferred and bundles on indifference curves with a smaller utility index make the individual worse off, in comparison.

If one adds the budget set to the picture, one can use the ordering induced by indifference curves to predict behavior.

Figure 7.8 displays a family of indifference curves that is derived from a utility function $u(x_1, x_2)$, and a budget set $B(p_1, p_2, b)$. Qualitatively there are four potential situations that can occur. These are denoted by consumption bundles A, B, C, and D. Consumption bundle A is affordable for Ann because it is within her budget set. However, it is not Ann's best choice. If one compares A and B, one can see that B is on a higher indifference curve than A, but still within Ann's budget set. Hence, she would prefer B to A. Is B optimal for Ann? One could argue that C is even better, because it is on an even higher indifference curve. However, note that a consumption bundle like C is outside of Ann's budget set: She would prefer C to B but cannot afford it. Hence, C cannot be her optimal choice either. What one therefore has to do in order to determine Ann's best choice is to look for the highest indifference curve that still belongs to her budget set. Consumption bundle D fulfills this requirement. D is associated with the highest indifference curve that still belongs to budget set $B(p_1, p_2, b)$.

A situation like D has a straightforward economic meaning that is important for understanding the concept of opportunity costs as well as the mechanics of the utility-maximization model. Note that the slope of the budget constraint and the slope of the indifference curve are identical at a point like D. The slope of the budget constraint measures the relative price of the two goods and the ratio at which they can be exchanged on the market. The slope of the indifference curve is the marginal rate of substitution (*MRS*) and thus the exchange rate between the two goods that makes Ann indifferent between two bundles. At a point like D, both exchange rates coincide and the marginal rate of substitution is equal to the relative price. Why is this condition economically meaningful? Look at the following example: Assume that the relative price of good 1 in terms of good 2 is -2 and that the marginal rate of substitution of good 1 in terms of good 2 is -4 at point B. (The budget constraint is less steep than the indifference curve.) Hence, Ann would be willing to give away four units of good 2 for an additional unit of good 1 to stay indifferent. However, given the market rate of exchange, she only has to give away two units. Hence, she can be better off by consuming more of good 1 at the expense of good 2. This logic applies to all consumption bundles for which the "internal" rate of exchange (the *MRS*) differs from the "external" rate of exchange (the relative price). Hence, only consumption bundles for which the marginal rate of substitution equals the relative price are consistent with the assumption of utility maximization.

The fact that the utility-maximizing consumption bundle is on the budget constraint and not in the interior of the budget set is a consequence of the assumption of monotonicity of preferences. With non-monotonic preferences, it could be that Ann is satiated without fully spending her income. Monotonicity, in this sense, can therefore be thought of as an expression of the underlying assumption of scarcity: With non-monotonic preferences, there could be situations with high incomes b such that all of Ann's desires are fulfilled. This would be the point at which scarcity—at least for Ann—ceases to exist. It is, ultimately, an empirical question as to whether such a point can ever be reached or not. One should, therefore, take the assumption with caution because its unscrutinized acceptance implies that one has implicitly commuted to the idea of quantitative growth in terms of some measure, like gross national product.

In addition, the fact that the MRS equals the relative price of the two goods at the optimum is a consequence of the assumption of the strict convexity of preferences (in fact, indifference curves additionally have to be continuously differentiable in order to guarantee this, otherwise they could have "kinks").

7.2.2 Analytical Solution

The utility-maximization problem can also be studied analytically. In order to do so, one starts by formally stating Ann's choice situation. One is confronted with an optimization problem that has the following structure: p_1, p_2, and b are the explanatory variables of the model, which means that the variables that determine Ann's consumption decisions are x_1 and x_2. They are, therefore, the explained variables. Hence, one needs to determine the functions $x_1(p_1, p_2, b)$, $x_2(p_1, p_2, b)$. How is this possible? By assuming that Ann maximizes her utility function, $u(x_1, x_2)$, under the constraint that she does not spend more on consumption than her income is, $p_1 \cdot x_1 + p_2 \cdot x_2 \leq b$, one assumes that her preferences are monotonic, one knows that Ann will spend her whole income, and one can write

$$\max_{x_1, x_2} u(x_1, x_2) \quad s.t. \quad p_1 \cdot x_1 + p_2 \cdot x_2 = b.$$

This notation needs some explanation. The $\max_{x_1,x_2}$-term indicates that one is looking for the maximum of the objective (utility) function with respect to the endogenous variables. The term s.t. abbreviates "such that," which indicates that Ann has to respect her budget constraint.

7.2.2.1 Necessary Conditions for a Maximum

Formally, this is a constrained optimization problem and there are several ways to solve it. As long as one restricts one's attention to two endogenous variables and an affine constraint, the solution does not require advanced mathematical techniques; instead one can simply use the constraint to eliminate one of the endogenous variables in the objective function. For more general (and realistic) problems in which Ann can choose between more than two goods, however, one needs a more general procedure. We will first derive the solution to this optimization problem by eliminating one variable before we will introduce the general approach.

In order to solve the problem, one can convert the budget constraint in the same way as I have shown before, $x_2 = b/p_2 - (p_1/p_2) \cdot x_1$, and denote the function that relates x_1 and x_2 by $X_2(x_1) = b/p_2 - (p_1/p_2) \cdot x_1$. This equation can be used to eliminate x_2 in the utility function. One, therefore, ends up with a modified, unconstrained optimization problem:

$$\max_{x_1} u(x_1, X_2(x_1)) = \max_{x_1} u(x_1, b/p_2 - (p_1/p_2) \cdot x_1).$$

In order to illustrate how this problem can be solved, assume that $u(x_1, x_2)$ is twice continuously differentiable and that the underlying preference ordering is strictly convex. If these assumptions are fulfilled, then an interior maximum is characterized by a value of x_1, such that the first derivative is equal to zero (first-order condition):

$$\frac{\partial u}{\partial x_1} + \frac{\partial u}{\partial x_2} \cdot \frac{\partial X_2}{\partial x_1} = \frac{\partial u}{\partial x_1} - \frac{\partial u}{\partial x_2} \cdot \frac{p_1}{p_2} = 0.$$

This condition can be simplified to

$$\frac{\partial u/\partial x_1}{\partial u/\partial x_2} = \frac{p_1}{p_2},$$

which is the optimality condition for the consumer-choice problem. In order to be able to interpret this condition, one has to understand the term on the left-hand side. In order to do so, one can use the total differential of the utility function

$$du = \frac{\partial u}{\partial x_1} \cdot dx_1 + \frac{\partial u}{\partial x_2} \cdot dx_2.$$

The total differential measures the total effect on utility with a change in the explanatory variable of dx_1 and dx_2, respectively. One is not interested in arbitrary changes but in changes that leave total utility constant, $du = 0$, because this keeps one on the same indifference curve. In other words, the set of all (x_1, x_2) that lead to the same level of utility constitutes the marginal rate of substitution:

$$du = \frac{\partial u}{\partial x_1} \cdot dx_1 + \frac{\partial u}{\partial x_2} \cdot dx_2 = 0$$
$$\Leftrightarrow MRS(x_1, x_2) = \frac{dx_2}{dx_1} = \frac{\partial u/\partial x_1}{\partial u/\partial x_2}.$$

However, this is exactly the left-hand side of the optimality condition. One can therefore conclude that a preference- or utility-maximizing individual chooses consumption in a way that the marginal rate of substitution equals the relative price of the goods.

The general solution makes use of a so-called Lagrange function (see Chap. 17 for a mathematical introduction of the concept). We continue to restrict attention to optimization problems with two goods. Let λ be the Lagrange multiplier, we can set up the following Lagrange function:

$$\mathcal{L}(x_1, x_2, \lambda) = u(x_1, x_2) + \lambda \cdot (p_1 \cdot x_1 + p_2 \cdot x_2 - b).$$

This function has three endogenous variables, x_1, x_2, and λ. In order to maximize this function, one needs the following three first-order conditions:

$$\frac{\partial \mathcal{L}(x_1, x_2, \lambda)}{\partial x_1} = \frac{\partial u(x_1, x_2)}{\partial x_1} + \lambda \cdot p_1 = 0,$$

$$\frac{\partial \mathcal{L}(x_1, x_2, \lambda)}{\partial x_2} = \frac{\partial u(x_1, x_2)}{\partial x_2} + \lambda \cdot p_2 = 0,$$

$$\frac{\partial \mathcal{L}(x_1, x_2, \lambda)}{\partial \lambda} = p_1 \cdot x_1 + p_2 \cdot x_2 - b = 0.$$

The third condition guarantees that the individual spends exactly its income b on the two goods. The first and second conditions determine the optimal combination of the two goods and can be combined to yield:

$$\frac{\partial u(x_1, x_2)/\partial x_1}{\partial u(x_1, x_2)/\partial x_2} = \frac{p_1}{p_2}.$$

But this is exactly the optimality condition that we have derived before.

Consumption bundles (x_1^*, x_2^*) that fulfill the first-order condition and lie on the budget constraint are the individual's utility-maximizing choices. Formally, they are functions of the explanatory variables $x_1(p_1, p_2, b)$ and $x_2(p_1, p_2, b)$ and are named *Marshallian demand functions* after Alfred Marshall. What is interesting, from the point of view of the structure of individual demand, is whether the Marshallian demand functions have any particular properties that allow one to better understand the structure of individual and, thereby ultimately, market demand behavior.

In addition, one can insert the Marshallian demand functions into the utility function, $u(x_1(p_1, p_2, b), x_2(p_1, p_2, b))$ to get the so-called *indirect utility function* $v(p_1, p_2, b)$. It measures the highest utility attainable at given market prices and income. Utility is still an ordinal concept, so for example the absolute value of v or differences in v for different prices or incomes have no meaningful economic interpretation. However, different values of v can be ordinarily compared: If $v(p_1^1, p_2^1, b^1) > v(p_1^2, p_2^2, b^2)$ in the two situations (p_1^1, p_2^1, b^1), (p_1^2, p_2^2, b^2) implies that the individual is better off in situation 1 compared to situation 2. We will come back to indirect utility functions in Chap. 8.

Here comes the challenge: the ultimate test for the usefulness of a theory is—according to Critical Rationalism (see Chap. 1 for a description of this position in the philosophy of science)—its empirical validity. Hence, one has to formulate a theory in a way that makes it empirically testable. The theory of consumer choice has two building blocks: preferences and choice sets that are determined by prices and income. It is relatively straightforward to empirically measure the latter elements of the theory, but it is not possible to determine individual preferences directly. This is bad news for empirical tests: Behavior is determined by both, choice sets and preferences. If one cannot observe preferences, one cannot test the theory. Hence, one can only measure the properties of the theory that are *independent* of the specific preference ordering underlying consumer choices. However, given that any choice of consumption can be rational for some preference ordering, the only hope that one has is that the theory is testable when one looks at *changes* in observable behavior that are caused by *changes* in prices or income. It may be that a change in prices or income induces stable and predictable reactions that can, in principle, be falsified by confronting them with empirical data. In order to be able to do so, however, one has to impose the (dogmatic, see Chap. 1) assumption that preferences remain stable over a period of time. This is why *comparative statics* plays such an important role in economics: If there is any hope for empirically testing the theory, it is because it produces refutable hypotheses regarding the change in Marshallian demand functions when prices or income change. Whether the theory can live up to these standards or not will be the subject of this investigation.

One important property is that Marshallian demand functions are homogeneous of degree zero, i.e., that a proportional change in all prices and income has no influence on individual behavior. Formally, this means that $x_i(p_1, p_2, b) = x_i(\alpha \cdot p_1, \alpha \cdot p_2, \alpha \cdot b)$ for $i = 1{,}2$ and $\alpha > 0$. Intuitively this means that it does not matter whether prices and income are measured in Swiss Francs or in Rappen, Euro or Cent; as long as the relative price of both goods and the purchasing power of income remains the same, the individual will not change her behavior. In order to see that this must be the case return to the budget constraint $x_2 = b/p_2 - (p_1/p_2) \cdot x_1$. If all prices and income are multiplied by the same factor α, one gets

$$x_2 = \frac{\alpha \cdot b}{\alpha \cdot p_2} - \frac{\alpha \cdot p_1}{\alpha \cdot p_2} \cdot x_1 = \frac{b}{p_2} - \frac{p_1}{p_2} \cdot x_1.$$

The effect of α cancels out and, therefore, leaves the location of the budget constraint unaltered. However, with an unaltered budget constraint, the optimal behavior of the individual must be unaltered as well, hence the Marshallian demand functions are homogeneous of degree zero in prices and income.

Digression 7.2 (Money Illusion and the Debate Between Keynesian and Neoclassical Economics)

The homogeneity of degree zero in prices and income of the Marshallian demand function may sound like an innocuous mathematical property, but, in fact, it marks a very important watershed in the history of economic thinking. Keynesian and neoclassical economists have profoundly disagreed on the role of economic policy to stabilize the economy. One important field of disagreement is monetary policy. Neoclassical economists are usually skeptic regarding the role that monetary policy can or should play, with the implication that price stability is usually the primary focus of neoclassical monetary policy. On the contrary, Keynesian economists usually see a much more active role for monetary policy in stimulating and stabilizing the economy (Keynes, 1936).

There are several reasons why these schools disagree, but at least one can be traced back to the homogeneity of degree zero of the Marshallian demand functions. If this property holds, the possibility to influence the economy by means of monetary policy is severely limited. Increasing or reducing money supply is like multiplying all prices and income by λ. However, if this is the case and if the model of utility- or preference-maximizing individuals is correct, then the real effects of these changes on the economy are zero: General inflation or deflation is like measuring prices in different currencies without changing the purchasing power of income or the relative prices of

(continued)

Digression 7.2 (continued)
goods. This property is sometimes also called the *absence of money illusion*. Without money illusion, monetary policy has no impact on the economy, because people will not change their behavior and, if people's behavior does not change, then everything remains the same. The only way monetary policy can influence behavior, according to this view, is if inflation or deflation change different prices and incomes differently, hence either changing relative prices, purchasing power, or both. This can happen if some prices are nominally fixed, while other prices can adjust to changes in money supply. A Keynesian economist, who sees an active role for monetary policy, therefore, either has to think that some prices or incomes are nominally fixed or that the model of preference or utility maximization is flawed to begin with.

7.2.2.2 Sufficient Conditions for a Maximum

The first-order condition is only a necessary condition for a utility maximum, and one does not know yet if it characterizes a local maximum, a local minimum, or a point of inflection. In order to say more, one has to check the second-order condition. The first-order condition is the function:

$$\frac{\partial u(x_1, x_2)}{\partial x_1} - \frac{\partial u(x_1, x_2)}{\partial x_2} \cdot \frac{\partial X_2}{\partial x_1}.$$

It characterizes a local maximum if its derivative, with respect to x_1, is smaller or equal to zero,

$$\frac{\partial^2 u(x_1, x_2)}{\partial x_1^2} + \frac{\partial^2 u(x_1, x_2)}{\partial x_1 \partial x_2} \cdot \frac{\partial X_2}{\partial x_1} + \frac{\partial X_2}{\partial x_1} \cdot \frac{\partial^2 u(x_1, x_2)}{\partial x_2 \partial x_1} - \left(\frac{\partial X_2}{\partial x_1}\right)^2 \cdot \frac{\partial^2 u(x_1, x_2)}{\partial x_2^2} \le 0.$$

This condition can be simplified, if one remembers that

$$\frac{\partial X_2}{\partial x_1} = -\frac{p_1}{p_2} = -\frac{\frac{\partial u(x_1, x_2)}{\partial x_1}}{\frac{\partial u(x_1, x_2)}{\partial x_2}}$$

and notes that

$$\frac{\partial^2 u(x_1, x_2)}{\partial x_1 \partial x_2} = \frac{\partial^2 u(x_1, x_2)}{\partial x_2 \partial x_1}.$$

This leads to

$$\left(\frac{\partial u(x_1,x_2)}{\partial x_2}\right)^2 \cdot \frac{\partial^2 u(x_1,x_2)}{\partial x_1^2} + \left(\frac{\partial u(x_1,x_2)}{\partial x_1}\right)^2 \cdot \frac{\partial^2 u(x_1,x_2)}{\partial x_2^2}$$
$$-2 \cdot \frac{\partial u(x_1,x_2)}{\partial x_1} \cdot \frac{\partial u(x_1,x_2)}{\partial x_2} \cdot \frac{\partial^2 u(x_1,x_2)}{\partial x_1 \partial x_2} \leq 0.$$

The first-order conditions allow it to simplify this condition as follows:

$$(\lambda \cdot p_2)^2 \cdot \frac{\partial^2 u(x_1,x_2)}{\partial x_1^2} + (\lambda \cdot p_1)^2 \cdot \frac{\partial^2 u(x_1,x_2)}{\partial x_2^2}$$
$$-\, 2 \cdot \lambda^2 \cdot p_1 \cdot p_2 \cdot \frac{\partial u(x_1,x_2)}{\partial x_2} \cdot \frac{\partial^2 u(x_1,x_2)}{\partial x_1 \partial x_2} \leq 0,$$

which can be further simplified to

$$p_2^2 \cdot \frac{\partial^2 u(x_1,x_2)}{\partial x_1^2} + p_1^2 \cdot \frac{\partial^2 u(x_1,x_2)}{\partial x_2^2} - 2 \cdot p_1 \cdot p_2 \cdot \frac{\partial u(x_1,x_2)}{\partial x_2} \cdot \frac{\partial^2 u(x_1,x_2)}{\partial x_1 \partial x_2} \leq 0.$$

If the condition holds at (x_1^*, x_2^*), then the indifference curve is locally convex at that point, hence it characterizes a local maximum. If the condition holds for every (x_1, x_2), then the indifference curve is globally convex. This condition is fulfilled only if the underlying preference ordering is convex. Hence, the assumption that the preference ordering is convex guarantees that the first-order condition characterizes a maximum. If the inequality is strict, then the preference ordering is strictly convex and the solution is unique.

Alternatively, one can check the second-order conditions of the optimization problem in Lagrange form. The so-called bordered Hessian matrix is used for the second-derivative test and has the following form:

$$H(x_1,x_2,\lambda) = \begin{pmatrix} \frac{\partial^2 \mathcal{L}}{\partial \lambda^2} & \frac{\partial^2 \mathcal{L}}{\partial \lambda \partial x_1} & \frac{\partial^2 \mathcal{L}}{\partial \lambda \partial x_2} \\ \frac{\partial^2 \mathcal{L}}{\partial x_1 \partial \lambda} & \frac{\partial^2 \mathcal{L}}{\partial x_1^2} & \frac{\partial^2 \mathcal{L}}{\partial x_1 \partial x_2} \\ \frac{\partial^2 \mathcal{L}}{\partial x_2 \partial \lambda} & \frac{\partial^2 \mathcal{L}}{\partial x_2 \partial x_1} & \frac{\partial^2 \mathcal{L}}{\partial x_2^2} \end{pmatrix} = \begin{pmatrix} 0 & p_1 & p_2 \\ p_1 & \frac{\partial^2 u}{\partial x_1^2} & \frac{\partial^2 u}{\partial x_1 \partial x_2} \\ p_2 & \frac{\partial^2 u}{\partial x_2 \partial x_1} & \frac{\partial^2 u}{\partial x_2^2} \end{pmatrix}.$$

A solution of the first-order conditions (x_1^*, x_2^*) characterizes a maximum if the so-called determinants of the principal minors of the bordered Hessian matrix, H_1, H_2, H_3 have alternating signs:

$$\det H_1 = 0 \geq 0,$$

$$\det H_2 = p_1^2 \leq 0,$$

$$\det H_3 = 2 \cdot p_1 \cdot p_2 \cdot \frac{\partial u(x_1, x_2)}{\partial x_2} \cdot \frac{\partial^2 u(x_1, x_2)}{\partial x_1 \partial x_2} - p_2^2 \cdot \frac{\partial^2 u(x_1, x_2)}{\partial x_1^2}$$
$$+ p_1^2 \cdot \frac{\partial^2 u(x_1, x_2)}{\partial x_2^2} \geq 0.$$

The conditions for H_1 and H_2 are trivially fulfilled, and the condition for $H - 3$ is identical to the one derived from the above solution to the direct problem.

A utility function with this property is called (strictly) *quasi-concave*. Quasi-concavity is weaker than concavity of functions, because it only guarantees that the not-worse-than-x sets (whose boundaries are the respective indifference curves) are convex sets, but makes no assumptions about the concavity of the rest of the function.

7.2.3 Three Examples

There are three utility functions that represent typical preference orderings and that play an important role in a lot of economic applications of the model. This subchapter will analyze these examples both graphically and analytically.

7.2.3.1 Homothetic Strictly Convex Preferences

An example of a so-called *homothetic* utility function is given by $u(x_1, x_2) = a \cdot (x_1)^\alpha \cdot (x_2)^\beta$, where a, α, β are positive real numbers. It is an example for a strictly quasi-concave utility function that has the additional property that the MRS is constant for proportional changes of the two goods ($x_1/x_2 = c$, with $c > 0$ being constant).

The following paragraphs focus on a special case in which $a = 1$ and $\alpha = \beta = 1/2$, because it is more convenient to solve mathematically. These assumptions imply that $u(x_1, x_2) = \sqrt{x_1} \cdot \sqrt{x_2}$. Before one derives the Marshallian demand functions, it makes sense to familiarize oneself with the structure of this function. One can, for example, derive the indifference curve for some arbitrary level of utility $\bar{u}$, $u(x_1, x_2) = \sqrt{x_1} \cdot \sqrt{x_2} = \bar{u}$. In order to derive the function, $X_2(x_1)$, that describes the indifference curve, one solves for x_2, $\sqrt{x_2} = \bar{u}/\sqrt{x_1} \Leftrightarrow x_2 = (\bar{u})^2/x_1$. This is a family of hyperbolic functions, one for each value of $\bar{u}$, which implies that the underlying preference ordering is strictly convex.

At this point, one can further illustrate that every monotonic transformation of a utility function represents the same preference ordering. If one squares the utility function (this is a monotonic transformation, because the underlying utility function only has positive values), one gets $v(x_1, x_2) = (u(x_1, x_2))^2 = (\sqrt{x_1} \cdot \sqrt{x_2})^2 = x_1 \cdot x_2$. It follows that the indifference curves of this function are also hyperbolic: $x_2 = \bar{u}/x_1$. The only difference between the two indifference curves is the *absolute* value of utility, but remember that this number has no meaningful interpretation.

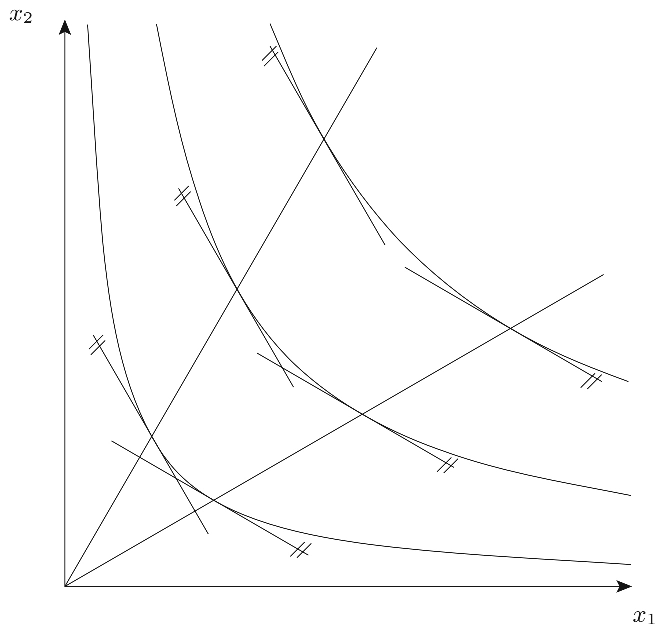

Fig. 7.9 MRS for homothetic strictly convex preferences

With these prerequisites one can move on to analyze Ann's demand if her preferences have a utility representation of $u(x_1, x_2) = \sqrt{x_1} \cdot \sqrt{x_2}$. Figure 7.9 displays a family of indifference curves for different utility levels. Given that they are hyperbolic, the MRS remains constant along a ray through the origin (points A, B, and C).

Figure 7.10a shows the same family of indifference curves and adds different budget constraints for different income levels $b^1 < b^2 < b^3$. The above-mentioned property that the MRS remains constant along a ray through the origin implies that the utility-maximizing choices for different income levels must be on a ray through the origin, as well. This path of optimal choices for different income levels is called the *income-consumption path*. This is depicted by A^*, B^*, and C^*. Figure 7.10b displays the demand of one of the two goods (say 1) as a function of income levels. The argument above implies that the relationship between income b and demand x_1^* must be linear. The straight line E reflects this fact. The relationship between income and utility- or preference-maximizing consumption is called an *Engel curve*. In this case, it is upward sloping, which means that the good is normal (see Chap. 4 for the definition of this term).

Figure 7.11a displays the same family of indifference curves and adds different budget constraints for different price levels of good 1, $p_1^1 < p_1^2 < p_1^3$. An increase in p_1 rotates the budget constraint inwards around the point $0, b/p_2$. The utility-maximizing consumption bundles are, again, depicted by A^*, B^*, and C^*. They lie

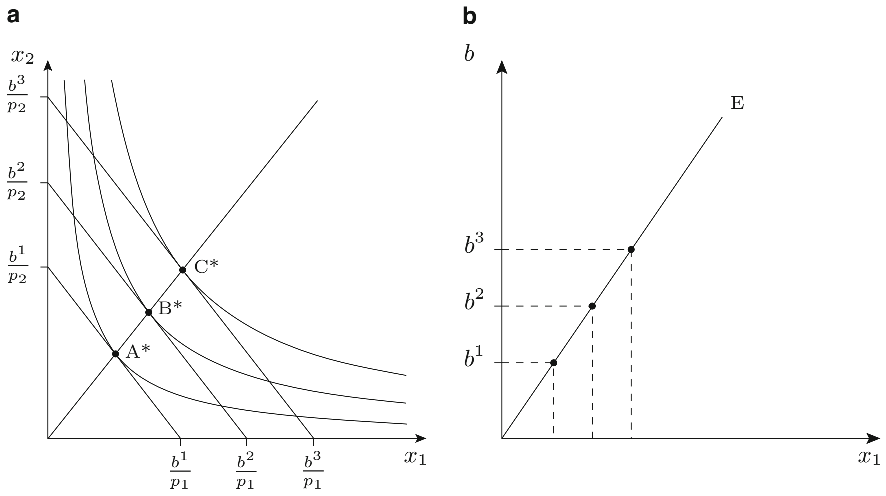

Fig. 7.10 Income-consumption path and Engel curve for homothetic strictly convex preferences

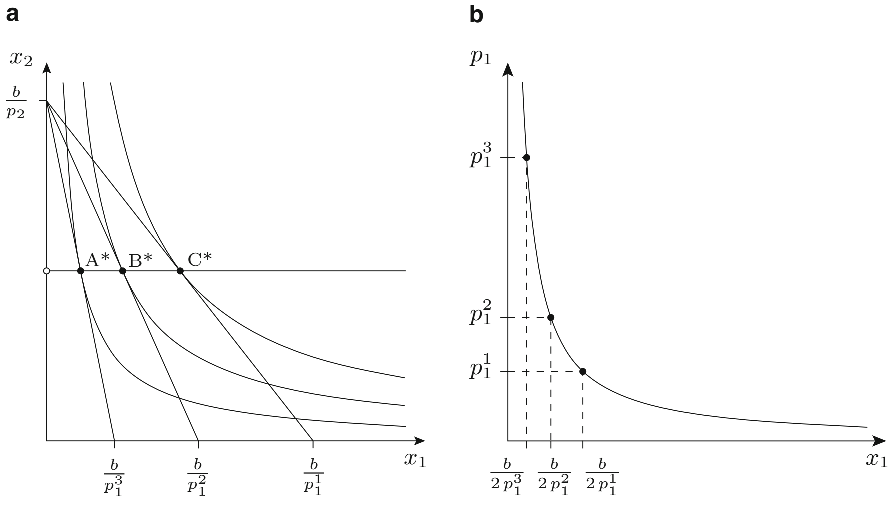

Fig. 7.11 The price-consumption path and demand function for homothetic strictly convex preferences

on the horizontal line displayed in the figure that is called the *price-consumption path*. Figure 7.11b displays the demand for good 1 as a function of its price p_1. This is the *individual demand function* that is already known from Chap. 4. It is downward sloping, which means that it is ordinary (see Chap. 4 for the definition of the term).

Alternatively, one can derive Ann's demand function analytically. In order to do so, one can either use the information that MRS has to be equal to the relative price directly, or start with the utility-maximization problem. In order to practice, I will follow the second road in the following paragraphs. Additionally, in order to simplify the mathematics I will use a utility representation $v(x_1, x_2) = x_1 \cdot x_2$ (try the other formulation to see if it leads to the same result):

$$\max_{x_1} \quad (x_1) \cdot (b/p_2 - (p_1/p_2) \cdot x_1).$$

To get the first-order condition, one can apply the product rule:

$$(b/p_2 - (p_1/p_2) \cdot x_1) - (p_1/p_2) \cdot x_1 = 0.$$

One can solve this condition for x_1 to get the Marshallian demand function for good 1:

$$x_1(p_1, p_2, b) = \frac{b}{2 \cdot p_1}.$$

Knowing that $x_2 = b/p_2 - (p_1/p_2) \cdot x_1$, one can also derive the Marshallian demand function for good 2:

$$x_2(p_1, p_2, b) = \frac{b}{2 \cdot p_2}.$$

The demand functions have three remarkable properties. First, they are linear in income, which is what one would have expected from the linearity of the Engel curve. Second, they are downward sloping and hyperbolic in their own prices, which is also what one would have expected from the graphic analysis. Third, they do not depend on the price of the other good.

These utility functions play an important role in economic applications, because of their simplicity. They can be generalized by assuming that the relative importance of the two different goods can be measured by some parameter $\alpha \in [0, 1]$ that yields $u(x_1, x_2) = x_1^{\alpha} \cdot x_2^{1-\alpha}$. It is, however, not clear if individuals behave as if they maximize preferences of this type. It is more useful as a thought experiment than an empirically supported claim about actual behavior.

7.2.3.2 Perfect Substitutes

The above utility function represents a case in which individuals prefer to consume the goods in relatively balanced bundles, but react to price changes by increasing the relative demand of the good that gets relatively cheaper. This need not be the case. There may be goods for which the individual has more extreme preferences: Ann consumes either one or the other, depending on which one is cheaper. If this is the

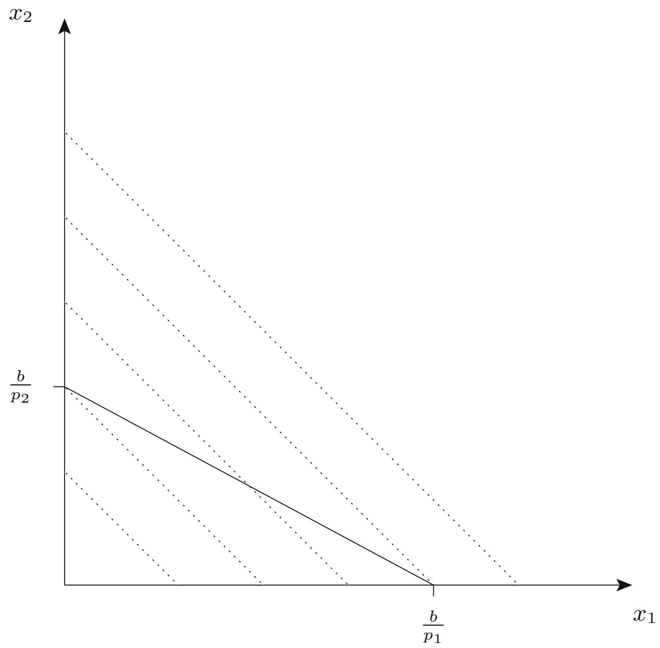

Fig. 7.12 Indifference curves and a budget constraint for perfect substitutes

case, the two goods are called *perfect substitutes* and such a taste can be represented by the following utility function:

$$u(x_1, x_2) = \alpha \cdot x_1 + \beta \cdot x_2,$$

in which α/β measures the relative importance of good 1 compared to good 2. This function is homothetic as well. In the following paragraphs, assume that they are of equal importance to Ann and normalize them to $\alpha = \beta = 1$. In this case, Ann's indifference curves are downward-sloping straight lines with a slope of -1. A family of indifference curves is denoted by the dotted lines in Fig. 7.12. I have also drawn a budget constraint in this figure. It is already known that its graph is a straight line with slope $-p_1/p_2$, so the optimal consumption bundle depends on the relative slope of the indifference curves and the budget constraint: If the former is steeper than the latter, then Ann only consumes good 2 (as in the Figure) and *vice versa*. If both curves have an equal slope, then Ann would be indifferent between both goods.

Given that Ann will only buy the relatively cheaper good, the Engel curves are easy to derive. They are a straight line with slope 0 for the relatively more expensive and a straight line with slope $1/p_i$ for the relatively cheaper good. Price changes can be analyzed as before, but have a somewhat different effect on demand. Figure 7.13a shows a family of indifference curves and—as in the first example of a utility function analyzed before—adds different budget constraints to different price levels

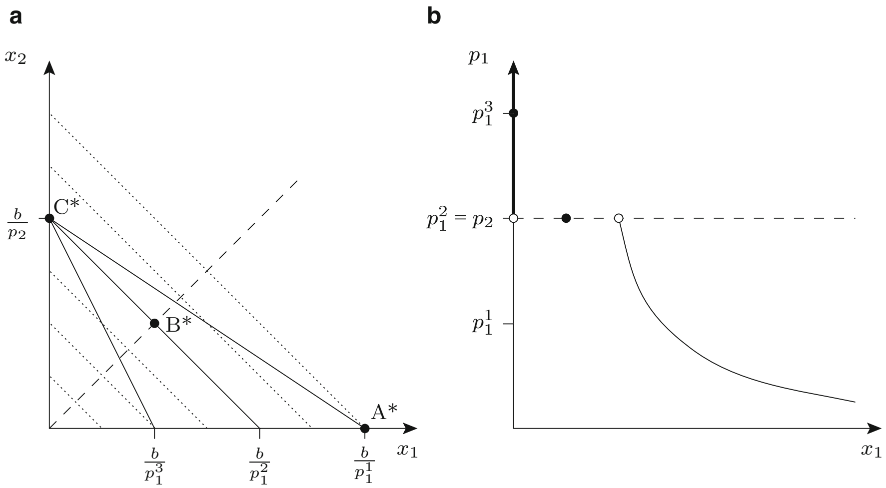

Fig. 7.13 Optimal choices and a demand function for perfect substitutes

for good 1, $p_1^1 < p_1^2 = p_2 < p_1^3$. An increase in p_1 lets the budget constraint rotate inwards around the point $(0, b/p_2)$. The utility-maximizing consumption bundles are, again, depicted by A^*, B^*, and C^*. If the price for good 1 is smaller than the price for good 2, then Ann spends all her income on good 1, which is indicated by point A^*. If both prices are equal ($p_1^2 = p_2$), then Ann is indifferent between both goods and we use the convention that she buys equal quantities, in this case. If p_1 rises further, then demand is zero, because Ann prefers the cheaper good. This behavior is illustrated by the demand function in Fig. 7.13b. It is discontinuous at $p_1 = p_2$ and hyperbolic for smaller prices of good 1.

If one remembers the analysis of competitive behavior in Chap. 4, this discontinuity can be problematic, because it may be that there is no intersection between market demand and market supply, in this case. This is why the continuity of both demand and supply functions are important to guarantee the existence of a competitive equilibrium and one has now seen a case in which this is not the case. This reveals an advantage of the behavioral foundation of the demand function: It leads to a better understanding of the deeper reasons behind the continuity or discontinuity of demand functions by linking them to individual preferences. As one can see, the potential non-existence of an equilibrium can be a result of preferences that are not entirely absurd. The deeper reason for the discontinuity is that the preference ordering is only convex, not strictly convex. With strictly convex preferences, "small" changes in prices will lead to "small" changes in demand, but this is not the case if goods are, for example, perfect substitutes.

In order to derive the Marshallian demand functions analytically, one has to be careful. Given that both the budget constraint and the indifference curves are linear, the utility maximum cannot be derived from the first-order condition. Fortunately, one has already collected almost all the information that is necessary to determine

Marshallian demand. One knows that Ann only buys the cheaper good and one has introduced the convention that she splits her income equally if both goods have the same price. The only step left is to formalize this information:

$$x_1(p_1, p_2, b) = \begin{cases} \frac{b}{p_1}, & p_1 < p_2 \\ \frac{b}{2 \cdot p_1}, & p_1 = p_2 \\ 0, & p_1 > p_2 \end{cases}, \qquad x_2(p_1, p_2, b) = \begin{cases} \frac{b}{p_2}, & p_2 < p_1 \\ \frac{b}{2 \cdot p_2}, & p_2 = p_1 \\ 0, & p_2 > p_1 \end{cases}.$$

7.2.3.3 Perfect Complements

The last example that I discuss is, in a sense, the opposite extreme from the case of perfect substitutes. There are some goods that Ann wants to consume together in fixed proportions, like left and right shoes, printer and toner, or hardware and software. If this is the case, she wants to spend her income on the two goods in a way that makes sure that she buys both goods in fixed proportions. A utility function that expresses such preferences is

$$u(x_1, x_2) = \min\{\alpha \cdot x_1, \beta \cdot x_2\},$$

in which α/β measures the number of units of good 2 that Ann needs to make use of an additional unit of good 1. This is also a homothetic function. To see this, assume that x_1 is the number of car bodies and x_2 is the number of wheels. It takes four wheels and a car body to assemble a useful car, so if $\alpha = 4$ and $\beta = 1$ one gets $\alpha/\beta = 4$, the number of units of good 2 (wheels) that is needed for one unit of good 1 (car bodies). The following paragraphs will focus on the easiest case in which $\alpha = \beta = 1$, i.e., Ann needs one unit of good 1 together with one unit of good 2, $u(x_1, x_2) = \min\{x_1, x_2\}$.

How do the indifference curves look like? I have drawn a family of them in Fig. 7.14a. They are L-shaped with a kink at the 45-degree line, which is where both goods are consumed in equal quantities. Increasing the quantity of one good while keeping the quantity of the other good constant is useless for Ann, which is why points on the vertical and horizontal lines are on the same indifference curve.

I have also added budget constraints for different income levels $b^1 < b^2 < b^3$. As one can see, the utility-maximizing consumption bundle is always at the kink, which is why they are along the 45-degree line through the origin. This is depicted by A^*, B^*, and C^*. It follows immediately that the Engel curve must also be a straight line as in Fig. 7.14b.

How about changes in prices? As before, an increase in the price of good 1 rotates the budget constraint inwards. Once again, I focus on three such prices $p_1^1 < p_1^2 < p_1^3$ and illustrate them in Fig. 7.15a.

One already knows that Ann will always buy both goods in equal quantities, i.e., stay on the 45-degree line. However, this implies that both the demand for good 1 and for good 2 is falling, if the price for good 1 goes up. Hence, the demand function for good 1 is given by the downward-sloping graph in Fig. 7.15b. Note that it intersects the abscissa at $x_1 = b/p_2$, because at $p_1 = 0$ Ann can afford b/p_2 units

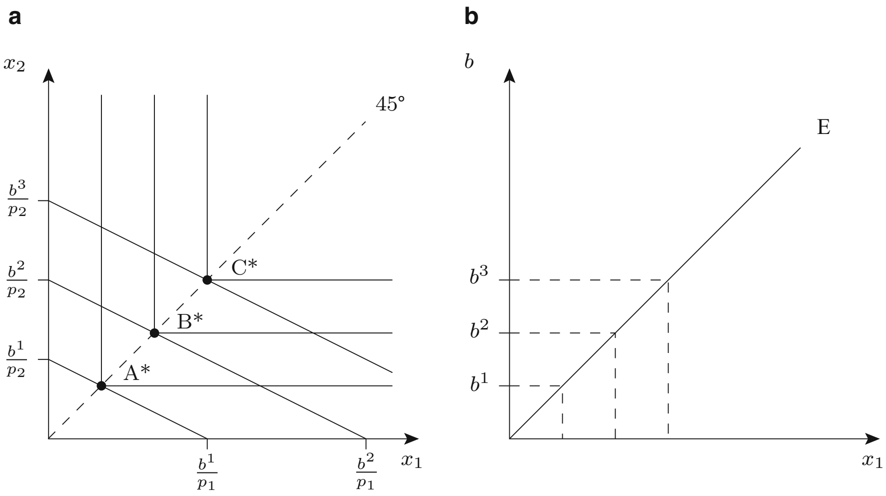

Fig. 7.14 Indifference curves, budget constraints, and an Engel curve for perfect complements

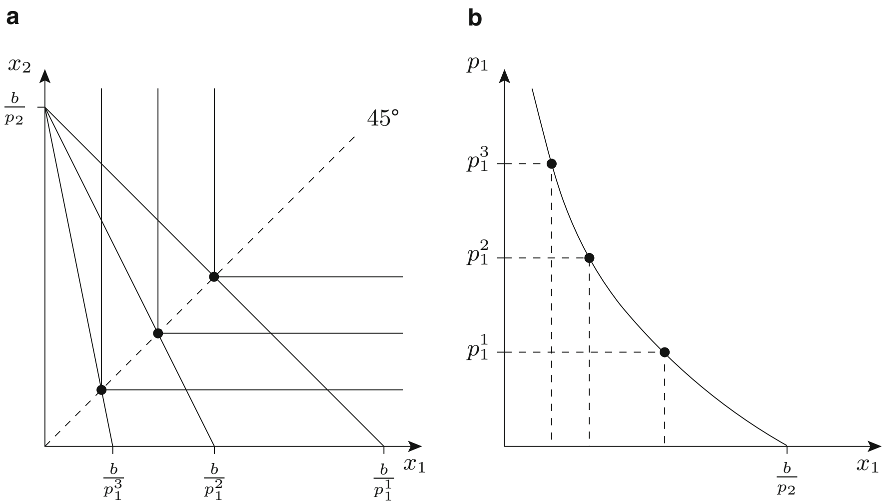

Fig. 7.15 Optimal choices and demand function for perfect complements

of both goods. It is illustrative to also look at x_2 as a function of p_1, which is done in Fig. 7.16.

One knows that Ann will always buy both goods in equal quantities. However, this implies that the demand of good 2, as a function of p_1, is *identical* to the demand of good 1, as a function of p_1.

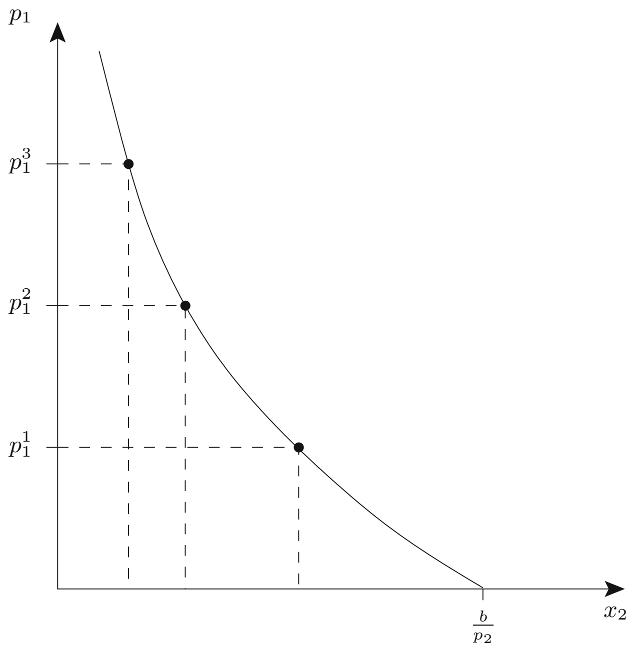

Fig. 7.16 The demand function for good 2 for perfect complements

In order to derive the Marshallian demand functions analytically, first note that one cannot use first-order conditions in this case either, because the indifference curves have a kink, which implies that they cannot be continuously differentiated. Fortunately, the problem is very intuitive to solve. One knows that Ann is constrained by her budget, $p_1 \cdot x_1 + p_2 \cdot x_2 = b$, and wants to consume both goods in equal quantities, $x_1 = x_2 = x$. This information can be used in the budget constraint to get $p_1 \cdot x + p_2 \cdot x = b$. However, this is a linear function in one endogenous variable, so one can solve it. The solution is

$$x_1(p_1, p_2, b) = \frac{b}{p_1 + p_2}, \qquad x_2(p_1, p_2, b) = \frac{b}{p_1 + p_2}.$$

7.2.4 Comparative Statics and the Structure of Market Demand

The three examples for potential preference orderings with associated utility functions have revealed that there is a stable relationship between the structure of preferences on the one and the structure of market demand on the other hand. In all three cases, one has seen that individual demand is decreasing in the price of the good and (weakly) increasing in income. The cross-price effects, however, seem to be more complex. They do not exist in the strictly convex and homothetic case, and they are (weakly) positive but extreme in the case of perfect substitutes and negative in the case of perfect complements. One has also seen that the strict convexity of the preference ordering seems to be important in order to guarantee that an equilibrium exists, because individual demand can otherwise be discontinuous.

Now one can find out if these findings can be generalized. Preferences are not directly observable and individuals seem to differ substantially with respect to their tastes. Hence, it would be nice if one did not have to make too many assumptions on the structure of preferences, as every assumption reduces the explanatory power of the theory, because they rule out certain preferences of which one does not know if they accurately describe real-life individuals. Thus, one can see how far one gets if one imposes monotonicity and strict convexity of a preference ordering with respect to the structure of individual demand. In order to do this, one can focus on two comparative-static experiments: a change in income and a change in the price of a good.

7.2.5 Changes in Income

One has already seen that a change in income leads to a parallel shift of the budget constraint. Furthermore, one has already seen in the above examples that goods can be normal (demand increases if income increases). The remaining question is if this property is an artifact of the specific preference orderings or whether it is a general property of demand functions that are derived from preferences. Figure 7.17 shows that this is unfortunately not the case.

It displays two income levels, b_1 and b_2, and the associated indifference curves that Ann can reach, if she maximizes utility. As can be seen, the demand for good 2 goes up if income goes up, but the demand for good 1 does not. Hence, good 2 is normal and good 1 is inferior for this change in income. (Note that these properties are local and that they can hold for some changes in income, but not for others.) Hence, strict convexity and monotonicity do not rule out the inferiority of one of the goods. Besides, they should not, because there are a lot of goods that are, in fact, inferior, like low-quality products that are replaced by higher-quality substitutes, if the individual gets richer.

7.2.6 Changes in Price

In addition to continuity, individual and market demand should be decreasing as the price of the good increases in order to guarantee the existence and uniqueness of a competitive equilibrium. If demand is increasing as its price increases, there may be cases in which an equilibrium does not exist at all or in which multiple equilibria exist. Figures 7.18a and b illustrate both cases.

Hence, it would be nice if one could show that goods are ordinary if individuals maximize a monotonic and strictly convex preference ordering. Unfortunately, this

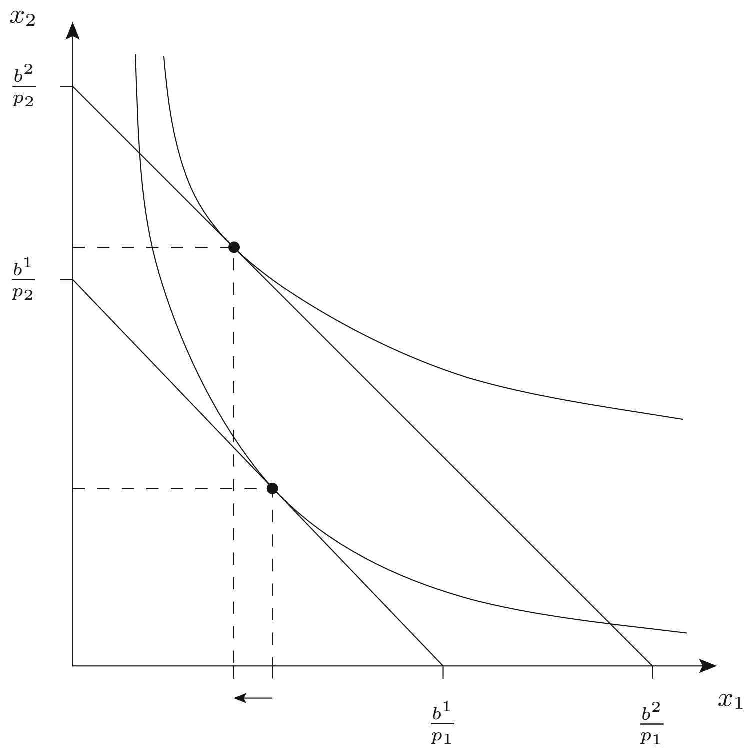

Fig. 7.17 Optimal choices for a change in income: an inferior good

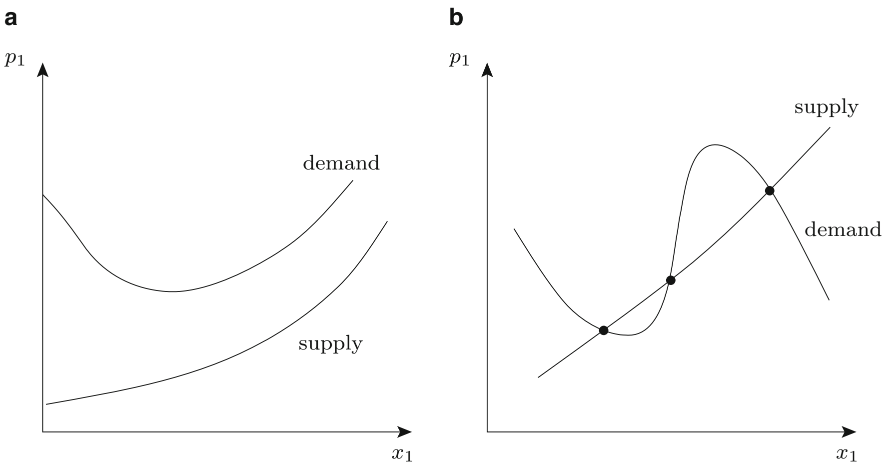

Fig. 7.18 Market equilibrium and non-monotonic demand functions

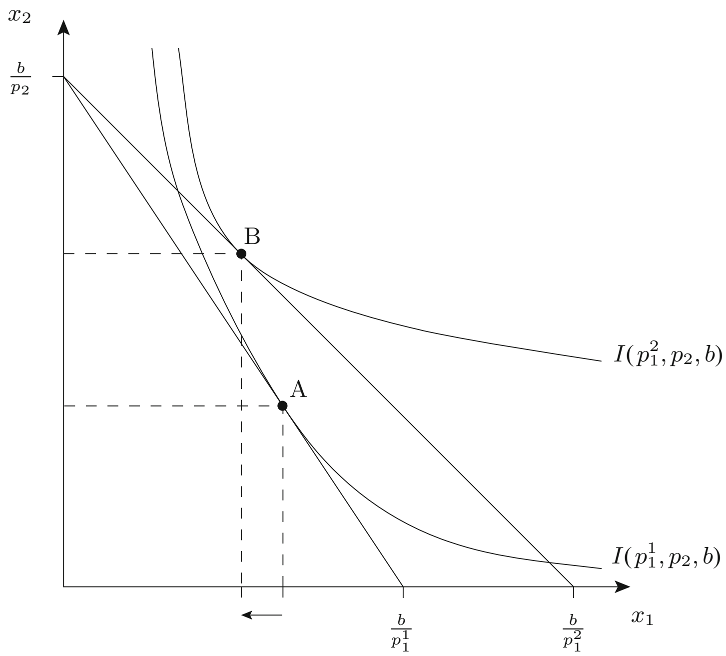

Fig. 7.19 Optimal choices for a change in prices: the Giffen paradox

is not the case. Figure 7.19 gives an example for the so-called *Giffen paradox*, which is a situation in which the demand of a good decreases despite the fact that its price decreases.

Figure 7.19 focuses on a decrease in the price of good 1 from p_1^1 to p_1^2. The utility-maximizing consumption bundle changes from $A = (x_1(p_1^1, p_2, b), x_2(p_1^1, p_2, b))$ to $B = (x_1(p_1^2, p_2, b), x_2(p_1^2, p_2, b))$ and the highest indifference curves that can be reached are denoted by $I(p_1^1, p_2, b)$ and $I(p_1^2, p_2, b)$. As can be seen, the demand for good 1 goes down (and the demand for good 2 goes up) and this follows necessarily from the strict convexity of the preference ordering, because one is moving *along* the indifference curve.

What is going on here? One gets closer to understanding this phenomenon if one focuses on the curvature of the indifference curves. If the change in p_1 did not induce a rotation around $(0, b/p_2)$ but instead induce a rotation *along* the indifference curve (see Fig. 7.20), then the effect of a decrease in the price of good 1 would have the expected negative sign: Good 1 gets relatively cheaper compared to good 2 and this isolated effect motivates Ann to buy more of good 1 and less of good 2. However, the reduction of p_1 not only has the effect that good 1 gets relatively cheaper, it also makes Ann richer, because her new budget set contains the old one as a subset. As a matter of fact, it is this latter effect that may cause the Giffen paradox.

In order to understand this, one has to disentangle the two effects in Fig. 7.21.

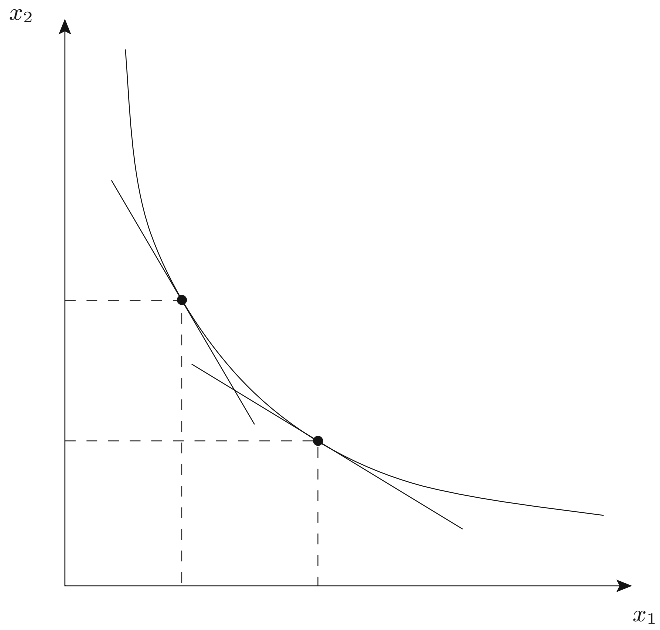

Fig. 7.20 The optimal choice for a compensated change in relative prices

Figure 7.21 is identical to Fig. 7.19, with the exception that I have introduced an artificial budget constraint for a hypothetical income level $\tilde{b}$. This hypothetical constraint is constructed to allow Ann to reach the same maximum indifference curve as before the price change, $I(p_1^1, p_2, b)$. In order to guarantee this, one has to change her income from b to some hypothetical income level $\tilde{b}$, such that $I(p_1^1, p_2, b) = I(p_1^2, p_2, \tilde{b})$. The utility-maximizing consumption bundle that results from this hypothetical budget constraint $p_1^2 \cdot x_1 + p_2 \cdot x_2 = \tilde{b}$ is denoted by $C = (x_1(p_1^2, p_2, \tilde{b}), x_2(p_1^2, p_2, \tilde{b}))$. One calls it the *compensated demand*.

This compensated demand for good 1 is larger than before, $x_1(p_1^1, p_2, b) < x_1(p_1^2, p_2, \tilde{b})$, i.e., the isolated effect of a change in the relative price is negative (a smaller price and a larger quantity). This compensated effect is called the *price effect*, and it brings us from A to C in the figure.

However, the compensation in income from b to $\tilde{b}$ is only the first step in the thought experiment. Therefore, in the next step, one will see what happens if one moves from $(p_1^2, p_2, \tilde{b})$ to (p_1^2, p_2, b). This change holds the relative price constant, but changes Ann's income and one has already seen what can happen. One already knows that this change brings one from C to B, but the additional insight is that this is only possible if the good is *inferior*; comparing C with B reveals that $x_1(p_1^2, p_2, b) < x_1(p_1^2, p_2, \tilde{b})$. This is called the *income effect*.

This thought experiment is important, because it allows one to better understand why individual demand may not fall as its own price falls. Any change in the price

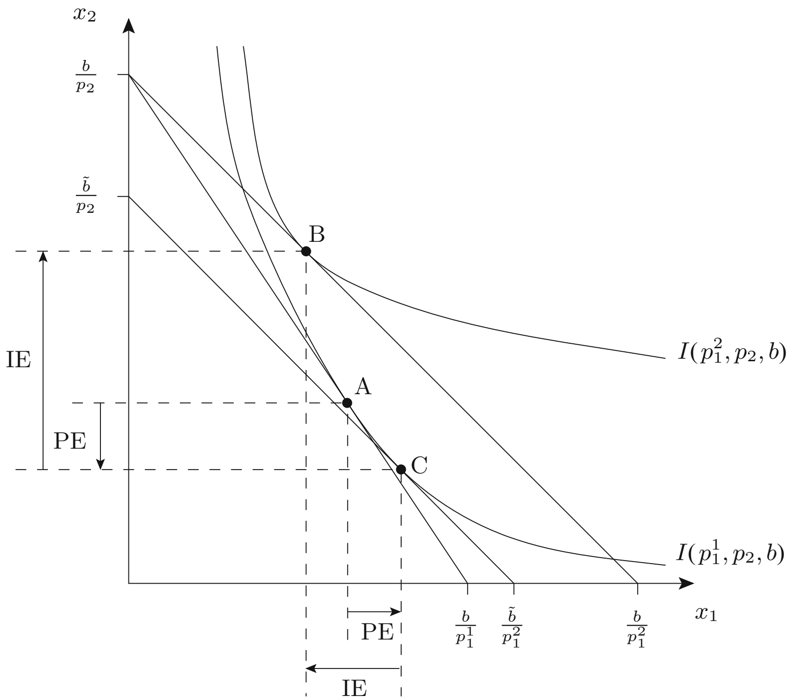

Fig. 7.21 Price-(PE) and Income effect (IE) and the Giffen paradox

of one good has a price as well as an income effect and it is the income effect that may cause the Giffen paradox: If the good is inferior for Ann, then it is possible that her demand is (locally) increasing as the price increases.

This result is perhaps intellectually fascinating and it allows one to understand the mechanics of the preference-maximization model more profoundly, but it is, at the same time, highly unsatisfactory. In the end, the whole exercise to develop a choice-theoretic foundation of market behavior was motivated to better understand the structure of demand functions on competitive markets. These demand functions have to fulfill certain properties, like continuity and ordinary goods, to ensure that a market equilibrium exists. What one can learn from the Giffen paradox and its deeper reasons is that the assumption of preference maximization alone (even with the further restrictive assumptions of strict convexity and monotonicity) is insufficient to guarantee that a unique equilibrium exists. As Chap. 4 described, existence and uniqueness are important for positive economics, because sound economic prognoses depend on them. As one has seen with the three examples of different preference orderings that we have discussed, existence and uniqueness can be guaranteed by imposing additional assumptions regarding preferences (like the assumption that all individuals have strictly quasi-concave utility functions), but this comes at the cost of sacrificing generality. Additionally, this cost is substantial indeed, because one does not have epistemic access to individual preferences, so one cannot know if any specific assumptions regarding their structure are empirically justified. However, this is the situation: If one wants a general theory of consumer choice that allows all types of preferences, then one cannot be sure that an equilibrium exists or that it is unique. And if one wants a unique existing equilibrium, then one has to start from specific assumptions regarding preferences.

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Decisions Under Uncertainty and Risk

8

This chapter covers...

- how to structure decision problems to analyze uncertainty or risk.
- how to structure decision problems to analyze uncertainty or risk.
- the difference between uncertainty and risk.
- important models for solving decision problems under uncertainty.
- important models for solving decision problems under risk.
- concepts for measuring risk attitude.
- how to apply the models to economic problems.

8.1 A Model of Uncertainty and Risk

> We live in a world full of contradiction and paradox, a fact of which perhaps the most fundamental illustration is this: that the existence of a problem of knowledge depends on the future being different from the past, while the possibility of the solution of the problem depends on the future being like the past.
> (Frank Knight, 1921)

The topics discussed so far had one thing in common: The decision makers knew the consequences of their behavior when they made decisions. However, most decisions are not like that; their consequences are not certain. For example, it is not certain whether the world champion on whom one is betting in a World Cup betting round will be the right one in the end. The quality of the device you bought from an online store or the future price of the share you bought is also uncertain. By the same token, the impact of a patient's treatment on her or his future health is also not certain. Most decisions that are made, no matter how trivial or significant, are characterized by the fact that their consequences cannot be known for sure.

To describe situation of uncertainty or risk, we use three concepts, *strategies*, *consequences*, and *states of the environment*. The idea is the following: A person

M. Kolmar, *Principles of Microeconomics*, Classroom Companion: Economics,
https://doi.org/10.1007/978-3-030-78167-5_8

chooses from a set of strategies that has consequences. Which consequences these are depends on the state of the environment. Since the state of the environment is not known at the time of the decision, the person does not know with certainty the consequence of choosing a particular strategy. We will describe the three concepts in turn and combine them into a decision theory.

To illustrate, we will use an example. Suppose Julia is planning to climb a mountain during the coming weekend, to which she must arrive the night before. There is also a music concert that takes place at the same time, which she would also like to attend. Depending on the weather, she would rather climb the mountain or attend the concert. If the weather is good, the climb will be successful, but if the weather is bad, it will not. The quality of the music concert is independent of the weather. Julia would most prefer to climb the mountain in good weather, least prefer to travel to the mountain only to find that bad weather does not permit such a climb. The utility from attending the concert lies in the middle. Since she does not know the weather at the time of her decision, the question is how she will decide (positive) or should decide (normative) in a situation like this. To summarize, Julia has two strategies, and the strategy set Julia can choose from is {*mountaineering, attending a concert*}. The set of environmental states relevant to the decision is {*good weather*, *bad weather*}. The possible consequences can be derived by combining the strategies with the environmental states. You will find them in the *consequence matrix* given in Table 8.1.

Each combination of a strategy and an environmental state forms a *consequence*. Thus, the consequence *successful climb* follows from the combination *mountaineering* and *good weather*, while the outcome *no successful climb* follows from the combination *mountaineering* and *bad weather*. From the strategy *attending a concert* always follows the outcome *concert night*, regardless of the environmental state. Nevertheless, this outcome must be defined for each environmental state in order to have a complete description.

Two elements are still missing to be able to solve the decision problem. One is Julia's preferences. We have already defined these as follows: *successful climb* $\succsim_C$ *concert night* $\succsim_C$ *no successful climb* (the index C stands for consequences). However, unlike in decision problems under security (see Chap. 7), this information is insufficient here. We need preferences on strategies to determine the best way to act, which could, for example, be *mountaineering* $\succsim_S$ *attending a concert* (the index S stands for strategies). In decision problems under certainty, this problem did not occur because there was a one-to-one relationship between strategies and consequences, so that a preference ordering on strategies could be unambiguously inferred from a preference ordering on consequences. Therefore, we did not even address the fact that preferences on strategies must actually be derived from pref-

Table 8.1 Julias consequences matrix

	Good weather	Bad weather
Mountaineering	Successful climb	No successful climb
Attending a concert	Concert night	Concert night

erences on consequences. A decision theory under uncertainty and risk, however, has to infer precisely this connection between preferences over consequences and preferences over strategies.

How can we derive a preference ordering $\succsim_S$ over strategies from a preference ordering $\succsim_C$ over consequences?

The rest of this chapter is devoted to answering this question. In doing so, we assume that there is a preference ordering $\succsim_C$ on the set of consequences that can be described by a utility function, see Chap. 7. For the given preferences, one can then compile a utility matrix as in Table 8.2. An important subclass of decision problems under uncertainty and risk deals with situations where consequences are measured in monetary terms, e.g., determining investment strategies in financial markets. In order to see how a situation like this can be incorporated into our model, imagine a variation of the above example. In this variation, Julia does not want to climb the mountain or go to the concert, but bet on the possibility that the mountain can be climbed. Suppose Julia finds a betting shop that offers such bets. In this case, the above strategies could be reinterpreted as follows. *mountaineering* would then be the strategy *place a bet*, and *attending a concert* would be the strategy *do not place a bet*. In this case, we would again have four combinations of strategies with environmental states. We assume that a winning bet results in a payoff of CHF 100, and a losing bet results in a payoff of CHF -10. If the bet is not made, the payoff is CHF 0. We can then write Julia's *payoff matrix* as in Table 8.3. Decision problems about money are important because, for example, firms pursue monetary objectives such as profit or revenue maximization, see Chaps. 12 and 13. Important special cases are the insurance industry and the financial industry, whose role, among others, is not only to enable real economic investments but also to shift money between different states of the environment in situations of uncertainty and risk. Therefore, a decision theory should encompass these cases.

Again, we see that this specification is not yet sufficient to answer the question of whether Julia should make the bet or not, because knowledge of monetary payoffs on consequences is not the same as determining preferences over strategies $\succsim_S$.

In many situations under uncertainty and risk probabilities p are assigned to the states of the environment. In the example, there may be a weather forecast that measures the probability of bad weather as 80% ($p = 0.8$) and the probability of good weather as 20% ($1-p = 0.2$). If such probabilities exist, we can determine the *expected payoffs* of the two strategies. They are $0.2 \cdot 100 + 0.8 \cdot (-10) = 12$ if Julia

Table 8.2 Julia's utility matrix

	Good weather	Bad weather
Mountaineering	10	0
Attending a concert	4	4

Table 8.3 Julia's payoff matrix

	Good weather	Bad weather
Place a bet	100	-10
Do not place a bet	0	0

places the bet, and 0 if she does not place the bet. Now, assuming that Julia wants to maximize her expected payoff, we can use this information to derive a preference ordering over strategies: she should place the bet since $12 > 0$. We have solved the decision problem.

We can also use an analogous procedure if we return to the original problem and work with utility instead of money. In this case, Julia would have an *expected utility* of $0.2 \cdot 10 + 0.8 \cdot 0 = 2$ if she goes mountaineering, and utility of 4 if she attends the concert. Assuming analogously that Julia wants to maximize her expected utility, we can again derive a preference ordering over strategies: she should go to the concert since $2 < 4$. In this case, too, we have solved the decision problem.

Two questions arise at this point:

- Is this procedure a good explanation of, or a good recommendation for, behavior in the presence of uncertainty and risk (positive or normative view)? If yes, how can it be generalized? If no, what can take its place?
- Is it always possible or reasonable to base the solution to the problem on probabilities? And if not, what alternative procedures for solving the problem can take its place?

The general question of this chapter posed above thus breaks down into these two sub-questions. In order to answer these questions, we will first introduce the terminology in more detail.

We assume that a person can choose from a finite set of strategies $s_1, s_2, \ldots, s_N$. This set is denoted by $S = \{s_1, s_2, \ldots, s_N\}$, and s_n is a strategy from this set. In the example we have $N = 2$, and $S = \{$*mountaineering, attending a concert*$\}$.

Furthermore, there is a finite set of states of the environment $\theta_1, \theta_2, \ldots \theta_L$ that can affect the selection problem. The set of all these states is $\Theta = \{\theta_1, \theta_2, \ldots, \theta_L\}$, and θ_l denotes a state from this set. In the example we have $L = 2$ and $\Theta = \{$*good weather, bad weather*$\}$.

We thus have $N \times L$ possible combinations of strategies and environmental states that are given by the Cartesian product of the sets S and Θ. One could interpret these combinations as consequences. However, in economic or general social-science contexts, one may want to add more structure to the model, so we define a mapping f from $N \times L$ to a *set of consequences* C. This *outcome function* $f : S \times \theta \rightarrow C$ maps each possible combination of strategies and environmental states to one of the possible elements of the set of consequences C.

In the example we had distinguished between three different outcome functions. The story underlying Table 8.1 leads to the following outcome function f^1:

- f^1(*mountaineering, good weather*) = successful climb,
- f^1(*mountaineering, bad weather*) = no successful climb,
- f^1(*attending a concert, good weather*) = concert night,
- f^1(*attending a concert, bad weather*) = concert night.

One can also define a mapping from $N \times L$ to utilities. Taking utilities from Table 8.2, we get the following outcome function f^2:

- f^2(*mountaineering, good weather*) $= 10$,
- f^2(*mountaineering, bad weather*) $= 0$,
- f^2(*attending a concert, good weather*) $= 4$,
- f^2(*attending a concert, bad weather*) $= 4$.

In the variant with monetary payoffs (see Table 8.3), C corresponds to the possible payoffs, and we get the following outcome function f^3:

- f^3(*place a bet, good weather*) $= 100$,
- f^3(*place a bet, bad weather*) $= -10$,
- f^3(*do not place a bet, good weather*) $= 0$,
- f^3(*do not place a bet, bad weather*) $= 0$.

For every outcome function, we obtain a set of consequences $C = \{c_{11}, c_{12}, \ldots, c_{NL}\}$. c_{nl} is the element of this set that results from the combination of strategy s_n and environmental state θ_l (see Table 8.4).

We can now define what we mean by a decision under uncertainty or risk.

▶ **Definition 8.1 Decision under risk or uncertainty** One deals with a decision situation under risk or uncertainty if a decision maker does not know with certainty the state of the environment $\theta_l \in \Theta$ at the time she chooses a strategy $s_n \in S$.

In some decision problems under risk or uncertainty one can assign probabilities to the different consequences. To do so, we assume that environmental state θ_l occurs with probability p_l, where p_l must be in [0, 1]. In addition, $\sum_{l=1}^{L} p_l = 1$ must hold. Such an assignment of probabilities to environmental states is called a *probability distribution*. Table 8.5 adds these probabilities to the consequences matrix. Certainty is then a special case where one environmental state $\theta_l, l = 1, \cdots, L$ is assigned probability 1 and all other environmental states are assigned probability 0.

Table 8.4 Consequences matrix

	θ_1	θ_2	$\cdots$	θ_L
s_1	c_{11}	c_{12}	$\cdots$	c_{1L}
s_2	c_{21}	c_{22}	$\cdots$	c_{2L}
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$
s_N	c_{N1}	c_{N2}	$\cdots$	c_{NL}

Table 8.5 Probabilities-consequences matrix

	θ_1	θ_2	$\cdots$	θ_L
$p(\theta_i)$	p_1	p_2	$\cdots$	p_L
s_1	c_{11}	c_{12}	$\cdots$	c_{1L}
s_2	c_{21}	c_{22}	$\cdots$	c_{2L}
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$
s_N	c_{N1}	c_{N2}	$\cdots$	c_{NL}

Digression 8.1 (What Are Probabilities?)
There are different views about what exactly probabilities are (i.e., questions regarding their epistemology and ontology, see Chap. 1 for these terms). In modern decision theory, probabilities are often interpreted as *degrees of belief*. According to this view, a proposition like "strategy s_n leads to outcome c_{nl}" is regarded as probable by a decision maker if she is convinced of its correctness (epistemic interpretation). However, this interpretation of probabilities is not necessary for the theories discussed in this chapter. There is also the notion of objective probabilities, according to which they are part of the physical world and do not denote subjective uncertainty about the state of the world (ontological interpretation). Also so-called *frequentist* interpretations are compatible with the theories presented here. They state that probabilities describe the relative frequencies of repeated observations. For example, if one flips a coin repeatedly and it turns out that the relative frequencies for heads and tails are both 0.5, then one would choose these relative frequencies as probabilities.

We can now distinguish between the concepts of *risk* and *uncertainty*.

Definition 8.2 Uncertainty and risk Uncertainty exists when a decision maker only knows the states of environment Θ and strategies S but does not assign or cannot meaningfully assign probabilities to consequences. Risk exists when a decision maker assigns or can meaningfully assign probabilities to consequences.

Whether it makes sense to assign probabilities to every decision situation is hotly disputed in decision theory. From a purely formal, mathematical perspective, it is always possible to assign probability distributions as long as one knows Θ. Whether this is also reasonable or rational is the subject of debate. One position is that a rational person should assign probabilities even if she knows nothing more than Θ. It is backed by the *principle of insufficient reason* that we will discuss later. A strategy s_n has maximum uncertainty in this case if one assigns the same probability to each possible outcome c_{nl}. The opposite position is that there exists a form of uncertainty that is so deep that the use of probabilities *per se* is unjustifiable.

Here is an example that illustrates the problem. Suppose one compares a toss of a fair coin to whether or not the world will be affected by a viral pandemic within the next 20 years from now. In both cases, there are two alternative states of the environment. In one case it is *heads* or *tails*; in the other case it is *pandemic* or *no pandemic*. In the first case, we know it is a fair coin, so assigning probabilities $(0.5, 0.5)$ seems rational and reasonable. In the second case, we know next to nothing. If this not knowing also leads us to assign probabilities $(0.5, 0.5)$ to the two states of environment, we treat both situations identically, even though they differ in depth of ignorance: in the first case we know quite a lot about the coin, in the other case we know next to nothing. Experiments have shown that people distinguish situations according to the depth of uncertainty and behave differently accordingly. The question is then whether this is rational or not.

Digression 8.2 (Epistemic Critique and Transformative Experiences)
There exist two fundamental critiques of the mainstream approach to modeling uncertainty and risk presented here. They go under the names *epistemic critique of consequentialism* and *argument from transformativity*. It refers to the *normative* interpretation of the theories as theories of *rational* decision.

Let us first turn to the epistemic critique. We had hitherto simply assumed that a person who has to make a decision knows the set Θ of environmental states and the set S of strategies, and thus has an idea about the conceivable outcomes or consequences of its decisions, even if it is unclear exactly what consequence will result. This way of modeling risk and uncertainty has been criticized on grounds that this assumption cannot be justified, since one cannot know the consequences that follow from our strategies, at least in the medium and long run. If this is so, Θ cannot be meaningfully determined, and thus the whole approach hangs in the air.

Here is an example to illustrate what may be meant by not knowing Θ. Today we know that diseases like the plague were a late consequence of the domestication of animals. But those people who started domesticating animals, had no knowledge of this long-erm consequence, not even categorically: the consequence *plague*, so to speak, did not occur and could not occur in Θ, because one did not even have an idea that something like the plague exists. One may argue against this example that it is not very relevant because of the long temporal distance between action and consequence, but one can easily find current examples where similar problems exist. In the case of the Corona pandemic, one does not know the long-term health consequences of the disease. Perhaps there are none, perhaps there are late effects of which we do not (cannot) know today. Therefore, we cannot expect to fully know Θ at the time decisions are made.

Furthermore, the critique states that strategies and states of environment are not simply objectively given, but are (narratively) constructed. People

(continued)

Digression 8.2 (continued)
do not perceive an objective reality that neatly divides into strategies and states of environment, but create it in the form of a mental model. But if the resulting structuring into strategies and environmental states is arbitrary, the theory loses a lot of its normative plausibility, since rationality sets in only when the mental model is already in place, which implies that its creation is not and cannot be rationally scrutinized or justified. We will return to this in Chap. 11.

Let us now turn to the argument from the transformativity, which refers to the evaluation of outcomes by preferences or utilities, which involves a fundamental epistemic problem whenever a person has never experienced a consequence for him- or herself. Before eating an apple for the first time, one can maybe describe the act of eating an apple, but one cannot know what it means to eat an apple, its taste, its texture, etc. The sensory experience of eating an apple cannot be communicated by means of language. Having an experience for the first time has a transformative quality. The linguistic representation of an experience cannot replace the immediate experience. In such a situation, one can assign utility values to consequences and thereby fully specify a problem in a formal sense, but the question arises whether this formal completion is meaningful if the assigned utility values are not based on past experience but are chosen arbitrarily.

Let us take the choice of your university major as an example. The strategy set is well determined (all possible majors). But what the choice of a major means for life, and whether one does justice to this meaning when one ascribes utility values to it, is unclear. Similar is the decision to procreate and raise a child. It is true that one knows various stories about what it means to have a child. But only when one is in the situation of actually raising a child with all the associated feelings and experiences, one understands what it means. These examples illustrate the point of the critique and how fundamental it is: It raises the possibility that the models and theories presented in this chapter create an illusion of rationality that does not do justice to the actual problem of the transformativity of experience.

The stakes for economic and decision theory are high. We have distinguished between virtue ethics, deontological ethics, and consequentialist ethics in Chap. 5. The decision theories used in economics are all special cases of a consequentialist view of rationality. As we can see, it is far from self-evident that this view is anything more than a mathematically consistent but ultimately substantively empty form of spurious rationality. Therefore, if the critique must be taken seriously, it undermines the legitimacy of the whole project of an economic theory of rational choice.

8.2 Decisions Under Uncertainty

In this section we will look at decisions under uncertainty and learn about different models that have been developed to support the decision process in such situations.

Let us start with an example. Cornelia plans to meet with friends in the summer. The activities they are planning to potentially do are a mountain hike, a sailing trip, a visit to the theater, and a wine tasting. Cornelia's task is to choose the activity. While she is clear about her preferences, she is completely unaware of the weather conditions on the day of the meeting. Her strategy set is

$$S = \{mountain\ hike,\ sailing\ trip,\ theater\ visit,\ wine\ tasting\}.$$

Cornelia would like to make her choice dependent on the weather. The set of relevant weather conditions and thus states of environment is

$$\Theta = \{windy, not\ windy\}.$$

The fact that other environmental states are not considered means that they are irrelevant to the decision from the point of view of Cornelia.

Depending on the possible weather, Cornelia assigns utility levels to each activity, which is contingent on the state of environment: $u : S \times \Theta \rightarrow C$. We summarize the utilities in Cornelia's consequences matrix (Table 8.6).

The weather on the day of the meeting is irrelevant to the utility from going to the theater or wine tasting. It also has little influence on the evaluation of the mountain hike. For the sailing trip, on the other hand, it is very relevant.

How can Cornelia make a meaningful decision in this situation? To answer this question, we can as a first step try to reduce the set of strategies. Obviously, there are two strategies, *mountain hike* and *theater visit*, which dominate the strategy *wine tasting* in the sense that they lead to higher utilities regardless of the state of environment θ_l. A rational decision rule should never arrive at the decision that a strategy dominated in the above sense is chosen. And we will also assume from the point of a positive theory that such strategies are also not chosen.

▶ **Definition 8.3 Dominated strategies** Strategy $\tilde{s}_n \in S$ is *dominated* by strategy $\bar{s}_n \in S$ if and only if

$$u(\bar{s}_n, \theta_l) \geq u(\tilde{s}_n, \theta_l)$$

Table 8.6 Cornelia's consequences matrix

	Not windy	Windy
Mountain hike	10	7
Theater visit	8	8
Sailing trip	2	15
Wine tasting	3	3

holds for all $\theta_l \in \Theta$, and there is at least one state of environment $\hat{\theta}_l \in \theta$ such that

$$u(\bar{s}_n, \hat{\theta}_l) > u(\tilde{s}_n, \hat{\theta}_l)$$

holds.

According to the *dominance principle*, a dominated strategy should never be chosen. We formulate this principle for the case of uncertainty, but it also applies to decision problems under risk. We will return to the question of whether this principle should be postulated not only as a normative principle of rational but also as a positive principle of observed behavior, in Chap. 10.

In our example, strategy *wine tasting* is dominated by both,*mountain hike* and *theater visit*. Thus, we can eliminate this strategy from the strategy set S since it will not be chosen by any rational decision rule. However, Cornelia is still faced with the question of which of the remaining three strategies to choose. We will see that the answer to this question depends on the decision rule, and that all decision rules have advantages and disadvantages.

8.2.1 Maximin Rule

Probably the best-known decision rule is the *maximin rule* proposed by the mathematician Abraham Wald. According to this rule, a decision maker considers the worst utility consequences of each strategy and chooses the strategy that has the least-worst consequences. For Cornelia, these are the environmental states *windy* in the case of the mountain hike and *not windy* in the case of the sailing trip, while weather conditions are irrelevant for the theater visit. Let s_1 = *mountain hike*, s_2 = *theater visit*, and s_3 = *sailing trip*. We can then determine the utility values as follows:

$$\min_{\theta_l \in \theta} u(s_1, \theta_l) = 7, \quad \min_{\theta_l \in \theta} u(s_2, \theta_l) = 8, \quad \min_{\theta_l \in \theta} u(s_3, \theta_l) = 2.$$

They are shown in the third column of Table 8.7.

Table 8.7 Evaluation of Cornelia's decision problem

	Not windy	Windy	$\min_{\theta_l \in \Theta} u(\cdot)$	$\max_{\theta_l \in \Theta} u(\cdot)$	$0.4 \times \max_{\theta_l \in \Theta} u(\cdot) + 0.6 \times \min_{\theta_l \in \Theta} u(\cdot)$	$\frac{u(\cdot,\theta_1)}{2} + \frac{u(\cdot,\theta_2)}{2}$
Mountain hike	10	7	7	10	8.2	8.5
Theater visit	8	8	8	8	8	8
Sailing trip	2	15	2	15	7.2	8.5

Based on this assessment, the decision maker then chooses the strategy that has the maximum utility from these options. In Cornelia's case, the result is 8 and corresponds to the utility resulting from s_n =*theater visit*.

▶ **Definition 8.4 Maximin rule** According to the *maximin rule*, one should pick the strategy $s_n \in S$ that guarantees the maximum of the minimal utilities that can occur in the different states of the environment $\theta_l \in \theta$. This *maximin utility* is equal to

$$\max_{s_n \in S} \min_{\theta_l \in \theta} u(s_n, \theta_l),$$

and a strategy that guarantees this utility is

$$\arg\max_{s_n \in S} \min_{\theta_l \in \theta} u(s_n, \theta_l).$$

If we apply the maximin rule to the example, we get

$$\max_{s_n \in S} \min_{\theta_l \in \Theta} u(s_n, \theta_l) = 8 \text{ and } \arg\max_{s_n \in S} \min_{\theta_l \in \theta} u(s_n, \theta_l) = \textit{theater visit}.$$

The maximin rule is also known as the *precautionary principle* and implements the idea that if you are in a situation of uncertainty, you should play it safe. Uncertainty means that one is in situations with so little information that probabilities cannot be meaningfully formed, and the precautionary principle states that one should then try to minimize the possible damage. However, the blind application of this principle can be quite problematic. Here is an example with two strategies and two possible utility consequences for each. In the first strategy, the two possible utilities are 100 and 100; in the other, they are 99 and 1,000,000. The maximin rule suggests that one should choose the first strategy. However, as you can see, in the bad case it is only slightly better than the second strategy, but in the good case it is much worse. Thus, one gains little by following the rule, but deprives oneself of the possibility of having a very large benefit. It can, however, play an important role if one is aware of the specific context to which it is applied. For example, if we change the utility consequences in the above example from 100 and 100 to 0 and 19 and from 99 and 1,000,000 to 20 and 20, the maximin rule seems much more attractive: one avoids 0 in one case and loses only one unit of utility in the other. Thus, it is often argued that the maximin rule or the precautionary principle are rational in situations when potential disasters have to be avoided and reliable probabilities are not available. Therefore, one often finds a precautionary principle in the context of the climate crisis, in pandemics, or to assess the impact of new technologies.

8.2.2 Maximax Rule

As we have seen, the specific context matters in assessing a decision rule such as the maximin rule. Are there alternatives that can take its place in contexts where it seems implausible? One alternative is the maximax rule. Unlike the maximin rule, the decision maker evaluates each strategy based on the environmental condition that leads to the highest utility. For Cornelia, this would be the environmental state *not windy* in the case of the mountain hike and *windy* in the case of the sailing trip. Formally these values correspond to

$$\max_{\theta_l \in \theta} u(s_1, \theta_l) = 10, \quad \max_{\theta_l \in \theta} u(s_2, \theta_l) = 8, \quad \max_{\theta_l \in \theta} u(s_3, \theta_l) = 15,$$

which are presented in column 4 of Table 8.7. Based on this evaluation, the decision maker will then choose the strategy that picks the strategy with the highest utility among those maximum utilities. In Cornelia's case, this utility is 15 and corresponds to strategy $s =$*sailing trip*. We can now formally define this decision rule.

Definition 8.5 Maximax rule According to the *maximax rule*, one should pick the strategy $s_n \in S$ that guarantees the maximum of the maximal utilities that can occur in the different states of the environment $\theta_l \in \theta$. This *maximin utility* is equal to

$$\max_{s_n \in S} \max_{\theta_l \in \theta} u(s_n, \theta_l),$$

and a strategy that guarantees this utility is

$$\arg\max_{s_n \in S} \max_{\theta_l \in \theta} U(s_n, \theta_l).$$

This definition implies for our example:

$$\max_{s_n \in S} \max_{\theta_l \in \Theta} u(s_n, \theta_l) = 15 \text{ and } \arg\max_{s_n \in S} \max_{\theta_l \in \theta} u(s_n, \theta_l) = \textit{sailing trip}.$$

As with the maximin rule, it is difficult to accept the maximax rule as a reasonable choice rule without further qualification. In particular, in situations with disaster risks, it would lead one to completely ignore the consequences of a catastrophe. Conversely, however, in situations where the negative consequences are less severe, the maximax rule avoids the problems of the minimax rule and instead orients action toward the best achievable options. Thus, it can be argued that a person who has a choice between a rather boring but secure career and an attractive but uncertain career as an artist (where the probability of succeeding or failing cannot be meaningfully calculated) acts rationally in the sense of the maximax rule if she or he chooses the latter.

Both decision rules mentioned so far do not always have to lead to an unambiguously best strategy. Thus, it may be that several strategies lead to the same maximin or maximax utilities. In such a case, one can either freely choose among those strategies, or one could repeat the procedure with the second lowest utility (maximin rule) or the second highest utility (maximax rule).

8.2.3 Hurwicz Rule

The results so far are unsatisfactory because the decision rules can give completely opposing guides for action. And it has already become clear that both rules are convincing only within a certain context. A natural question therefore is whether there is one or more decision rules that avoid the weaknesses of the maximin and maximax rules and at the same time propose convincing strategies in all conceivable situations. Several such rules are discussed in the literature.

The so-called *Hurwicz rule*, named after the economist Leonid Hurwicz, represents a specific compromise between the maximin and maximax rules mentioned before. It uses a linear combination of the minimal and maximal utility levels that can be achieved with each strategy s_n:

$$\alpha \cdot \max_{\theta_l \in \theta} u(s_n, \theta_l) + (1 - \alpha) \cdot \min_{\theta_l \in \theta} u(s_n, \theta_l).$$

$\alpha \in [0, 1]$ is a parameter that determined the relative weight of the relevant maximum in relation to the relevant minimum.

The value α is sometimes called *optimism parameter*, because large values of α imply that one assigns a large weight to the maximum compared to the minimum. We avoid the terms optimism and pessimism whenever possible in this context, however, since they refer to mental phenomena of the decision maker. If we interpret the decision rule as a positive description that allows it to predict behavior under uncertainty, such an interpretation might be harmless, although one would then have to see whether people actually perceive a situation in terms of optimism and pessimism. However, if one interprets the decision rule as a normative theory of rational behavior under uncertainty, such terms have no place. One would rather have to argue why a certain value of α is rational. Unfortunately, the literature is very vague with respect to these issues, so it is unclear whether the Hurwicz rule is supposed to be a rule of rational choice under uncertainty or a positive rule allowing us to make predictions.

We come back to the example and assume that $\alpha = 0.4$. In this case, the Hurwicz rule produces the results documented in the 5th column of Table 8.7. In a final step, we then search for the maximum of these values for all s_n.

▶ **Definition 8.6 Hurwicz rule** According to the Hurwicz rule, one weights the maximum utility over all environmental states $\theta_l \in \Theta$ with a factor $\alpha \in [0, 1]$ and the minimum utilities over all states by a factor $(1 - \alpha)$ for each strategy $s_n \in S$. These values are maximized over $s_n \in S$:

$$\max_{s_n \in S} \left\{ \alpha \cdot \max_{\theta_l \in \Theta} u(s_n, \theta_l) + (1 - \alpha) \cdot \min_{\theta_l \in \Theta} u(s_n, \theta_l) \right\}.$$

The strategies that maximize this value are

$$\arg\max_{s_n \in S} \left\{ \alpha \cdot \max_{\theta_l \in \Theta} u(s_n, \theta_l) + (1 - \alpha) \cdot \min_{\theta_l \in \Theta} u(s_n, \theta_l) \right\}.$$

In our example and $\alpha = 0.4$, the Hurwicz rule leads Cornelia to plan a mountain hike.

8.2.4 Minmax-Regret Rule

Another decision rule we will look at is the *minmax-regret rule*. This involves making a comparison between what I am doing and what I would do if I knew the future. The idea is this: In Cornelia's decision problem, the maximum utility at state *no wind* is equal to 10 (if she chooses to organize a mountain hike). If she decides to go to the theater instead, and it turns out to be not windy, her utility is equal to 8. But she knows in that case that she could have achieved a utility level of 10 if she had chosen the mountain hike. This decision rule assumes that she regrets this (hypothetical) loss of utility and assigns a value of $10 - 8 = 2$ to this regret. Analogously, if she had decided to go sailing and there is no wind, she would again regret this decision and assign a value $10 - 2 = 8$ to this regret. The behavioral hypothesis is that Cornelia chooses her strategy to minimize her maximum regret.

More formally, for each environmental state θ_l, there is a strategy s_n that leads to a maximum level of utility, $\max_{s_n \in S} u(s_n, \theta_l)$. One can now fix this environmental state and determine the utility levels $u(s_n, \theta_l)$ for all the strategies in this environmental state. The term *regret* then refers to the difference between the maximum utility achievable in this state and the utilities that result from these other strategies.

$$r(s_n, \theta_l) = \max_{s_n \in S} u(s_n, \theta_l) - u(s_n, \theta_l).$$

To apply this rule, we need to transform the matrix of consequences shown in Table 8.7 into a regret matrix as given in Table 8.8. Thus, each entry in the regret matrix is the difference between the utility of a strategy and the maximum utility possible given the same environmental state. In Cornelia's case, the regret matrix is given in Table 8.9. In a final step, we then choose the strategy $s_n \in S$ that minimizes the maxima over all rows in Table 8.8. In Cornelia's example, this is the strategy *theater visit*, since $7 < 8$.

Definition 8.7 Minimax-regret rule According to the minimax-regret rule, the strategy $s_n \in S$ whose maximum regret is minimal compared to all other strategies is chosen,

$$\min_{s_n \in S} \max_{\theta_l \in \theta} r(s_n, \theta_l),$$

Table 8.8 Regret matrix

	θ_1	θ_2	$\cdots$	θ_L
s_1	r_{11}	r_{12}	$\cdots$	r_{1L}
s_2	r_{21}	r_{22}	$\cdots$	r_{2L}
$\vdots$	$\vdots$	$\vdots$	$\ldots$	$\vdots$
s_N	r_{N1}	r_{N2}	$\cdots$	r_{NL}

Table 8.9 Cornelia's regret matrix

	Not windy	Windy
Mountain hike	0	8
Theater visit	2	7
Sailing trip	8	0

and the strategy which minimizes the maximum regret is

$$\arg \min_{s_n \in S} \max_{\theta_l \in \theta} r(s_n, \theta_l).$$

The minimax-regret rule once again illustrates the peculiar methodological status of the literature on decision theory under uncertainty. As with the other rules, it is unclear whether it is intended as a positive rule to explain behavior, or as a normative rule of rational behavior in the face of uncertainty. From the perspective of a positive theory, it can be argued that people do have a tendency to regret decisions when uncertainty unravels over time and one finds that one would have liked to behave differently in light of the new information. But from the point of view of a positive theory, it is completely implausible to assume that people are exclusively motivated to behave as to minimize regret in the sense defined here. And the fact that one would have decided differently with additional information does not imply that the decision was irrational given the information one had at the time of decision. A theory that puts the minimization of regret at its center seems to rely on a very strange idea of rationality in the presence of uncertainty. Thus, the decision rules discussed here so far cannot claim more than the status of being more or less plausible heuristics. They are far from a complete normative theory of rational behavior in the context of uncertainty, and their role as positive theories that explain or predict behavior is also unclear.

8.2.5 Laplace Rule

So far, we have assumed that uncertainty implies that one cannot assign probabilities to consequences. However, we have already denoted that this view is not unchallenged. The main tradition of thought that holds that probabilities can be assigned even in the presence of uncertainty goes back to the mathematician and physicist Pierre-Simon Laplace, who formulated the *principle of insufficient reason*.

Recall that uncertainty does not equate to a complete lack of knowledge. Rather, we have assumed that S and Θ and therefore C is known. In such a situation, Laplace argues, it is rational to assign the same probability $1/L$ to each of the L possible consequences for each strategy, because one has no reason to distinguish between the environmental states.

Following the principle yields another, far simpler decision rule, which—as we shall see—also builds a bridge to decision theory under risk:

▶ **Definition 8.8 Laplace rule** According to the Laplace rule, the same probability $1/L$ is assigned to each of the L possible environmental states. A strategy s_n is then chosen that has the highest *expected utility* or *monetary payoff*, where probabilities $\frac{1}{L}$ are used as weights,

$$\max_{s_n \in S} \left\{ \sum_{\theta_l \in \Theta} \frac{1}{L} \cdot u(s_n, \theta_l) \right\}.$$

The strategies that maximize this value are

$$\arg\max_{s_n \in S} \left\{ \sum_{\theta_l \in \Theta} \frac{1}{L} \cdot u(s_n, \theta_l) \right\}.$$

Applying this rule, Cornelia is indifferent between the mountain hike and the sailing trip but prefers both to going to the theater (see column 6 in Table 8.7).

A normative justification of the Laplace rule based on utilities is given in the coming section on risk when we introduce the so-called von Neumann and Morgenstern expected utility function that plays an important role in decision theory. Comparing the Laplace rule with the four rules discussed earlier, it becomes apparent that a central question is whether or not it is rational to assign probabilities according to the principle of insufficient reason even in the presence of uncertainty. For if this is the case, then the previous decision rules that do not involve probabilities become obsolete if one identifies von Neumann's and Morgenstern's theory with rationality. A detailed discussion of this question, however, is beyond the scope of an introductory textbook.

8.3 Decisions Under Risk

As we have already seen, decisions under risk are characterized by assigning probabilities P to the elements of the set of consequences C. Digression 8.1 made the point that probabilities can be interpreted in different ways.

In the following, we will assume that the probabilities can be both objective and subjective, i.e., that they can be based on the subjective assessments of the individuals. Furthermore, no further assumptions are made on the nature of the consequences C. Often, however, the following special cases are examined: One possible outcome function f^m is a mapping from $S \times \Theta$ onto money (in the form of, e.g., income, wealth, or profit). In this case, the elements of C are monetary values. Another possible outcome function f^u is a mapping from $S \times \Theta$ to utility. If $S \times \Theta$ itself is measured in monetary terms, then the utility function is an indirect utility function $v(.)$, otherwise, it is a direct utility function $u(.)$, see Chap. 7.

8.3.1 Lotteries and Expected-Payoff Rule

Let us first assume that outcomes C are measured in monetary terms and use an example. Suppose that we are offered a bet. A fair coin is to be tossed. The stake is equal to CHF 50. With *heads*, you win CHF 100, with *tails*, you win zero. Table 8.10 represents this example. B represents the strategy *take the bet* and NB represents the strategy *do not take the bet*.

A decision rule that is used in risky decisions about money is the *expected-payoff rule* (also called Bayes' rule or μ rule). As the name suggests, it requires to choose the strategy with the highest expected payoff. The expected payoff of a strategy s_n is equal to the sum of all payoffs weighted by their respective probabilities:

$$EV(s_n) = p_{n1} \cdot c_{n1} + p_{n2} \cdot c_{n2} + \ldots + p_{nL} \cdot c_{nL},$$

where p_{nl} is the probability of consequence c_{nl}.

In the example, it follows that

$$EV(B) = \frac{1}{2} \cdot 100 + \frac{1}{2} \cdot 0 = 50$$

and $EV(NB) = 50$; the expected value is identical in both cases.

Another example for a decision problem under risk is a bet at a roulette table. We assume that the table is a European roulette table: 37 winning numbers, 18 red, 18 black, and *zéro* (green). Assume the potential bet is CHF 100, and it is on the black. Table 8.11 represents this case, where B stands for the strategy *bet on black*, while NB stands for *no bet*. Let us look at the problem a little more generally. The set $\{C, P\}$ defines all possible consequences together with their associated probabilities. To each strategy $s_n \in S$ belongs a row C_n in C and a row P_n in P, which together determine the possible consequences of strategy s_n along with the associated probabilities. One can also write these as tuples (c_{nl}, p_{nl}), $l = 1, \ldots, L$. A list

$$\mathcal{L}_n = \{(c_{n1}, p_{n1}); (c_{n2}, p_{n2}); \ldots; (c_{nL}, p_{nL})\}$$

Table 8.10 Fair coin

	Heads	Tails
B	100	0
NB	50	50

Table 8.11 Roulette

	Black	Red	*zéro*
B	200	0	0
NB	100	100	100

is called a *lottery to strategy* s_n. We will use the generic term *lottery* if the specific strategy is obvious or irrelevant.

Roulette has the following representation as lotteries:

$$\mathcal{L}_B = \left\{\left(200, \frac{18}{37}\right); \left(0, \frac{18}{37}\right); \left(0, \frac{1}{37}\right)\right\}$$

and $\mathcal{L}_{NB} = \{(100, 1)\}$. Here, the strategy NB leads to a *degenerate lottery* where the payoff 100 occurs with probability 1.

Thus, each strategy has its associated lottery as consequence, and the decision-theoretic problem of choosing a strategy is to compare these lotteries and then choose the best one.

We can define the expected value $EV(\mathcal{L}_n) = \sum_{j=1}^{L} p_{nj} \cdot c_{nj}$ for each lottery $\mathcal{L}_n$, which allows us to define the expected-payoff rule.

▶ **Definition 8.9 Expected-payoff rule** The *expected-payoff* requires to choose the strategy s_n whose associated lottery $\mathcal{L}_n$ has the highest expected payoff,

$$\max_{s_n \in S} EV(\mathcal{L}_n).$$

A strategy that maximizes this expected payoff is

$$\arg\max_{s_n \in S} EV(\mathcal{L}_n).$$

Thus, in the roulette example, we get

$$EV(\mathcal{L}_B) = \frac{18}{37} \cdot 200 + \frac{18}{37} \cdot 0 + \frac{18}{37} \cdot 0 \approx 97.3,$$

and

$$EV(\mathcal{L}_{NB}) = 100.$$

Thus, a person who maximizes the expected payoff would not participate in roulette.

In roulette, the two events *red* and *zéro* have the same payoff, 0. These cases (states of environment) occur with probabilities $18/37$ and $1/37$. Therefore, an alternative lottery $\hat{\mathcal{L}}_B$ can be defined as follows:

$$\hat{\mathcal{L}}_B = \left\{\left(200, \frac{18}{37}\right); \left(0, \frac{19}{37}\right)\right\}.$$

Table 8.12 Compound lottery

Payoff	Probability
200	$\frac{1}{3} \cdot \frac{18}{37} + \frac{2}{3} \cdot \frac{1}{2} = \frac{55}{111}$
0	$\frac{1}{3} \cdot \frac{19}{37} + \frac{2}{3} \cdot \frac{1}{2} = \frac{56}{111}$

Both lotteries have the same expected payoff. We call lotteries like $\hat{\mathcal{L}}_B$ *reduced* and lotteries like $\mathcal{L}_B$ *elementary*. This observation and notation is important because the consequences of a lottery can themselves be lotteries, so one gets a hierarchy of nested lotteries until one finally arrives at the level of elementary lotteries. Nested lotteries are called *compound*. The fact that the reduced and the elementary lotteries defined above have the same expected payoff means that elementary lotteries can always be transformed into reduced lotteries and reduced lotteries into elementary lotteries.

The following game illustrates the principle. We assume that an (ideal) dice is thrown. If the numbers 1 or 2 appear, one bets CHF 100 on *red* on a European roulette table. On the other hand, if the numbers 3, 4, 5 or 6 appear, one bets CHF 100 that a fair coin will show *head*.

There are two elementary lotteries in this game,

$$\mathcal{L}_1 = \left\{ \left(200, \frac{18}{37}\right); \left(0, \frac{18}{37}\right); \left(0, \frac{1}{37}\right) \right\}, \mathcal{L}_2 = \left\{ \left(200, \frac{1}{2}\right); \left(0, \frac{1}{2}\right) \right\},$$

representing the roulette game and the coin toss, respectively. Both lotteries can then be interpreted as results of the upstream dice roll. This is represented by the compound lottery

$$\mathcal{L}_C = \left\{ \left(\mathcal{L}_1, \frac{1}{3}\right); \left(\mathcal{L}_2, \frac{2}{3}\right) \right\}.$$

By the same token, we can derive a reduced lottery $\mathcal{L}_R$ from a compound lottery following the ideas presented above. To do this, the probabilities of the elementary lotteries are multiplied by the probabilities of the compound lottery for each payoff $c_l \in C$ (since there is no strategy choice in the example, a strategy index can be omitted). We then obtain the probabilities of the reduced lottery $\mathcal{L}_R$ which are shown in Table 8.12.

The reduced lottery is

$$\mathcal{L}_R = \left\{ \left(200, \frac{55}{111}\right); \left(0, \frac{56}{111}\right) \right\},$$

and the expected payoff of this lottery is equal to

$$EV(\mathcal{L}_R) = \frac{55}{111} \cdot 200 + \frac{56}{111} \cdot 0 = \frac{11{,}000}{111} \approx 99.1.$$

By construction, it corresponds to the expected payoffs of the elementary lotteries weighted by the probabilities of the compound lottery $\mathcal{L}_C$:

$$\frac{1}{3} \cdot EV(\mathcal{L}_1) + \frac{2}{3} \cdot EV(\mathcal{L}_2) = \frac{1}{3} \cdot \frac{3600}{37} + \frac{2}{3} \cdot 50 = \frac{11{,}000}{111}.$$

The expected-payoff rule has the advantage that its application is very simple. However, from the perspective of a positive theory, it can be asked whether people actually behave as if they maximize expected monetary payoffs. We will deal with this question in the next section. It is, however, very relevant for companies whose objective is to maximize profits or some other monetary measure of success.

From the point of view of a normative theory, it can additionally be asked whether all situations should be evaluated in terms of money. For example, when it comes to risks where people may die, we can assign monetary values to human lives or life years, and we can use these values to determine decisions. This is sometimes done in practice, and the value of a (U.S.) life is typically valued at \$5–10 million. From an ethical perspective, the question then becomes whether such an approach is legitimate.

8.3.2 Critique of the Expected-Payoff Rule

Until the seventeenth century, the expected-payoff rule was understood to be the correct or rational way to evaluate decisions under risk. It was not until the mathematician Nikolaus Bernoulli pointed out in a letter written in 1713 that people violate this rule when making decisions.

Here is the problem that has been developed to illustrate this point: In a fictitious St. Petersburg casino, guests are offered the following bet: A fair coin is tossed until *head* appears for the first time. Should *head* appear after the first toss, the player receives 2 rubles. If *head* appears after the second roll, the player receives 4 rubles, 8 rubles if *head* appears after the third roll, etc. Thus, the payoff after the nth roll is equal to 2^n. How much should a rational person be willing to pay to play the game? If the expected-payoff rule is used to answer this question, the advice is unambiguous: One should be willing to pay any finite fee to be allowed to participate in this game. The reason for this result is that the expected payoff of this game converges to infinity. The probability that *head* appears after the first roll is $\frac{1}{2}$. What is the probability that *head* appears for the first time after the second roll? It is equal to the probability that *number* appears on the first roll and *head* appears on the second roll. Thus, the probability is $\frac{1}{2} \cdot \frac{1}{2} = \frac{1}{4}$. However, the monetary value has doubled, it increases from 2 to 4 rubles. This correlation between decreasing probabilities and increasing payoffs drives the result. The probability of *head* appearing for the first time after the nth roll is equal to $\frac{1}{2^n}$. The payoff in this case is 2^n. Thus, the expected payoff of this lottery is

$$EV(\mathcal{L}) = \frac{1}{2} \cdot 2 + \frac{1}{4} \cdot 2^2 + \frac{1}{8} \cdot 2^3 + \cdots = \sum_{j=1}^{\infty} \frac{1}{2^j} \cdot 2^j = 1 + 1 + \cdots \to \infty.$$

Thus, according to the expected-payoff rule, one should be willing to pay any finite price to participate in this game. However, one would probably have difficulty finding someone who would be willing to pay more than a very moderate amount of money to play it. Therefore, a paradox arises: although the expected payoff of the game is infinite, people are not willing to pay a lot of money to participate in it.

A solution to the problem was proposed independently and almost simultaneously by the mathematician Gabriel Cramer and Nicolas Bernoulli's cousin, the mathematician Daniel Bernoulli. He also used the term *St. Petersburg paradox* in his publication from 1738, see Bernoulli (1954/1738) [1738]. Both mathematicians solved the problem by arguing that people do not maximize expected payoff, but the expected *utility* players experience from a payoff. Thus, they replaced expected monetary payoffs with expected utility. The idea was that if money has diminishing marginal utility, an infinite expected payoff can have a finite expected utility.

Let us illustrate this fact with an example. With a utility function $u(c) = \ln(c)$, we get a marginal-utility function $u'(c) = \frac{1}{c}$, which is decreasing in c. The utility that a player experiences from the payoff if *head* first shows up after j rolls is $u(c_j) = \ln(2^j)$. If we replace payoffs c_j with utilities $u(c_j)$ in the above equation, one gets

$$\sum_{j=1}^{\infty} \frac{\ln(2^j)}{2^j} = \frac{\ln(2)}{2} + \frac{\ln(4)}{4} + \frac{\ln(8)}{8} + \cdots .$$

This value converges to 1.39. What we have calculated is the *expected utility*, EU, of the above game, when the utility function is $u(c) = \ln c$.

In general, the expected utility of a lottery $\mathcal{L}$ is calculated as follows:

$$EU(\mathcal{L}) = \sum_{j=1}^{L} p_j \cdot u(c_j),$$

where $u(c_j)$ is called a *Bernoulli-utility function* to distinguish it from the expected-utility function $EU(\mathcal{L})$. Thus, an individual with the above Bernoulli-utility function $u(c) = \ln(c)$ will achieve an expected utility of ≈ 1.39. We can also calculate the maximum willingness to pay x for the game, which is equal to

$$u(x) = EU(\mathcal{L}) \Leftrightarrow \ln(x) \approx 1.39 \Leftrightarrow x = e^{1.39} \approx 4.01.$$

Digression 8.3 (The Solution to the St. Petersburg Paradox)
As mentioned earlier, the works of Gabriel Cramer and Daniel Bernoulli are considered to be the first solutions of the St. Petersburg paradox. Cramer's and Bernoulli's solutions consisted in proposing a specific, sufficiently concave

(continued)

Digression 8.3 (continued)
transformation of monetary payoffs, which Cramer called *valeur morale*, that is, moral value. Cramer's and Bernoulli's argument in favor of using such a transformation was that the additional moral value of a payoff decreases in its absolute value. Bernoulli's work proposed a logarithmic transformation, Cramer's proposal was a root function Seidl (2013). However, strictly speaking, this is not a solution to the spirit of the original problem because, as mathematician and economist Karl Menger (1934/1979) has shown, the paradox may recur if one uses a different sequence of monetary payoffs. For example, if the monetary payoff is e^{2^n} in the case where *head* appears for the first time after roll nth, the expected utility would be equal to $\ln\left(e^{2^n}\right) = 2^n$. Hence, the expected utility now converges to infinity, as the expected payoff in the original game. The same is true for Cramer's specification if we assume a payoff of 2^{2^n} if *head* appears for the first time after roll n. Thus, Menger has shown that for any utility function u that converges to infinity as c converges to infinity, one can find a strictly increasing transformation of the monetary payoffs such that the expected utility converges to infinity (Buchak, 2013). Thus, the only way to prevent this from happening is by using a utility function $u(c)$ that has an upper bound $\bar{u}$ for $c \to \infty$.

From the point of view of a decision theory, Bernoulli's solution of the paradox is interesting as it paved the way for the development of modern expected-utility theory presented below. A sufficiently concave transformation from money to utility is a psychological solution to the problem because it presupposes that people make subjective evaluations of money that are responsible for behavior. However, the use of utility functions is by no means the only possible solution to the paradox. Rather, arguments can be found that see the paradox as an artifact of neglecting scarcity.

- The most direct argument notes that when resources are scarce, such a game can never be credibly offered because it is based on the existence of infinite resources. Individuals must therefore be irrational if they take the bet seriously, and not just a mathematical curiosity without real-life consequences.
- A similar argument goes back to economist Paul Anthony Samuelson (1960), who noted that even with infinite resources, such a bet can never be credibly offered because there are no mutual gains from trade: "Paul will never be willing to give as much as Peter will demand for such a contract; and hence the indicated activity will take place at the equilibrium level of zero intensity."

The implication of the first two points is that the paradox is a mathematical artifact which has no relevance to economic problems. There are other arguments that introduce scarcity even if the amount of resources were in principle infinite.

- Another argument brings into play the factor of time and the opportunity costs associated with it. If people value future payments less than present payments, they will discount them. Therefore, if the game has a temporal structure and each subsequent coin flip occurs at a later time, discounting implies that the present value of the game is less than its expected monetary value.

  To make the point concrete, assume that a person discounts a payoff that is one period in the future by the discount factor $\delta < 1$. Then, the present value of the game is

$$EV(\mathcal{L}) = \sum_{j=1}^{\infty} \delta^{j-1} \cdot \frac{1}{2^j} \cdot 2^j = \frac{1}{1-\delta}.$$

  Therefore, the discounted expected payoff is finite, and the more patient the person (larger δ), the higher this value.

  A formally identical but conceptually different argument is based on a different concept of opportunity costs of time: if people have a certain probability λ of dying (mortality rate) at any point in time, they may die before they win the game. Formally, this has the same consequences as discounting time, and we get

$$EV(\mathcal{L}) = \sum_{j=1}^{\infty} \lambda^{j-1} \cdot \frac{1}{2^j} \cdot 2^j = \frac{1}{1-\lambda}.$$

  The interpretation is different, however: people with a lower probability of dying place a higher value on the game.

It can be shown empirically that people and firms discount the future, and this can be rational, as the example of mortality rates shows. Therefore, it becomes clear that the introduction of utilities is not the only solution to the St. Petersburg paradox. And this is an important observation. As we see in Chap. 12, economic theory assumes that firms maximize profits. But profits are measured in terms of money. Therefore, if utilities were the only way to solve the paradox, one would have a problem. Rather, in research areas like investment and finance, one solves the problem of potentially infinite expected payoffs by introducing discount factors.

- If one looks at the evolution of probabilities over the different stages of the game, one finds that they rapidly converge to zero. Moreover, one can empirically observe that many people do not use objective probabilities p in their calculus, even if they are available. They behave as if they use subjectively perceived probabilities $\pi(p)$ (also called decision weights, see Chap. 10). Empirically, most people cannot accurately distinguish between small probability differences. The difference between a probability of 0.0001 and a probability of 0.00001 is clear to very few people and is likely to be neglected, even though it may be of great importance in the present game. This property of the people's mental models can

resolve the paradox if the large payoffs are evaluated with a decision weight that is smaller than the objective probability.
Something similar applies to the perception of payoffs. In this game, monetary payoffs increase very quickly, and again, at some point most people no longer comprehend the involved numbers. Again, their mental model is distorted.

This solution of the paradox questions the assumption of rationality and thus opens the door to *behavioral economics*, a field of research that we will discuss in Chap. 10.

As stated earlier (and already applied in the section on uncertainty), economic theory assumes that people evaluate lotteries with utility functions, and in the case of risk in the special form of an expected-utility function, $u(\mathcal{L}) = EU(\mathcal{L})$. To motivate such an approach, an axiomatic justification has been given, and we will now have a closer look at it.

8.3.3 Expected-Utility Theory

The reason we have mostly talked about expected payoffs so far has been that we have assumed an outcome function f^m that maps strategies and environmental states $S \times \Theta$ onto monetary payoffs C. We have already said that another possible outcome function f^u maps $S \times \Theta$ onto utilities. In this case, expected values over lotteries $\mathcal{L}$ automatically have the structure of an expected-utility function $EU(\mathcal{L})$. One could leave it like that and see what follows from this assumption for behavior in different contexts. However, the literature evolved otherwise and has derived this specific structure of a utility function axiomatically from a more general, so-called axiomatic approach. This approach allows us to understand the concept of rationality in decision-making under risk in much more detail.

Therefore, we start with an arbitrary outcome function f that maps strategies and environmental states $S \times \Theta$ onto a set C that can be anything except utility (e.g., parties in an election, professions, food in a restaurant, but also money). However, the outcomes c_{nl} are relevant to an individual's decisions. It is plausible to assume that the probabilities P with which the outcomes occur are also relevant.

The formal problem now is that an individual chooses a strategy that maximizes her preference relation $\succsim$ on a set of all lotteries $\mathbf{L} = \{\mathcal{L}_1, \mathcal{L}_2, \ldots\}$. As in Chap. 7, we assume that the preference relation $\succsim$ is rational in the sense of being complete and transitive.

▶ **Definition 8.10 Rationality** The weak preference relation $\succsim$ over the set of possible lotteries $\mathbf{L}$ is complete and transitive:

1. For all $\mathcal{L}_i, \mathcal{L}_j \in \mathbf{L}$, either $\mathcal{L}_i \succsim \mathcal{L}_j$, or $\mathcal{L}_j \succsim \mathcal{L}_i$, or both.
2. For all $\mathcal{L}_i, \mathcal{L}_j, \mathcal{L}_k \in \mathbf{L}$ holds: if $\mathcal{L}_i \succsim \mathcal{L}_j$ and $\mathcal{L}_j \succsim \mathcal{L}_k$, then $\mathcal{L}_i \succsim \mathcal{L}_k$.

This is consistent with the concept of rationality defined in Chap. 7. Therefore, all remarks made in that chapter still apply, and we do not discuss them any further.

The following two additional assumptions go beyond the standard assumption of rationality and stem from work by John von Neumann and Oskar Morgenstern (1944), which we will encounter again in Chap. 9 on game theory. Both assumptions together are both necessary and sufficient for individuals to behave as if they were maximizing an expected-utility function.

Definition 8.11 Continuity Preferences on the set of lotteries $\mathbf{L}$ are *continuous* if for all lotteries $\mathcal{L}_i, \mathcal{L}_j, \mathcal{L}_k$ with $\mathcal{L}_i \succsim \mathcal{L}_j \succsim \mathcal{L}_k$ there is a probability $p \in [0, 1]$ such that $p \otimes \mathcal{L}_i \oplus (1-p) \otimes \mathcal{L}_k \succsim \mathcal{L}_j \wedge \mathcal{L}_j \succsim p \otimes \mathcal{L}_i \oplus (1-p) \otimes \mathcal{L}_k$.

The symbols $\oplus$ and $\otimes$ refer to the fact that we are not dealing with addition and multiplication in the above operation. The symbols mean that, for example, lottery i is realized with probability p, and lottery j is realized with probability $(1-p)$.

An operation like $p \otimes \mathcal{L}_i \oplus (1-p) \otimes \mathcal{L}_k$ is called a *linear combination* of the two lotteries $\mathcal{L}_i$ and $\mathcal{L}_k$ with weights p and $(1-p)$ and is itself a compound lottery. The assumption implies that it is always possible to find exactly one linear combination of a good ($\mathcal{L}_i$) and bad ($\mathcal{L}_k$) lottery that makes an individual indifferent to a middle lottery ($\mathcal{L}_j$).

If there is a best and worst lottery in $\mathbf{L}$, continuity implies any lottery can be represented by an indifferent compound lottery composed of the best and worst lotteries in $\mathbf{L}$.

This property can be illustrated with the help of a probability simplex. Figure 8.1 shows the case of three elementary lotteries $\mathcal{L}_i$, $\mathcal{L}_j$, $\mathcal{L}_k$. The gray-shaded triangle

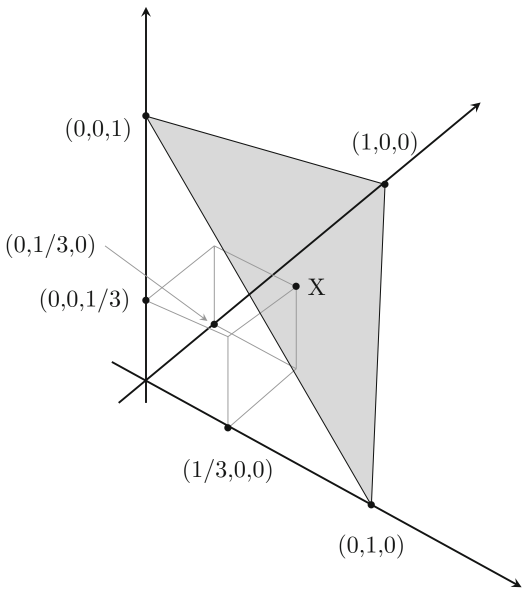

Fig. 8.1 Construction of a probability simplex

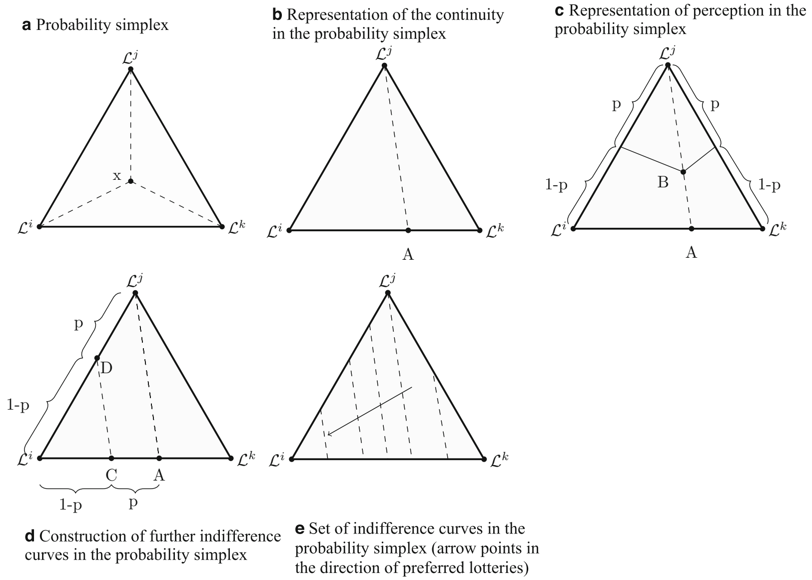

Fig. 8.2 Probability simplex

passes through the points $(1, 0, 0)$, $(0, 1, 0)$, $(0, 0, 1)$, which can be described as special cases where lottery $\mathcal{L}_i$ occurs with probability 1 and the other two occur with probability 0 ($(1, 0, 0)$), etc. The set of all compound lotteries that can be constructed from these elementary lotteries is the set of all probability weights $(p_i, p_j, 1 - p_i - p_j)$ (linear combinations). This set corresponds to the gray-shaded triangle which is called a probability simplex. Point X shows one such compound lottery with weights $(1/3, 1/3, 1/3)$.

If we focus only at the triangle, we get an equilateral triangle with the elementary lotteries $\mathcal{L}_i, \mathcal{L}_j, \mathcal{L}_k$ at the three corners (Fig. 8.2a). Continuity then means that there is a linear combination of $\mathcal{L}_i$ and $\mathcal{L}_k$ (point A in Fig. 8.2b) such that the individual is indifferent between this linear combination and $\mathcal{L}_j$.

▶ **Definition 8.12 Independence** Preferences on the set of lotteries are *independent* if for all lotteries $\mathcal{L}_i$, $\mathcal{L}_j$, $\mathcal{L}_k$ with $\mathcal{L}_i \succsim \mathcal{L}_j$ and $p \in (0, 1]$ it follows that $p \otimes \mathcal{L}_i \oplus (1 - t) \otimes \mathcal{L}_k \succsim p \otimes \mathcal{L}_j \oplus (1 - t) \otimes \mathcal{L}_k$ holds.

What is the intuition for the assumption? Suppose one has a preference ordering over two lotteries. If you construct compound lotteries from these two lotteries by adding to both *the same* third lottery with *the same* probability (less than 1), your original preference ordering should not change.

The implications of independence can be illustrated using the probability simplex. In Fig. 8.2c, we have turned lottery A into a new compound lottery by adding lottery $\mathcal{L}_k$ with probability $(1 - p)$. This new lottery is denoted by B and must lie on the straight line between A and $\mathcal{L}_k$. Independence states that B must be indifferent to A.

We can now state the central theorem.

▶ **Result 8.1 von Neumann and Morgenstern Theorem** A preference relation $\succsim$ over lotteries $\mathcal{L} \in \mathbf{L}$ satisfies the axioms of rationality, continuity, and independence if and only if there exists a utility function $EU : \mathbf{L} \rightarrow \mathbb{R}$ which represents $\succsim$ and has the expected-utility property

$$EU(\mathcal{L}) = \sum_{j=1}^{I} p_j \cdot u(c_j).$$

What is the intuition for this result? We will forgo a formal proof, but we can convey its idea using the probability simplex. First, it follows from the expected-utility function that utility is linear in probabilities. In other words, an individual maximizing such a function perceives probabilities as complete substitutes (see Chap. 7). Looking at Fig. 8.2c, we see that lottery B lies on the straight line between A and $\mathcal{L}_j$ and that B is indifferent to both, A and $\mathcal{L}_j$. In other words, the straight line $(A, \mathcal{L}_k)$ forms an indifference curve.

If we can show all other points (possible lotteries) within the probability simplex also form indifference curves that are straight lines, and if these straight lines are all parallel, we have shown the expected-utility property. To do so, start from lotteries A and $\mathcal{L}_j$ in Fig. 8.2d. We now form two new lotteries C and D by adding lottery $\mathcal{L}_i$ with the same probability p. By the independence axiom, an individual must be indifferent between these two lotteries, and again by the independence axiom, all points on the straight line between C and D must also be indifferent to C or D; they form an indifference curve. (Since these contain a larger fraction of the best lottery $\mathcal{L}_i$, the individual prefers lotteries on this indifference cure to lotteries on the indifference curve through A and $\mathcal{L}_j$). By the intercept theorem, this new indifference curve must be parallel to the indifference curve through A and $\mathcal{L}_j$, since the same fraction p of lottery $\mathcal{L}_i$ is added in each case. This finding completes the intuition why indifference curves in the probability simplex must be parallel straight lines, see Fig. 8.2e.

A utility index is still missing to complete the proof. Since there is a best lottery ($\mathcal{L}_b$) and a worst lottery ($\mathcal{L}_w$), we know by continuity that every other lottery has an indifferent lottery that can be constructed as a linear combination $p \otimes \mathcal{L}_b \oplus (1 - p) \otimes \mathcal{L}_w$ of these two. Now, if we assign utility 1 to the best lottery and utility 0 to the worst, the utility value of each other lottery is p.

What has been gained by this theorem? From a methodological perspective, the axiomatic approach allows us to understand in much more detail whether expected-utility maximization is normatively convincing in the case of risk. If we look at the two assumptions, we can conclude that they seem very reasonable as maxims for rational behavior. That it should be possible to form a compound lottery from a best and a worst lottery that is indifferent to an intermediate lottery sounds convincing. And that adding the same lottery to two other lotteries in equal parts should not change the ordering also sounds reasonable. Thus, one can argue that the two aspects continuity and independence grasp an important aspect of rationality in situations of risk.

If we agree to this point, the implication of the theorem is extremely strong as it implies that expected-utility maximization is the normatively correct way to make decisions under risk. If one agrees, in addition, with Laplace's principle of insufficient reason, the implication becomes even stronger, because then expected-utility maximization is the standard of rationality even in situations of uncertainty. And it cuts both ways: If one is not happy with expected-utility maximization as a standard of rationality, one has to explain what is wrong with the two assumptions.

But the theorem is also relevant from the perspective of positive science. The classical rationality assumptions plus continuity and independence are complex, and people cannot be expected to always act consistently with them in real life, even if they wanted to. In this case, however, they nonetheless play an important role because they can be used to identify systematic deviations in order to better understand if, how, and when people deviate from them. Here is an example: We have previously argued that people do not handle small probabilities well. In this case, we would expect that the indifference curves in the probability simplex are not continuous, parallel, straight lines. We will return to this point in more detail in Chap. 10. To get a taste for such deviations we will now take a closer look at the Allais paradox, an example of a systematic violation of expected-utility theory.

8.3.4 The Allais Paradox

Suppose that an individual is faced with a choice between the following lotteries:

- The (degenerate) lottery A guarantees a payoff of CHF 1 million with probability 100%.
- With lottery B one wins CHF 5 million with probability 10%, with probability 89% CHF 1 million, and with probability 1% CHF 0.

Here is the summary:

$$\mathcal{L}_A = \{(1, 1)\}, \quad \mathcal{L}_B = \{(5, 0.1); (1, 0.89); (0, 0.01)\}.$$

In addition, the individual also faces a choice between two other lotteries:

- With lottery C one wins CHF 1 million with probability 11%, and with probability 89% CHF 0.
- With lottery D one wins CHF 5 million with probability 10%, and with probability 90% CHF 0.

Here is the summary again:

$$\mathcal{L}_C = \{(1, 0.11); (0, 0.89)\}, \quad \mathcal{L}_D = \{(5, 0.1); (0, 0.9)\}.$$

The experiment goes back to economist Maurice Allais (1952). As it turns out, most subjects preferred lottery A to lottery B ($\mathcal{L}_A \succ \mathcal{L}_B$), while they preferred lottery D to lottery C ($\mathcal{L}_D \succ \mathcal{L}_C$).

We now want to check whether these revealed preferences are consistent with the axioms of expected-utility theory: If an individual decides $\mathcal{L}_A \succ \mathcal{L}_B$, it must follow that

$$\begin{aligned} & EU(\mathcal{L}_A) > EU(\mathcal{L}_B) \\ \Leftrightarrow \quad & u(1) > 0.1 \cdot u(5) + 0.89 \cdot u(1) + 0.01 \cdot u(0) \\ \Leftrightarrow \quad & 0.11 \cdot u(1) > 0.1 \cdot u(5) + 0.01 \cdot u(0). \end{aligned}$$

If the same individual decides $\mathcal{L}_D \succ \mathcal{L}_C$, it must follow that

$$\begin{aligned} & EU(\mathcal{L}_D) > EU(\mathcal{L}_C) \\ \Leftrightarrow \quad & 0.1 \cdot u(5) + 0.9 \cdot u(0) > 0.11 \cdot u(1) + 0.89 \cdot u(0) \\ \Leftrightarrow \quad & 0.1 \cdot u(5) + 0.01 \cdot u(0) > 0.11 \cdot u(1). \end{aligned}$$

Obviously, these equations contradict each other: consistent would be if an individual preferred both, A and C, or both, B and D. Thus, individuals with such preferences violate at least one of the von Neumann-Morgenstern axioms.

Let us use an example to make clear how to find out which one it is. Suppose we are standing in front of a roulette table with 100 pockets. 50 of the pockets are red, 49 are black, and one is green. We will represent the lotteries as bets on this roulette table. To do so, we denote lotteries $\mathcal{L}_A$ and $\mathcal{L}_C$ as compound lotteries

$$\mathcal{L}_{A'} = \{(1, 0.89); (1, 0.1); (1, 0.01)\}$$

and

$$\mathcal{L}_{C'} = \{(0, 0.89); (1, 0.1); (1, 0.01)\},$$

which represent the same probability distributions over the set of payoffs as lotteries $\mathcal{L}_A$ and $\mathcal{L}_C$. For a comparison between $\mathcal{L}_A$ and $\mathcal{L}_B$, the first column of Table 8.13 is irrelevant: In both cases, one wins CHF 1 million with probability 89%. According to the independence axiom, this component of both lotteries should be irrelevant for preferences. Thus, one prefers lottery A to lottery B if the following condition holds

$$\left\{\left(1, \frac{10}{11}\right); \left(1, \frac{1}{11}\right)\right\} \succ \left\{\left(5, \frac{10}{11}\right); \left(0, \frac{1}{11}\right)\right\}.$$

Table 8.13 Allais paradox

Lottery	Red 89%	Black 10%	Green 1%
$\mathcal{L}_A$	1	1	1
$\mathcal{L}_B$	1	5	0
$\mathcal{L}_C$	0	1	1
$\mathcal{L}_D$	0	5	0

Let us now consider lotteries C and D. Again, the first column of Table 8.13 is irrelevant, as the individual wins 0 with probability 89% in both cases. Thus, it prefers lottery D to lottery C if the following condition holds:

$$\left\{\left(5, \frac{10}{11}\right); \left(0, \frac{1}{11}\right)\right\} \succ \left\{\left(1, \frac{10}{11}\right); \left(1, \frac{1}{11}\right)\right\}.$$

However, completeness implies that both conditions contradict each other.

As mentioned earlier, the paradox is a violation of independence. To see this, let us look again at lotteries A and B: Lottery A guarantees a prize of CHF 1 million. Lottery B, however, opens the opportunity for winning nothing, even if the probability is low. One possible explanation for why individuals prefer A to B is that they want to play it safe when they have the chance to get CHF 1 million for sure. As soon as there is a positive probability for winning nothing, people perceive the situation in a qualitatively different way. So, a change in probabilities from 1 to 0.99 is perceived differently from a change from 0.11 to 0.10. Independence does not allow such a qualitative difference.

Allais (2018) interpreted his findings in the following way: "I viewed the principle of independence as incompatible with the preference for security in the neighborhood of certainty shown by every subject and which is reflected by the elimination of all strategies implying a non-negligible probability of ruin, and by a preference for security in the neighborhood of certainty when dealing with sums that are large in relation to the subject's capital." Much has happened since the work by Allais. Today we know that people regularly and systematically violate the assumptions of expected-utility theory. We will return to this in Chap. 10.

8.3.5 Propensities Towards Risk

From now on we assume that consequences C are measured in money, but that lotteries $\mathcal{L}$ are evaluated by means of an expected-utility function. In such a situation, we can distinguish between the expected utility $EU[\mathcal{L}]$ of a lottery and the utility from the expected payoff of the lottery $u(EV(\mathcal{L})$. This distinction plays an important role in economic theory.

Suppose that an individual faces the following lottery: $\mathcal{L} = \{(c_1, p_1) ; (c_2, p_2)\}$. We assume that the individual's Bernoulli-utility function $u(c)$ has positive and decreasing marginal utility of money c, so that $u'(c) > 0$ and $u''(c) < 0$ holds

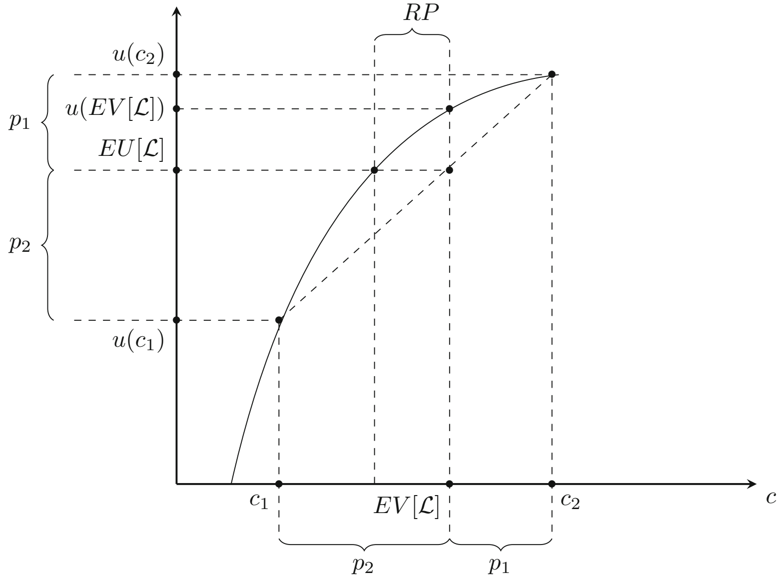

Fig. 8.3 Bernoulli-utility function characterizing risk-averse behavior

(the function is strictly concave). It is thus formally equivalent to an indirect utility function $v(.)$ that we derived in Chap. 7.

Figure 8.3 illustrates the strictly concave shape of the Bernoulli-utility function as a function of c. At c_1, this utility function has a value $u(c_1)$, and at c_2, its value is $u(c_2)$. The expected utility of this lottery is

$$EU(\mathcal{L}) = p_1 \cdot u(c_1) + p_2 \cdot u(c_2).$$

The expected utility corresponds to a linear combination of the utilities at $u(c_1)$ and $u(c_2)$ with factors p_1 and $p_2 (= 1 - p_1)$. This linear combination can be measured along the ordinate.

In contrast, the expectation payoff $EV(\mathcal{L})$ corresponds to a linear combination of $c_1 = 150$ and $c_2 = 50$ with factors p_1 and $p_2 (= 1 - p_1)$,

$$EV(\mathcal{L}) = p_1 \cdot c_1 + p_2 \cdot c_2.$$

This linear combination can be measured along the abscissa.

What is the utility of a safe amount of money equal to $EV(\mathcal{L})$? It is equal to $u(EV(\mathcal{L}))$. It follows that the utility from the (safe) expected payoff exceeds the expected utility $EU(\mathcal{L})$ of the lottery. We call an individual with such a Bernoulli-utility function *risk-averse*.

Risk-loving behavior, on the other hand, results if the individual, given a choice between an uncertain lottery or its expected payoff, chooses the lottery. In this

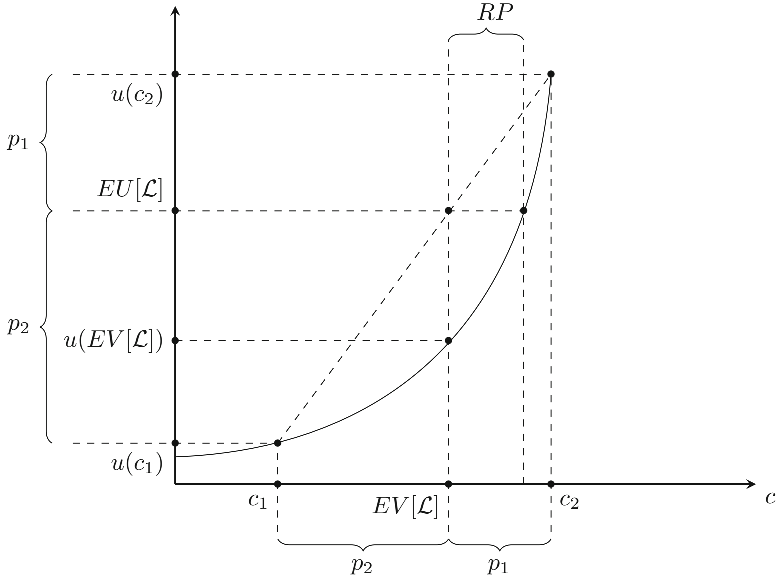

Fig. 8.4 Bernoulli-utility function characterizing risk-loving behavior

case the expected utility is larger than the utility of the expected payoff. This case occurs if the Bernoulli-utility function has positive and *increasing* marginal utility, $u'(c) > 0$ and $u''(c) > 0$ (it is strictly convex). It is shown in Fig. 8.4. As before, the expected utility is the linear combination of $u(c_1)$ and $u(c_2)$ along the ordinate, and the expected payoff is the linear combination of c_1 and c_2 along the abscissa. The Bernoulli utility of the expected payoff is smaller than the expected utility this time.

The limiting case between risk aversion and risk loving is *risk neutrality*. In this case, the expected utility is equal to the utility of the expected payoff, which happens if the Bernoulli-utility function is linear, $u'(c) > 0$ and $u''(c) = 0$.

The following definition summarizes the concepts.

Definition 8.13 Propensity towards risk An individual's propensity towards risk is determined by the difference between the expected utility of a lottery $EU[\mathcal{L}]$ and the utility of the expected payoff of that lottery, $u(EV(\mathcal{L}))$. An individual is called

$$\begin{aligned} &\text{risk-averse, if } EU(\mathcal{L}) < u(EV(\mathcal{L})),\\ &\text{risk neutral, if } EU(\mathcal{L}) = u(EV(\mathcal{L})),\\ &\text{risk loving, if } EU(\mathcal{L}) > u(EV(\mathcal{L})) \end{aligned}$$

is satisfied.

Table 8.14 Risk measures

Risk averse	$u''(c) < 0$	$EU(\mathcal{L}) < u(EV(\mathcal{L}))$	$CE < EV(\mathcal{L})$	$RP > 0$
Risk neutral	$u''(c) = 0$	$EU(\mathcal{L}) = u(EV(\mathcal{L}))$	$CE = EV(\mathcal{L})$	$RP = 0$
Risk loving	$u''(c) > 0$	$EU(\mathcal{L}) > u(EV(\mathcal{L}))$	$CE > EV(\mathcal{L})$	$RP < 0$

A look at Fig. 8.3 also shows that a safe payoff of CE leads to a level of utility that is equal to the expected utility of the lottery $\mathcal{L}$. Thus, CE is equal to the payoff that makes the individual indifferent between this payoff and the lottery, $u(CE) = EU[\mathcal{L}]$. CE is called *certainty equivalent*. In the case of a risk-averse (risk-neutral, risk-loving) individual, the certainty equivalent is less than (equal to, greater than) the expected payoff of the lottery (see Figs. 8.3 and 8.4).

In the case of risk aversion, the individual is willing to pay a strictly positive price of at most $EV[\mathcal{L}] - CE$ to avoid the risk of the lottery (see Fig. 8.3). This amount is called *risk premium* (RP). In the case of risk loving, the risk premium is negative (see Fig. 8.4). Here, the (negative) risk premium can be interpreted as the maximum price the individual is willing to pay to expose itself to the risk. In the presence of risk neutrality, the risk premium is equal to 0.

The results are summarized in Table 8.14. At this point, it should be emphasized again that the above risk measures are defined only for the case where the C is monetary. For lotteries where utility is defined on, e.g., multidimensional bundles of goods, or on political parties in the case of elections, these concepts are not well defined. As we have seen when we have introduced the concept of an indirect utility function, it is sometimes possible to solve this problem (for example, in the case of fully competitive markets that allow the identification of such a function). Also, an application of risk measures in political decision situations is in principle possible if a person judges parties exclusively on the basis of the expected consequences on its income, wealth, or profit (then C can be expressed in money again). In all other cases, however, this is not possible. Expected-utility theory remains applicable, of course, but one can no longer use concepts like risk aversion. Let us illustrate the concepts by means of an example. Matteo earns his monthly income from sales on an online platform. In good months his income equals $c_1 =$ CHF 2500, while in bad months it equals $c_2 =$ CHF 900. If we assume that the probabilities for good and bad months are $p_1 = 0.6$ and $p_2 = 0.4$, the expected monthly income equals $EV(\mathcal{L}) = \frac{3}{5} \cdot 2500 + \frac{2}{5} \cdot 900 =$ CHF 1860. Let Matteo's Bernoulli-utility function be $u(c) = \sqrt{c}$, so that the utility from his activity is $u(2500) = 50$ in good and $u(900) = 30$ in bad months. His expected utility is therefore $EU(\mathcal{L}) = \frac{3}{5} \cdot 50 + \frac{2}{5} \cdot 30 = 42$. Matteo's neighbor offers him a job in his bar that guarantees him a secure monthly wage of CHF 1700 CHF. We can compute Matteo's certainty equivalent (CE) to determine the (monthly) minimum wage that makes him indifferent between his current job and an alternative job with fixed income. To determine it, we set $\sqrt{CE} = EU(\mathcal{L})$ and solve for CE. The result is $CE = 1764$. Thus, if Matteo is an expected-utility maximizer, he will reject this offer because the monthly wage is less than his certainty equivalent.

In some applications, it seems appropriate to use a quantitative measure of an individual's propensity towards risk. This may be the case, for example, when one wants to compare the risk attitudes of two different individuals. The best-known quantitative measure is the *Arrow-Pratt measure*, which goes back to economists Kenneth Arrow and John Winsor Pratt. We will present two variants of this measure: so-called *absolute* risk aversion one so-called *relative* risk aversion.

▶ **Definition 8.14 Arrow-Pratt measure** Assume a Bernoulli-utility function u is twice continuously differentiable. The Arrow-Pratt coefficients of absolute (ARA) and of relative risk aversion (RRA):

$$ARA(c) = -\frac{u''(c)}{u'(c)},$$

$$RRA(c) = -\frac{u''(c)}{u'(c)} \cdot c.$$

For risk-averse (risk-loving) individuals, these values are positive (negative).

Looking at Fig. 8.5, it seems plausible that the curvature of the utility function $u(c)$ is responsible for the extent of risk aversion. We have plotted utilities for the same lottery and different Bernoulli-utility functions $u(c) = c^{\alpha}$. This function has the following first and second derivatives: $u'(c) = \alpha \cdot c^{\alpha-1}$, $u''(c) = (\alpha-1) \cdot \alpha \cdot c^{\alpha-2}$. These can be used to calculate the two risk measures:

$$ARA(c) = \frac{1-\alpha}{c}, \quad RRA(c) = 1-\alpha.$$

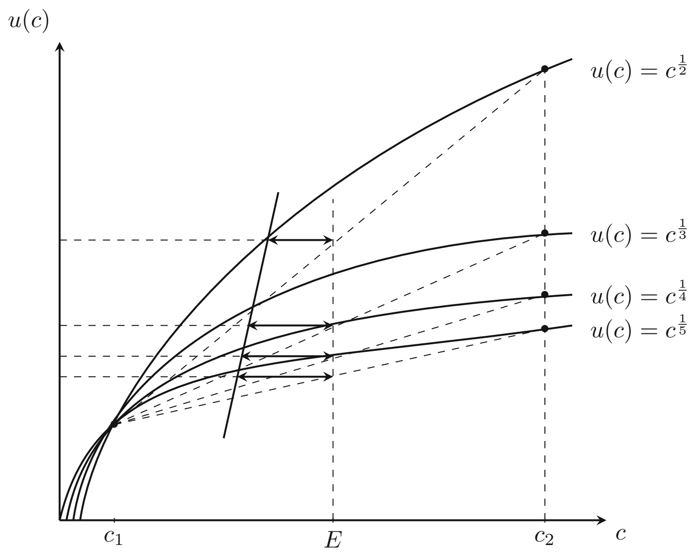

Fig. 8.5 Different degrees of risk aversion

α is a measure of the curvature of the function. For $\alpha < 1$ (risk aversion), the smaller α, the more curved the function. For $\alpha = 1$ (risk neutrality), both measures are equal to zero. It can also be seen that $RRA(c)$ is dimensionless in the sense that it does not depend on how c is measured. This is different for $ARA(c)$. Both measures are decreasing in α in case of risk aversion.

Halek and Eisenhauer (2001), using data from life-insurance contracts in the United States, were able to show that different population groups differ significantly with respect to RRA. For example, population groups that had already demonstrated risk-loving preferences (through migration) were, on average, less risk-averse compared to people without migration background. The same was true for people who were unemployed. This study has also shown that women and men differ in their degree of risk aversion. On average, women turned out to be more risk-averse than men. However, more recent studies show that these differences appear to be less pronounced than previously thought (see Filippin 2016; Bouchouicha et al. 2019). These studies also do not clarify whether such gender differences are natural or cultural.

8.3.6 Insurance

We have seen that risk-averse individuals have a willingness to pay that is equal to their risk premium to avoid a risk. This is the reason for the existence of insurance markets, and we will conclude this chapter by looking at the demand for insurance. In particular, we will look at property insurance.

The central trade-off for a potential insured person is as follows: Buying insurance reduces his or her income. In return, is offers protection against income losses in case of a loss. The *loss coverage* is the amount of money the insured person receives from the insurance company in case of a loss. What is the demand for insurance when loss coverage is offered at a given price (the *insurance premium*)?

In a first approach, we will analyze insurance demand in a situation where insurance companies offer a fixed coverage. We will extend this model to allow for a situation where the insured person can choose the coverage in a second step.

8.3.6.1 A Model with Fixed Coverage

Suppose that a risk-averse individual with Bernoulli-utility function $u(c)$ has wealth $c_0 > 0$. In the event of a damage, it is reduced to $c_0 - D$. That is, the monetary value of the damage is $D > 0$. The probability of a damage is p (state of environment θ_D), and with probability $1 - p$, no damage occurs (state of environment θ_N). Thus, the individual faces the following lottery without insurance:

$$\mathcal{L} = \{(c_0 - D, p); (c_0, 1 - p)\}.$$

This lottery leads to an expected wealth of

$$EV(\mathcal{L}) = p \cdot (c_0 - D) + (1 - p) \cdot c_0 = c_0 - p \cdot D.$$

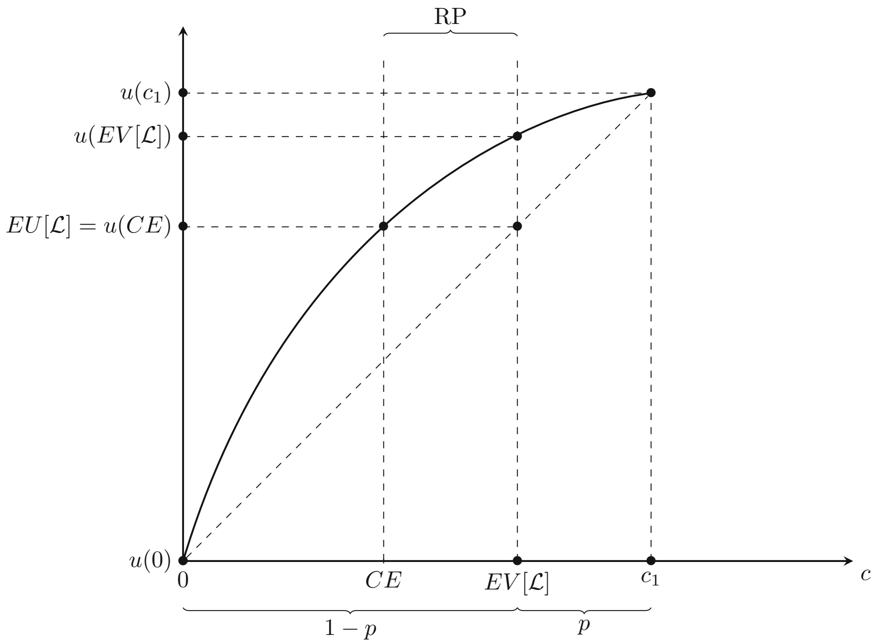

Fig. 8.6 A lottery with $D = c_0$

Figure 8.6 shows this situation for $D = c_0$.

Suppose further that an insurance company is offering an insurance policy that fully covers D in case of damage. Full coverage means that the individual has the same wealth regardless of the state of the environment. If no damage occurs, the individual pays the insurance premium IP. If a damage occurs, the individual receives coverage D but also pays the insurance premium. Thus, this *full-insurance* policy replaces the risky lottery with a state-independent (and therefore secure) wealth $c_0 - IP$.

Suppose that the insurance company charges a so-called *actuarially fair* premium IP^f. A premium is actuarially fair, if it is equal to the expected loss $IP^f = p \cdot D$. With such a premium, the individual's wealth is equal to $c_0 - IP^f = c_0 - p \cdot c_0 = (1-p)\cdot c_0$, regardless of the damage. The fact that this wealth is equal to the expected value of the lottery $EV(\mathcal{L})$ follows because the insurance premium is actuarially fair. Since the individual is risk-averse, buying such a policy increases its utility, since the utility of the expected wealth exceeds the expected utility (see Table 8.14). Thus, we can conclude that a risk-averse individual will always buy insurance if the premium is actuarially fair.

Thus, with an actuarially fair premium, there is a positive consumer surplus for the individual. We can now ask, conversely, what the individual's *maximum* willingness to pay for full insurance would be. It is implicitly defined by the following equation:

$$u(c_0 - Z) = p \cdot u(c_0 - D) + (1 - p) \cdot u(c_0).$$

With an insurance premium equal to $IP = Z$, the individual would be indifferent buying and not buying insurance. However, unlike the case of an actuarially fair premium, we cannot explicitly compute Z without knowing the Bernoulli-utility function. Therefore, to get a better intuition for the model, we will assume that the individual has a Bernoulli-utility function $u(c) = c^{1/2}$ and that the damage is $D = c_0$. The actuarially fair premium is $IP^f = p \cdot c_0$ in this case. The maximum willingness to pay Z can then be calculated by solving

$$u(c_0 - Z) = p \cdot u(0) + (1 - p) \cdot u(c_0) \Leftrightarrow (c_0 - Z)^{1/2} = (1 - p) \cdot c_0^{1/2}.$$

The solution is $Z = (2 - p) \cdot p \cdot c_0$. We can now compare the solution to the actuarially fair premium:

$$Z - IP^f = (2 - p) \cdot p \cdot c_0 - p \cdot c_0 = (1 - p) \cdot p \cdot c_0 \geq 0.$$

This difference is zero at $p = 0$ as well as $p = 1$ and positive otherwise. It is zero at $p = 0$ because no damage can occur and therefore no insurance is needed. It is zero at $p = 1$ because damage always occurs and therefore no insurance is possible. However, for all other values of p, the maximum willingness to pay exceeds the fair premium.

8.3.7 A Model with Endogenous Coverage

Next, we will address the question of what the optimal level of coverage is if the insuree can choose that level of coverage. This analysis will draw on techniques we have already learned in Chap. 7.

Let us start with an example. Emma has bought a mountain bike at a cost of CHF 2000. Unfortunately, there are many bike thefts in the city where she lives. If her bike gets stolen, the damage is $D = 2000$. We assume that p is the probability of theft (state of environment θ_2). Accordingly, $1 - p$ is the probability of no theft (state of environment θ_1), and let $p = 0.02$. The lottery associated with this situation is

$$\mathcal{L} = \{(0, 0.02); (2000, 0.98)\}.$$

Since Emma is risk-averse, she considers taking out a bike insurance, and she can choose the *coverage* herself. The coverage denotes the amount of money I that will be paid by the insurance company in case of a claim. The insurance premium q is proportional to the coverage and corresponds to CHF $q = 0.02$ per CHF 1 coverage.

Table 8.15 Bike insurance

Coverage (I)	Premium ($q\,I$)	c_1	c_2
0	0	2000	0
400	8	1992	392
800	16	1984	784
1200	24	1976	1176
1600	32	1968	1568
2000	40	1960	1960

Thus, for a coverage of I, the premium IP is equal to $q \cdot I = 0.02 \cdot I$. Table 8.15 presents Emma's choice problem for arbitrarily chosen values of coverage I. c_2 is Emma's wealth in the case of theft and c_1 represents her wealth in the case of no theft.

If Emma purchases insurance with coverage I, she has the following wealth constraints:

$$c_1 = c_0 - q \cdot I,$$
$$c_2 = -q \cdot I + I = (1 - q) \cdot I.$$

If $I = 0$, the constraints correspond to the wealth positions of the lottery $\mathcal{L}$ without insurance.

We can now examine Emma's decision problem, which consists of choosing the amount of coverage I that maximizes her expected utility. Analogous to the budget line in Chap. 7, we can represent her choice set by a so-called *insurance line*. It represents all wealth positions in the two environmental states θ_1 and θ_2 that are attainable given the possibility for insurance. To calculate this line, one solves equation $c_1 = c_0 - q \cdot I$ for coverage I,

$$c_1 = c_0 - q \cdot I \Leftrightarrow I = \frac{c_0 - c_1}{q},$$

to replace I in $c_2 = (1 - q) \cdot I$:

$$c_2 = \frac{(1-q)}{q} \cdot c_0 - \frac{(1-q)}{q} \cdot c_1.$$

Inserting the numerical specifications, we end up with

$$c_2 = \frac{2000 - 0.02 \cdot 2000}{0.02} - \frac{0.98}{0.02} \cdot c_1 = 98{,}000 - 49 \cdot w_1.$$

This is the insurance line, which we denote by IL. It has the structure of a budget line, where the two axes represent the effective wealth for each level of coverage in the two environmental states. It intercepts with the axes at the maximum possible wealth levels in both states. Let us start with $c_2 = 0$: Emma maximizes her wealth in the no-loss state by buying no insurance. In this case, $c_1 = c_0$. The converse case, $c_1 = 0$, is only admissible if Emma can insure more than 100% of the loss. Let us assume that this is not possible, and that the maximum coverage is 100% of the loss. In this case, the maximum effective wealth in the loss state is bounded by the constraint $c_1 = c_2$ (the effective wealth is the same in both states of the environment). The maximum effective wealth in case of loss is $c_2 = (1 - q) \cdot c_0$. The expression on the right-hand side of this equation corresponds to the net wealth if $I = c_0$ units of coverage are purchased.

The slope of the insurance line, $-(1 - q)/q$, indicates for a given premium q by how much net wealth in the loss case c_2 has to decrease if net wealth in the no-loss case c_1 increases by one unit. An increase in insurance coverage by CHF 1 decreases net wealth c_1 by the additional premium payment of CHF q. At the same time, it increases net wealth c_2 in the loss state by CHF $1 - q$, since Emma receives an additional CHF 1 but has to pay an additional CHF q. The larger the premium q, the higher the price the policyholder has to pay to transfer money from state θ_N to state θ_S. Since $q = 0.02$ in the numerical example, the slope of the insurance line equals -49.

This relationship is illustrated in Fig. 8.7. The effective wealth in the loss state θ_2 is plotted along the ordinate and the effective wealth in the no-loss state θ_1 is plotted along the abscissa. The straight line AB represents the insurance line, point A corresponds to Emma's wealth in the case without insurance $(c_1, c_2) = (c_0, 0) = (2000, 0)$, while point B represents Emma's wealth with full insurance $(c_1, c_2) = ((1 - q) \cdot c_0, (1 - q) \cdot c_0) = (1960, 1960)$ (see Table 8.15). At this point, coverage

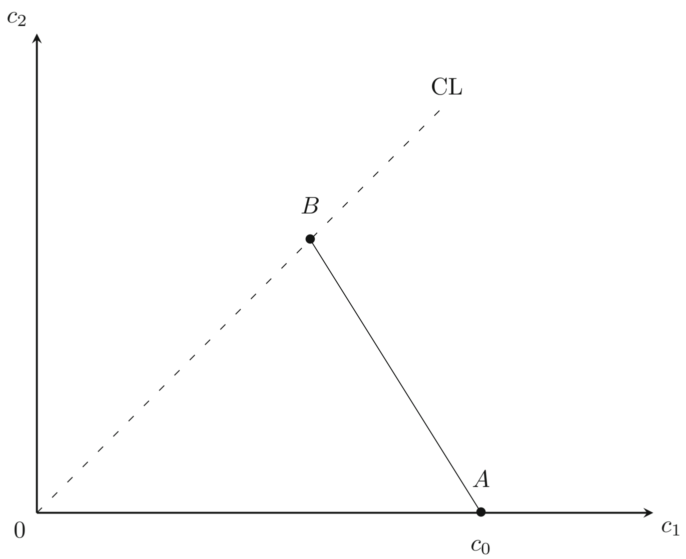

Fig. 8.7 Emma's potential strategies

equals the loss, $I = D$, so the wealth is the same in both states. This point is on the dashed line called *security line* CL). It connects all net-wealth positions with $c_2 = c_1$, which implies that the individual is fully insured.

Having analyzed Emma's choice set, we will next consider Emma's preferences. Except for I, all quantities are parameters from Emma's point of view, i.e., they cannot be influenced by Emma. Neither the proportional premium q, nor the damage D. She therefore chooses I. We assume that Emma is an expected-utility maximizer:

$$EU(\mathcal{L}) = p \cdot u(c_2) + (1 - p) \cdot u(c_1).$$

Following Chap. 7, we will say that all net-wealth positions that give the same expected utility lie on the same *indifference curve*. We determine the slope of the indifference curve with the help of the total differential of the expected-utility function $EU(\mathcal{L})$:

$$dEU = \frac{\partial EU}{\partial c_2} \cdot dc_2 + \frac{\partial EU}{\partial c_1} \cdot dc_1 = p \cdot \frac{\partial u}{\partial c_2} \cdot dc_2 + (1 - p) \cdot \frac{\partial u}{\partial c_1} \cdot dc_1.$$

Since $dEU = 0$ holds along an indifference curve, we obtain for the following slope of the indifference curve:

$$\frac{dc_2}{dc_1} = -\frac{\frac{\partial EU}{\partial c_1}}{\frac{\partial EU}{\partial c_2}} = -\frac{(1-p) \cdot \frac{\partial u}{\partial c_1}}{p \cdot \frac{\partial u}{\partial c_2}}.$$

The slope of the indifference curve answers the following question: how must the net wealth be shifted between the two environmental states θ_1 and θ_2 such that expected utility remains constant? We have called this slope the marginal rate of substitution (MRS) in Chap. 7. We can continue to use this concept but must be careful to properly distinguish between the expected- and the Bernoulli-utility function. The numerator of (8.3.7) corresponds to the marginal expected utility, which is $(1 - p)$ times the marginal utility of the Bernoulli function, and analogously for the denominator. Thus, the term "marginal rate of substitution" refers to the expected-utility function and not to the Bernoulli-utility function. What we see, however, is that the marginal rate of substitution is affected by the ratio of probabilities and is *ceteris paribus* increasing in p.

Figure 8.8 plots two indifference curves. The indifference curve through point A corresponds to expected utility without insurance and the indifference curve through point B corresponds to expected utility with full insurance.

Regardless of the level of expected utility, the marginal rate of substitution stays constant along the security line CL and is equal to the ratio of probabilities: along the security line, net wealth is identical across states, $c_1 = c_2$. It follows that marginal (Bernoulli) utilities are also equal, which implies that their ratio is equal to one. Thus, it follows that the slope of the indifference curve is equal to $-(1 - p)/p$

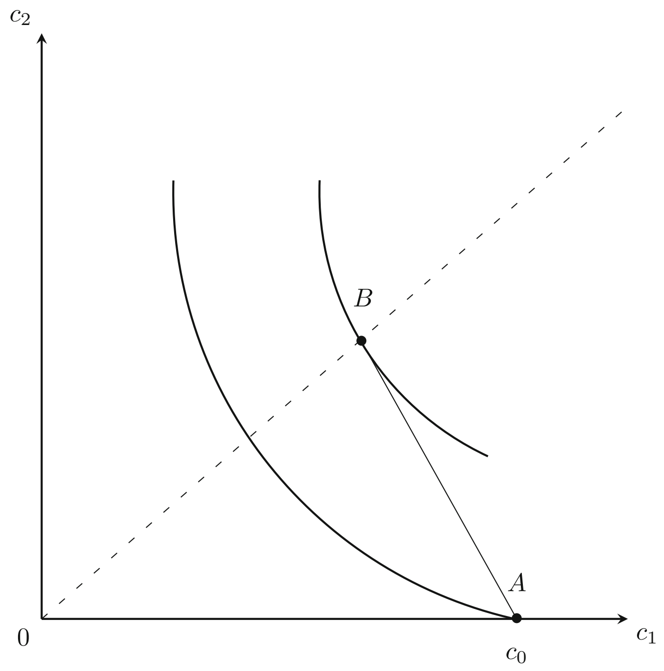

Fig. 8.8 Emma's potential choices

at $c_1 = c_2$. In the numerical example, the probability of theft is $p = 0.02$, so the slope of the indifference curve is -49 at these points.

The property that the marginal rate of substitution is constant for fixed ratios of c_1 and c_2, $c_1 = \gamma \cdot c_2$ is general. For any given ratio γ, we get a fixed rate τ of marginal Bernoulli utilities, $u(a \cdot c_2)/u(c_2) = \tau$. Hence, the slope of the indifference curve is constant and equal to $-((1-p)/p) \cdot \tau$. (a, γ, and τ are parameters.)

We can now determine Emma's expected-utility maximizing strategy. In order to do so, we turn to Fig. 8.9. We know from Chap. 7 that a utility maximum is reached when the slope of the budget line equals the marginal rate of substitution. This intuition holds in the insurance model as well, except for the case that the insurance line is steeper than the indifference curve at point B. When can this happen? In the numerical example, the premium $q = 0.02$ is equal to the probability of theft $p = 0.02$. This is the case of an actuarially fair premium for the case of proportional coverage.

In this case, the slope of the insurance line is equal to the slope of the indifference curve at the point $c_1 = c_2$. Thus, the highest indifference curve is reached at this point, and Emma chooses full coverage of $I = 2000$, resulting in a premium payment of $IP = q \cdot I = 0.02 \cdot 2000 = 40$. Thus, the effective wealth in both environmental states is $c_1 = c_2 = 1960$. This result is general: an expected-

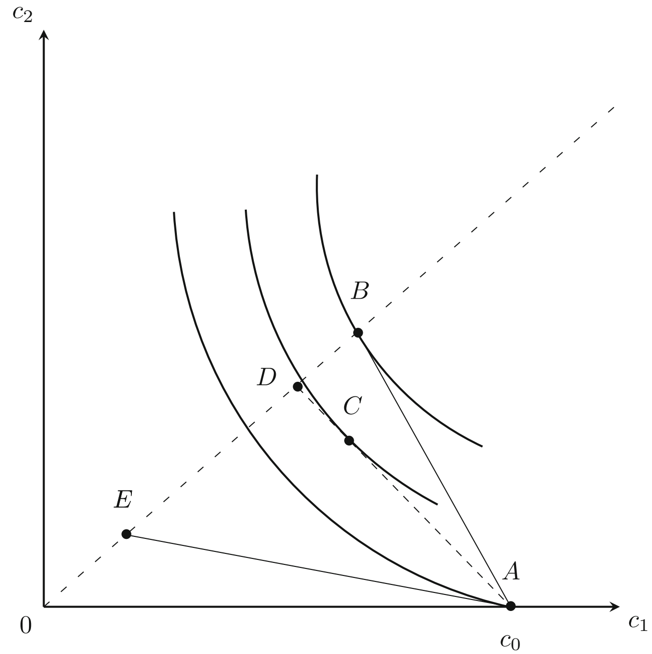

Fig. 8.9 Emma's choice problem

utility maximizing, and risk-averse individual will fully insure against risk given an actuarially fair premium.

We can now analyze the demand for insurance if the premium is not actuarially fair, $q > p$. This changes the achievable net-wealth pairs, since a net-wealth transfer from state θ_1 to state θ_2 becomes more expensive. Graphically, this means that the insurance line turns inwards around point A, see Fig. 8.9. This means that the point of tangency between the insurance line and the indifference curves must shift downward-leftward because—due to constant marginal rates of substitution along a ray through the origin—the marginal rate of substitution decreases. Since $\gamma > 1$ below the security line, it follows that $\tau < 1$, and hence the slope $((1 - p)/p) \cdot \tau$ decreases. Emma will thus choose lower coverage at $q > p$. See, for example, the case of an insurance line AD with (expected) utility maximum C in Fig. 8.9. To explicitly determine the amount of coverage, one needs to know her Bernoulli-utility function $u(c)$.

It is possible that the price $q > p$ is so high that the optimal coverage is $I = 0$. Such a case is illustrated by the insurance line through AE in Fig. 8.9. Whether this case occurs or not again depends on the specific Bernoulli-utility function $u(c)$.

What happens if the premium is lower than the actuarially fair one, $q < p$? In this case, the insurance line becomes steeper so that the theoretical point of tangency is above the security line. Therefore, Emma would like to *overinsure*, that is, she would choose coverage that pays out more than the amount of the claim in the event of a loss. If this is not possible, she will be left with full insurance.

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Principles of Game Theory

9

This chapter covers . . .

- game theory as a mathematical method for analyzing situations of strategic interdependence.
- the basic definitions and solution concepts of games.
- how games can be used to analyze complex social interactions.
- how games can be used to help one understand real-world problems, like the decision of firms to enter a market, the economic mechanisms underlying climate change, the political incentives to engage in tax competition, etc.

9.1 Introduction

> I am willing to take life as a game of chess in which the first rules are not open to discussion. No one asks why the knight is allowed his eccentric hop, why the castle may only go straight and the bishop obliquely. These things are to be accepted, and with these rules the game must be played: it is foolish to complain of them. (W. Somerset Maugham, 1949)

Game theory addresses the analysis of strategic interdependencies between the actions of different decision makers. Many of the early contributions to game theory dealt with the analysis of parlor games. Two of the most important works on game theory of the early twentieth century were Ernst Zermelo's "Über eine Anwendung der Mengenlehre auf die Theorie des Schachspiels" (On an Application of Set Theory to the Theory of the Game of Chess, Zermelo & Borel (1913)) and John von Neumann's "Zur Theorie der Gesellschaftsspiele" (On the Theory of Parlor Games, von Neumann (1928)). The term *game* obtained a totally different meaning, referring to all kinds of situations where individuals interact. Game theory is, by

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now, an indispensable tool in many scientific disciplines, apart from economics, mostly in political science and finance, but also in biology, law, and philosophy. The goals of game theory are various and reach from explaining societal phenomena, to predicting individual decision-making, to providing consultation.

Many economists would even state that it was the development of game theory that made economics a scientific discipline of its own. Traditional economic reasoning has been based on more or less informal theories or on models which were frequently adapted from physics. The analysis of imperfect competition on markets, bargaining, conflicts between individuals and groups, and competition between states are only some of the fields in which techniques from game theory are successfully applied. In the course of the appearance of game theory, economists developed a subfield called "market design." This discipline has strong similarities to engineering, because it applies scientific theories to design market mechanisms that help to facilitate structured transactions and improve efficiency. Market design became known to a wider audience because of the auctioning of UMTS telecommunications licenses, for which many countries used auction formats that had been developed by economists using methods from game theory. Another example for market design is the development of algorithms facilitating organ donations and labor markets. For instance, in some countries, they are used to facilitate kidney exchanges or to allocate doctors to hospitals. Game theory is also the backbone of behavioral economics, a field of research in which economists study the structure of cooperative behavior and the limitations of rational decision-making, see Chap. 10.

A classic field of study within economics, in which game theory is often used, is the analysis of oligopoly markets. The central characteristic of those markets is that firms have some control over prices, similar to a monopolist, but the existence of competitors restricts this control and makes the optimal price and quantity decision dependent on each firm's expectations about the behavior of the competitors and, hence, the decisions are interdependent. In order to study these interdependencies and, thus, be able to make predictions about these market types (as well as many other societal phenomena), I give a short introduction to game theory in this chapter.

9.2 What Is a Game?

A "game" describes a situation of strategic interdependence. The involved decision makers, for example individuals and firms, are called "players." Strategic interdependence in the game-theoretic sense exists, if the actions of players potentially influence one another. Here is a simple example that illustrates the problem. Assume there were no rules about on which side of the road one should drive. Two cars, moving in opposite directions, meet. The driver of each car wants to go on driving without an accident. If both stay on their right or left lane, then no harm is done. However, if one goes left and the other one goes right, then the result is an accident. Probably, everybody knows similar situations from crowded market places and sidewalks, where people go in opposite directions and try to avoid bumping into each other. A good way to navigate through the crowds depends on the actions of all the others and, hence, this is a situation of strategic interdependence.

Another illustrative example is the "rock-paper-scissors" (RPS) game. Two players face each other and have to choose one of the following gestures: *rock*, *paper*, or *scissors*. *Rock* beats *scissors*, *scissors* beats *paper*, and *paper* beats *rock*. If both players choose the same gesture, then nobody wins and the game ends in a draw. If a player wants to win the game, then his optimal gesture depends on the gesture of his opponent. If the other player chooses *rock*, then one optimally chooses *paper*; if the other chooses *scissors*, then *rock* would be the optimal gesture.

9.3 Elements of Game Theory

In order to analyze a situation of strategic interdependence using game theory, it is necessary to (1) systematically describe a game, (2) to form hypotheses about players' behavior, and (3) to apply a so-called solution concept.

The description of a game Γ usually starts with listing the involved decision makers, the *players*. The set $N = \{1, 2, \ldots, n\}$ denotes all $n \geq 1$ players involved in a game. In the example of RPS, this set is $N^{\text{RPS}} = \{1, 2\}$, i.e., the set listing players 1 and 2.

Next, one has to specify what the players can do. An action of a player is called a *strategy*. The set of all, m_i, possible strategies of a player, $i \in N$, is denoted by $S_i = \left\{s_i^1, s_i^2, \ldots, s_i^{m_i}\right\}$, and s_i^j, $j \in \{1, 2, \ldots, m_i\}$ denotes one specific strategy from this set. In the example of RPS, both players have the same strategy sets: $S_1^{\text{RPS}} = S_2^{\text{RPS}} = \{rock, paper, scissors\}$.

A *strategy profile* assigns a strategy to each player and is denoted by $s \in S = S_1 \times S_2 \times \cdots \times S_n$ (the mathematical operator "$\times$" refers to the Cartesian product of the sets S_i, $i = 1, 2, \ldots, n$). S is the set of all possible strategy profiles. In RPS, it is equal to the set of all combinations of the form $(s_1 \in S_1^{\text{RPS}}, s_2 \in S_2^{\text{RPS}})$, which is the set with the elements $(scissors, scissors)$, $(rock, scissors)$, $(paper, scissors)$, $(scissors, rock)$, $(rock, rock)$, $(paper, rock)$, $(scissors, paper)$, $(rock, paper)$, and $(paper, paper)$.

Each strategy profile is a possible course of the game. Starting from the strategy profiles $s \in S$, one can determine the possible outcomes of a game induced by the different profiles. The outcome function, $f : S \to E$, assigns to each strategy profile $s \in S$ an outcome e, from the set of potential outcomes E. In the example of RPS, the set of possible outcomes is $E^{\text{RPS}} = \{\text{player 1 wins, player 2 wins, draw}\}$. The function $f(s)$ determines an outcome $e \in E$ for every $s \in S$. For example if, in RPS, the strategy profile is $s = (scissors, rock)$, then the function $f(s)$ determines the outcome "e = player 2 wins." If $s = (paper, paper)$, then the outcome is "e = draw."

Finally, in order to be able to determine what the players will do, one has to connect the outcome of a game with the players' evaluations of this outcome. The functions $u_i(e)$ assign an evaluation for each player and for each possible outcome, namely $u_i : E \to \mathbb{R}$ for player i. Economists use the convention that larger numbers are assigned to preferred outcomes. This convention suggests that one calls u_i player i's *utility*. In RPS, if one assumes that players prefer winning to having a draw, and having a draw to losing, then any assignment of numbers to outcomes with the following property is consistent with this evaluation:

$$u_i(\text{player } i \text{ wins}) > u_i(\text{draw}) > u_i(\text{player } i \text{ loses}).$$

For example, each player could assign 1 to the outcome "win," 0 to the outcome "draw," and -1 to the outcome "lose."

The above elements describe a game and can be summarized in the following way:

$$\Gamma = \left\{N, S, f, \{u_i\}_{i=1,\ldots,N}\right\}.$$

It is often quite useful to sidestep the somewhat lengthy definition by directly conditioning the players' utilities on strategy profiles instead of outcomes. This is possible, because a strategy profile determines an outcome, which in turn determines utilities: $S \to E \to \mathbb{R}$. One can therefore skip the step in the middle and assign utilities directly to strategy profiles: $u_i : S \to \mathbb{R}$. This shortens the description of a game and one gets

$$\Gamma' = \left\{N, S, \{u_i\}_{i=1,\ldots,N}\right\}.$$

This representation of a game will be used in the remainder of this chapter. However, it loses some of the societal content of the situation that is being analyzed: One no longer knows why players prefer this strategy over that strategy. This is not relevant from a technical point of view, but it may be important for understanding the social context that is represented by the game. In RPS, one only knows that a player prefers $(rock, scissors)$ to $(scissors, rock)$, if one specifies Γ'. The more lengthy specification Γ allows one to answer why this is the case: because the player wins with the first strategy profile and loses with the second.

In order to be able to make predictions about the way players play the game, one needs a hypothesis about the players' behavior and the way this behavior is coordinated. Usually, economists work with the so-called (expected) utility-maximization hypothesis, which states that each player chooses a strategy to maximize her (expected) utility (see Chap. 8). If the players are competing firms and if utility can be identified with profits, then the already familiar profit-maximization hypothesis is an example. However, altruistic or even malevolent motives can also be taken into account, if one uses the more general concept of utility. For example, an altruistic player prefers a distribution of profits (5,5) to a distribution of profits (10,0), whereas a profit maximizer always prefers (10,0), irrespective of the other player's profits.

Knowing this, one can assign the optimal reaction of a player to the strategies of the other players. This information is contained in the so-called *reaction function*. Let $s_i \in S_i$ denote a strategy of each player, $i \in N$, and let the strategy profile of all players except i be denoted by $s_{-i} \in S_{-i}$ ("$-i$" refers to the set of all players except i). Player i's best responses to the other players' strategy profile s_{-i} specifies the subset of strategies that maximize player i's utility, given strategy profile s_{-i}. The reaction function of player i collects this player's best responses to all possible strategy profiles of the other players. The idea can again be exemplified by using RPS. If player 2 chooses *scissors*, then the best response of player 1 is to choose *rock*. If player 2 chooses *rock*, then player 1's best response is *paper*.

▶ **Definition 9.1 Reaction Function** A strategy, $s_i^* \in S_i$, that maximizes a player's utility, $u_i(s_i, s_{-i})$, given the strategies of all other players, $s_{-i} \in S_{-i}$, is called his or her *best response* to s_{-i}:

$$u_i(s_i^*, s_{-i}) \geq u_i(s_i, s_{-i}) \text{ for all } s_i \in S_i.$$

A function that specifies a best response for all possible strategy profiles of all other players is called the *reaction function* of player i.

The concepts "best response" and "reaction function" are convenient for solving a game. A particular kind of best response is called a *dominant strategy*, which means that a strategy is a best response to all the other players' possible strategy profiles:

▶ **Definition 9.2 Dominant Strategy** A strategy, $s_i^d \in S_i$, is called a *dominant strategy*, if it is a best response to all possible strategy profiles, $s_{-i} \in S_{-i}$:

$$u_i(s_i^d, s_{-i}) \geq u_i(s_i, s_{-i}) \text{ for all } s_i \in S_i \text{ and for all } s_{-i} \in S_{-i}.$$

If a player has a dominant strategy, then her best response is the same for all s_{-i}. Therefore, a dominant strategy is a borderline case of strategic interdependence, because the strategies of all other players, s_{-i}, may influence the utility of player i, but do not impact which strategy she optimally chooses. However, dominant strategies often do not exist, as in the example of RPS.

9.4 Normal-Form Games

In a so-called normal-form game, all players choose their strategies simultaneously and are not allowed to alter them during the course of the game. If there are only two players with only a few strategies, then a normal-form game can be represented in matrix form, see Table 9.1 for an example. The m_1 strategies of player 1 are represented by the different rows of the matrix, and the m_2 strategies of player 2 are represented by the different columns. Each field of the matrix represents a strategy

Table 9.1 Matrix representation of a game

	s_2^1	...	$s_2^{m_2}$
s_1^1	$u_1(s_1^1, s_2^1), u_2(s_1^1, s_2^1)$	...	$u_1(s_1^1, s_2^{m_2}), u_2(s_1^1, s_2^{m_2})$
s_1^2	$u_1(s_1^2, s_2^1), u_2(s_1^2, s_2^1)$	...	$u_1(s_1^2, s_2^{m_2}), u_2(s_1^2, s_2^{m_2})$
$\vdots$	...	...	...
$s_1^{m_1}$	$u_1(s_1^{m_1}, s_2^1), u_2(s_1^{m_1}, s_2^1)$	...	$u_1(s_1^{m_1}, s_2^{m_2}), u_2(s_1^{m_1}, s_2^{m_2})$

profile and displays the corresponding utility levels. For example, $u_2(s_1^2, s_2^{m_2})$ is player 2's utility level from the strategy profile $(s_1^2, s_2^{m_2})$, which is implemented, if player 1 chooses strategy 2 and player 2 chooses strategy m_2.

The best-response function tells us what each player is expected to do when confronted with the other players' strategy profiles. What is not known, at this point, is how these best responses are coordinated. In order to be able to make predictions about the way people are playing games, one has to make an assumption about how they coordinate their behavior. Such an assumption is called an *equilibrium concept*. The most important equilibrium concept for normal-form games is called a Nash equilibrium, which is named after the US mathematician John F. Nash. A Nash equilibrium is defined in the following way:

▶ **Definition 9.3 Nash Equilibrium** A strategy profile, $s^{ne} = \{s_1^{ne}, \ldots, s_n^{ne}\}$, is called *Nash equilibrium*, if the strategies of all the players are best responses to the equilibrium strategies of all the other players:

$$u_i(s_i^{ne}, s_{-i}^{ne}) \geq u_i(s_i, s_{-i}^{ne}) \text{ for all } s_i \in S_i \text{ and for all } i \in N.$$

The idea behind a Nash equilibrium is relatively easy to grasp. Assume there are two players. Player 1 has two strategies, going to the movies or going to a bar, and player 2 has two strategies, as well: going to the movies or going to a bar. Each player i assumes that the other player will stick to his strategy no matter what player i does. This allows i to determine reaction functions (in which they treat the other players' strategies as parameters).

However, the players do not only have to figure out what they but also what the other player will do. Assume that it is the best response of player 1 to go to the movies, if player 2 goes to the movies, and to go to a bar, if player 2 goes to a bar (he wants to meet the other player). What should player 1 do? In order to answer this question, he has to get into the head of player 2. Assume that player 2 will go to the movies no matter what 1 is doing. Then, player 1 knows that he should go to the movies if player 2 does so, and that player 2 will go to the movies no matter what: Thus, the best responses are mutually consistent. The conjecture that player 2 will go to the movies induces player 1 to go there as well and it is a best response of player 2 to stick to his plan. This mutual consistency is the missing link between individual reaction functions and the outcome of the game. A Nash equilibrium is nothing more than such a consistency condition. To see why, focus on the other possible conjecture that player 1 could make, namely that player 2 will go to a bar. In that case, the best response would be to go to a bar, as well, to which player 2 reacts by going to the movies, which is not consistent with the conjecture that player 2 will go to the bar.

The above argument shows that the players have to be able to figure out the planned equilibrium strategies of the other players and that they have to believe that deviations in their own strategy will not cause deviations by any other player (which is why they can treat their strategies as parameters). However, this is not all. At this point a player can figure out his or her best strategy for some strategy profile of the other players and also the best strategies of the other players for some given strategy profile. What is missing is that the players know that the other players will use this logic to solve the game and furthermore that the players know that the other players know that they will use this logic, and so on. The term *common knowledge* refers to a situation where the players have this special kind of knowledge about the beliefs of the other agents.

There is common knowledge of some state, z, in a group of players, N, if all players in N know z, they all know that they know z, they all know that they all know that they know z, and so on *ad infinitum*. The next digression illustrates why common knowledge is important.

Digression 9.1 (A Tale About the Importance of Common Knowledge)
On an island, there live 100 blue-eyed persons. The rest have a different eye color. They are perfect logicians and never talk about eye color. An old custom, to which all citizens adhere, demands that, as soon as a citizen knows that he or she has blue eyes, he or she will leave the island during the subsequent night. However, because the citizens never talk about their eye color and because there is no reflecting surface on the island, no one knows his or her eye color. Consequently, no one ever leaves the island.

One day, an outsider comes to the island. She is allowed to stay and soon acquires a reputation for being completely trustworthy. After a while, a ship lands and the outsider leaves the island again. At the time of her departure, all citizens gather at the harbor and the last thing the outsider tells the citizens is: "By the way, there is at least one blue-eyed person on the island!"

What happens during the subsequent nights? Additionally, what does all this have to do with the concept of *common knowledge*? The answer is that, during the 100th night after the announcement, all the blue-eyed people will leave the island.

Why does the announcement of the outsider make a difference? Before his announcement, each islander knew that there are blue-eyed persons on the island, but she did not know that the other islanders knew it as well, knew that she knows it, etc. Thus, the knowledge that there are blue-eyed islanders

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Digression 9.1 (continued)
was not common knowledge. This changed with the announcement by the outsider. From that moment on, the existence of blue-eyed persons became common knowledge.

Why does it make a difference? To see this, one can use an inductive argument. If there is exactly one person with blue eyes, that person knows that there is no other person with blue eyes on the island. Before the announcement of the outsider, it was a possibility that there is no one with blue eyes on the island, so there was no need to leave. However, given the information by the outsider, the blue-eyed person learns that she must have blue eyes, so she leaves at night one.

Next, assume that there are two persons with blue eyes. There is no need for any of them to leave during the first night, because there is a possibility that there is only one person with blue eyes and that it is the other person. Thus, both will still be around the next day. However, given that both are still around the next morning, they have to realize that both of them must have seen another person with blue eyes. Given that there is no one else around, it must be herself. Therefore, both will leave during night two.

The same argument holds if there are n blue-eyed persons: induction states that no one will leave during the first $n-1$ nights. However, given that everyone is still around after night $n-1$, each blue-eyed person has to conclude that there are n persons with blue eyes in total, one of them being him- or herself.

Thus, the rather innocuous-sounding announcement by the outsider allows the islanders to eventually figure out the color of their eyes.

To further illustrate, take the game represented in Table 9.2 as an example. In this game, two players $i=1,2$ have two strategies each. The game has one Nash equilibrium, (U, L). First, one has to show that this strategy profile is, in fact, an equilibrium. Suppose player 2 chooses "L." Player 1's best response is then to choose "U" because $4>2$. Hence, "U" is a best response to "L." If it is a Nash equilibrium, then "L" must also be a best response to "U," which is indeed the case, because $3>2$. Thus, no player has an incentive to unilaterally deviate from this strategy profile. The strategies are mutually best responses and (U, L) is a Nash equilibrium.

There is an easy procedure to determine the set of Nash equilibria for games in matrix form. First, one successively goes through all the strategies of player 1

Table 9.2 An example for a matrix game

	L	R
U	4,3	3,2
D	2,1	1,4

and marks the respective best response(s) of player 2. Then one repeats the whole procedure with the strategies of player 2 and marks player 1's best responses. If there are fields in which there are marks for both players, then the strategy profile associated with that field is a Nash equilibrium.

A Nash equilibrium is a prediction about the outcome of a game, but why should a game actually be played in such a way? One could argue that an important property of a Nash equilibrium is stability in the following sense: No player has an incentive to unilaterally deviate from the equilibrium strategy profile, because strategies are, by definition, best responses to each other. Players do not regret their choices of strategies once they find out what the other players are doing. This idea of consistency sounds plausible and rather innocuous. A potential problem is, however, that players make their choices simultaneously, that is without observing the strategies of all other players, and can commit to the strategies while the game is being played. Hence, each player has to be able to not only determine her own optimal strategy, but also the optimal strategies of the other players, and therefore to understand and solve the utility-maximization problems of these players. The concept of a Nash equilibrium requires both, a large extent of implicit agreement between players that they are in fact seeking to find a Nash equilibrium, as well as strong cognitive abilities to be able to think through all the different strategic situations from the perspective of all the players. For instance, in the above example, player 2 needs to ponder which strategy player 1 will choose. If player 1 chooses "*D*" instead of "*U*," then her best response would not be "*L*," but "*R*." She needs to conjecture that player 1 will actually assume that a Nash equilibrium will be chosen and must then put herself into player 1's position. In the example, complexity is reduced, though, because player 1 has a dominant strategy. Because "*U*" is always a best response, it is the best choice player 1 can make, independent of player 2's decision. Player 2, being aware of that, is able to predict that 1 will always choose this strategy, if she is rational. Hence, she will always choose "*L*" herself. If a given player, i, has a dominant strategy, then the complexity of the game is significantly reduced, because it is easier for all the other players to make predictions.

One can conjecture that the predictive power of Nash equilibria is better in situations that are not very complex and if players are more experienced with the situation with which they are confronted.

As this subchapter has shown, the problem of cognitive overload can be reduced significantly, if the solution concept is not a Nash, but a "dominant-strategy equilibrium." In such an equilibrium, each player follows a dominant strategy and hence no player needs to conjecture about the strategy choices of all the other players, because her own optimal choice does not depend on the strategies of all the others.

▶ **Definition 9.4 Dominant-Strategy Equilibrium** A strategy profile, $s^{ds} = \{s_1^{ds}, \ldots, s_n^{ds}\}$, is called a *dominant-strategy equilibrium*, if the strategy of each player is a dominant strategy:

$$u_i(s_i^{ds}, s_{-i}) \geq u_i(s_i, s_{-i}) \text{ for all } s_i \in S_i, \text{ for all } s_{-i} \in S_{-i} \text{ and for all } i \in N.$$

Table 9.3 Dominant-strategy and Nash equilibria

	L	*R*
U	2,2	1,1
D	1,1	1,1

Table 9.4 The game "Rock, Paper, Scissors" in matrix form

	R	*P*	*S*
R	0,0	−1,1	1, − 1
P	1, − 1	0,0	−1,1
S	−1,1	1, − 1	0,0

Unfortunately, dominant-strategy equilibria exist only for a very limited class of games, such that it is rarely possible to predict the outcome of a game based on this equilibrium concept. Hence, using this concept instead of a Nash equilibrium does not really solve the problem.

A dominant strategy equilibrium is always a Nash equilibrium, but not *vice versa*. This property is exemplified by the game in Table 9.3.

This game has two Nash equilibria, (U, L) and (U, R), and each player has a dominant strategy, namely "*U*" for player 1 and "*L*" for 2. Therefore, (U, L) is also a dominant-strategy equilibrium, while (U, R) is not. "*U*" is only a best response if player 2 chooses "*R*," and similarly "*R*" is only a best response if player 1 chooses "*U*."

Digression 9.2 (Existence of a Nash Equilibrium)
As we have seen when we have analyzed the game in Table 9.3, it is often not easy to predict the outcome of a game because there may be multiple equilibria. Another problem, which is at least as fundamental as the multiplicity, is the (non-)existence of Nash equilibria, a potential problem one already knows from the subchapter covering dominant strategies. Is it possible that a game has no Nash equilibrium? If so, then what would be a good prediction of the game's outcome?

An example for a game in which no Nash equilibrium exists is RPS. A matrix representation of the game can be found in Table 9.4. Whenever a player chooses a best response to the strategy of her opponent, the opponent must end up with a payoff that is smaller than the one that could be achieved by a different strategy, yielding her a utility of -1. Hence, there cannot be a profile of strategies that are mutually best responses and, thus, no Nash equilibrium exists.

A game that does not have an equilibrium is quite unsatisfactory, because this means one cannot make a prediction about the way people play it, which was why we started with game theory in the first place. Consequently, researchers started searching for a way out of this problem and found one in

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Digression 9.2 (continued)
the idea of "mixed strategies." The idea is quite simple: put yourself in the position of a player in RPS. It is immediately clear that you want to avoid the other player knowing what you will do, because she could then exploit this knowledge, which would guarantee you a payoff of -1. Hence, how can you ensure that she does not know what you will do and is not able to predict it, either? One possibility is to delegate the strategy choice to a random generator that chooses each strategy with a given probability that you determine at the beginning. This is precisely the idea underlying mixed strategies. A *mixed strategy* is a probability distribution over the (as they will be called from now on) pure strategies at your disposal. If one allows players to choose probability distributions over pure strategies, then one increases the set of possible strategies, because each probability distribution over pure strategies also becomes a strategy—a mixed strategy. A Nash equilibrium, in which at least one player uses a mixed strategy, is called a *mixed strategy Nash equilibrium*.

However, what is the point of this exercise? In games like RPS, no Nash equilibrium exists in pure, but only in mixed strategies. In RPS, the equilibrium is easy to find: Each player chooses a pure strategy with the probability of 1/3. For example, if player 1 chooses a pure strategy with that probability, then player 2 receives the following expected utility from each of her pure strategies:

$$\begin{aligned} u_2\left(R, (\tfrac{1}{3}, \tfrac{1}{3}, \tfrac{1}{3})\right) &= \tfrac{1}{3} \cdot 0 + \tfrac{1}{3} \cdot (-1) + \tfrac{1}{3} \cdot 1 = 0, \\ u_2\left(P, (\tfrac{1}{3}, \tfrac{1}{3}, \tfrac{1}{3})\right) &= \tfrac{1}{3} \cdot 1 + \tfrac{1}{3} \cdot 0 + \tfrac{1}{3} \cdot (-1) = 0, \\ u_2\left(S, (\tfrac{1}{3}, \tfrac{1}{3}, \tfrac{1}{3})\right) &= \tfrac{1}{3} \cdot (-1) + \tfrac{1}{3} \cdot 1 + \tfrac{1}{3} \cdot 0 = 0. \end{aligned}$$

Player 1's mixed strategy makes player 2 indifferent between all of her pure strategies and, thus, each of her pure strategies is a best response. This is, in turn, the precondition for her to be willing to randomize herself. If she randomizes herself with the same probabilities, then player 2 is also indifferent between all her pure strategies and each pure strategy, as well as the mixed strategy, is a best response. Therefore, it is a Nash equilibrium in mixed strategies, if both players randomize and choose each pure strategy with a probability of 1/3.

As the example shows, one can come up with a clear prediction of the game's outcome, if one allows for a more comprehensive concept of a strategy. It was one of John Nash's seminal contributions to show that such an equilibrium exists under very general conditions.

(continued)

Digression 9.2 (continued)

Existence Theorem (Nash) Every game with a finite number of players and a finite number of pure strategies has at least one Nash equilibrium in mixed strategies.

This result of Nash's theorem is of fundamental importance, because it guarantees that a prediction about the outcome of a game, based on the concept of a Nash equilibrium, is possible under very general conditions. I omit the proof of the theorem, because it involves advanced mathematical methods.

Another example of a game in which no Nash equilibrium exists in pure strategies is the penalty kick in soccer. The goalkeeper decides which part of the goal to defend, while the kicker simultaneously decides where to place the shot. If the goalkeeper conjectures the kicker's strategy correctly, then she successfully defends the shot; otherwise the kicker is successful. In order to be able to analyze this situation one can simplify and assume that each player has the pure strategies "left," "middle," and "right." The game has a Nash equilibrium in mixed strategies, in which each player randomizes by choosing among the pure strategies with a probability of 1/3. Economists studied the behavior of goalkeepers and kickers based on data from the Italian and French professional soccer leagues. They found that the observed behavior was consistent with theoretical predictions.

9.4.1 Multiple Equilibria

This chapter has shown so far that some games, for example the one in Table 9.3, have multiple Nash equilibria. There are at least two problems caused by the multiplicity of equilibria. First, the predictive power of a theory that makes several predictions is limited and, second, it is only of limited use in supporting players with identifying optimal strategies. The problems are dramatic in the game represented by Table 9.3 because *any* strategy of a player can be rationalized, even if there are only two equilibria. The players have to, somehow, coordinate on one of the two equilibria in order to exclude some kinds of behavior as implausible. Without such a coordination, a formal analysis of the game is useless, from the point of view of the predictive power of the theory as well as from the point of view of giving advice how to play it.

One solution to this problem is to employ a stronger solution concept, for example an equilibrium in dominant strategies. The game in Table 9.3, for example, has two Nash equilibria, but only one equilibrium in dominant strategies. As argued before, not many games have equilibria in dominant strategies and, among them, there are some that have more than one.

Another possible solution to the problem of multiple equilibria is to hypothesize that players can coordinate on the so-called focal strategies. The term *focal* was coined by Schelling (1960) and implies that some equilibria are, in a sense, more "salient" than others. However, the concept of focality is weak. It is not quite clear how to precisely define what makes an equilibrium focal and whether or not an equilibrium is focal depends on many things, such as the context of the respective game. In Schelling's own words (p. 57): "People can often concert their intentions or expectations with others if each knows that the other is trying to do the same. Most situations—perhaps every situation for people who are practiced at this kind of game—provide some clue for coordinating behavior, some focal point for each person's expectation of what the other expects him to expect to be expected to do. Finding the key, or rather finding a key—any key that is mutually recognized as the key becomes *the* key—may depend on imagination more than on logic; it may depend on analogy, precedent, accidental arrangement, symmetry, aesthetic or geometric configuration, casuistic reasoning, and who the parties are and what they know about each other." The idea of focal points is, therefore, not a full-fledged theoretical concept, but merely a heuristic one that helps determine how players behave in certain situations. Here is an example. Assume that you and another player have to pick one out of three numbers. If you pick identical numbers, then everybody wins CHF 10; otherwise, nobody gets anything. In that game, each pair of identical numbers is a Nash equilibrium and dominant-strategy equilibria do not exist. Now, assume the set of numbers you can pick from is 0.73285, 1, and 1.3857. In this situation, many people intuitively pick the integer 1. All pairs, {0.73285, 0.73285}, {1, 1}, and {1.3857, 1.3857}, are Nash equilibria, but only {1, 1} is focal, although it is very difficult to theoretically identify why.

In some games with multiple equilibria, the equilibria can be ranked according to the payoffs or utilities that the players receive. If one equilibrium makes everyone better off than all the others, it is a strong candidate for a focal point.

▶ **Definition 9.5 Pareto Dominance** A Nash equilibrium is Pareto dominant, if each player's utility is strictly larger in it than in all other Nash equilibria.

An example for such a situation is depicted in Table 9.5. The basic story underlying this payoff matrix goes as follows. Two businessmen are planning to meet at noon in New York City, but have forgotten to fix a meeting point. The possible meeting points are the information desk at Grand Central Terminal (GCT), the main entrance to the Empire State Building (ESB), and the bull and bear statue at Wall Street (WS). If they do not meet, they get a utility of zero each. If they meet

Table 9.5 Meeting in New York

	GCT	ESB	WS
GCT	3,3	0,0	0,0
ESB	0,0	1,1	0,0
WS	0,0	0,0	1,1

at ESB or WS, both of them get a utility of 1. However, because their favorite cafe is close to GCT, they get a utility of 3, if they manage to meet there.

The game has three Nash equilibria: all the strategy profiles where the businessmen go to the same place. However, since there are multiple equilibria, it is not possible to predict what the businessmen will end up doing on the basis of this solution concept alone. In addition, there are no equilibria in dominant strategies. However, the equilibrium (GCT, GCT) Pareto improves the others and, hence, might be focal. Using the idea of Pareto improvements as a means to select between equilibria is promising, because it can be assumed that people have a strong tendency to coordinate on the better ones.

Still, it has to be taken into account that, while the concept of Pareto dominance may often be helpful in predicting the outcome of a game, this is not always the case. First, it may be the case that equilibria cannot be ranked according to Pareto dominance, such that the concept is not applicable to these games. Second, there may be multiple Pareto dominant Nash equilibria. In these games it may be possible to reduce the number of plausible Nash equilibria, but the multiplicity problem cannot be overcome completely. If, for example, the utility of meeting at the ESB is also 3 for each player, then it is possible to exclude (WS, WS) as a "likely" equilibrium, but a prognosis about the game's outcome is still not possible; both the (GCT, GCT) and the (ESB, ESB) equilibria are Pareto dominant.

It is even possible for players to coordinate to play out a Pareto-dominated equilibrium, even though each of them would prefer a different outcome? Even the worst equilibrium (in utility terms) is an equilibrium and unilateral deviations are not beneficial. An example for such a situation is inefficient production standards, like the so-called QWERTY keyboard, which stems from the arrangement of letters on the (US) keyboard that begins with the sequence q,w,e,r,t,y. The arrangement of the letters on a keyboard was determined in the times of the mechanical typewriter. The purpose of its design was to maximize an *effective* typing speed. With mechanical typewriters, there is always the risk that the typebars will entangle, if one's typing is too fast. For that reason, the arrangement of letters on the QWERTY keyboard did not maximize the potential, but instead the effective typing speed. With the invention of the electric typewriter, the problem of entangled typebars was solved, but the then inefficient QWERTY arrangement remains in use until today. The standard is inefficient, but it is also an equilibrium. In that example, one of the reasons why it is hard to coordinate on another, more efficient equilibrium is that the expectations of the players are shaped by history. The new, more efficient equilibrium is counterfactual and it lives only in our imagination, whereas the other, less efficient equilibrium has been played out for years and decades. History can, therefore, be a more powerful focal mechanism than Pareto dominance is.

Another important example for multiple equilibria is public transportation. Suppose creating and maintaining a public transportation system has fixed as well as variable costs per user. In order to cover the fixed costs, users must pay taxes that equal the fixed costs divided by the number of users and the variable costs (for example as user fees). If the number of users is small, the costs per user are high, which implies that it is individually rational to rely on private transportation. If the number of users is high, costs per user are low and this can create a virtuous circle where people rely heavily on public transportation. Switzerland is an example for a country with a dense, reliable, and affordable public transportation system, whereas most metropolitan areas in the USA heavily rely on private transportation.

Digression 9.3 (The Economics of Social Media)
The QWERTY keyboard may seem like an odd example for inefficient standards that is without much relevance for the functioning of the economy. The conclusion that coordination problems are only of secondary relevance would be premature, however, because the problem of multiple equilibria underlying the choice of inefficient production standards is at the heart of a lot of digital technologies. Take social media as an example. The attractivity of websites like Facebook or AirBnB depends on the number of users. The more users these websites have, the more attractive they are. This phenomenon is called a *network externality*. Network externalities can easily dominate quality differences between the different sites, like user friendliness, transparency, or privacy. A platform that offers poorer quality may nonetheless survive (and even thrive), simply because it is used by a larger number of customers.

When one looks at these industries, one finds a typical pattern. In the early stages, there are usually several competing platforms, like Facebook, Friendster, MySpace, or Xanga, and it is, *ex ante*, unclear which one will succeed. In the language of game theory, the game has multiple equilibria: one where the majority of users coordinate on Facebook and others where they coordinate on any one of the other platforms. Objective differences in the quality of the different platforms are a poor predictor for their future success. The number of users, however, is. The fastest-growing platforms are usually the ones that will outcompete the others and, once they dominate the market, it is very hard for new entrants to succeed, even if they offer much better quality. The large quantity of users protects the incumbent against market entries.

9.4.2 Collectively and Individually Rational Behavior

Another important topic that is, by now, better understood, because of game-theoretic reasoning, is whether or not one should expect that self-interested behavior of individuals leads to outcomes that benefit a group's welfare. Game theory can play an important role in answering these questions by identifying mathematical structures that lead to certain equilibria. The structural characteristics of such a game, which lead to certain types of equilibria, can help social scientists to detect patterns that help them to interpret and grasp situations in the real world.

In order to illustrate this point, I will introduce one of the most famous games: the prisoner's dilemma. What is the historical background of this game? I discussed the First and Second Theorem of Welfare Economics in Chap. 5. According to these theorems, market equilibria are Pareto-efficient under certain conditions. The Coase Irrelevance Theorem has generalized these conditions and opened a perspective for a better understanding of the factors that explain differences between institutions: transaction costs. Way into the twentieth century, many economists were convinced that the "invisible hand," as Adam Smith had coined it, is reality: if man follows his or her self-interest, then the interests of the rest of society are taken care of and there is no tension between individual self-interest and societal welfare.

This vision of a frictionless society can be illustrated by the following "invisible-hand game given in Table 9.6:" In this game, the two players have two strategies, M, F, each and both have a dominant strategy to play F. Hence, (F, F) is a unique Nash, as well as a dominant-strategy, equilibrium. It is, at the same time, Pareto-efficient.

The "invisible-hand game" reveals no deeper truth about our social reality; in the end, it should not surprise one that it is possible to tinker with utilities such that a unique, Pareto-efficient equilibrium exists. The really important question is whether the game is meaningful to describe the social world.

Now that one has started to tinker with utilities, one will most likely end up with the game given in Table 9.7. Together with the invisible-hand game, this game became the most famous metaphor for the logic of social interactions. It was developed by the mathematicians Merrill Flood and Melvin Dresher. The name "prisoner's dilemma" is due to Albert W. Tucker, who adapted the game by Flood and Dresher, but framed it in a different context where two individuals have committed a crime and can either confess or not. (Both are better off collectively, if they do not confess, but each person is individually better off confessing. Hence, the name prisoner's dilemma.)

The game is a parable applicable to many economically relevant situations, for example the tragedy of the commons that was discussed in Chap. 6. Table 9.7 shows a prisoner's dilemma in matrix form. Two players can choose between two strategies, "*M*" and "*F*." The central characteristic of the game is that it is optimal to choose "*M*" for each player individually; that (M, M) is a dominant-strategy equilibrium. However, in a concerted effort, both players could increase their respective utility by choosing "*F*." Applied to the example of the tragedy of

Table 9.6 Invisible-hand game

	M	F
M	3,3	5,5
F	5,5	10,10

Table 9.7 Prisoner's dilemma

	M	F
M	3,3	10,1
F	1,10	7,7

the commons, one can interpret the game as follows: Two fishermen live on a lake, where they catch fish to make a living. While going out to catch fish, they have the choice between catching many fish ("*M*") or just a few ("*F*"). If both choose "*F*," both can sell only a smaller quantity, but at higher prices and the fishing grounds stay intact, which guarantees future income. One normalizes the utility associated with this strategy to 7. If both choose "*M*," they can sell a lot, but prices are low and fish stocks dwindle due to overfishing. This leads to utilities of 3. If one fisherman chooses "*M*," while the other chooses "*F*," the fish stocks also dwindle, but to a lesser extent. The fisherman choosing "*M*" sells a lot at moderate prices, while the other sells a small quantity. In this situation, the fisherman choosing "*M*" gets a utility of 10, while the other receives only 1.

Because both players have the dominant strategy to choose "*M*," it seems clear, if one believes in invisible hands, that the equilibrium should have good welfare properties. But this is wrong. If both players could coordinate and play "*F*," then both would be better off. The decentralized decisions of the players are individually, but not collectively, rational.

9.4.3 Simple Games as Structural Metaphors

Coming back to the starting point of this chapter, the analysis of two-player two-strategy games reveals a lot about the fundamental problems that can exist when individual decisions are mutually dependent. These simple games illustrate the problems societies are confronted with in a nutshell.

- There can be situations with a unique equilibrium that is also efficient. In such a situation, there is no tension between individual and collective rationality.
- There may be a unique equilibrium that is inefficient. In such a situation, there is tension between individual and collective rationality. Situations of this type are referred to as "cooperation problems," because individual incentives impede beneficial cooperation.
- Multiple equilibria may exist. Situations like these are called "coordination problems," because they represent the fundamental challenge to coordinate on an equilibrium.

The above classification of potential problems is useful, because it provides a framework for interpreting problem structures in many different societal contexts. Chap. 6 already analyzed the problem of overfishing (the tragedy of the commons) and showed that it is inherently a cooperation problem. It can also be argued that the social and economic causes of anthropogenic climate change are unresolved cooperation problems.

Digression 9.4 (Cooperation Problems and Externalities)
This is a good point to hint at an important link between different concepts that have been discussed in this book. I discussed the concept of externalities in Chap. 6. An externality exists, if the acts of an individual, *A*, have an impact on the well-being of another individual, *B*, that *A* does not take into consideration: It is a non-internalized interdependency. Looking at cooperation problems, like the prisoner's dilemma, one sees that it is exactly an externality that is at the heart of the problem: The rational behavior of one individual makes the other individual worse off, but the individuals do not find a way to internalize this effect. Hence, cooperation problems are metaphors for situations with mutual externalities, like anthropogenic climate change.

I also discussed the ontology of money in Chap. 3, and one can now interpret it in the context of a simple game. Money has no intrinsic value and its value, as a medium of exchange and storage of wealth, relies on a convention: an agreement between people to accept money as a medium of exchange. If everybody complies, the simplified exchange of goods has positive effects on the economy and this is also an equilibrium. If a single individual stops accepting money, nothing bad happens for the rest of society. However, if nobody accepts money as a medium of exchange, it is rational for each individual to not accept money, either, and the economy has to rely on barter. The important fact is that both, a monetary and a barter economy, are equilibria. Due to the multiplicity of equilibria, one of the central challenges of an economy that relies on some abstract medium of exchange is to stabilize peoples' expectations, such that they believe in the convention and are willing to accept money. The stabilization of expectations is not always easy, as can be seen in times of economic crises when there is in danger of so-called bank runs. A bank run is a situation in which many people lose trust in a bank's solvency and try to get back their savings. If enough people do that, then the belief becomes a self-fulfilling prophecy and the bank actually gets into trouble. Many phenomena on financial markets have a similar structure and are better understood once they are interpreted as coordination problems. Bank runs and financial crises are examples of why game theory is important in macroeconomics and finance and why it came to new fame during the global financial crises 2008/2009.

The three classes of problems described above are, in principle, prototypes for most of the problems that one will encounter during one's studies. If one keeps them in mind, it will be easier to understand the fundamental structure underlying the different theories.

Digression 9.5 (The Cold War as a Game)

> Deterrence is the art of producing in the mind of the enemy the fear to attack. (Stanley Kubrick, Dr. Strangelove)

During the Cold War, the USA and the Soviet Union were in a nuclear standoff. Thus, the RAND Corporation (a major US think tank) hired some of the world's top game theorists to study the situation. At the time, both nations had the same policy, "If one side launched a first strike, the other threatened to answer with a devastating counterstrike." This became known as Mutually Assured Destruction, or MAD, for short. Game theorists got worried about the rationality and, thereby, the credibility of MAD. The argument goes like this, "Suppose the USSR launches a first strike against the USA. At that point, the American President finds his country already destroyed. He doesn't bring it back to life by now blowing up the world, so he has no incentive to carry out his original threat to retaliate, which has now manifestly failed to achieve its point. Since the Russians can anticipate this, they should ignore the threat to retaliate and strike first. Of course, the Americans are in an exactly symmetric position, so they too should strike first. Each power will recognize this incentive on the part of the other, and so will anticipate an attack if they don't rush to preempt it. What we should therefore expect is a race between the two powers to be the first to attack." (Don Ross, 2016)

This analysis led the RAND Corporation to recommend that the USA take actions designed to show their commitment to MAD. One strategy was to ensure that "second-strike capability" existed. A second strategy was to make leaders appear irrational. The CIA portrayed President Nixon as either insane or a drunk. The KGB, which appears to have come to the same conclusion as RAND, responded by fabricating medical records to show that General Secretary Brezhnev was senile.

Another strategy was to introduce uncertainty about the ability to stop a counterstrike, for example by building more nuclear missiles and storing them in numerous locations (which made it less likely that the President could stop all of them from being launched in the event of a Soviet attack). A third strategy was to make MAD credible by creating "doomsday machines": technologies that carry out a counterstrike automatically, without the ability of human beings to interfere. The USSR went so far as to create Perimeter, or Dead Head, which was the closest thing this world has ever seen to such a doomsday machine. It was able to automatically trigger the launch of intercontinental ballistic missiles, if a nuclear strike is detected by seismic, light, radioactivity, and overpressure sensors.

It is commonplace to suggest that the strategic situation during the Cold War was a case of the prisoner's dilemma. However, it is far from obvious that

(continued)

Digression 9.5 (continued)
the leaderships in either country in fact attached the necessary payoffs in their utility functions—preferring the destruction of the world to their own unique destruction—that would have been required for their situation to actually have been a prisoner's dilemma.

9.5 Extensive-Form Games

Up until this point, one has not been able to analyze situations where players choose their strategies sequentially instead of simultaneously. Many social phenomena cannot be adequately described as simultaneous-move games, because timing plays an important role.

If the order of play is important, then games are usually not depicted in matrix representation but with the help of a *game tree*. A game tree describes what actions any given player has at the different points in time and how these actions influence the further course of the game. Formally, a game tree is a directed graph with nodes as positions in a game, where the players have to make decisions and edges represent the possible decisions (moves). The nodes are also called *decision nodes* in game theory.

As an example for such a game tree, take Fig. 9.1. The game is a version of the so-called centipede game (it is called that, because the game tree looks a bit like a centipede, if there are enough decisions that the players have to make). There are two players, $i = 1, 2$, and three decision nodes, $T = \{1.1, 2, 1.2\}$. Player 1 has to make a decision at nodes 1.1 and 1.2, while player 2 only decides at node 2. Both players have a choice between the same actions at every node, $A_i^t = \{a, f\}, t \in T$.

The concept of a strategy is more complex than before. A strategy is a rule that determines an action for every *potential* node in the game. Because player 1 has to make a decision at two decision nodes, a strategy assigns an action to both, irrespective of whether both nodes are reached during the course of the game or not. This complete list of actions, one for each decision node where a player has to make a decision, is called an *action profile*.

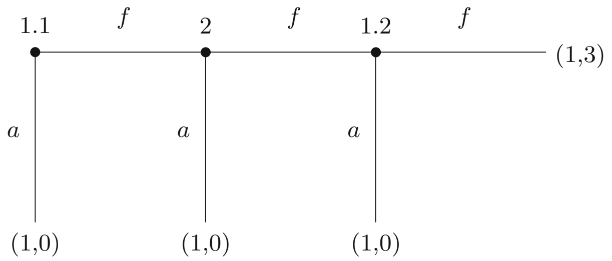

Fig. 9.1 Centipede game

One has to specify a complete contingency plan for each player, because otherwise it would not be possible to solve the game. If a player contemplates her optimal strategy, she has to be able to figure out how the game ends, if she goes for this or for that strategy. Conceptually, what is happening here is that each player has to determine the contingent optimal plans of all the other players as well in order to be able to determine its own optimal plan. The complete contingency plan therefore exists in the heads of each player because otherwise they would not be able to figure out what to do. This is also the moment where the assumption of common knowledge plays a role because all players must agree that they are playing the same game and use the same solution concept.

This is only possible, if all players specify what they will do at each decision node.

The set of possible strategies of a player equals the set of possible action profiles. Player 1's strategy set is $S_1 = \{aa, af, fa, ff\}$ where, for example, $s_1 = af$ is interpreted as player 1 choosing a at decision node 1.1 and f at decision node 1.2. Because player 2 decides only once during the game, at node 2, her strategy set equals the set of actions she has at this node, $S_2 = A_2^2 = \{a, f\}$.

As in normal-form games, each strategy profile leads to an outcome, which is represented by the players' utilities. For instance, the strategy profile (af, f) implies that the game ends immediately and that players' utilities are $u_1(af, f) = 1$ and $u_2(af, f) = 0$.

Solution concepts are defined by means of an analogy to normal-form games and, hence, extensive-form games can basically be solved in the same way as games in normal-form once the strategies are defined. However, due to the more complex structure, there may be some problems related to the concept of a Nash equilibrium that did not exist before: Nash equilibria can be based on the so-called empty threats. In order to see what that means, take a look at the game in Fig. 9.2, the chainstore game (or market-entry game). Two firms, $i = 1, 2$, are potentially competing in a

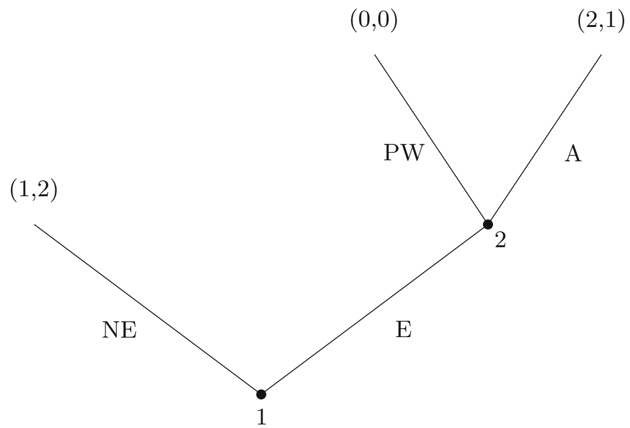

Fig. 9.2 Chainstore or market-entry game

market. If firm 1 does not enter the market, *NE*, then the incumbent firm, 2, has a monopoly. If firm 1 enters, *E*, then firm 2 has two options: to start a price war, *PW*, or to accommodate, A. The game has two Nash equilibria in pure strategies: NE, PW and E, A. Because no player has a dominant strategy and no equilibrium is Pareto dominant, the concepts that were discussed thus far are of little help in determining the game's outcome.

However, one can use the sequential structure of the decisions to distinguish between the different equilibria. Because firm 1 makes her decision before firm 2, firm 2's choice "*PW*" is not credible. If firm 1 enters the market, firm 2's best response is "*A*." The threat to start a price war if firm 1 enters is not credible, because it relies on the assumption that firm 1 does not enter. However, (NE, PW) is still a Nash equilibrium, since unilateral deviations are not beneficial for any firm.

A concept that will help one to identify such non-credible strategies is called *backward induction*. Intuitively, backward induction can be described as "thinking ahead and reasoning backward": In a first step, one determines the individual "subgames" of a game, i.e., the parts of the game tree that can be interpreted and analyzed as independent games. For example, the chainstore game has two subgames: one starting with firm 2's decision node and another that is the whole game.

In a next step, one looks at the *terminal* subgames and determines the optimal actions chosen at these nodes. A subgame is a terminal subgame, if the game ends thereafter, no matter what the player who makes a decision does. In the chainstore game, the subgame that starts at firm 2's decision node is a terminal subgame, whereas the whole game is not because, if firm 1 enters the market, the game goes on and firm 2 makes a decision.

Once the optimal decisions at the terminal nodes have been determined, then the terminal subgame is replaced by the utilities the players get from the optimal play. For example, in the chainstore game, the terminal subgame starts at decision node 2 and firm 2's best action is to choose "*A*," because this yields a higher utility than starting a price war "*PW*." Hence, in this step, the last subgame is replaced by the utilities achieved through this action, (2,1). Replacing the terminal subgame with the utility vector makes the game tree "shorter," and there are new terminal subgames. This procedure needs to be repeated until the start of the game is reached. In the chainstore example, this is the case after replacing node 2, when firm 1 faces the decision to enter the market, which gives her a utility of 2, or to stay out of the market, which gives her a utility of 1. Since entering the market gives her a greater utility, she will do exactly this and choose "*E*." Therefore, only one Nash equilibrium remains after backward induction, (E, A), and the other equilibrium, (NE, PW), which contained the empty threat to start a price war, is eliminated.

By solving the game from its end, one can reduce its complexity step by step. Players who need to determine their optimal choices at earlier nodes can rely on a continuation of the game that is always (at every decision node) optimal for each player. An equilibrium determined by backward induction is also called *subgame-perfect* Nash equilibrium because it is a Nash equilibrium in every subgame of the game.

Digression 9.6 (Chess and the Existence of Backward-Induction Equilibria)
One of the first formal game-theoretic studies was Ernst Zermelo's analysis of the game of chess. Chess can be interpreted as an extensive-form game between two players, but the game's complexity makes it impossible to write down the players' strategies, to draw a game tree, or to solve it (at least with today's means). However, Zermelo was able to show that there is an optimal, deterministic way to play chess. This result also illustrates why backward-induction equilibria must exist, if each player has a finite number of strategies.

Certain rules in chess guarantee that it cannot go on forever (see Article 5.2 of the official Fide chess rules) and, thus, every player has finitely many strategies. The conditions that Zermelo found to be necessary in his proof are hence met and it is, therefore, proven that either white has a winning strategy, or that black has a winning strategy, or that both can force at least a draw.

Until now, nobody has been able to find out whether white or black has a winning strategy or whether each player can force a draw. Therefore, of course, nobody knows the optimal strategy to play chess. Zermelo's result is, in this respect, a rather strange mathematical theorem: One knows that there is an optimal way to play chess, but one does not know what the optimal strategies are. Fortunately, one might say, because this is why the game of chess remains interesting.

Zermelo's theorem has important implication for other games, as well. First, it reveals that, under quite general conditions, a pure strategy equilibrium exists when players move sequentially. Furthermore, it shows that this equilibrium is not based on empty threats. These two points are of importance for the ability to predict the outcomes of extensive-form games.

9.6 Summary

One has seen that game theory is an analytical tool that helps one to analyze situations of strategic interdependence. This method has proven to be extremely versatile and has generated interesting insights far beyond the narrow field of economics, ranging from political science, law and business administration to evolutionary biology. A topic that I have not covered in this chapter is that the insights of game theory also paved the way for behavioral economics and neuroeconomics. Even in simple games, the required cognitive abilities for the players to find a Nash equilibrium are so high that it became apparent that rational-choice models of decision-making have poor predictive power in a number of situations. In addition, problems like the prisoner's dilemma spurred literatures on the cultural and genetic roots of cooperative behavior, which has been generating fascinating insights into the evolutionary and cultural forces that have shaped our brains and our perceptions of reality.

Digression 9.7 (Games as Structural Metaphors: Further Examples)
This chapter has already clarified that game theory is a method and that games with specific sequences of moves and payoff structures are problem structures, which are not tied to specific interpretations, but that can be used as metaphors for a wide array of social phenomena. This versatility is one of game theory's strengths, because it allows one to understand the strategic similarities between, apparently, very different social spheres. Here are some examples for social phenomena that have aspects of the chainstore game:

- **Military conflicts:** Situations that are very similar in their logic to the market-entry problem can be found in many military conflicts. Often, one party in a conflict threatens to attack another party, should that party continue with some provocative action. However, if there were an actual attack, both parties would be worse off.
- **Bailouts:** The state has an interest in ensuring that its major banks are managed in a way that makes situations of serious financial stress unlikely. However, if a major bank gets into financial trouble, the economic consequences for the rest of the country are so severe that the state bails it out. If banks anticipate this incentive, they know that they are at least partially insured against failure and so they have an incentive to invest in riskier strategies, which increases the likelihood that a bailout will become necessary. The major challenge for a state is, therefore, to make a no-bailout strategy credible. This is, of course, the exact situation that Switzerland, the USA, and other European countries faced during the financial crises that started in 2007, and it also illustrates some of the EU's problems regarding institutional reforms in some of its member states.
- **Legalization of illegal immigrants:** Countries want to restrict and control illegal immigration. Therefore, it is in their best interest to signal a tough policy towards potential illegal immigrants in order to prevent them from attempting to migrate. It is in light of this background that the debate about the legalization of illegal immigrants in the USA can be understood. The Obama administration was largely in favor of legalizing this group of people. President Barack Obama said in a press conference on September 06th, 2014 that, although his "preference is to see Congress act," he intended to take unilateral action in order to give illegal aliens "some path" to "be legal," if Congress did not enact the sort of immigration legislation he wanted (at that time congress was being controlled by a Republican majority that was mostly against legalization). Advocates of the pro-legalization camp typically use two types of arguments to support their

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Digression 9.7 (continued)

views: humanitarian and economic (illegal immigrants are, for example, an important part of the Californian agricultural industry). Opponents often argue that legalization sends the wrong signals, because it encourages immigration.

- **Touchiness can pay off:** Now, it is time to get to the really important stuff. Think of a typical situation in a partnership. You can stay home for the night with TV and crackers (your partnership has reached a mature stage) or you can go out with friends, but without your significant other. You think the latter alternative is much more fun, but only if your significant other does not create a scene the next morning. Your partner would be jealous if you go out without him or her, but he or she also shies away from making a scene. Thus, if you actually went he or she would give in and make the best out of the evening. However, he or she would profit from a reputation of being touchy.

The art and craft of a social scientist is to boil complex social phenomena down to their essential strategic structures. This is not always easy, as the discussion of the Cold War as a prisoner's dilemma game has shown, and a reconstruction of the above situations as chainstore games may be wrong or misleading in a given situation. Everyone is well aware that, if one has a hammer, everything looks like a nail and it is the same with game theory: If one has, for example, the prisoner's dilemma as a device for making sense of things, then suddenly everything looks like a cooperation problem.

It is now time to come back to the analysis of prototypical markets, which is why I had to cover game theory in the first place. Markets rarely fit to the ideals of perfect competition or monopoly and, next, I will apply the methods from game theory to creating a better understanding of the functioning of oligopoly markets. Usually, firms have some control over prices. However, that is limited by the existence of competitors. Thus, there are important strategic interdependencies that have to be taken into account, if one wants to make meaningful predictions about the functioning of these markets. Game theory is the analytical toolbox for achieving this.

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Behavioral Economics

10

This chapter covers . . .

- the basic ideas of behavioral economics.
- what a bias is and how a bias can be defined.
- important biases.
- how to distinguish between non-rational and non-selfish behavior.
- models to explain cooperative behavior.
- models of boundedly rational behavior.

10.1 Introduction

> Wouldn't economics make a lot more sense if it were based on how people actually behave, instead of how they should behave? (Dan Ariely, 2008).

> The world is better served by syncretic economists and policymakers who can hold multiple ideas in their heads than by "one-handed" economists who promote one big idea regardless of context. (Dani Rodrik, 2011)

Behavioral economics uses insights from psychology to better understand economic decision-making and the functioning of institutions like markets. Many of these insights go beyond the rational choice model of behavior introduced in Chaps. 7 and 8 and contradict it in some of its aspects. This involves questions of rationality as well as the social embeddedness of decisions. The results of this field of research have implications not only for our understanding of decision-making, the design of institutions, and economic policy, but also for the logic underlying our own daily decisions. In many cases, experiments are used to understand how decisions are made. The related field of research is called *experimental economics*.

M. Kolmar, *Principles of Microeconomics*, Classroom Companion: Economics,
https://doi.org/10.1007/978-3-030-78167-5_10

The integration of psychological findings into economics is not new. It goes back to the beginnings of economics and to classical utility theory of the late nineteenth century. Adam Smith often argued psychologically. His writings anticipated many of the psychological effects that are discussed in behavioral economics. Here is an example: "[W]hat are the benefits we have in mind in any great ultimate goal of human life that we call 'improving our circumstances'? That we should be noticed, that we should be looked after, that we should be noted with sympathy, pleasure, and approval [. . .]. It is vanity, not well-being or pleasure, that attracts us to it." (Adam Smith, Theory of Ethical Sentiments). This passage focusses on the social embeddedness of the human being and a particular motivation for action.

By the end of the nineteenth century, there was a great closeness between psychological and economic research. Due to a shift in the methodological principles that were considered being essential for a good scientific theory (according to which a theory should be empirically testable and thus should be based exclusively on observable variables), mental processes (which are not observable) disqualified as elements in good theories. A "behaviorist" turn occurred, which laid the way for the development of the modern decision theory prevalent in the economic mainstream. (It is an afterwit in the history of science that the rediscovery of psychology by economists was called "behavioral economics" as behaviorism was traditionally a school of thinking that wanted to get rid of all mental processes.) Pareto was a leading proponent of what then became the mainstream. He justified the elimination of psychological elements in economic theories in a letter of 1897 as follows: "It is an empirical fact that the natural sciences have progressed only when they have taken secondary principles as their point of departure, instead of trying to discover the essence of things. [. . .] Pure political economy has therefore a great interest in relying as little as possible on the domain of psychology."

The starting signal for a reassessment of psychological research came in 1979 with a paper and a theory developed by psychologists Daniel Kahneman and Amos Tversky which they dubbed *Prospect Theory*. We will discuss this theory in detail later. They had studied individual risk behavior and were able to show that the von Neumann-Morgenstern theory (see Chap. 8) cannot explain individual behavior well in many situations.

The goal of this chapter is to provide a basic understanding of behavioral economics, to detail some of its important results, and to show what implications can be derived from them for our understanding of decisions and the functioning of institutions. However, we will also go beyond this task and ask, in a methodological reflection on behavioral economics, how we can critically reflect the methods and results of this field of research. To do so, we will first start with a definition.

▶ **Definition 10.1 Behavioral economics** Behavioral economics uses variations of traditional economic assumptions along with psychological insights to explain and predict behavior (positive economics) and to make policy recommendations (normative economics).

Traditional and behavioral economists share fundamental principles. They believe that people try to choose the best possible course of action (optimization) and that the predictions of a theory must be empirically falsifiable. However, they differ significantly on the question of what the best possible course of action is and what it means that people try to choose it. Without already going into specifics, one can formulate six principles that summarize the state of the research.

▶ **Principle 1:** People try to choose the best course of action, but sometimes they fail to do so.
It may come as no surprise that an important finding of this field of research is that people make mistakes all the time. But what is interesting is that these mistakes often have a predictable structure. In most situations, people resort to simple heuristics (rules of thumb) rather than optimization to determine behavior. If one knows the error structure and the heuristics, one can influence behavior in a predictable way. It also turns out that mistakes are more prevalent if people are inexperienced. This observation has two dimensions. Firstly, the frequency of errors decreases with experience. And secondly, behavior is adapted to specific environments and usually works well in them. If the environment changes, behavior need no longer be appropriate and must be relearned.

▶ **Principle 2:** People often compare and evaluate a situation (in part) by means of a reference point.
It turns out that people often do not apply an absolute standard to their evaluation of alternatives, but rather orient themselves relative to a reference point. This reference point can be a certain endowment of goods (from which they evaluate gains and losses). In an experiment, the participants' maximum willingness to pay for a cup that they did not own differed from the minimum willingness to sell the same cup that they owned (which is called *endowment effect*). This phenomenon should not occur according to standard theory. However, dependence on reference points can also be observed, for example, with respect to the behaviors of a reference group of other people. For example, one would like to behave in conformity with certain group norms.

▶ **Principle 3:** People have problems with their self-control.
An important principle of standard theory is that people act according to their preferences. But this presupposes that there is a unified interest in their minds and brains that corresponds to their preferences. Rather, it seems that different and even contradictory interests can coexist and compete to become action-guiding. We have already discussed the phenomenon of procrastination as a problem of self-commitment in Chap. 7, and we have generalized commitment problems in Chap. 9. But

problems of self-control do not need a temporal dimension. In another study, it could be shown that participants that had the choice between an unhealthy but sweet and a healthy snack chose an unhealthy snack more often when they had to solve a mentally demanding task compared to a control group that had to solve a less demanding task.

► **Principle 4:** Although behavior is often selfish, sometimes the situation of other people, their actions, or their intentions are taken into account when determining behavior.
Selfish behavior can often be observed when the individual lacks information about other people when making decisions. This is the case, for example, in abstract market contexts where one does not know more than the price. In situations with richer social context, selfish behavior can frequently be observed, but one also observes a whole range of other behaviors. These include altruism (I share even though I do not have to), spite (I harm other people even if it is costly for me), reciprocity (I cooperate if other people cooperate as well, otherwise I do not), social pressure (I base my behavior on the social norms of my environment), and intentions (I try to find out whether another person has good or bad intentions tailor behavior accordingly).

► **Principle 5:** Sometimes a market context results in psychological factors not playing a role. However, there are also situations in which psychological factors do play a role in markets.
As mentioned in Principle 4, abstract market contexts can sometimes force selfish behavior because there is neither the information nor the opportunity to behave differently (e.g., one is a price taker or knows only the price). However, in market contexts that give a richer social context, people behave according to all the motivations mentioned in Principle 4. Therefore, the results of behavioral economics are relevant for an understanding of the functioning markets.

► **Principle 6:** In theory, paternalistic interventions can avoid or correct mistakes and improve welfare.
The first three principles are often seen as indicative of boundedly rational behavior. However, since mistakes are not simply random, they can be controlled by means of incentives. Knowledge of the structure of boundedly rational behavior can be used by companies and other organizations to influence behavior in their favor. But it can also be used by the state. If the state is interested in the welfare of individuals, this form of interference is called *paternalism*. *Hard paternalism* means acting through prohibitions, obligations, or, e.g., monetary incentives and is therefore coercive. Ideally, it changes individual behavior in ways that benefit them in the end. In contrast, *libertarian paternalism* is not

based on coercion. Instead, it uses knowledge about the irrationalities and quirks of individual behavior to influence it without limiting freedom. Interventions like these are called *nudges*. An example for such a *nudge* is the selection of an alternative as *status quo*. Whenever one has a choice between, say, two alternatives, one of these can be made the fallback-alternative chosen when nothing else is decided. It has been shown that there is some inertia in decision-making that makes the *status-quo* alternative more likely to be chosen (this is called the *status-quo* bias). A real-world example can be found in medicine. In most countries there are shortages of suitable organs for transplantation. In order to manage the supply of organs, there are two ways to get the consensus of potential donors. One is called consent and the other dissent solution. Under the consent solution, organs may only be removed after death if the person has explicitly given permission beforehand. Under the dissent solution, organs may always be removed if the person has not explicitly objected beforehand. Empirically, the availability of organs increases with the dissent solution.

Digression 10.1 (Does Studying Economics Make People More Selfish?)
We have seen in Principles 1 and 3 that people learn appropriate behavior (and therefore make fewer mistakes over time) and that they tend conform to the expectations of a group. Since a certain understanding of rationality is taught in economics, it is natural to test whether one can observe differences in selfishness between economics and other students.

A team of economists (Frank et al., 1993) summarized studies that had addressed this question. The irony of this study is that the assumption of selfishness does not even have the status of a rationality postulate in economic theory, but is often made out of convenience in applied models. Nevertheless, many people and also students of economics assume that a rational homo oeconomicus must also be selfish.

Situation 1 First, this question was explored in a so-called free-rider or public-good game. In this game, each participant is given an endowment of money X at the beginning. They can either save it in a private account to get it paid back at the end. Or they can invest it in a joint account, where it will earn a positive return but will be split between all the investors at the end.

Let us say there are six participants and the amount deposited into the joint account triples. What would a selfish homo oeconomicus do in this case? She or he would deposit nothing into the joint account, because x units of money yield $3 \cdot x/6 = 0.5 \cdot x$, which is less than $1 \cdot x$, the yield on the private account. Thus, she or he goes home with X units of money. A fully cooperative investment by all participants would result in a monetary payoff of $6 \cdot 3 \cdot X/6 = 3 \cdot X$ for each participant, which exceeds the amount on

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Digression 10.1 (continued)
the private account. What did we empirically observe in the experiment? "[Researchers] found that economics students contributed an average of only 20 percent of their endowments to the public account, significantly less than the 49 percent average for all other subjects."

Situation 2 There are two participants in an ultimatum game. One of them is given an amount of money X, which can then be shared with the other participant, $(X - y, y)$. The second participant may or may not accept the offer. If she accepts, the money is shared according to the proposal; if she declines, neither gets anything. Rational behavior means that the first person makes a minimal offer to the second person, which the second person accepts (a little money is better than no money at all; we will make this argument more precise later on). In the experiment, it was found that these strategies were most often chosen by economics students. With an average field of participants, one finds offers of about 40% of the money amount and rejection rates of about 16%.

Situation 3 In another study, the authors compared the donation behavior of professors of economics with colleagues in other disciplines. Donating is considered irrational, at least in the short run, if one assumes selfish preferences, even if there is agreement that the purpose of the donations is an important one. Therefore, the prediction of the model of rational behavior would be that no donation is made. What were the results? " Members of every discipline, even economics, fell far short of the prediction of the [...] free rider hypothesis. But the proportion of pure free riders among economists (that is, those who reported giving no money to any charity) was more than double that of any of the other six areas included in the survey."

Situation 4 Furthermore, it was investigated whether there is a difference in the honesty of people with regard to their field of study. For this purpose, a survey was conducted in which study participants were asked about their behavior in ethical dilemmas (e.g., whether one would return a lost purse or call attention to an error in a bill, even if the error favored one). The results were that students of economics were less likely to engage in honest behavior than students of astronomy (who also chose a mathematical major, but one where selfishness is not part of the curriculum).

Thus, systematic differences exist; students of economics behave more selfishly on average than other students. What could not be definitively clarified in these studies, however, is whether this behavior is learned or whether economics tends to attract more selfish students.

10.2 Basic Concepts

The adaptability of the homo oeconomicus model makes it difficult to precisely understand what the results of behavioral economics imply with respect to the reference case of rational behavior. Two interpretations coexist.

- *Adjustment of the structure of preferences:* This direction attempts to use empirical data on behavior to adjust the structure of preferences to fit the empirical data. It adheres to the rationality paradigm and the assumption that behavior can be explained by maximizing a preference ordering. Principle 4 summarizes this direction of research.
- *Bounded Rationality:* This direction attempts to explain observed behavior that conflicts with the preference-maximization model as a deviation from the assumptions of rationality. In addition, it attempts to explain empirical behavior as following heuristics and tries to identify the ones most frequently used. *Heuristics* are simple procedures that allow people to make decisions in situations of limited knowledge and constrained cognitive capacities. Depending on the context, decisions based on heuristics often deviate from optimal decisions. The use of stereotypes to evaluate other people is an example. Principles 1, 2, 3 summarize this direction of research.

As we will see, an important theory of behavioral economics, *prospect theory*, incorporates both approaches. If one follows them one deviates from the strict *revealed-preference* view of preferences (see Chap. 7) because one must make assumptions about the structure of those preferences that go beyond those that are otherwise commonly made. Here is a simple example to illustrate the problem. Suppose two people A and B play what is called a *dictator game* in which one person (A) is given an amount of money that she or he can share with person B. The proposal of A can only be accepted, and the game ends. Suppose that A gives 40% of the money to B. What can be learned from this observation? Without further assumptions on the structure of preferences and rationality of behavior, the answer is: not much. Why is this so? Suppose that A is assumed to be rational. Then the behavior indicates that A must have some form of altruistic preferences, otherwise A would not share the money. Conversely, suppose that A is selfish in the sense that more money is better than less money. In this case, we would describe the same behavior as irrational. The example therefore shows that we cannot readily learn from a person's behavior whether, for example, she violates rationality or has specific preferences. This is a general methodological problem of behavioral economics and of any science that wants to draw conclusions about mental processes from behavior. Since so-called *auxiliary assumptions* are needed for any interpretation of empirical findings, the resulting problem is also called the *problem of auxiliary assumptions*.

The comparison of the two interpretations of the behavior in the dictator game shows that it is not a matter of correct or incorrect empirical interpretations to condense data about behavior into a theoretical model of perception and behavior, but of different paradigmatic approaches. Even simple heuristics can always be reconstructed as preference maximization, if only the set alternatives from which to choose are made sufficiently complex and phenomena such as cognitive constraints are modeled as transaction costs.

Consider the use of stereotypes as an example. Suppose there are two groups A and B. Members of each group can always be precisely assigned to them. On average, a feature m exists more often in group A than in group B, $p(m|A) > p(m|B)$, and feature m has positive consequences for a decision maker E. In this case, the heuristic "always choose a member of group A" corresponds to the outcome of an optimization problem where E has no information about individual members of the groups but knows that $p(m|A) > p(m|B)$ holds.

The example shows that the classification of behavior as rational or not or selfish or social is not always as clear-cut as one would hope. Therefore, the principle that theories have to be empirically falsifiable must be taken with a grain of salt. As we have already seen in Chap. 1, every theory has a core that cannot be tested empirically, and in behavioral economics, part of this core is the auxiliary assumptions. A naïve understanding of empirical testing that does not take this fact into account runs the risk of erroneous conclusions.

Important parts of research have focused on the identification of so-called *biases* and their importance in explaining behavior (positive) and designing incentives (normative). Therefore, it is necessary to define this term.

▶ **Definition 10.2 Bias** A behavior exhibits a *bias* if it deviates in a systematic way from a reference behavior.

This reference behavior plays an important role in both, positive but even more prominently in normative theory. An important example is the literature on *nudging* (see principle 6). Proponents of *nudging* argue on the basis of certain biases that the actual behavior of individuals deviates in a systematic way from what is considered optimal (rational?) behavior. From this, a need for interventions and economic policy is derived that goes beyond the usual objectives like the internalization of externalities or redistribution. But at this point one immediately recognizes that the justification of *nudges* must be traced back to the justifiability of the reference behavior. For it is this reference behavior that determines whether empirical behavior exhibits a bias or not.

In behavioral economics, it is common to define rational behavior (in the sense of maximizing a transitive preference ordering) as reference behavior. However, as the problem of auxiliary assumptions has shown, this definition of a bias is often not sufficient, but assumptions on the motives for action like selfishness have to be added. This is unproblematic for positive economics in the sense that these assumptions carry no implications for the *evaluation* of behavior. Rationality plus some motive to act plays the role of the frictionless pendulum in physics: even if such a state is not attainable, it is easier to understand the phenomenon of friction by comparing it to a fictitious frictionless situation (as a systematic deviation from the reference point). Within a normative theory such as *nudging*, however, the reference behavior becomes central because it then serves as a *normative* reference point. For example, rational behavior is then interpreted as a normative expectation of *correct* behavior. Deviations from rationality are mistakes that should be corrected by state intervention, if necessary. We will return to the question of the justifiability of the reference behavior in the concluding section of this chapter.

10.3 Social Preferences

Research on social preferences seeks to gain a better understanding of individuals' motives to act. We have already seen in Principle 4 that motives can be very different. Altruism, spite, reciprocity, social pressure, and intention-based behavior are all expressions of behavior that is in some sense "social." Thus, in a departure from the colloquial understanding, social does not necessarily mean moral or kind.

In order to understand the results on social preferences, however, it is first necessary to define some terminology. The following definitions have proven helpful in delimiting the terms selfishness and self-interested behavior.

▶ **Definition 10.3 Self interest** A person's behavior is called *self-interested* if it maximizes his or her preferences, regardless of the structure of those preferences.

▶ **Definition 10.4 Selfishness** A person's behavior is called *selfish* if it is mutually disinterested. Mutual disinterest means that a person is indifferent to the consequences of his behavior for others and, conversely, is also disinterested in the behavior of others.

For example, altruism can therefore be self-interested but not selfish. In order to draw conclusions about the existence and structure of social preferences based on observed behavior, one usually adds rationality as an auxiliary assumption.

Therefore, in order to unambiguously define social preferences and to study them empirically, we define them as resulting from systematic deviations from selfish behavior. We call such behavior *cooperative*.

Research on social preferences got a particular boost from the fact that experimental economics observed behavior in many empirical studies that violated the assumption of selfish preferences; such violations are also called *anomalies*. Therefore, the question of how to interpret such behavior arose. The anomalies we will focus on can be derived from the so-called dictator, ultimatum, and prisoner's-dilemma games.

Dictator Game A dictator game is not a game in the strict sense, because there is no strategic interaction: Individual 1 receives an amount of money x, from which it

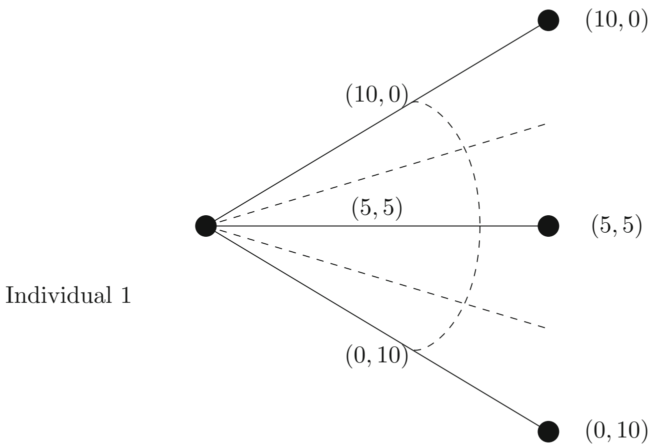

Fig. 10.1 Dictator game

can give an amount x_2 to Individual 2 and keep x_1 for her or himself, $x_1 + x_2 = x$. Individual 2 must accept this offer, and the game ends. Figure 10.1 represents the extensive form of this game (note that the outcomes are in monetary units, not utility, since utility cannot be empirically observed).

The game is simple to analyze: A selfish individual 1 has the dominant strategy of keeping all the money, so $x_2 = 0$ is the only equilibrium hypothesis for this game.

The dictator game has been extensively tested in the laboratory, and the overwhelming evidence is that the empirical behavior does not match the theoretical prediction. A substantial fraction of individuals 1 share the money, and the amounts given typically average between 10% and 25% of x. However, the variance between proposals is relatively large, suggesting that participants in these experiments are heterogeneous in their willingness to share. The modal (most common) values are 0 and 50%. In addition, there is also evidence that the absolute amount x is important for the willingness to share. In a meta-analysis that manipulated the size of the participants monetary endowment, Larney et al. (2019) found that people give less in high-stakes dictator games, and the effect increases as stakes increase.

Furthermore, the results of the dictator game were shown to depend on whether individuals believe they have a legitimate claim to the money or not. This was shown in an experiment in which individual 1 had to earn the money x in an earlier stage of the game. In this case, the probability of offering $x = 0$ increased to 80%, while this value occurs only in 17% of the cases when the money is given by the experimenter. These results indicate cooperative but at the same time context-dependent behavior, and it is interesting to understand what this means exactly.

Ultimatum Game The ultimatum game is similar to the dictator game with the difference that individual 2 now has the option of either accepting or rejecting

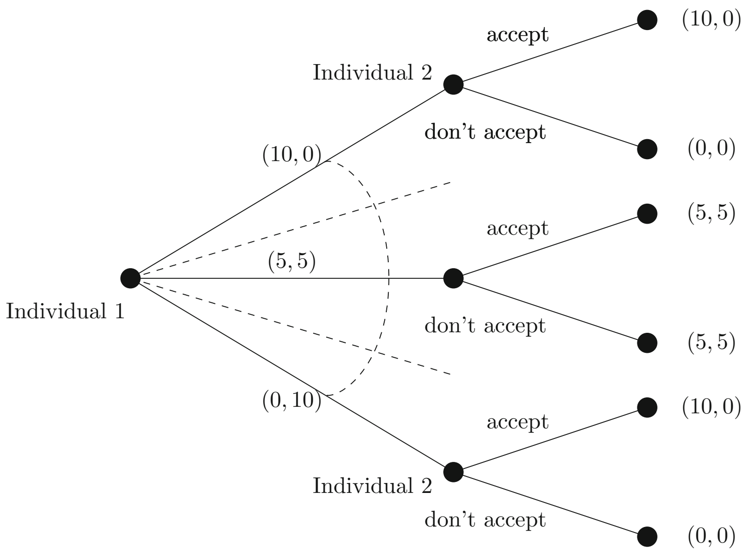

Fig. 10.2 Ultimatum game

the proposal. If it accepts, the money is allocated according to the proposal; if it rejects, both receive zero. In both cases, the game ends after individual 2's decision. Figure 10.2 depicts the extensive form of this game (again, the outcomes are monetary, not utilities).

In what follows, we assume that individuals coordinate on a subgame-perfect Nash equilibrium, see Chap. 9 for details. The increase in agency of the second individual, compared to the dictator game, is of little benefit in the case of selfish, rational behavior: Individual 2 has an incentive to accept any offer greater than or equal to zero. This is anticipated by 1, so that the offer x_2 is zero.

This hypothesis is also not supported by the empirical evidence: Individuals 2 are willing to reject positive offers if they consider them inadequate, and individuals 1 make substantial offers. On average, offers are higher than in comparable dictator games:

1. Individuals 1 offer, on average, between 40 and 50% of x.
2. Individuals 2 reject offers that are less than 20% of x in 40–60% of the time.
3. The probability of rejection decreases with the amount of the offer.

In an experiment in the Slovak Republic, x was varied between 4 and 100% of an average weekly salary. In a similar experiment in Indonesia, x varied between 2.5 and 300% of (local) weekly average earnings. Both experiments reach the same conclusion: the influence of the amount of money x that participants had to distribute on the (relative) amount of the proposal x_2 as well as the rejection rate were negligible. Moreover, the proposals of individual 1 were always far from the theoretical prediction. This result can be generalized. In the above-mentioned meta-analysis, Larney et al. (2019) found that stakes have no effect on Ultimatum Game offers, regardless of how big stakes are. However, the willingness to accept bad offers increases slightly.

To explain behavior in an ultimatum game, one must look at both individuals separately. First, it must be explained why individual 2 should be willing to sacrifice money. For this purpose, the results of an experiment that changed the narrative context of the game are illustrative. As in the dictator game, context variables turned out to play an important role for behavior in the ultimatum game. In this experiment, individual 1's offer was not determined by her- or himself, but by computer generating random numbers, and individual 2 was informed about this fact. This experimental design allows it to investigate the extent to which player 2's rejection of an offer is due to the player being dissatisfied with the amount of the offer x_2 (relative to x or x_1) (in which case the question of whether the offer is determined by the player or a computer should be irrelevant), or whether the player wants to punish player 1's behavior or (inferred) intention. It turned out that behavior was significantly different in in both scenarios.

Second, one has to understand the motives of individual 1. However, the proposer's calculus is complex. Positive offers can be the result of cooperative preferences, as in the dictator game, but they can also be explained by selfish preferences, assuming that Individual 1 fears that too low offers will be rejected.

Prisoner's-Dilemma Game In a prisoner's-dilemma game, two individuals 1 and 2 can either cooperate or not. The associated (monetary) payoffs are summarized in Table 10.1 which represents the game in normal form. Individual 1 is the row player and individual 2 is the column player ($0 < a < 9$):
Here, "coop." and "no coop." represent the two strategies *cooperation* and *no cooperation*. Since a ranges from 0 to 9, no cooperation is a dominant strategy for both players. This outcome comes at a significant social cost: Both players lose a monetary units compared to a situation where they both cooperate.

In experiments, this hypothesis is regularly rejected. Individuals cooperate much more often than theoretically predicted, but cooperation appears to be quite fragile; when the game is repeated several times, periods of cooperation alternate with periods of noncooperation. This behavior also requires explanation.

In what follows, we will present some of the main models from the literature on social preferences and discuss the extent to which they are able to explain the behaviors described before.

Table 10.1 Prisoner's dilemma

	Coop.	No coop.
Coop.	2+a,2+a	1,11
No coop.	11,1	2,2

10.3.1 Kin Selection

Cooperative behavior can make evolutionary sense if it promotes the survival and spread of genes. From the perspective of genetic selection, a human is a mechanism evolved to ensure just that. From this, one can hypothesize that cooperative behavior between organisms should depend on their degree of relatedness. The closer the degree of kinship, the more genes are shared and the more likely one should observe cooperation. For example, helping one's sister raise her children indirectly promotes the future spread of one's genetic information because one shares a relatively large number of genes. Evolutionary biologist Alexander Hamilton developed the theory of *kin selection* and tested it empirically using many different species. His hypothesis is that cooperative behavior can spread exactly when the costs of cooperation is smaller than the benefits of cooperation (in terms of gene propagation).

Formally, this relationship can be represented as follows. If B is the benefit and C is the cost of a particular behavior for gene propagation, then a behavior that has consequences only for the individual would be expected to be observed if $B > C$. In this situation, the so-called *degree of relatedness* r is equal to 1. r measures the fraction of genes that two organisms share. If the behavior generates costs for one individual and benefits in another, one can determine the net benefit by multiplying the total benefit by r. One then obtains the hypothesis that cooperative behavior should be observed if $r \cdot B > C$. This is a simplified form of *Hamilton's rule*, which is central to evolutionary biology and explains cooperative behavior as a result of genetic relatedness. Here is an example: the degree of relatedness in siblings is $r = 0.5$. Then the rule states that cooperative behavior between siblings should be observed if the evolutionary benefits B are at least twice the evolutionary costs C.

The theory makes no explanatory contribution with respect to the experiments discussed before, since kinship did not play a role there. Hamilton's theory, however, has nonetheless found impressive empirical support, and it explains cooperative behavior among genetically related members of a species. The open question is whether we can observe and explain such behavior even if the degree of relatedness is so small that it should play little role for behavior?

10.3.2 Reciprocity

One explanation for cooperation without genetic relatedness is *reciprocity*. It is a social norm that requires responding to cooperative behavior of others in a cooperative manner as well. This is called *positive reciprocity*. Conversely, it may also be true that the norm requires to responded to uncooperative behavior uncooperatively. This is called *negative reciprocity*.

A simple form of reciprocity is the behavioral heuristic *tit for tat*, which can be applied in repeated interactions between two persons. Here, one's own behavior in a period t depends on how the other person behaved in period $t - 1$. If she cooperated, you cooperate. If she did not cooperate, you do not cooperate either.

From an evolutionary point of view, reciprocity seems to have advantages compared to an unconditional willingness to cooperate. For example, a person who always shares regardless of how she is treated by others may be exploited in the long run, which then hinders the spread of the sharing trait. Contingently cooperative behavior makes this form of exploitation impossible.

Up to this point, it is unclear whether reciprocity is a special kind of selfish behavior, or whether such behavior is the result of a cooperative behavioral disposition that is engrained in preferences. In a stable, repeated relationship in which cooperative behavior has mutual advantages, reciprocity may well be reconstructed as selfish behavior if individuals have a sufficiently long time-horizon. On the other hand, if reciprocity can be detected in short-term social interactions, this points to a behavioral disposition. We will return to this point later.

Important for the emergence of cooperation based on reciprocity are repeated interactions in stable groups. In an anonymous market, where trading partners meet only once, the conditions are not in place for reciprocal behavior to emerge. Therefore, it can explain, for example, cooperative behavior in a repeated prisoner's-dilemma game. If periods of cooperation alternate with periods without cooperation, this may indicate that repeated attempts are made to support cooperative behavior by establishing norms of reciprocity, but this does not always succeed. Negative reciprocity may also explain why bad offers are rejected in the ultimatum game. If there is a fairness norm in a group that the proposal does not meet, such a proposal is turned down even if this wastes money.

10.3.3 Altruism and Spite

Another possible explanation for cooperative behavior is *altruism*, which is a form of unconditional cooperation.

Altruism is typically defined as follows. We assume that there are two individuals i and j whose utility depends on a good x, which can be money in the simplest case. (x_1, x_2) is a distribution of the good among the two individuals. The utility of individual i can now depend on both the quantity x_i that it receives itself and the quantity x_j that the other individual receives:

$$u_i(x_i, x_j).$$

If the good is money, then it is an indirect utility function as introduced in Chap. 7. Using this model, altruism can be defined as follows:

Definition 10.5 Altruism An individual i is called *altruistic* if the first derivative of the utility function $u_i(x_i, x_j)$ with respect to x_j is always positive:

$$\frac{\partial u_i(x_i, x_j)}{\partial x_j} > 0.$$

Thus, depending on the distribution of the good, an altruistic individual i is willing to give up some of its own good to make the other individual better off. For example, assuming that the utility functions are $u_i(x_i, x_2) = \ln x_i + a \cdot \ln x_j$, $a \geq 0$, and further assuming that individual 1 is to divide an amount of ten units of money, the first-order condition is the equation $1/x_1 - a/(10 - x_1) = 0$. Solving this equation for x_1 gives $x_1 = 10/(1 + a)$. When $a = 0$, individuals are selfish, and therefore there is no sharing. However, as a increases, altruism increases, and so does the amount of money 1 gives away.

There is another form of altruism called *parochial*. In this case, the individual makes a distinction between different individuals; it divides them into groups and restricts altruism to members of some or one of them (e.g., nationality, ethnicity, religion, profession, football club, ...). In contrast, it behaves neutrally (i.e., selfishly) or even hostile toward members of other groups. There is much empirical evidence for such a form of group-level altruism, and we will return to this phenomenon in detail in Chap. 11.

We can further distinguish between two forms of altruism in addition to the above distinction. In the first case, individual i cares only about other individual's well-being or consumption, regardless of how this well-being or consumption comes about. In the second case, individual i wants itself to be the one giving help, behaving cooperatively, etc. This second case is known as *warm-glow-giving*. The term is explained by the fact that the altruistic act generates a "warm glow" of feeling in the individual. Consider an example with three individuals, where individual 3 needs help (e.g., without help has zero consumption), which can be provided by individuals 1 or 2 (e.g., because they are endowed with positive quantities of the good). Warm-glow-giving then implies that it is important for individuals 1 or 2 to help themselves. Therefore, from the point of view of individual 1, it makes a difference whether it helps individual 3 herself, or whether individual 2 is the helper, even if individual 3 ends up with the same quantity of the good in each case. Empirical studies show that such a *warm-glow* effect is observable.

This distinction could be modeled formally, but we refrain from doing so here. For the empirical findings presented here, this distinction is also irrelevant. Altruism can explain positive offers in both the dictator game and the ultimatum game, but not the changing behavior in the prisoner's-dilemma game, nor the rejection of positive offers in the ultimatum game (individual 2 harms both of them by rejecting offers). However, this kind of behavior can be explained by the following model.

Social preferences can also include the case of antisocial behavior. The opposite of altruism is called spite and can be defined as follows:

▶ **Definition 10.6 Spite** An individual i is called *spiteful* if the first derivative of the utility function u_i with respect to x_j is always negative:

$$\frac{\partial u_i(x_i, x_j)}{\partial x_j} < 0.$$

A spiteful individual increases its utility when the quantities of goods consumed by other individuals decrease. We have thus captured the opposite of altruism, so to speak. Again, in principle, a distinction could be made according to whether the individual is concerned with making the other individual worse off itself (which might be called *warm-glow-taking*), or whether it is enough that the other individual is harmed for some reason.

How can spite explain the rejection of positive offers in the ultimatum game? Let us again look at a functional specification of the utility function and a situation where individual 1 has made an offer $(x_1, 10 - x_1)$. If individual 2 has a utility function $u_2(x_1, x_2) = x_2 - a \cdot x_1$, then the utility of rejecting an offer is equal to $u_2(0, 0) = 0$. On the other hand, the utility of accepting the offer is $u_2(x_1, 10 - x_1) = 10 - (1 + a) \cdot x_1$. This utility is less than or equal to zero exactly if $x_1 \geq 10/(1+a)$. For $a = 0$, individual 2 is selfish, and will accordingly accept all offers. As a increases, however, it becomes increasingly spiteful and therefore rejects better and better offers. If individual 1 knows this, even if it is selfish, it will always make an offer $x_2 = (10 \cdot a)/(1 + a)$ that will be accepted. The behavior looks altruistic, but it is not.

If individual 1 is altruistic, then depending on the strength of altruism, it will either offer $x_2 = (10 \cdot a)/(1 + a)$ (weak altruism) or even more (strong altruism).

If 1 is itself spiteful, it would like to offer $x_2 = 0$. This offer, however, faces the threat of rejection. Therefore, in the case of two spiteful individuals, an interesting situation may result. Suppose the utility function of 1 is $u_1(x_1, 10 - x_1) = x_1 - b(10 - x_1)$. Individual 1 must offer at least $x_2 = (10 \cdot a)/(1 + a)$ to not get rejected. Thus, the utility for this offer is equal to $10/(1 + a) - b \cdot (10 \cdot a)/(1 + a)$, and this expression is greater than or equal to zero if $1 - a \cdot b \geq 0$. When mutual spite is weak $(a \cdot b \leq 1)$, we observe that the minimum offer is made and accepted. However, if mutual spite is strong $(a \cdot b > 1)$, the only equilibrium is one where offers are made that get rejected. So both individuals go home with nothing. Overall, therefore, mutual spite better explains behavior in the ultimatum game than altruism. Altruism, in turn, explains behavior in the dictator game better than spite. Thus, we have not yet found a model that can fully explain the above experimental results.

10.3.4 Inequality Aversion

The definition of altruism and spite assume that the marginal utility of an individual i from the other individual j's consumption is always positive or negative. However, this need not be the case. And there is a class of models that explain cooperative and selfish behavior by *inequality aversion*. Here, the utility from a distribution of goods depends on how the goods are distributed between the individuals, as they do not like inequality. The behavioral motive here is not to help the other individual, as in the case of altruism, but to avoid too much inequality. The resulting behavior can be such that it looks as if the individual is locally altruistic (the other individual has less) or locally spiteful (the other individual has more).

We present two models with inequality aversion. In both cases, individuals care not only about the absolute amount of goods they get, but also about their amount of goods relative to other individuals. We assume two individuals i and j. In the first model, individuals care about their own consumption compared to *relative* consumption:

$$u_i(x_i, \sigma_i),$$

where $\sigma_i = x_i/(x_i + x_j)$ is the relative consumption of player i, and $\partial u_i/\partial \sigma_i \gtreqless 0$. For the case of an additive utility function $u_i(x_i, \sigma_i) = v_i(x_i) + w_i(\sigma_i)$, for example, a natural specification would be to assume $\partial w_i/\partial \sigma_i \gtreqless 0 \Leftrightarrow \sigma_i \lesseqgtr 1/2$. The first term captures the familiar selfish motivation, and the second term expresses inequality aversion.

A functional specification is $u_i(x_i, \sigma_i) = x_i - 2 \cdot (\sigma - 0.5)^2$. If we assume that individual 1 gets one unit of the good that it can distribute to both individuals, then $x_1 + x_2 = 1$, and utility simplifies to $x_1 - 2 \cdot (x_1 - 0.5)^2$. Determining the optimal allocation for 1, we obtain $x_1 = 0.75$: Individual 1 claims more than half for itself, but unlike in the case of selfish preferences, does not take the whole amount of the good.

We can therefore explain both, the empirical behavior in the dictator game, and the offers in the ultimatum game. But what about the rejection of positive offers in the ultimatum game? The utility of rejection is zero. Therefore, for an offer of 2 to be accepted, it must hold that $10 - x_1 - 2 \cdot ((10 - x_1)/10 - 0.5)^2 \geq 0$. We denote the critical value at which the left-hand side of the inequality is equal to zero by $\hat{x}_1$. Individual 2 will reject an offer if $x_1 > \hat{x}_1$. The term on the left is a quadratic equation whose positive root is $\hat{x}_1 \approx 9.58$. That is, individual 2 will reject any offer smaller than 0.42 because the inequality is perceived as being unacceptably large. Thus, the model is able to explain the behavior of both individuals in the ultimatum game.

The alternative model works similarly. There, it is assumed that preferences are given by a utility function

$$u_i(x_i, x_j) = x_i - \alpha_i \cdot \max\{x_j - x_i, 0\} - \beta_i \cdot \max\{x_i - x_j, 0\}.$$

The first term captures the selfish motive, and the following two terms capture inequality aversion. A distinction is made between advantageous and disadvantageous inequality. α_i and β_i are parameters expressing the intensity of inequality aversion when i has less (disadvantageous) or more (advantageous) of the good than j. It is usually assumed that $\beta_i \leq \alpha_i$: individuals care less about inequality when they are on the sunny side of the street. To better understand the structure of the utility function, we assume that $x_i > x_j$. In this case, the second term of the utility function is zero, and the marginal utility of i's income is $(1 - \beta_i) < 1$: Advantageous inequality dampens the marginal utility of the good by a factor β_i compared to selfishness. In the opposite case $x_j > x_i$, the third term is zero, and the marginal utility of the good of individual i is $(1 + \alpha_i) > 1$: Disadvantageous inequality makes additional quantities of the good more valuable than under selfishness because it helps the individual catch up to the other individual.

For two individuals, the two models do not differ in their qualitative predictions. Therefore, this model is also able to explain the behavior in the dictator and ultimatum games if the parameters α and β are adequately chosen.

If we look at the last two models, we can see that it can be problematic to give a motivational explanation to behavior like altruism, spite, or inequality aversion. What can be reconstructed as spite in the altruism-spite model appears to be as inequality aversion in the two models presented above. We could present many more results from experiments pointing in one direction, the other direction, or a different direction whatsoever, and no consensus emerges as to the correct comprehensive model of social preferences. Pareto's skepticism, discussed at the beginning of the chapter, about the integration of psychological elements into economics thus seems not entirely unwarranted, for once we start tinkering with the utility function, a great many explanations for the same behavior may be given, without ever being able to know whether we have found the right explanation. Concepts like altruism, spite, or inequality aversion are mental concepts that can never be conclusively inferred from behavior. And maybe it is also the case that there is not one right explanation, but that depending on the context, sometimes reciprocity, sometimes altruism, sometimes spite, sometimes inequality aversion, and sometimes something else entirely guides action.

10.3.5 Intention-Based Preferences

Finally, we want to deal with an example of cooperative behavior that cannot be explained by consequentialist but by deontological motives to act. We have introduced different ethical theories in Chap. 5 and have shown that the mainstream of normative economics is a special case of *consequentialism*. Thus, it is not surprising that cooperative behavior is mainly conceptualized in consequentialist terms in behavioral economics. And both, the altruism-spite, and the inequality-aversion models are consequentialist because the assume utility functions that evaluate the distribution of money or goods (which are consequences of behavior).

But this need not be the only motivation for individuals to cooperate with others, and there is a literature that focuses on the imputed *intentions* of another person. The idea is that one is willing to help people who have good intentions, regardless of whether the consequences of their actions are good or bad. This is a *deontological* explanation of cooperation, an example for which is Immanuel Kant's concept of morality that places the *good will* of a person center stage.

Here is an example. Suppose an acquaintance of yours donates his money to support a violent *coup d'état* that is universally condemned on moral grounds. Somehow, however, the money ends up at a charity that uses it to save children's lives. So, the consequences of the donation are good, which means that one would have to applaud the acquaintance's behavior on consequentialist grounds. However, most people would agree that this is not the right approach. They would argue that it is the acquaintance's intentions that should count in judging the behavior, and that your acquaintance had bad intentions.

If an individual has the willingness to behave cooperatively toward others if and only if it senses a good will in the other person, this is called *intention-based fairness*. Unfortunately, it is rather complicated to model this type of behavior formally as one needs to focus on the processes of expectation formation.

10.3.6 Conclusions

In this concluding section, we will discuss two more methodological issues that are important to better understand the relevance of the above theories.

External Validity Most of the empirical evidence that motivated the development of the models of individual decision-making presented in this section stems from experiments. It is therefore important to understand whether the behavior of individuals in the laboratory is representative of their behavior in real life. Three factors turn out to be important for the so-called *external validity* of behavior: (1) the amounts of money at stake, (2) the fact that study participants are aware that they are participating in a study and that their behavior is being observed by others, and (3) the contextual framing of the decision process.

We had already said something about point (1). (2) The fact that people are aware of the fact that they are participating in an experiment is a problem that distinguishes the social from the natural sciences. Particles in the laboratory are, as far as we know, unaware of the fact that they are participating in an experiment. In the social sciences, however, this is different. The philosopher Charles Sanders Pierce (1908) addressed the problem in the following way: "It is to the highest degree probable that the subject['s] [...] general attitude of mind is that of ready complacency and cheerful willingness to assist the investigator in every possible way by reporting to him those very things which he is most eager to find, and that the very questions of the experimenter [...] suggests the shade of reply expected [...]. Indeed [...] it seems too often as if the subject were now regarded as a stupid automaton." And indeed, evidence is found that cooperation decreases significantly when people feel unobserved. Another study compared the willingness to donate in the lab with the willingness to donate of the same people in real life. It turned out that individuals who had never donated to charity in the past were willing to give away 60% of their cash in the lab. And most individuals who gave away more than 50% of their endowment in the lab did not give to charity in the 2 years following the experiment. Such results raise important questions because observable cooperative behavior is clearly not based on a deeply embodied and context-invariant structure of preferences. What then, if not social preferences, do we measure in the laboratory? And what normative consequences follow from the fact that we can reconstruct behavior in the laboratory as the maximization of a particular utility function, but that this utility function is not uniquely determined? Every game in the laboratory is embedded in the "game of life" people play. Therefore, and following up on

(3), even if the experimenter tries to control as many aspects of the game in the laboratory as possible, she can never control the social embeddedness of the decision situation from the subjects' points of view. They bring their own lives and experiences to the lab, and that can be a problem when it comes to interpreting the results.

Human behavior is much more complex than the *rational-choice* model with selfish behavior suggests. At this stage, however, it would be premature to replace the traditional model of *homo oeconomicus* with a more complex model with different kinds of preferences and apply it to all kinds of decision problems. It is still too early to identify the contexts which specific forms of cooperative behavior guide actions.

Normative Implications The normative implications of our discussion of social preferences depend on whether individual preferences are correctly described by any of the above models, because in economics, efficiency, and welfare are measured in terms of these preferences. As we have seen before, different models of social preferences can explain the same behavior. The approach of inferring preferences from behavior leads to sufficient but not necessary conditions for a preference ordering. Therefore, a key problem is to justify the choice of any particular type of preference ordering to measure efficiency and welfare. But now that Pandora's box of different motives to act has been opened, it becomes clear that this problem is also relevant for preferences used in traditional theory.

Even if this problem of underdetermination did not exist and we could specify exactly one preference ordering that explains behavior and is used to measure well-being, an even more fundamental normative problem arose. As we have seen for the case of spite, there may be motives for action that are ethically problematic. But if this is so, the question arises whether they should be used to evaluate efficiency and well-being. We have seen that strong spite may imply that it can be better for both individuals to destroy everything, and this outcome is efficient. Are such motives to act legitimate? The economic mainstream has not had to face the question of ethically legitimate and illegitimate preferences, either because motives for action have been ignored or because selfish preferences have been assumed to be given. As has been shown, however, this is empirically wrong. Economist Kenneth Arrow (1983) summed up the problem: "[A] standard liberal point of view in political philosophy [. . .] asserts that an individual's preferences are or ought to be [. . .] concerned only with the effects of social action on him. But there is no logical way to distinguish a particular class of concerns which pertain to a given individual. If I feel that my satisfaction is reduced by somebody else's poverty [. . .], then I am injured in precisely the same sense as if my purchasing power were reduced. [. . .] The only rational defense of what may be termed a liberal position, or perhaps more precisely a principle of limited social preference, is that it is itself a value judgment. In other words, an individual may have as part of his value structure precisely that he does not think it proper to influence consequences outside a limited realm."

10.4 Boundedly Rational Behavior

In order to understand deviations from rational behavior, we shall first summarize how we have defined rationality so far. The assumptions relating to rationality underlying the preference-maximization model are the

(a) *transitivity* of preferences,
(b) *maximization* of preferences, and
(c) *consistency* of interest and behavior

in general decision problems (see Chap. 7), and the

(d) *independence* of preferences, and
(e) *continuity* of preferences,

in choice problems under risk (see Chap. 8). Finally, underlying these assumptions is the

(f) *invariance* of preferences.

This property seems to be so self-evident that it is usually not stated as an explicit assumption. It means that the specific formulation of a choice problem should not affect behavior if the real consequences are unaffected by the formulation. For example, it should be irrelevant whether a person is first given a choice between A and B and then a choice between the preferred alternative and C, or if it has first the choice between B and C and then a choice between the preferred alternative and A.

In order to be able to prove deviations from these standards of rationality and to understand them in their structure, the literature usually assumes that individuals have selfish preferences in the relevant decision situations. This occurs as an auxiliary assumption but is not itself part of the concept of rationality. In experiments, this auxiliary assumption can be controlled by designing choice situations that are unrelated to other people, so that social preferences (even if they exist) cannot play a role.

10.4.1 Prospect Theory

With and after the development of the expected-utility theory presented in Chap. 8, the theory was seen both as a normative reference point of rational behavior and as a positive theory of human behavior under risk and possibly also uncertainty (if one accepts Laplace's principle of insufficient reason, see Chap. 8). However, as we have already seen with the Allais paradox, it became clear quite quickly that the explanatory power is restricted. In particular, through work by Daniel Kahneman and Amos Tversky (among many others), it became clear over the years that people deviate not only sometimes and unsystematically, but regularly and systematically from the behavioral hypotheses of expected-utility theory. With the knowledge of the systematic nature of the violations, a whole class of alternative positive theories was developed. The one that can most comprehensively integrate the empirical evidence and that has been widely accepted is *prospect theory*, which has been developed by Kahneman and Tversky. A more detailed account of the theory is warranted not only because of its importance, but also for methodological reasons, because one can learn how empirical evidence can be systematically used to develop a theory of decision.

For the formal presentation of the theory, we follow up on Chap. 8 and make the simplifying assumption that there are only three possible outcomes c_1, c_2, c_3 that occur as a result of the possible strategies $s_i \in S$ with probabilities p_{i1}, p_{i2}, p_{i3}. And unless otherwise stated, the outcomes are monetary payoffs. Prospect theory is based on five key insights.

- People evaluate outcomes not in absolute terms, but relative to a *reference point*. This reference point expresses what a person considers normal or adequate in a situation. Deviations from this state of normality are then interpreted as gains or losses. Thus, if outcome c_2 is perceived as a reference point (e.g., an expected wage), and $c_1 < c_2 < c_3$ holds, then realizing outcome c_1 would be a loss ($c_1 - c_2 < 0$) and realizing outcome c_3 would be a gain ($c_3 - c_2 > 0$) relative to reference point c_2. (In the first case, a lower than expected wage is offered, and in the second case, a higher than expected wage is offered.) It follows that people do not use utilities for the evaluation of outcomes. Rather, the evaluate the difference between the actual outcome and the reference point. These relative evaluations are given by *subjective values* v. They are defined on the differences $c_1 - c_2$, $c_2 - c_2$, $c_3 - c_2$, such that $v(c_1 - c_2) < v(c_2 - c_2) = v(0) \equiv 0 < v(c_3 - c_2)$. These subjective values assume the role of the Bernoulli-utility function of expected-utility theory.

  Kahneman and Tversky (1979, p. 277) see this relative valuation as an example of a basic evolutionary principle of human perception and valuation: "An essential feature of the present theory is that the carriers of value are changes in wealth or welfare, rather than final states. This assumption is compatible with basic principles of perception and judgment. Our perceptual apparatus is attuned to the evaluation of changes or differences rather than to the evaluation of absolute magnitudes. When we respond to attributes such as brightness, loudness, or temperature, the past and present context of experience defines an adaptation level, or reference point, and stimuli are perceived in relation to this reference point. Thus, an object at a given temperature may be experienced as hot or cold to the touch depending on the temperature to which one has adapted. The same principle applies to non-sensory attributes such as health, prestige, and wealth. The same level of wealth, for example, may imply abject poverty for one person and great riches for another-depending on their current assets." In Chap. 11 we will discuss the dopamine system as an example which illustrates how such relative evaluations are encoded in the brain.

- Reference points are formed both, by a process of cultural expectations, norms, external guidelines, past experiences, etc., and by an initial examination of the concrete decision problem. During this examination, a *mental model* of the decision problem is formed. In general, a difference exists between an actual decision problem and a person's perception of it. This difference is ignored in traditional theories. But it turns out that this neglect obstructs an understanding of the rules of construction and simplification that people use to make sense of a problem. And these rules turn out to be relevant to explaining behavior.

  The creation of such a mental model is partly active and conscious, partly automatic and unconscious. The reference point is one part of the mental model. These models are not objective or identical between individuals but can differ between persons. The formation of a mental model is also about reduction of complexity, which is necessary to make a decision problem manageable. Therefore, there is also no objective reference point in a decision situation that is identical for all individuals. It will rather depend on personal experience, etc.

  Once a person has constructed an acceptable mental model, this is usually used and retained even if new information arises that could justify an update. This is called *acceptance*.
- If losses or gains are evaluated asymmetrically, people are risk-averse toward gains and risk-loving toward losses. Moreover, they put more weight on losses than on gains. This is called *loss aversion*.
- People do not use probabilities even in situations where objective probabilities exist. Rather, they behave as if they perceive them in a systematically distorted way. This phenomenon is called *decision weighting*. Thus, in the above example, if a strategy s_i is associated with the probabilities p_{i1}, p_{i2}, p_{i3}, there exists a function π mapping probabilities onto decision weights $\pi(p_{i1}), \pi(p_{i2}), \pi(p_{i3})$, that with few exceptions differ from probabilities, $\pi(p_{ij}) \neq p_{ij}$ These decision weights, like all other elements of the theory, are part of the mental model and are action-guiding.
- A decision is understood as a two-stage process in which the mental model is created in a first phase (*editing phase*) and a decision is made based on this model in a second phase (*evaluation phase*). However, this two-stage process is not to be understood descriptively (as a description of actual problem-solving processes), but methodologically.

Once a mental model has been created in the editing phase, it results in a so-called *value function* for each possible lottery from which an individual can choose. Let the outcome c_2 be the reference point in our three-outcomes example $c_1 < c_2 < c_3$. In this case, the following value function results:

$$V(p_{i1}, p_{i3}, c_1, c_2, c_3) = \pi(p_{i1}) \cdot v(c_1 - c_2) + \pi(p_{i3}) \cdot v(c_3 - c_2).$$

This value function takes the role of the expected-utility function. It is used to evaluate the alternatives or lotteries in the evaluation phase. The behavioral hypothesis is that an individual chooses the alternative or lottery from the set of all possible alternatives or lotteries that maximize the value function.

Summing up all these elements, it is not surprising that prospect theory can explain behavior that systematically contradicts expected-utility theory. But how does one come to construct such a theory? With expected-utility theory, the approach was simple: postulate "plausible" assumptions about rational behavior under risk and see what these assumptions imply. The approach in developing prospect theory was different. There, attempts have been made to incorporate as many empirical observations as possible into the model in order to make it fit the observations. During this development, expected-utility theory played an important role as a reference point of its own right from which empirically observable behavior could be better interpreted and classified.

Many of the deviations from the model of rational behavior become apparent when we look at how a mental model emerges in the editing phase. We will first deal with this phase. One of the central empirical findings is that numerous and at first sight irrelevant phenomena have a decisive influence on the mental model. Classical decision theory starts with a given mental model, which is identical for everyone and with the real decision situation. Therefore, it is blind to the fact that mental models are constructions. Most people intuitively share this view and are not aware of the construction of their own mental models (or even the fact that they perceive reality through the filter of such a model). This is called *naïve realism*.

Here is an example showing that people regularly violate the assumption of invariance. In one experiment, participants were asked to imagine making preparations for the outbreak of an unusual disease that, without further action, was expected to kill 600 people. Two alternative programs to control the disease were proposed.

Problem 1

A With probability 100%, 200 people will be saved.

B With probability 33.3%, 600 people will be saved and with probability 66.7%, no one will be saved.

Participants were then asked to choose one of the two alternatives. The vast majority (72%) chose Program A. Another group was offered the following alternatives:

Problem 2

C With probability 100%, 400 people will die.

D With probability 33.3%, no one will die and with probability 66.7%, all people will die.

The vast majority (76%) chose program D. However, the pairs *A* and *C* as well as *B* and *D* are identical with respect to their consequences. They differ only in the narratives, which accentuated either survival or death. When different ways of presenting otherwise identical alternatives lead to changes in behavior, this is called a *framing* effect.

In another study, physicians were asked whether they would treat a form of cancer with radiation therapy or surgery. In the first version of the choice problem, the alternatives were:

Problem 3

A Surgical intervention has an immediate survival probability of 90%, a 1-year survival probability of 68%, and a 5-year survival probability of 34%.

B Radiation therapy has an immediate survival probability of 100%, a 1-year survival probability of 77%, and a 5-year survival probability of 22%.

In a second variant, the alternatives were:

Problem 4

C 10% die during the surgical intervention, 32% die during the first year, and 66% die during the first 5 years after treatment.

D No one dies during radiation therapy, 23% die during the first year, and 78% die during the first 5 years after treatment.

Again, both choice problems are identical in terms of consequences, but the choice behavior differed significantly. In Problem 3, 18% chose radiation therapy, and in Problem 4, 44% chose radiation therapy. The participants were physicians.

The effect also occurs for decisions about money. In another experiment, participants were presented simultaneously with two pairs of lotteries, and they had to choose their preferred ones. The first pair was:

Problem 5

A A profit of $240 with probability 100%.

B A profit of $1,000 with probability 25%, or a profit of $0 with probability 75%.

84 % of participants chose A. Since the expected value of B is $250, risk aversion is present here. The second pair was:

Problem 6

C A loss of $760 with probability 100%.

D A loss of $1000 with probability 75%, or a loss of $0 with probability 25%.

87% of participants chose D. Since the expected value is $750, risk loving is present here.

This behavior alone is not a violation of expected-utility theory because risk attitude is defined locally, not globally. However, since the four lotteries were presented *simultaneously*, one can infer a preference of A and C over B and D.

Because of simultaneity, it follows from the independence axiom that the choice of A, C and B, D must be equivalent to the choice between the combined lotteries AC and BD, which are as follows:

Problem 7

AC A gain of \$240 with probability 25%, or a loss of \$760 with probability 75%.
BD A gain of \$250 with probability 25%, or a loss of \$750 with probability 75%.

But BD dominates AC, so it is rational to choose B and D together, rather than A and C. It follows that either independence or invariance are violated here. Apparently, it is only in the aggregate representation that the participants realized what the overall consequences of their behavior were.

This behavior reveals a general feature of mental models: participants considered both problems separately, activated a gain frame with corresponding behavior in Problem 6 and a loss frame with corresponding behavior in Problem 7, resulting in corresponding behavior. However, the overall consequences of the two choice decisions were ignored. This phenomenon is called *segregation*. In contrast, the independence axiom implies that people will always aggregate different lotteries into one overall representation. Humans can do this in principle, but apparently they do not do so intuitively.

10.4.1.1 The Structure of Subjective Value Functions

The assumption that individuals behave in a risk-averse manner for gains and in a risk-loving manner for losses entails, that the value function v is s-shaped and that it has a point of inflection at 0. Loss aversion, moreover, means that it is *ceteris paribus* steeper for losses than for gains. Figure 10.3 shows an example.

This structure has been derived from numerous empirical studies. An example of such a function is

$$v(x,r) = \begin{cases} (x-r)^{\alpha} & \text{for } x \geq r, \\ -\lambda \cdot (r-x)^{\alpha} & \text{for } x < r. \end{cases}$$

r is the reference point to which payoffs x are related. If $x \geq r$ holds, the subjective value of x is equal to $(x-r)^{\alpha}$, where $0 < \alpha < 1$ ensures that the function represents risk aversion. For $x < r$, the subjective value of x is equal to $-\lambda\,(x-r)^{\alpha}$, where the constraint on α now ensures that the function represents risk loving. The parameter $\lambda > 1$ measures loss aversion. To see this, we assume identical gains $(x-r)$ and losses $(r-x)$. If λ were equal to one, we would get $-v(x-r) = v(r-x)$. Multiplication by a term larger than 1 ensures that $-v(x-r) > v(r-x)$ holds, defining loss aversion.

We have already learned about the s-shape of the subjective value function in the analysis of Problems 5 and 6. The following experiment demonstrates the

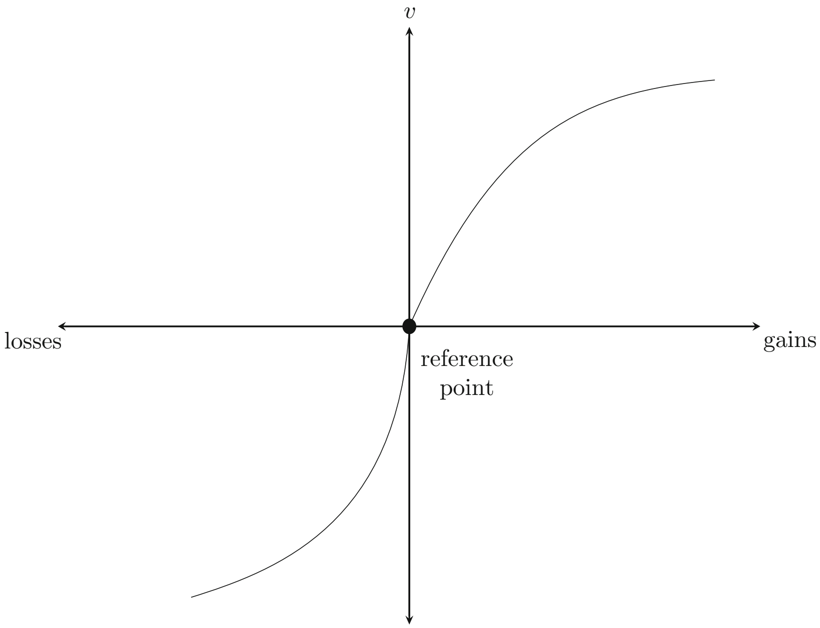

Fig. 10.3 Subjective value function

effect again and also makes clear how *framing* can shift a reference point. Again, participants had the choice between two pairs of lotteries. The first pair was:

Problem 8
Suppose you are \$300 richer than you actually are. Choose from the following two alternatives:

A A profit of \$100 with probability 100%.
B A gain of \$200 with probability 50%, or a gain of \$0 with probability 50%.

72% of participants chose alternative A. The second pair was:

Problem 9
Assume you are \$500 richer than you actually are. Choose from the following two alternatives:

C A loss of \$100 with probability 100%.
D A gain of \$0 with probability 50%, or a loss of \$200 with probability 50%.

64% of participants chose alternative D. It is straightforward to see that Alternatives A and C and B and D are identical in terms of consequences. Thus, an expected-utility maximizer should be indifferent between the two. The difference in behavior can be explained if one assumes that the different framings of Problems 8 and 9 activated different reference points, leading to different perceptions of gains and losses and thus different behavior.

Digression 10.2 (Framing and Narratives)
Narratives, the stories that we tell, play an important role in determining reference points. For example, it has been shown that naming a price change as a discount or a surcharge makes a difference. It is easier for people in an otherwise equal situation to refuse a discount than to accept a surcharge, because the price difference is perceived as a gain in the first and as a loss in the second situation. We see the same mechanism in wage negotiations. Workers are significantly more willing to accept nominal-wage increases below the inflation rate (and thus real-wage cuts) in periods of high inflation than to accept nominal-wage cuts leading to the same real-wage cut in periods of low inflation. In the first case, the nominal-wage increase is apparently perceived as a gain; in the second case, the nominal-wage cut is apparently perceived as a loss, although the effect on real wages is identical.

10.4.1.2 The Structure of Decision Weights

We have already said that individuals generally do not rely on probabilities p when making decisions, but instead replace them with decision weights $\pi(p)$, even when the probabilities are objective and given in the experiment. Empirical studies show that the function $\pi(p)$ has the following properties.

1. $\pi(0) = 0$ and $\pi(1) = 1$: impossible outcomes are not weighted and certain outcomes are also considered certain.
2. For small probabilities (greater than zero), probability weights are larger than probabilities, $\pi(p) > p$. The reverse is true for large probabilities (less than one), these are underweighted.
3. Decision weights are *subadditive*, $\pi(p) + \pi(1-p) < 1$. This also means that, unlike probabilities, decision weights do not necessarily sum to one.
4. Decision weights are *subproportional*, $\pi(p \cdot r)/\pi(p) < \pi(p \cdot q \cdot r)/\pi(p \cdot q)$. The property states that for any ratio of probabilities r, for small probabilities the ratio of decision weights is biased upward and for large probabilities the ratio of decision weights is biased downward.

Figure 10.4 shows a weighting function that satisfies these assumptions.

How do you come up with these properties? Here are two experiments that illustrate the properties.

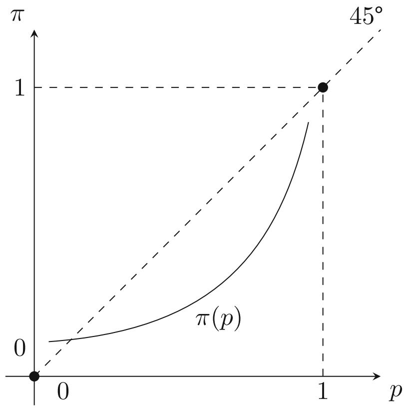

Fig. 10.4 Example of a weighting function

Problem 10
Suppose there are marbles of different colors in a box. Depending on which color you draw, you win or lose money. You have the choice between the following two boxes:

A (90% white, win $0); (6% red, win $45); (1% green, win $30); (1% blue, loss $15), (2% yellow, loss $15).
B (90% white, gain $0); (6% red, gain $45); (1% green, gain $45); (1% blue, loss $10), (2% yellow, loss $15).

The expected payoff for Box B is higher than the expected payoff for Box A, and the probabilities for the different colors are identical. Therefore, Box B dominates Box A. And 100% of the participants in fact chose Box B.

Here comes a variation of the situation, where colors that lead to identical payoffs are combined (for A these are blue and yellow, for B these are red and green). Nothing else changes.

Problem 11
C (90% white, gain $0); (6% red, gain $45); (1% green, gain $30); (3% yellow, loss $15).
D (90% white, gain $0); (7% red, gain $45); (1% green, loss $10), (2% yellow, loss $15).

Fewer options exist with this framing, but one can no longer readily see the dominance of D. 58% of participants chose Box C this time. If one compares the decision between A and B and C and D, one again finds a violation of invariance. This can only happen with biased decision weights.

The structure of the decision weights shown in Fig. 10.4 points to a discontinuity at the edges $p = 0$ and $p = 1$. The transition from certainty to uncertainty leads to small changes in probabilities but to large changes in the decision weights. This can also be justified experimentally. In the following experiment, participants had to choose in three different choice problems presented to them in the following order:

Problem 12
Choose one of the following two alternatives:

A A profit of $30 with probability 100%.
B A gain of $45 with probability 80%, and a gain of $0 with probability 20%.

78% chose alternative A, 22% chose alternative B.

Problem 13
Choose one of the following two alternatives:

C A gain of $30 with probability 25%, and a gain of $0 with probability 75%.
D A gain of $45 with probability 20%, and a gain of $0 with probability 80%.

58% chose alternative D, 42% chose alternative C.

Problem 13 is generated from Problem 12 by reducing the probability of winning a positive prize by a factor of 4. Since this is done for both alternatives, it follows from the independence axiom of expected-utility theory that a preference for A must imply a preference for C, and that a preference for B must imply a preference for D. This is not found to be true in the experiment.

How can we tell that the independence axiom is violated? If we assume that $u(0) = 0$, it follows from Problem 12 that A is preferred to B if and only if $0.8 \cdot u(45) < 1 \cdot u(30)$ holds. And it follows from Problem 13 that D is preferred to C if and only if $0.2 \cdot u(45) > 0.25 \cdot u(30)$ holds. The second inequality is obtained by dividing the first inequality by 4, violating the independence axiom.

This inconsistency is called the *certainty effect* because going from a situation of certainty (i.e., 100%) to 25% has a larger effect than going from 80% to 20%. The discontinuity and subproportionality of the decision weights can explain this behavior. The certainty effect is also responsible for the Allais paradox, which we have discussed in Chap. 8.

The next experiment exposes yet another facet.

Problem 14
Consider the following two-stage game. In the first stage, the game ends with probability 75%, and you win $0. With probability 25%, you reach the second stage. There you have the following choice between the following two alternatives:

E A win of $30 with probability 100%.
F A gain of $45 with probability 80% and a gain of $0 with probability 20%.

You must make your decision before stage 1.

74% chose alternative E and 26% chose alternative F. Since the decision must be made before stage 1, it follows again from the independence axiom that C and E and D and F must be perceived as being indifferent, because the sequential structure of Problem 14 does not affect expected utility. As can be seen from the results, participants behaved differently. Rather, their behavior resembles that in Problem 12, which corresponds to the second stage of the game in Problem 14. It looks like they only refer to this second stage of the game when evaluating their options and ignore that it is embedded in a first stage. And there is a certain option in stage 2. This behavior is also called *pseudo-certainty effect* because the perception of the problem (one ignores stage 1) creates a feeling of the existence of a certain alternative, but this is not the case at all at the time of the decision.

One gets an idea of how mental models can arise when comparing Problems 12–14: In this example, an aspect of reality that is relevant from the point of view of expected-utility theory is suppressed, which implies that people solve a simpler but incorrect (in the sense of expected-utility theory) problem. We have already encountered a related phenomenon in the discussion of Problem 7, segregation. However, since the overall problem is not decomposed into simpler subproblems here, but the embeddedness of a subproblem in a relevant bigger problem is neglected, this effect is called *suppression*.

The following weighting function is frequently used in formal models of prospect theory:

$$\pi(p) = \frac{p^\gamma}{\left(p^\gamma + (1-p)^\gamma\right)^{\frac{1}{\gamma}}}.$$

This function satisfies all the assumptions made above except for the discontinuity around the extreme points $p = 0$ and $p = 1$. The parameter γ can be used to specify how much the weighting function differs from the probabilities. Kahneman and Tversky (1992) assessed it to be in between 0.61 and 0.69. This weighting function coincides with probabilities at three points: at $p = 0$, $p = 1$, and (because of its continuity) $\hat{p}$. For $p \in (0, \hat{p})$, it is larger, and for $p \in (\hat{p}, 1)$, it is smaller than p. For the estimated value of $\gamma = 0.61$, $\hat{p} = 0.34$. Figure 10.5 illustrates this function.

10.4.1.3 Applications

A Simple Investment Problem To illustrate the behavioral implications of prospect theory, let us look at the following investment problem. Suppose that an individual with wealth $m = 1{,}000{,}000$ is faced with the decision to invest an amount $a = 100{,}000$ in risky stocks. After one period, the value of the stocks is equal to 150,000 with probability $p = 0.6$, and it is equal to 50,000 with probability $p = 0.4$. Alternatively, the individual can invest the same amount at an interest rate of 0 in safe bonds, so that at the end of the period it will get back the amount $a = 100{,}000$ with probability $p = 1$. One can now determine the lotteries for both alternative investments, which are $\mathcal{L}_1 = \{(1{,}050{,}000, 0.6); (950{,}000, 0.4)\}$ for the stocks and $\mathcal{L}_2 = \{(1{,}000{,}000, 1)\}$ for the bonds.

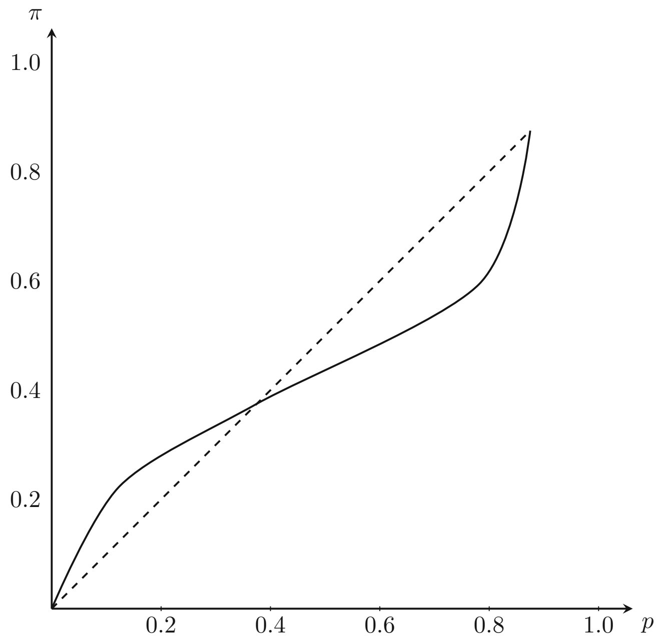

Fig. 10.5 A weighting function

Suppose first that the individual maximizes its expected utility with Bernoulli-utility function $u(x) = x^{0.5}$. It follows that it will invest in stocks if and only if

$$0.6 \cdot (1{,}050{,}000)^{0.5} + 0.4 \cdot (950{,}000)^{0.5} \geq (1{,}000{,}000)^{0.5} \Leftrightarrow 1{,}004.7 \geq 1,000$$

is fulfilled, which is the case in the example. The individual is risk-averse, but because of the high wealth (and the associated flat curvature of u in this domain) and the higher probability of a profit, it is nevertheless attractive to invest in the risky stocks.

Let us now assume that the individual has a reference point (for reasons unexplained) $r = m = 1{,}000{,}000$, so that all wealth smaller m is perceived as loss and all wealth larger m is perceived as gain. The subjective values of the three possible net-wealth positions are then $v(1{,}050{,}000 - 1{,}000{,}000) = v(50{,}000)$, $v(1{,}000{,}000 - 1{,}000{,}000) = v(0) = 0$, and $v(95{,}000 - 1{,}000{,}000) = v(-50{,}000)$.

Thus, the value function for an investment in stocks is equal to

$$V_1 = \pi(0.5) \cdot v(50{,}000) + \pi(0.5) \cdot v(-50{,}000).$$

And for an investment in bonds it is equal to

$$V_2 = \pi(1) \cdot v(0) = 0.$$

Thus, the individual will invest in stocks if and only if

$$\pi(0.5) \cdot v(50{,}000) + \pi(0.5) \cdot v(-50{,}000) \geq 0$$

is fulfilled. Let us consider the value on the left-hand side of the inequality for the functional specification of a subjective value function introduced earlier. With this functional specification we get

$$\pi(0.6) \cdot (50{,}000)^{\alpha} - \pi(0.4) \cdot \lambda \cdot (50{,}000)^{\alpha} = (\pi(0.6) - \lambda \cdot \pi(0.4))\,(50{,}000)^{0.5}.$$

This expression is larger than or equal to zero if and only if $\pi(0.6) - \lambda \cdot \pi(0.4) \geq 0$, which is equivalent to

$$\lambda \leq \frac{\pi(0.6)}{\pi(0.4)}.$$

Assume for the moment that the decision weights correspond to the probabilities. Then, the above inequality simplifies to $\lambda \leq 1.5$ holds. This condition defines a critical value of loss aversion. If loss aversion is relatively weak ($\lambda \leq 1.5$), the risky investment in stocks is preferable. If, on the other hand, loss aversion is more pronounced ($\lambda > 1.5$), the potential losses of the risky investment are so important that the individual prefers the safe investment. The ratio $\pi(0.6)/\pi(0.4)$ changes the critical value for λ in this example, but otherwise the intuition remains the same.

The Disposition Effect The theory can also be used to explain the so-called *disposition effect*. The effect refers to the tendency to sell assets that have increased in value and retain assets that have decreased in value. According to expected-utility theory, only the expected future utility is relevant for a decision to buy or sell, but not events from the past, unless information about future prices can be derived from past price developments. An explanation of the disposition effect would then imply, however, that past increases in prices increase the probability of future decreases in prices and *vice versa*. Thus, the disposition effect is compatible with expected-utility theory only under very special assumptions.

Consider the following example, in which we assume that past have no effects on future prices (such a phenomenon is also called a *random walk*). To be more specific, a stock rises or falls by an amount L in each period with probability 50%. An individual bought the stock at a purchase price of P in period $t-1$. Two cases can occur in period t.

- The price decreases to $P - L$. We call such a stock a *loser*. The individual has two options: It can sell the stock at $P - L$ or it can keep the stock. If the stock is kept, the price in period $t+1$ can again decrease or increase with probability 50% to either $P - 2 \cdot L$ or P.
- The price increases to $P + L$. We call the stock a *winner*. The individual has again two options: It can sell the stock at $P + L$ or it can keep the stock. If the stock is

kept, the price in period $t + 1$ can again decrease or increase with probability of 50% to either P or $P + 2 \cdot L$.

We assume that the purchase price P of the stock is the reference point for the individual from which gains and losses are determined, and we consider the decision problem at the beginning of period t for the two possible cases *loser* and *winner*.

- For the *loser* case, selling is perceived as a loss of L, which has a subjective value $v(-L)$. If the individual keeps the stock and its price increases in $t + 1$, the difference between the purchase and selling price is zero, so that a subjective value $v(0) = 0$ is attributed to this state. In case that the price decreases again in $t + 1$, the difference between purchase and selling price is $-2 \cdot L$, so a subjective value $v(-2 \cdot L)$ is attributed to this state. In summary, the individual will keep the stock if and only if

$$\pi(0.5) \cdot v(-2 \cdot L) + \pi(0.5) \cdot v(0) = \pi(0.5) \cdot v(-2 \cdot L) \geq v(-L)$$

  is satisfied. Let us assume that $\pi(0.5) = 0.5$. Since $-L = 0.5 \cdot (-2 \cdot L) + 0.5 \cdot 0$ is equal to the expected loss, the expression on the left-hand side is equal to the expected subjective value if $\pi(0.5) = 0.5$, and the expression on the right-hand side is equal to the value of the expected loss. Given a risk-loving attitude (we are in the domain of losses), the inequality must be satisfied so that the individual keeps the stock. However, $\pi(0.5) = 0.5$ is not given in general. However, as long as $\pi(0.5) < 0.5$, the decision does not change.
- For the *winner* case, selling the stock is perceived as a gain of L, which has a subjective value of $v(L)$. If the individual keeps the stock and the price increases again in $t + 1$, the difference between the purchase and the sales prices is $2 \cdot L$, to which a subjective value $v(2 \cdot L)$ is attributed. If the price of the stock goes down in $t + 1$, the difference between purchase and sales price is 0, so a subjective value $v(0) = 0$ is attributed to this state. In summary, the individual will sell the stock if and only if

$$\pi(0.5) \cdot v(2 \cdot L) \leq v(L)$$

  is satisfied. As before, assume that $\pi(0.5) = 0.5$. Since $L = 0.5 \cdot (2 \cdot L) + 0.5 \cdot 0$ is equal to expected gain, for $\pi(0.5) = 0.5$ the expression on the left-hand side is equal to the expected subjective value and the expression on the right-hand side is equal to the value of the expected gain. Because of risk aversion (we are in the realm of gains), the inequality must be satisfied, so the individual sells the stock. Again, as long as $\pi(0.5) < 0.5$ holds, the decision does not change.

Thus, we have derived an explanation for the disposition effect: the reference point creates a specific perception of gains and losses, which leads to the fact that, unlike in expected-utility theory, decisions are determined not only by expectations about the future, but also by the past by its influence on the reference point.

We had argued that the reference point is not objective but depends on what an individual considers "normal." Therefore, we modify the above example to in order to better understand the effect of the reference point on behavior. Instead of the purchase price P we now assume that the sales price is used as reference point. An implication is that the reference point becomes contingent on the development of prices. For a *winner* stock, the reference point is $r_g = P + L$, and for a *loser* stock, the reference point is $r_L = P - L$. What does this modification imply for the perception of gains and losses?

- Let us start with the *winner* stock. Three financial positions can occur, $P + 2 \cdot L$ (the price increases in $t + 1$), P (the price falls in $t + 1$), and $P + L$ (the stock is sold in t). Together with reference point r_g, the subjective values of these states are $v(P + 2 \cdot L - (P + L)) = v(L)$, $v(P - (P + L)) = v(-L)$, and $v(P + L - (P + L)) = v(0) = 0$.
- Let us now turn to the *loser* stock. Again, there can be three financial positions, P (the price increases in $t + 1$), $P - 2 \cdot L$ (the price falls in $t + 1$), and $P - L$ (the stock is sold in t). Together with reference point r_L, the subjective values are $v(P - (P - L)) = v(L)$, $v(P - 2 \cdot L - (P - L)) = v(-L)$, and $v(P - L - (P - L)) = v(0) = 0$.

Comparing the two cases, we see that the new contingent reference points result in identical perceptions of gains and losses across the two states. Therefore, the decision problem is identical in both cases. The individual should sell the stock if and only if

$$\pi(0.5) \cdot v(L) + \pi(0.5) \cdot v(-L) \leq v(0) = 0 \Leftrightarrow \pi(0.5) \cdot (v(L) + v(-L)) \leq 0$$

is satisfied. Therefore, the decision depends only on the sign $v(L) + v(-L)$. However, this is always negative due to loss aversion. Therefore, the individual would always sell the stock in this case.

10.4.1.4 Summary

We have seen that prospect theory adheres to the assumption that individuals maximize an objective function. Therefore, the systematic locus for the identification of boundedly rational behavior is the editing phase in which a mental model is created in the process of which—as we have seen—violations of the other rationality assumptions can occur. We have identified violations of invariance, continuity, and independence. This does not mean, however, that the other rationality assumptions are not affected. Rather, it cannot be ruled out that, for example, intransitive decisions result as a consequence of violations of the other assumptions. Problems 10 and 11 have even shown that individuals violate the dominance principle if the problem is not presented in such a way that dominance is directly apparent.

In the editing phase, simplifications such as the aforementioned segregation or suppression are applied. However, there is no one-size-fits-all procedure of creating mental models. There are patterns (such as those just named), but people are different; the process of *framing* in creating a mental model is complex and individual-specific. Therefore, no formal and complete theory of the editing phase exists. Rather, there are conceptual ideas coupled with specific modeling assumptions. This underdetermination of the theory leads to the problem that the theory may explain *too much*, since one can develop a mental model for arbitrary types of behavior from which these behaviors can be consistently derived. Thus, the theory would no longer be falsifiable without further constraints. At the same time, however, it must be accepted that people are different in creating mental models, so that an exploration of the rules and patterns of these models becomes an important focus of attention for further research.

We will discuss two additional important implications of the theory in greater detail. First, the implications of prospect theory for our understanding of the functioning of markets, and second the implications of the theory for our normative understanding of rationality as well as the efficiency of markets.

Let us first turn to the functioning of markets. As we have seen from the two examples on investment problems, prospect theory may differ from expected-utility theory in terms of predicted market behavior. This may not be surprising, since it was constructed to accommodate behavioral anomalies that exist in standard theory. But nonetheless, the empirical evidence on which it is built did not come from real market contexts, so it is initially unclear whether it is relevant outside the laboratory. Therefore, the two simple theoretical examples of investment problems give an indication that the two theories also differ in terms of their predictions about how real, i.e., stock-, markets work. However, empirical studies involving real market behavior are difficult because one must assume heterogeneity among market participants and individual behavior cannot be readily observed in stock markets. Therefore, there is always the possibility that *individual* effects cancel when aggregated into market supply and demand functions. Nevertheless, empirical evidence exists for the presence of the disposition effect (see Weber & Camerer, 1998 for a review). One study was able to analyze 10,000 individual records of *discount brokers*. Weber and Camerer (1998, p. 169) summarize the findings as follows: “Several different tests all show disposition effects, and all the effects are hugely significant because of the large samples and independence across investors. Investors hold losers longer (a median of 124 days) than they hold winners (104 days). Across the entire year, investors realize about 24% of the gains they could realize by selling, but they realize only 15% of their losses.” The authors conducted a complementary experimental study that comes to the same conclusion. This and other evidence let us conclude that prospect theory must play an independent role in the positive analysis of markets and the prediction of market behavior.

It does not follow, however, that the standard model fails in its predictive content in all markets and on all occasions. We had seen that the complexity of a situation plays an important role in explaining rational behavior (see Problems 10 and 11). Therefore, in simple and repeated situations where learning is possible, we can expect the mental model to be fairly accurate. Kahneman and Tversky (1986, p. 274) summarize as follows: “The assumption of the rationality of decision-making is often defended by the argument that people will learn to make correct decisions and sometimes by the evolutionary argument that irrational decision makers will be driven out by rational ones. There is no doubt that learning and selection do take place and tend to improve efficiency. [. . .] Effective learning takes place only under certain conditions: it requires accurate and immediate feedback about the relation between the situational conditions and the appropriate response. The necessary feedback is often lacking for the decisions made by managers, entrepreneurs, and politicians because (i) outcomes are commonly delayed and not easily attributable to a particular action; (ii) variability in the environment degrades the reliability of the feedback, especially where outcomes of low probability are involved; (iii) there is often no information about what the outcome would have been if another decision had been taken; and (iv) most important decisions are unique and therefore provide little opportunity for learning [. . .]. The conditions for organizational learning are hardly better." We expressed this view in Principle 5 at the beginning.

Let us now turn to the normative understanding of rationality as well as the efficiency of markets. From its very beginnings, expected-utility theory has played a dual and not always unambiguous role as both, a positive theory of behavior *as well as* a normative theory of rational (and thus *desirable*) behavior. The fact that people do not behave according to expected-utility theory in a lot of real-world situations does not, therefore, deprive it of its role as a normative yardstick. If we use it as a standard of rationality, prospect theory plays an important role in identifying behaviors that one would like to avoid, and also their causes. For example, one can imagine that problems resulting from the use of decision weights $\pi(p)$ can be in principle mitigated by delegating decisions to algorithms programmed to use the correct probabilities p. And one can, as we addressed in Principle 6, in principle infer a need for government regulation that has the purpose to bring individuals in line with rational behavior through incentives, nudges, and framing. We have addressed some of the potential problems with this legitimation of government intervention before, so we will leave those problems as they are for now. (However, one should keep in mind that not only the government, but also individuals, firms, or other actors who understand the structure of mental models can use this knowledge to influence individual decisions by creating incentives, nudges, and framing.)

As the economic-policy debate regarding the legitimacy of nudging shows, we have lost the central result of normative economics, the First Theorem of Welfare Economics (perfectly competitive markets are Pareto-efficient, see Chap. 5). The violations of the assumptions of rationality cast into doubt that we can count on consistency, the fact the individuals always act in accordance with their self-interest. Prospect theory puts this assumption in serious jeopardy. For example, if people violate the dominance principle, can they still be said to behave in their best interest? If one wants to reconcile the consistency assumption with the results of prospect theory, one is forced to accept any mental model on which a person (implicitly) bases its decisions as a meaningful measure of his or her well-being. However, the ways these models are constructed makes this conclusion not very plausible. If one agrees, one can no longer assume that even competitive markets are always and everywhere Pareto-efficient.

But a broader question arises as well: If the behavioral implications of rationality assumptions are in general at odds with human behavior, do we not have to think again about the status of this specific understanding of rationality? In what sense are these assumptions normatively justified? Why should we be convinced that orienting individual behavior and economic policy toward rationality in this sense promotes well-being in society? We will deal with this question at the end of this chapter. Before that, however, let us briefly look at two additional biases.

10.4.2 Anchoring

The *anchoring effect* is a cognitive bias that describes the tendency to rely too heavily on the first phenomenon to come to mind (the 'anchor') when making decisions. Anchoring occurs when individuals use some initial phenomenon that catches their attention to make subsequent judgments. These anchors may be causally completely unrelated to the decision problem, so they provide no relevant information. Therefore, they should play no role in rational decision-making. Once an anchor is set, other phenomena are interpreted around the anchor. For example, the initial price offered for a car may influence the price paid at the end. The tendency for anchoring seems to be a structural property in the formation of mental models.

Here is an example of how the way a problem is framed influences the answer. Asking first whether Gandhi was older than 114 when he died and then asking his exact age at death yields higher estimates than asking first whether he was older than 35 when he died. This phenomenon seems to result from the use of heuristics that have a tendency be influenced by the first phenomenon available in situations with uncertainty. The anchor acts as a reference point. Does anchoring also influence economic decisions? In an experiment, MBA students could buy a bottle of wine. In a first step, they were asked whether they would be willing to pay a price corresponding to the last two digits of their social-security number. In a second step, they were then asked about their actual willingness to pay. According to the classical understanding of rationality, the social-security number should have no influence on the willingness to pay. In the experiment, however, this proved to be wrong. It turned out that students whose social-security number ended with a number less than 50 reported a willingness to pay that was far below the willingness to pay of students whose social-security number ended with a number larger than 50. The average willingness to pay of the first group was €11.62, whereas the second group was willing to pay €19.95 on average. Apparently, it is enough to recall the social-security number to change the willingness to pay of a person.

Since we are dealing with a decision problem under certainty in this experiment (the possible uncertainty about the quality of the wine is assumed to be negligible), we may be dealing with a violation of transitivity, maximization, invariance, and/or consistency here, unless we want to assume that participants actually want to tie their willingness to pay to their social-security number (and thus their different willingness to pay indicates that their preferences are conditional on that number and therefore rational). With only two alternatives, one cannot directly test for transitivity. Using the methodological approach of prospect theory, one would therefore suspect a violation of consistency or invariance, and invariance is probably the right candidate here. Thus, the anchoring effect adds to our skepticism regarding the Pareto-efficiency of markets.

The anchoring effect also occurs on financial markets, but as we have seen, it plays an important role in everyday decisions. Therefore, it can be used to explain a number of marketing strategies such as arbitrary rationing: Customers buy on average more units of a good if the retailer imposes a (high) maximum sales constraint than if he does not.

10.4.3 Confirmation Bias

The *confirmation bias* describes the behavior of selectively seeking, interpreting, and preferring information that confirms and supports one's beliefs or values. We can also see it as an element of mental models. This bias allows it to better understand a whole range of social phenomena. It arises unconsciously and cannot be completely avoided. However, it can be controlled through an awareness of its existence and critical reflection. Controlling the confirmation bis requires to overcome naïve realism, the tendency to think that reality and perception of reality are the same. One has to be willing to see one's mental models as constructions to be critically scrutinized.

We find one of the first references to confirmation bias in the English philosopher Francis Bacon (1620/1939, p. 36): "The human understanding when it has once adopted an opinion [...] draws all things else to support and agree with it. And though there be a greater number and weight of instances to be found on the other side, yet these it either neglects and despises [...]; in order that by this great and pernicious predetermination the authority of its former conclusions may remain inviolate."

An example for the tendency to prefer information that supports one's opinion comes from Lord et al. (1979). In an experiment, participants who were either supporters or opponents of the death penalty were presented with two constructed but real-looking studies. One study appeared to confirm the deterrent effect of the death penalty, and the other appeared to refute it. It was found that in each case, participants found the study that reinforced their original opinion more convincing. It was also found that participants applied higher standards of evidence to the study that contradicted their opinion.

Another study (Westen et al., 2006) was conducted during the 2004 U.S. presidential election. Participants (who were either strongly leaning towards either George W. Bush (Republican candidate) or John Kerry (Democratic candidate) were given the task of judging the consistency of statements made by the two candidates or a neutral figure. These statements were potentially contradictory and threatening to the candidates. It was found that participants were much more likely to rate the statements of the political opponent as contradictory than the statements of their own candidate. This effect did not occur when judging statements attributed to the neutral control person. Furthermore, the control persons' statements were rated identically by Democrats and Republicans. This variant of the confirmation bias is called *motivated reasoning*.

During the task, brain activity was recorded in an MRI scanner. Here, among many other results, a typical picture emerged when the participants were confronted with the contradictions of their own candidate: There was activation of brain regions correlated with negative emotions (e.g., the amygdala) and of brain regions that play an important role in emotion regulation (e.g., the ventromedial prefrontal cortex). The contradictions apparently generated some kind of emotional fear or pain response that was contained by affect control.

The confirmation bias may contribute to explaining some of the polarization processes we are currently observing in a lot of societies. People frame facts, theories, and evidence to fit their opinions. They tend to take confirming evidence at face value and to look for even the faintest weakness when confronted with conflicting evidence. Combined with group behavior (see the notion of parochial altruism in this chapter and in Chap. 11) and reinforced by the logic of social-media algorithms, this can quickly result in polarizations in a society. But it can also play a role in market contexts: if one has intuitively decided on one of two products, one will asymmetrically evaluate further evidence that speaks for or against the purchase.

In this context, no one is immune to the confirmation bias, and it is found in science as well. Two studies of scientific peer-review procedures found that scientists evaluated studies more positively that were consistent with their initial beliefs compared to studies contradicting them (Koehler, 1993; Mahoney, 1977). Nevertheless, science is the sphere of society that arguably offers the greatest protection against confirmation bias through its methods and procedures.

One might think that confirmation bias is an inefficient learning strategy that comes with a number of disadvantages. As one's worldview becomes more and more distant from reality, there is increasing risk of making wrong decisions. And there is indeed potential evidence for the use of inefficient learning strategies. Wason (1960) asked participants in an experiment to find the mathematical rule behind a given sequence of numbers. The experimenter chose a sequence of three numbers (for example, $(2, 4, 8)$). Subsequently, the participants had to form a hypothesis regarding the rule used and, on the basis of this rule, form further sequences. These were presented to the experimenter, who then confirmed the consistency or non-consistency of this new sequence with the rule he had used. Importantly, the experimenter used the rule 'the numbers must be increasing.'

As it turned out, most participants developed further sequences of numbers that were consistent with their first hypothesis that most of the time was something like "double the preceding number." They did not experiment with further hypotheses that were consistent with the previous sequences of numbers and would have allowed to actively falsify the first hypothesis. Since any sequence of three numbers can be consistent with a very large set of rules, sticking to the first hypothesis that comes to mind made it impossible to find the correct rule. Any sequence of numbers $(x, 2 \cdot x, 4 \cdot x)$ confirms the original hypothesis and is consistent with the experimenter's rule. Thus, the participants created sequence after sequence, all these sequences got confirmed, but they were nevertheless unable to find the correct rule.

Whether the strategy of forming more number sequences corresponding to the original hypothesis is reasonable, however, cannot be readily answered. It is a simple heuristic among others that may or may not be effective depending on the problem to which they are applied. The heuristic applied in the experiment is called *positive confirmation*. The difficulty of *positive confirmation* in the example is that the rule to be found is so general. In terms of optimal learning theory, one would like to use a learning heuristic that maximizes the information content of the answer. The information content of a heuristic depends on the exact circumstances. Suppose there were a set of possible rules R and a set of possible sequences S. In Wason's study, the subset of sequences S^r that matched the rule to be found was relatively large. Therefore, *positive confirmation* does not have a high information content, since it cannot be easily falsified (see Chap. 1). However, this heuristic may well have high information content if the subset of sequences S^r corresponding to the rule to be found is small. In this case, the reverse heuristic of looking not for positive confirmation but for *negative confirmation* would not be very useful because there are so many possible negative confirmations. So, now this alternative heuristic is not very useful.

This observation opens a new perspective on confirmation bias, biases, and mental models more generally: whether they are functional or dysfunctional depends on the circumstances under which they are applied. It therefore suggests itself to ask the question of rationality or irrationality more generally. Classical decision theory assumes that there are universal standards of rational or irrational behavior. We see from this example, however, that such universalism may not be appropriate. We deal with this conjecture in the following section.

10.5 An Evolutionary Perspective on Biases and Rationality

The results of behavioral economics raise profound questions about the motivation and rationality of behavior. In this section, to put the results into a larger context, we will explore the question raised earlier about how exactly to justify the reference point necessary to define a bias.

As stated earlier, the usual reference point is rational behavior, often coupled with selfishness. Rationality has so far been justified theoretically by the plausibility of the assumptions defining it, and bounded rationality—as a deviation from the standards of rationality—has been implicitly classified as a bias. We now approach the question of the normative justifiability of the reference point from a different perspective and develop an argument from evolutionary biology that helps us to better understand which kinds of behavior are likely to emerge in a process of adaptation and selection.

To do so, two concepts from evolutionary biology must be introduced. From an evolutionary perspective, humans can be understood as impulse-response mechanisms that arose through adaptation to their respective environments. From an evolutionary point of view, the *ultimate level of explanation* is genetic adaptation and the *proximate level of explanation* is the behavioral patterns (*traits*) of an individual (its preferences). We will argue, as is standard in the literature on evolutionary biology, that the behavioral traits we will be focusing on have been selected long enough to be successful adaptations into their environments.

This approach has the advantage that it can assess behavioral traits from a different angle: their contribution to the survival of genes or humans as carriers of genes. Thus, we are creating a necessary change in perspective that allows it to ask and answer the question whether economic rationality is adaptive or not which, in a second step, allows it to discuss the relationship between reference point and bias more generally. And indeed, we will find that many of the behaviors usually considered biases in behavioral economics are reasonable adaptations within their evolutionary contexts. This finding highlights the importance of the reference point in defining a bias and, more generally, calls into question the approach of identifying this reference point with a particular ideal of rationality without further justification.

One can distinguish three different views on biases.

- *Heuristics:* Here, a *bias* arises due to evolutionary constraints on information processing that are unavoidable due to scarce resources. The emerged heuristics function reasonably well within the environments and contexts for which they were selected (in terms of passing on genetic information). If they are used outside of these contexts, they can be systematically maladaptive.
- *Artifacts:* With the context-dependence of the adaptive value of heuristics, a problem arises for the classification of research findings. Apparent *biases* can be artifacts of research strategies in the sense that the experiment presents a context that differs from the context in which a human makes decisions or the contexts in which these heuristics evolved. These strategies include formats (e.g., on a computer in a laboratory rather than in daily life) as well as content (e.g., abstract descriptions rather than concrete real-life experience) of the experiments. Such deliberate deviations from the context of life may be important or inevitable for the identification of biases. However, the question remains whether the biases remain in real-life contexts. We have introduced the term of *external validity* before to highlight this problem, and we are now in a position to more systematically look into it.
- *Error-management bias:* People, like all organisms, make errors, and errors are associated with costs. If error costs vary, there is selective pressure to bias perception and behavior toward the less costly errors. The effect is that the net probability of making errors increases at the same time as the net costs of decision-making decreases. Hence, in the presence of asymmetric error costs, optimal decision rules do not minimize errors and are biased in this sense. Haselton and Nettle (2006) write in this regard: “We have reviewed a large number of cases where apparently irrational biases in cognition are explained by the existence of asymmetric error costs and significant uncertainty. Thus, bias in cognition is no longer a shortcoming in rational behavior, but an adaptation

of behavior to a complex, uncertain world. Biased mechanisms are not design defects of the human mind, but rather design features. [...] [I]t seems likely that the mind is equipped with multiple, domain-specific cognitive mechanisms, with specific biases appropriate to the content of the task and the particular pattern of costs, benefits, and likelihoods." Such *biases* are therefore adaptive to the underlying error costs, but they can become dysfunctional when the error costs shift. We will develop this idea in a formally precise way.

We will discuss error-management biases in more detail below, assuming that the reference point for behavior underlying behavioral economics is rational preference maximization in the sense of Assumptions a-f from before, so that a bias describes a systematic deviation from these assumptions.

At this point, a remark is necessary. The ultimate adaptivity of traits does not imply that they are normatively justified simply because they are adaptive. No one would voluntarily lead a live that is devoted to the procreation of one's genes. Such a position is sometimes called *social Darwinism* and is rejected in ethics as a legitimate justification for behavior. We will return to this important issue later.

From the point of view of ultimate adaptivity, one has to understand the survival value of each different trait. Rational preference maximization can be considered a trait because it leads to specific patterns of interaction with the environment. We can therefore make the following classification.

1. The trait "rational preference maximization" may turn out to be ultimately adaptive. In this case, a bias is maladaptive at the ultimate and irrational at the proximate level.
2. Rational preference maximization may turn out to be maladaptive at the ultimate level. In this case, a bias could be adaptive at the ultimate level and nonetheless be classified as irrational at the proximate level. In this case, a fundamental debate regarding the appropriateness of the reference point cannot be avoided.
3. Rational preference maximization as well as a bias can be maladaptive at the ultimate level. As before, this raises the question of the normative appropriateness of the reference point.

Having gotten to this point, we see that the question of rationality gets a different meaning. Indeed, it becomes visible that rationality is not an abstract property, that can be defined without reference to the environment in which a person acts and the normative purposes and goals of behavior. The potential maladaptation of the trait "rational preference maximization" makes clear that the whole idea of rationality can only be addressed when it is seen as a means towards the end of a person's successful interaction with an environment. And success, as a normative concept, must have something to do with human flourishing, happiness, the good life.

In order to answer the question about the possible adaptive value of a bias, one can refer to a *signal-extraction model*. The starting point is a so-called *null* *hypothesis* about a state of the world. Against the background of this null hypothesis, the following four cases are possible:

- the hypothesis is true and accepted (TP, *true positive*),
- the hypothesis is false and not accepted (TN, *true negative*),
- the hypothesis is true and not accepted (FP, *false positive*),
- the hypothesis is false and accepted (FN, *false negative*).

Given these possibilities, we can link behavior to the assessment of a situation. Here is an example. A hungry person sees a food in front of him, which he may or may not eat. The four cases are: TP: the food is healthy and is judged to be healthy, TN: the food is contaminated and is judged as being contaminated, FP: the food is healthy and is judged as being contaminated, FN: the food is contaminated and is judged to be healthy. The main point is that the (evolutionary) costs and benefits of the four possible cases may differ. We capture this idea with so-called net-fitness effects:

- net-fitness effect of TP: v_{TP},
- net-fitness effect of TN: v_{TN},
- net-fitness effect of FP: v_{FP},
- net-fitness effect of FN: v_{FN}.

Net-fitness effects should be considered comprehensively, including all types of behaviors in dealing with a situation (like eating the food or not) and their effects (replete and sick, replete and healthy, hungry and healthy). For example, one could assign the following values to the different outcomes (v_{TP} is normalized to 100, because only the relative ranking with the other outcomes is relevant): $v_{TN} = 50$ (the person stays healthy but hungry), $v_{FP} = 50$ (the person stays healthy but hungry), $v_{FN} = -50$ (the person gets sick).

In many everyday situations, biased signal evaluation is common, and the determination of an optimal bias is a central issue in hypothesis testing. In so-called *hazard-detection systems*, false negatives (no warning even though a danger exists) are typically more costly than false positives (false alarm). An example is a fire alarm when the null hypothesis is that there is no fire. In this case, a false negative (no fire alarm, there is a fire) and a false positive (fire alarm, there is no fire) are having different costs. Given that false negatives and false positives cannot be avoided, one would bias such a system towards false positives.

As can be seen, the “bias” is a deliberate property of an optimally designed hazard-detection system, not a bug. If we transfer this intuition to evolutionary processes, one can use it as an analogy about the selection of behavioral ‘biases’. Examples are coughing (one coughs even if nothing has entered the trachea to avoid missing a particle that can harm the bronchi or lungs) or fear (one feels fear (including the behaviors attached to it such as caution) even if there is nothing threatening out there to avoid missing a threatening situation). Therefore, the general hypothesis is that asymmetric net-fitness effects would be expected to bias a system toward the less costly error.

To make this idea formally precise, let s be a true state of the world and S be the hypothesis that s is the true state of the world. Then we get the following logical structure of the four cases from above $TP : S \wedge s$, $TN : \neg S \wedge \neg s$, $FP : S \wedge \neg s$, $FN : \neg S \wedge s$. The problem one has to solve is to determine the amount of evidence required to believe in hypothesis S. Let e be a measure of the available evidence supporting s and $p(e|s)$ be the probability that e is observed if s is the true state of the world. By the same token, $p(e|\neg s)$ is the probability that e is observed if $\neg s$ is the true state of the world. Uncertainty then means that $p(e|s) > 0 \wedge p(e|\neg s) > 0$.

In order to be able to derive the optimal rule for accepting S, we need a definition of bias in this context.

▶ **Definition 10.7 Unbiased decision rule** A decision rule is *unbiased*, if it maximizes the proportion of true hypotheses.

Suppose that the *a-priori* probabilities for s and $\neg s$ are equal. It then follows that S is accepted if and only if $p(e|s) > p(e|\neg s)$, or $p(e|s)/p(e|\neg s) > 1$ holds (the so-called *likelihood ratio* is larger than one). For general *a-priori* probabilities it generalizes to $p(e|s)/p(e|\neg s) > p(\neg s)/p(s)$ holds.

As mentioned earlier, such a rule need not be optimal. The general fitness function is

$$
\begin{aligned}
E[V] = p(s) \cdot (p(S|s) \cdot v_{TP} + p(\neg S|s) \cdot v_{FN}) \\
+ p(\neg s) \cdot (p(\neg S|\neg s) \cdot v_{TN} + p(S|\neg s) \cdot v_{FP}) .
\end{aligned}
$$

The decision rule that maximizes this objective function was determined by Green and Swets (1966, pp. 21–23) and has the following form: Accept S, if and only if

$$
\frac{p(e|s)}{p(e|\neg s)} > \frac{p(\neg s) \cdot (v_{TN} + v_{FP})}{p(s) \cdot (v_{TP} + v_{FN})}
$$

is satisfied. The optimal decision rule is biased if the right-hand side of the above inequality is different from 1. What can be said about this inequality? The optimal decision rule has and upward- (downward-) if and only if $(v_{TN} + v_{FP}) > (<) (v_{TP} + v_{FN})$.

A number of biases have to do with avoidance. They vary a theme succinctly summarized by Lima and Dill (1990): "Few failures are as unforgiving as failure to avoid a predator:" It is often less harmful to perceive a non-dangerous situation as dangerous than a dangerous one as non-dangerous. Here are some examples:

- Our fear-reactions (like the fight-and-flight response) can be quickly triggered. The cost of FP (fear although the situation is harmless) is lower than the cost of FN (no fear although situation is dangerous).
- Food aversions. The cost of FP (avoidance of healthy food) is generally lower than the cost of FN (sickness due to toxic food).

- Overattribution of causality. The cost of FP (assumption of a causal relationship between two unrelated events) is often lower than the cost of FN (assumption that two causally related events are unrelated).
- Assumption that third parties have a negative attitude against oneself. The cost of FP (assumption that third parties have negative attitudes, although this is not true) is often lower than the cost of FN (assumption that third parties are neutral or friendly, although this is not true).
- Illusion of control and self-efficacy. The cost of FP (assumption that one has agency in a situation, although this is not true) is often lower than the cost of FN (assumption that one does not have agency in a situation, although one does).
- Positive illusions regarding one's future. The cost of FP (optimism regarding, e.g., one's future health, even though this is unfounded) is often lower than the cost of FN (pessimism regarding, e.g., one's future health, even though this is unfounded). This is called *optimism bias*.

At this point, it may appear that we are dealing with a paradox, since there seems to be overpessimism and overoptimism at the same time. Haselton and Nettle (2006), however, see this apparent paradox as a core of adaptive behavior: "The two different smoke detector biases predicted by [the theory] – excessive sensitivity to potential harms coming from outside and excessive optimism about benefits that can be obtained by the self – predict that reasoning in domains controlled by the self may display different biases to reasoning in domains beyond the self's control. This is the essence of the paranoid optimism phenomenon, predicting paranoia about the environment but optimism about the self."

What follows from all this for the question of the relationship between rationality, adaptivity, and bias? Economic standards of rationality are properties at the proximate level of explanation. It is unclear whether these are adaptive from an ultimate level. Many behaviors that appear to be biases from the point of view of economic rationality could be adaptive from an ultimate perspective. Rather, the above argument suggests that biases in this sense are the rule rather than the exception. Cosmides and Tooby (1994) summarize this idea: "'Rational' decision-making methods [...] logic, mathematics, probability theory [...] are computationally weak: incapable of solving the natural adaptive problems our ancestors had to solve reliably in order to reproduce. [...] This poor performance on most natural problems is the primary reason why problem-solving specializations were favored by natural selection over general-purpose problem-solvers. Despite widespread claims to the contrary, the human mind is not worse than rational [...] but may often be better than rational."

Here is an example. Expected-utility theory presupposes a sharp divide between cognitive and affective mechanisms of the brain. Bernoulli utilities are proxies for experiential phenomena like feelings, whose correlation with consumption or other activities is taken as given. On top of that are probabilities that are conceptualized as cognitive processes like the calculation of frequencies, etc. This divide is partly preserved in prospect theory as the value function keeps the basic structure of expected utility and merely replaces Bernoulli utilities with subjective values and probabilities with decision weights. There is empirical evidence that the dichotomy between probabilities/decision weights and Bernoulli utilities/subjective values is wrong, and this evidence tells us something about economic rationality. The optimism bias tells us that people, on average, have an overly rosy perception of their future which must be reflected in probabilities or decision weights. This bias qualifies as a violation of economic rationality. Alloy and Abrahamson (1979) have argued that people who suffer from mild forms of depression (dysphoria) make more realistic inferences (in terms of probabilities/decision weights) about the future than non-depressive (nondysphoric) individuals, which links the affective (Bernoulli utilities/subjective values) with the cognitive experience of reality. In experiments, dysphoric individuals were better able to assess their degree of control over a task while nondysphoric individuals suffered from an illusion of control. They made more accurate self-ratings about their performance in completing a task, and they could more accurately infer attributional patterns in social events. In this latter study, participants were confronted with 80 sentences describing 40 positive (e.g., ‘A friend sent you a postcard.’) and 40 negative (e.g., ‘A friend ignored you.’) social events. Participants were asked to imagine the event happening to them and select the most likely cause (self (internal), another person/situation (external)). Nondysphoric participants showed a self-serving bias and attributed too many evens on themselves, whereas dysphoric participants demonstrated a balanced attributional pattern. Given that the average person is nondysphoric, is seems as if evolutionary forces have favored the selection of a bias where people feel irrationally happy. And most people would probably agree that if there is a trade-off between rationality and hedonic well-being, a nondysphoric mindset with distorted perception serves them better than a dysphoric mindset with a more accurate perception of reality.

An important part of what we call progress is a gradual or disruptive process of changing the environments in which we live, so the adaptivity of our behavioral and perceptual dispositions cannot be taken for granted. Rather, a guiding hypothesis must be that perceptual and behavioral dispositions are adaptive whenever they encounter environments similar to those in which they were selected. From this perspective, a hypothesis can be formulated about the identification and structure of many biases discussed in the literature: a bias is the result of a mismatch between the behavioral and perceptual repertoire of a person and the environment in which it acts. Mistakes become more likely when a person is confronted with an environment that is unfamiliar to him. Perceptual and behavioral dispositions that are no longer adapted in this environment continue to have an effect: “We occupy a world that is governed by novel economic rules, and knowledge of the ways in which our evolved psychology causes us to behave in ways that contrast with our self-interest in light of these rules should prove substantively important to human happiness.” (Haselton and Nettle 2006, p. 742).

Suppose we had clearly demonstrated that a trait that is in conflict with economic rationality is adaptive. At that point, at the latest, the fundamental question would arise as to what criteria one applies to justify a normative standard of rationality. A normative *justification* differs methodologically and conceptually from a scientific *explanation*. Justification and explanation must be neatly separated if only to avoid naturalistic fallacies (see Chap. 1). Hence, adaptivity in itself is no normative justification for any kind of behavior, and except in exceptional cases, people would not accept genetic adaptivity as a normative goal on the basis of which—if this were possible—biases can be explained and at the same time evaluated and corrected by means of economic policies like nudging.

What can be inferred, however, from the above line of reasoning is the need to think about adequate normative concepts of rationality at a fundamental level. And it also became clear that a meaningful concept of rationality must be derived from the tension between the objectives of people (like having a meaningful life, being happy, …) and the environment in which they live. And such a concept cannot be merely a form of instrumental (means-end) rationality, but relates to questions regarding the structure of preferences, and even more fundamentally, to the question of what reasons we have for accepting preferences and only preferences as a measure for well-being and human flourishing.

To summarize, behavioral economics has opened an important door to a better understanding of human behavior. Many of the identified peculiarities of human beings—whether classified as boundedly rational behavior or as social preferences—allow us to understand the complex background and processes of human behavior much better than the model of homo oeconomicus. Following Ockham's razor (see Chap. 1), the ultimate test of behavioral economics as positive science is the extent to which it is able to make more accurate predictions about behavior and the functioning of markets as well as other institutions than theories with the simpler model of homo oeconomicus. This, as we have seen, has succeeded time and again. However, if one integrates these insights into a normative theory, fundamental questions arise about how we justify the benchmark against which we measure biases. At this point, as we have seen, behavioral economics has so far been unconvincing, since it generally invokes the standard of rational behavior of the homo oeconomicus model without further justification.

The door pushed open by behavioral economics allows fascinating and important insights into human behavior. At the same time, one sees other doors in the room of behavioral economics that lead not back to homo oeconomicus, but to spaces where, for example, results from neuroscience or narrative psychology allow even more fundamental insights into human behavior, perception, and well-being. The rich rewards of entering the room of behavioral economics should encourage us to pass through these doors as well and see what else we can learn in the next rooms. This brings us back to the introductory quote from Dan Ariely: "Wouldn't economics make a lot more sense if it were based on how people actually behave, instead of how they should behave?" We will deal with this in the following Chap. 11.

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11 Foundations of Perception and Decision-Making

This chapter covers · · ·

- insights from evolutionary biology, neuroscience, and psychology about human behavior, perception, and adaptation,
- a multilevel model of adaptation,
- how the human brain learns and adapts to its environment,
- important affective mechanisms,
- how the self is created as a process of narration,
- implications of these findings for the standard model of homo oeconomicus, and
- implications of these insights for a happy and fulfilling life and an economy supporting it.

11.1 Introduction

> [T]he horrific struggle to establish a human self results in a self whose humanity is inseparable from that horrific struggle. [. . .] [O]ur endless and impossible journey toward home is in fact our home. (David Foster Wallace Wallace 2011)

> To put it bluntly, the discipline of economics has yet to get over its childish passion for mathematics and for purely theoretical and often highly ideological speculation, at the expense of historical research and collaboration with the other social sciences. [. . .] [Economists] must set aside their contempt for other disciplines and their absurd claim to greater scientific legitimacy, despite the fact that they know almost nothing about anything. (Thomas Piketty 2014)

The model of man underlying economics, which we discussed in Chap. 7, is parsimonious: both behavior and well-being can be derived from a preference ordering, which (for simplicity) can be represented by a utility function. And in the *revealed-preference* tradition, not even this preference ordering is taken as given, but it is merely assumed to be inferable from observed behavior. The reason for this

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parsimony has to do with scientific methodology. As we argued in Digression 7.1, traditional concepts of utility were based on unobservable speculations about brain or mental processes. Since most of these assumed processes were unobservable at the time, economists tried their best to rid their underlying decision theory of these speculations. Time has moved on, however, and the impressive advances that have been made in psychology, neuroscience, and evolutionary biology in recent decades call for a reassessment of the foundations on which economic decision theory rests.

This reassessment includes behavioral economics (see Chap. 10). For example, as we have seen, behavioral economics challenges the role of rationality and selfishness in explaining behavior and identifies specific properties of preferences (such as loss aversion or social preferences) that appear to be better able to explain behavior. What most of the literature maintains, however, is the assumption that there is such a thing as a stable preference ordering that can be inferred from observations and that this preference ordering does not change systematically over time. These assumptions lose some of their plausibility when we look at important findings from neuroscience and psychology.

The findings we will present in this chapter, however, primarily challenge normative economics. If one argues that the main purpose of positive economics is to make correct predictions about behavior, even if the models used are descriptively wrong (which they necessarily always are, see Chap. 1), the standard model of homo oeconomicus may be a good choice because it is a relatively simple and straightforward component of a theory that has the purpose to make predictions. The touchstone of such a theory is its empirical test, not the correctness of its assumptions. Following Occam's razor, it is only justified to switch to a more complex model if the predictive accuracy of alternative models of decision-making exceeds the predictive accuracy of the homo oeconomicus model. From a normative perspective, however, the underlying model of man is important as long as we use it to measure well-being in society.

The purpose of this chapter is mainly methodological: it challenges the model of man that we developed in Chaps. 7 and 8. But the purpose is not merely methodological. As you will see, the insights and patterns we present are interesting in themselves and allow us to better understand who we are and why we do the things we do. The model of man that will become visible at the end will likely have important implications for how we think about the economy and decision-making, even if an alternative normative theory is not yet fully developed.

The model of man we will develop has the following characteristic features:

- The brain and body are constantly learning and adapting into the respective environment, and adaptation occurs at many different levels. This challenges the notion that preferences are exogenous and stable over time.
- Behavior can be triggered by many different, interrelated, and coexisting processes. Therefore, behavior is likely to be less stable than implied by the assumption of a stable preference ordering, especially in new and unstable environments.

- Most of our daily behavior results from unconscious or semiconscious processes. We become aware of a situation only when it is new or surprising and important. This challenges the notion of rationality as a conscious, intentional choice between alternatives.
- Even when we become aware of a situation, our narrative understanding of a situation often follows from *confabulation*, a rationalization of feelings and behaviors in the form of stories. Confabulation also challenges the idea of rationality.

11.2 A Multilevel Model of Adaptation

From an evolutionary perspective, a species, as well as each of its members, is the result of an ongoing process of adaptation into its respective environment that is itself adaptive (that is, other living beings are part of that environment). Evolution is the result of three basic principles: (1) There are traits that are heritable. (2) There is variability in traits. (3) Some traits are more adapted to their environment than others. This implies that members of a species that share these traits can pass more copies to the next generation.

For our purposes, it is useful to distinguish between five levels of adaptation, *genetic*, *epigenetic*, *affective*, *cognitive*, and *metacognitive*, see Fig. 11.1. Human behavior, cognition, and well-being are determined by all the five levels.

This system of different interacting levels is not static. Humans have developed a remarkable ability to adapt to their environment, to protect themselves from threats, and to prosper. The basic mechanisms of adaptation and learning that occur within the lifespan of an individual are found in many animals, but they are particularly pronounced in humans. We adapt constantly by creating new memories, associating them with emotions or feelings, and using them to act or plan. Adaptation and learning are possible because the brain is plastic, which is a prerequisite for the ability to change behavior through adaptation. But adaptation is not arbitrarily

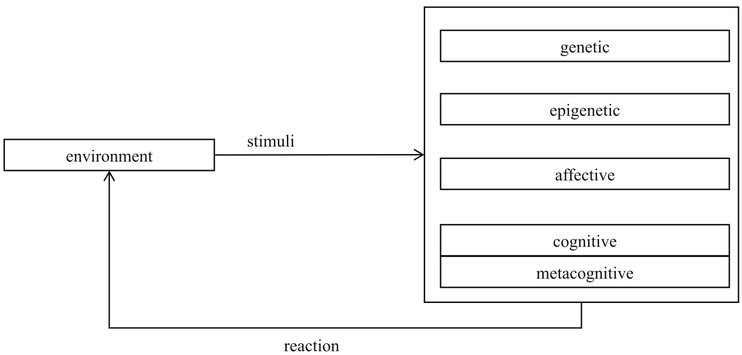

Fig. 11.1 Levels of adaptation

versatile. Even though the brain remains plastic into old age, new experiences build on older ones. And there are different mechanisms on which adaptation must rely, like nonassociative learning mechanisms (such as habituation and sensitization) or associative learning mechanisms (such as classical and operant conditioning). Nonassociative learning involves a relatively permanent change in the strength of the response to a stimulus due to repeated exposure to it. In the case of habituation, for example, the strength of the response decreases with repetition. Associative learning, on the other hand, is a process in which an association is made between two stimuli or a type of behavior and a stimulus.

The term *habit* refers to a stable pattern of behavior elicited by a *trigger* or cue. Normally, the process of habit formation is based on both associative learning, such as classical conditioning (the ringing of a bell signals a coffee break), and nonassociative learning, such as habituation (one more or less automatically goes to the coffee machine and has a coffee).

Habits are ubiquitous. It is the body's and brain's way of dealing with complexity as it recognizes patterns over time. The process of conditioning and habituation reduces the cognitive burden of decision-making and frees up resources to focus on other things. Sometimes the formation of new habits is the result of a conscious decision ("I want to learn how to play the guitar"), but most of the time new habits form without our knowledge and without a conscious decision. Habit formation is a default mode of the brain. Habits influence behavior regardless of whether we are aware of the experiences that formed those habits or whether we know that habits exist at all. These mechanisms of habit formation are automatic; we cannot prevent this type of learning. What we can do, however, is influence the habits we develop over time by consciously either seeking or avoiding certain experiences.

Not only is the process of habit formation one of the brain's default modes of dealing with complexity, habits of feeling and thinking also influence our conscious experience of reality and our preferences, as will become clear later. Few people are aware of the fact that the way one experiences reality is the more or less arbitrary and preliminary endpoint of a process of habit formation. Even when one is aware of this fact, it can be difficult to change habits when they are problematic or dysfunctional.

What is also striking is our ability to learn not only (in this broad sense) from good or bad experiences. We can also learn from cultural transmission. And this process of cultural transmission is not necessarily cognitive and conscious. Listening to stories or watching a movie, for example, can change one's affective experience of reality not only temporarily but also permanently, even if one is not aware that this kind of learning is taking place. This mechanism has a lot of potential advantages from an evolutionary point of view, as it becomes possible to learn from other people's experiences. However, the potential disadvantage is that affective memory also responds, for example, to invented stories and associates affects with imagined threats that do not exist in reality. This is because affective memories can be long-lasting, with the consequence that the "affective map of reality" that emerges from this process may not correspond to reality.

Another aspect of the process of learning by creating habits is that they become more automatic and unconscious over time. We will discuss both aspects of the process of habit formation later. Our brains are constantly trying to reduce the cognitive load of decision-making by developing routines that "sink" into the unconscious over time. The theoretical physicist Erwin Schrödinger (2015/1967) formulated very precisely the properties of this process in the form of a conjecture and in anticipation of later findings in neuroscience: "Any succession of events in which we take part with sensations, perceptions and possibly with actions gradually drops out of the domain of consciousness when the same string of events repeats itself in the same way very often. [...] The gradual fading from consciousness is of outstanding importance to the entire structure of our mental life, which is wholly based on the process of acquiring practice by repetition. [...] [C]onsciousness is associated with the *learning* of the living substance; its *knowing how* (Können) is unconscious."

If humans are constantly adapting to their environment, an important normative question is: are all adaptations equally conducive to a good life, or is it useful to distinguish between good and bad adaptations and habits? And this question raises the broader question of how to define and measure a well-adapted personality. Questions like these are standard in evolutionary biology and also in medicine but are foreign to mainstream economics. This follows because of the concept of exogenous preferences, which *by definition* are expressions of self-interest and well-being. In evolutionary biology, the reference point is adaptation: traits and behaviors are adaptive if they promote survival and reproduction. In medicine, the reference point is health: trauma, for example, is considered a disease because it makes it difficult for the sufferer to live a normal, happy life. Defining a reference point for a well-adjusted personality in economics, however, is much more difficult, and it is not the purpose of this chapter to address this issue. We will return to it, however, when we discuss virtue ethics later.

Although we do not specify what a good life actually is or could be and leave it to individuals to figure it out, we can note three possible reasons for the formation of habits that people might find problematic:

- If the individual experiences that shape the learning process are not representative of the environment in which one lives. The resulting habits may then lead to mistakes, an increased need for cognitive control and reduced well-being.
- The slowness and permanence of the learning process can lead to maladaptation in a world with a rapidly changing environment. In this case, the learning process always lags behind, and if it is slower than the changes in the environment, potential problems increase over time.
- A lack of knowledge about the long-term consequences of a behavior for health and well-being can lead to behaviors and over time habits that prove detrimental to well-being.

Digression 11.1 (Positive Psychology)
An example of how a concept of well-being and human development can be operationalized and used is *positive psychology*. Positive Psychology has the *PERMA* model at the core of its understanding of happiness, flourishing, and the good life. PERMA is an acronym for the five factors existential to a good life. The model states that (1) positive feelings, (2) engagement in fulfilling activities, (3) meaningful relationships with other people, (4) meaning and purpose, and (5) achievements and mastery are the key dimensions of a good life. Using this model, it is possible to conceptually understand and also measure the potential maladaptations mentioned above. Positive psychology is inspired by virtue ethics (see Chap. 5), to which we will return at the end of this chapter. One of the main points of virtue-ethical concepts of the good life is that human flourishing requires that one tries to actively influence the process of habit formation. From the perspective of human flourishing and happiness, the risks and rewards of this process of conditioning and habituation are obvious: we might develop habits that bind us once they become embodied. When these habits are well adapted to the environment, they play a positive role in a good life. However, when they are dysfunctional, they hinder it. We will return to this point at the end of the chapter.

11.2.1 Genetic Adaptation

Adaptation at the *genetic level* is a process that occurs between generations through sexual reproduction and mutation. Genetic mutations within the lifespan of a single individual are usually maladaptive. In what follows, we focus on a given individual and take as given the genetic makeup encoded in DNA. If genetic adaptation were the only mechanism by which adaptation to an environment could occur, behavior could be described by a fixed stimulus–response scheme containing at most stochastic elements. The assumption of exogenous preferences fits this model.

From the perspective of evolutionary biology, there must be adaptive advantages for organisms that have the ability to modify their stimulus–response schemes within a lifetime. The resulting flexibility may be advantageous in an unstable environment. If the environment were stable, genetic adaptation would lead to an optimally adapted organism in the long run. However, once the environment is constantly changing, faster adaptation processes may be advantageous and create room for behavioral change within the lifetime of an individual organism.

11.2.2 Epigenetic Adaptation

A very basic mechanism is *epigenetic adaptation*. Not all of the genes in the DNA are active, some of them are “switched on” and others “switched off” (which is referred to as *gene expression*). This mechanism does not change the DNA itself but determines its active and passive parts. The position of these gene switches is determined in part by environmental factors, implying that this is a learning mechanism that allows an organism to modulate the way it interacts with its environment. Diet, exposure to certain chemical elements, and other factors influence the position of gene switches, which in turn influences metabolism, behavior, and even conscious experience. In the following, we will give some important examples.

A variety of environmental influences affect gene expression, ranging from exposure to *in utero* stress to both maternal and paternal ages. In addition, recent research shows that the position of at least some gene switches is heritable. This means that the mother's environment can have an impact on the child's health, behavior, and cognition.

The mechanism of environment-dependent gene expression can have both positive and negative effects on an individual's well-being. Most of the current research focuses on negative effects on physical and mental health, such as the relationship between certain genes and the development of depression in adulthood after, for example, exposure to childhood maltreatment. The effects on physical and mental health range from increased propensity for addiction, anxiety disorders, increased likelihood of developing depression, and anxiety conditioning.

The importance of this adaptive mechanism is that it demonstrates that environmental factors have important and far-reaching consequences for physical and mental health, as well as for cognition (e.g., anxious or optimistic). The epigenetic effects of the environment on human health alone warrant inclusion of these effects in economic policy. But more importantly from the perspective of preference or utility theory, the epigenetic effects of behavior and perception show that what are called preferences are fundamentally endogenous and malleable at the epigenetic level. The way we think, feel, and behave is influenced not only by our genetic heritage but also by the epigenetic effects of our history and the history of our ancestors. If we want to identify the behavioral and perceptual consequences of our epigenetically calibrated DNA with preference orderings, we see that they are endogenous at a very fundamental level. The way reality is perceived (e.g., as threatening or not), the way we behave, and our associated well-being are, to a degree that is difficult to assess with the given state of research, consequences of the contingencies of our past.

If we identify behavior with interest, we implicitly assume that these contingencies are normatively irrelevant. But such a position is highly counterintuitive. Take psychological phenomena such as depression or post-traumatic stress disorder as (extreme) examples. Most people would agree that the sufferers' perceptions, as well as some aspects of their behavior, are not an expression of their true self-interest, but part of an underlying problem. And even focusing on less extreme examples, epigenetics challenges the idea that well-being can simply be identified with preference fulfillment; rather, the process of preference formation comes into view as a normative problem in its own right.

11.2.3 Affective Adaptation

The next level is *affective adaptation*. We distinguish between *emotions*, *feelings*, and *affects*. Emotions are physiological (including the brain) response mechanisms to external (e.g., food) or internal (e.g., thoughts of food) stimuli. Physiological changes can include muscle tone, heart rate, posture, blood pressure, etc. They are part of the body's regulatory system that helps an organism survive and reproduce. These response patterns are partly autonomous and given, partly the body and brain learn to associate certain stimuli with certain emotions and thus adapt to the environment.

Emotions, as adaptive response mechanisms, are *by definition* not conscious. Feelings, on the other hand, are. Feelings are the names we give to certain bodily response patterns when they cross the threshold of consciousness. Therefore, we experience feelings as conscious, mental concepts. And thus they have a narrative form (e.g., we use the word "love" for a particular set of bodily responses to a stimulus). Consequently, we cannot separate language and culture from feelings, and so we cannot separate the social conventions that shape language and the subtle layers of meaning associated with words, concepts, and so on. The implication is that feelings depend on culture.

The term affect encompasses both emotion and feeling. Affects belong to what can be called *approach* and *avoid mechanisms*. An organism must approach things like food and water, and an organism must avoid things like toxins, pathogens, and predators in order to survive and thrive. Also, in order to reproduce, it must attract and be attracted to members of the opposite sex. And it must seek and maintain group status.

Emotions are an important mechanism for determining an organism's behavior. And without the ability of the emotional system to adapt to the specific environment, it would be far less effective. Well-adapted emotions are a very effective way to interact with the environment. The organism does the right things (from the standpoint of survival or reproduction) automatically, usually unconsciously and almost effortlessly.

Many different emotions contribute to behavior and perception. We will discuss a selection of well-studied emotions that allow us to gain a deeper—albeit incomplete—understanding of the complexity of the factors that explain both.

11.2.3.1 Dopamine

Dopamine is related to expected and actual rewards. It is an important part of the approach mechanisms. The brain releases dopamine during sex, eating, aesthetically pleasurable experiences, observation of cooperative behavior, and punishment for norm-defying behavior, among others. It is also released when thinking about these activities. In addition, it plays an important role in activities involving social rank and status. For example, there is an important difference in the response of the dopamine system to losing a lottery (which tends to be perceived as random) compared to losing at auctions (which tends to be perceived as losing to other people). In an experiment, when participants lost at the lottery, there was no measurable effect in the reward system. However, when they lost the auction, dopamine release was actively inhibited: losing to other people is perceived as a threat to one's social status, whereas losing to "nature" is not. A similar response is observed when a person envies another person: the feeling of envy correlates with activations in the brain associated with pain. If the envied person suffers a misfortune, a release of dopamine occurs in the brain of the envied person. This release is positively correlated with the degree of envy of a person.

Looking at this pattern, it is clear that dopamine plays a central role in ensuring survival. This includes food intake, sex, and high positions in a social hierarchy.

However, dopamine does not simply encode reward. The system has three distinctive properties: (1) it encodes relative reward, (2) it encodes positive surprises, and (3) it is involved when the relationship between environmental stimuli and rewards is learned (when new habits are formed).

- Despite the fact that dopamine feels good at the conscious level, the evolutionary task of this mechanism is not to make a person happy, but to trigger behaviors that contribute to survival and reproduction. Therefore, the task is to evaluate different alternatives *relative* to each other.
- In the early stages of research, most researchers thought that dopamine was directly encoded as reward, leading to a *hedonic* interpretation of the dopamine reward system (as in the traditional interpretation in economics as *pleasure minus pain*). However, this view has been refuted. Dopamine release is associated with a particular type of reward error: at each point in time, the brain appears to expect a "normal" course of events. When this expectation turns out to be false and the future turns out better than expected, dopamine is released. This is the *reward-prediction error hypothesis*: "[D]opamine responds to the difference between how 'rewarding' an event is and how rewarding it was expected to be. One reason that this theory has generated so much interest is that a reward prediction error of this type is a key algorithmic component of reinforcement models of learning: such a signal is used to update the value attached to different actions. This has led to the further hypothesis that dopamine forms part of a reinforcement learning system that drives behavior. The so-called reward-prediction error hypothesis (RPEH) is considered one of the great success stories of cognitive neuroscience." (Colombo 2014)
- Consistent with the reward-prediction error hypothesis, dopamine plays a special role in learning or habit formation because dopamine release decreases over time when the reward remains the same (habituation). Figure 11.2, which summarizes findings from experiments with monkeys, illustrates the pattern.

  The experiments were as follows: the monkey received a signal (flashing light) and was able to pull a lever. If it pulls the lever after the signal, it gets a reward (fruit juice). In the surprise phase, the monkey had no idea what was going on and started experimenting. If it pulled the lever at the right moment, the reward was triggered and a dopamine release was observed in the monkey's brain. When the experiment was repeated, the monkey learned the causal structure of events and what it must do to get the reward. At an

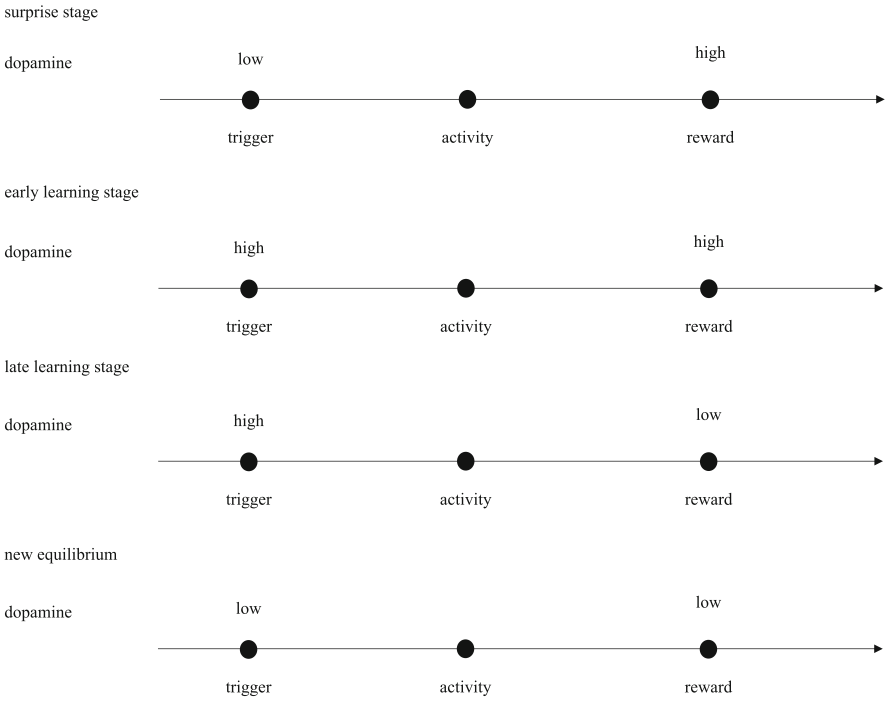

Fig. 11.2 Stages of habit formation

early point in this learning process, dopamine was also released when the signal was given. This is called *anticipatory dopamine reward*, and it motivates the monkey to stay focused and do whatever it takes to get the reward. A second release of dopamine was observed when it actually received the reward. When the experiment was repeated further, the anticipatory dopamine reward was still observable, but dopamine release declined when the fruit juice was released. When the experiment was continued for a longer time, even the anticipatory reward disappeared. The new behavior was fully habituated, and a new habit had been formed.

This pattern makes sense from an evolutionary perspective: the purpose of dopamine reward is to trigger the right kind of behavior and to maintain attention while learning what to do to get a reward. The encoding of positive surprise is an efficient way to achieve this goal because it economizes on the scarce resource dopamine. If the monkey (or a human) lives in a stable environment, there is no need to waste resource-intensive dopamine after the behavior conducive to survival has been fully habituated.

There is another interesting finding about how the dopamine reward system works: the amount of anticipated reward depends on two factors. One is the attractiveness of the anticipated reward (positive correlation). And the other is the probability that the reward will actually occur: if there is some uncertainty about whether the reward will be released or not, the dopamine system responds more strongly to the conditioning trigger than if reward is certain. And the encoding of uncertainty has a typical temporal profile: for example, if the reward comes with 50% probability, the conditioning stimulus is associated with the usual release of dopamine during the learning phase. However, in the period between the completion of the task (pulling the lever) and the delivery of the reward, there is a further release of dopamine that is not observed when the reward is 100% certain. The uncertainty, "after completion of the task," but before resolution of uncertainty, is "rewarded" with additional dopamine. It has been shown that this additional dopamine release is largest at maximum uncertainty (the probability of reward is 50%). It is also interesting to note that the conditioning stimulus (the trigger) can itself become a reward: the signal becomes a fetish. This is the case, for example, in humans when the dopamine system responds to money as a symbol of rewards that are directly useful for survival (such as food).

These findings have three possible implications for economic decision theory:

- If behavior were triggered solely by the dopamine system (which it is not), the reward-prediction error hypothesis implies that people can end up in a hedonic treadmill because dopamine is correlated with novelty. Once people get used to new things, the dopamine reward drops, and it no longer feels good. This may partly explain why people keep buying things even though they do not need them from a purely functional or utilitarian (in the colloquial sense of the word) perspective. This realization also explains why partnerships tend to cool off a bit over time. People need constant novelty to keep the dopamine flowing. Given that the dopamine system is such a powerful motivator of behavior, these findings point to deeper normative implications: if observed behavior is motivated in part by the (unconscious) desire for dopamine rewards, is dopamine a reasonable proxy for human well-being or happiness? This question becomes particularly pressing when one understands the hedonic treadmill that results when one answers this question in the affirmative.
- A second aspect (to which we will return later) is the implicit attitude towards risk and uncertainty: the pattern of dopamine rewards would lead to behavior that we called risk loving in Chap. 8.
- Third, the purpose of the dopamine system is to allow a person to adapt effectively to his or her environment. Therefore, in the short term or in an environment that lacks long-term stability, or when a person is constantly motivated by the dopamine treadmill and seeks novelty, the brain creates new habits. As a result, we cannot expect the behavioral stability that is taken for granted in the concept of preferences. Behavior is constantly evolving, which means that preferences are also constantly changing. Stable preferences, according to this mechanism of habituation, can only be expected in a long-term equilibrium when all habits are firmly established and the environment no longer changes. At that point, however, there is no longer any dopamine reward for the individual.

We will return to these points at the end of this chapter when we bring all the various findings together.

11.2.3.2 Fear and Anxiety

Fear and anxiety are an important part of the body's avoidance mechanisms that play an important role in risk-taking behavior. They enable us to stay healthy and alive by avoiding events that threaten our survival or physical integrity.

Both fear and anxiety are well researched. While research on other affects is not as advanced, the consensus seems to be that for them the basic mechanisms are likely similar. The *high road–low road model* states that there are two pathways in the brain to process visual stimuli of threatening events or objects. Take as an example a visual signal of a serpentine object. This signal goes from the retina of the eye to the sensory thalamus (unconscious recognition of the object) and then directly to the amygdala (*low road*), which makes an initial, rough assessment of the relevance of the object (still without conscious recognition). The signal also goes to the sensory cortex, which is responsible for conscious recognition of the object (*high road*). Figure 11.3 summarizes the model.

The serpentine shape can lead to a *freeze* response and an activation of the body's fight-or-flight response (increase in heart rate, muscle tone, and so on) initiated by the amygdala. This is an emotional response. A signal can then be sent from the sensory cortex to the amygdala and *vice versa*. The signal from the sensory thalamus to the sensory cortex always takes longer than the signal from the sensory thalamus to the amygdala, which means that the first physical reaction necessarily occurs without one being aware of it. Only now, and only when the emotional response is judged to be sufficiently important, does one become aware of the situation and gather more information to form a better hypothesis about the serpentine object.

When the event crosses the threshold of consciousness, two signals are combined into a conscious understanding of the situation, the visual information about the serpentine object (called *exteroception*) and a representation of the physical responses triggered by the amygdala (called *interoception*) in the form of the feeling of fear. The resulting conscious representation has two parts, it can confirm or reject that it is a snake, and it becomes aware of the emotional response in the form of the feeling of fear. If the interpretations of the snake-like object are consistent, there is no conflict between the emotional reaction and the conscious interpretation. When

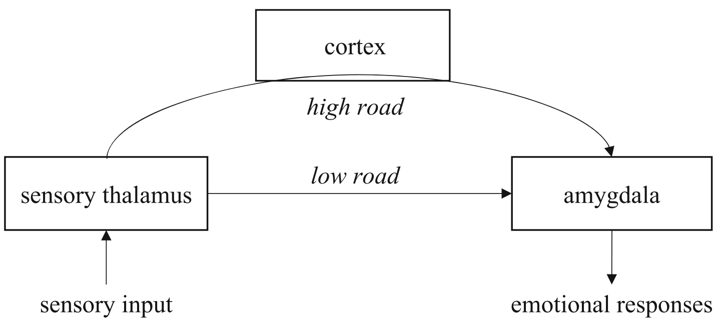

Fig. 11.3 The high road–low road model

they are inconsistent, either the conscious knowledge that there is no dangerous object or the emotional response, represented as fear, can become dominant. This conflict of interest is biased in favor of the emotional response because there are more neural pathways going from the amygdala to the sensory cortex than *vice versa*. This implies that it is difficult to calm down when the emotional circuit is in full swing, even when one consciously knows that there is no danger.

It is important to note that this rapid and unconscious response challenges an intuitive understanding of the role of emotions in decision-making: it is not that we react to a threat because we feel threatened. On the contrary, our conscious mind interprets information about the outside world (snake) and information about body reactions (contracted muscles, increased heart rate, and so on) as fear.

What are the possible implications of these findings for economic decision theory?

- The *high road–low road* model makes the role of consciousness in decision-making more explicit. Most of our daily activities occur at a mostly unconscious level, and initial responses to threats are *necessarily* triggered by unconscious processes. Thus, if preferences or utility functions are to accurately summarize this finding, they cannot be proxies for conscious decision processes. But this in turn means that a normative interpretation of preferences as proxies for well-being is called into question because the intuitive understanding would be that an increase in well-being must feel like something, which is not the case if the behavior is unconscious or is unconsciously triggered.
- A second aspect is related to risk attitude: the amygdala responds to perceived threats by activating the fight-or-flight response. Therefore, it is consistent with both risk-averse and risk-seeking behaviors (see Chap. 8).

11.2.3.3 Disgust

Disgust is a second important example of an avoid mechanism. It has the goal of keeping humans alive and healthy. First, it leads to keeping an organism away from pathogens and toxins. For example, spoiled food or diseases trigger a disgust response. An area of the brain called the insula plays an important role in triggering a number of autonomic (emotional) responses, such as lowering heart rate, protecting the eyes, nose and mouth by activating certain facial muscles, gag reflex, etc. Conversely, the perceived purity of food and water and the health of people are important positive signals for their sense of safety. Reactions of the insula, however, can be triggered not only by direct contact with disgusting objects but also indirectly by looking at people who show signs of disgust, by listening to disgusting stories, or by thinking about disgusting scenarios. All of this is referred to as "physical disgust."

In addition, the insula also plays an important role when disgust is symbolically transferred to other areas of life, especially in "morally disgusting" or repulsive behavior. The behavior and appearance of other people can trigger disgust reactions that contribute to moral "gut feelings" about the rightness and wrongness of behavior. Moral disgust, like physical disgust, can have a biological basis (because the behavior actually threatens health), but it can also be purely symbolic and cultural. Evolution is a plumber, not a designer, and it seems that the network of brain areas (including the insula) responsible for the affect of physical disgust has been co-opted to deal also with situations that in a direct sense have nothing to do with risks from pathogens or toxins. When it comes to moral disgust, the narratives we use to make sense of our feeling have the purpose of aligning our feelings with the behaviors we are confronted with. Concepts such as purity and cleanliness therefore take on a symbolic meaning that can be completely divorced from any biological threat. This symbolic dimension of disgust turns out to be very relevant for an understanding of perception and behavior.

- People tend to reject or devalue others when their behavior crosses important moral boundaries. Disgust plays a key role here, and concepts such as purity/impurity, clean/dirty, etc. are key terms that people use to describe morally relevant behaviors or characteristics (with moral purity being the metaphorical equivalent of, for example, pure, i.e., uninfected food or a pure, i.e., uninfected body). This tendency explains many of the attitudes and behaviors in contexts not directly related to disease.
- People differ in their sensitivity to disgust. In general, high sensitivity is positively correlated with a tendency to make more severe moral judgments (hence moral disgust). Disgust sensitivity is also a good predictor of prejudice and discrimination, e.g., against people of color or obese people (the amygdala is also active in racial prejudice, and its role in fear and anxiety has already been discussed). One also finds a positive correlation between physical and moral disgust thresholds: people who are easily disgusted by food, for example, also have a low tolerance for moral transgressions.
- Moral disgust can be triggered by causally unrelated signs of physical disgust. In a study from the USA, participants had to rate the morality of a behavior. To do this, different groups were positioned in different environments (clean or dirty desk, neutral or foul-smelling room, etc.). Participants in a dirty environment rated individual behavior more harshly. The same pattern was found in many other studies: participants placed in a disgusting environment (smell of vomit or feces, etc.) rated behaviors such as premarital sex, theft, pornography, etc. more negatively than participants who were able to make choices in a neutral environment. And participants are generally unaware that their moral evaluations were caused by eliciting physical disgust. When asked for the reasons for their evaluations, they confabulated a story but were unable to give the real reason.

Disgust also plays an important role in explaining individuals' political leanings. In another study, participants had to rank themselves on a scale from conservative to liberal. They were also ranked in terms of their disgust sensitivity (they had to indicate their agreement with statements such as "I never let any part of my body touch the toilet seat in a public restroom"). It turned out that people with higher disgust sensitivity were more tolerant of income and wealth inequality, had more negative attitudes towards homosexuality, valued authoritarian leadership styles more, and were more negative towards foreign immigration. In other words, they had a more conservative mindset. The authors explain these findings as follows: "[W]e found that contamination disgust was most strongly associated with political conservatism. These results are consistent with research linking contamination disgust to a more general 'behavioral immune system' that may have evolved in order to shield individuals from exposure to novel pathogens or parasites [. . .]. The emotion of disgust may thus serve to encourage avoidance of out-groups who are likely to expose individuals to novel pathogens–for example, out-groups who differ in their practices regarding cleanliness, food preparation, and sexual behavior. A particularly strong desire to avoid contamination—that is an especially active behavioral immune system—may be the basis for some of the attitudes that have been consistently noted to differ across conservatives and liberals (such as attitudes toward sexuality and immigration). This argument is also consistent with recent experimental work demonstrating that reminders of cleanliness promote a more conservative political orientation[. . .]." (Inbar et al., 2012). These differences in political attitudes and sensitivity to disgust are not only demonstrable in the laboratory but also in actual voting behavior.

The cultural construction of purity and repulsion/disgust can be seen as a dialectical pair found in many narratives and stories. If we follow this path, we will find a whole field of metaphors in our narratives. Here are a few examples. (1) The Catholic Church's dogma of the Immaculate Conception of Mary, seen as freed from the stain of original sin (the state without sin is pure and the state with sin is impure). (2) The so-called "racial doctrines" focus on something like racial or ethnic purity, with "contamination" occurring through coexistence with other ethnic groups. Many strategies of devaluing other groups and minorities use metaphors that associate members of the other group with disgusting images; they are equated with dirt, worms, rats, and so on. Physical disgust serves to reinforce perceptions of differences between groups and to devalue the other group. (3) Pilate's demonstrative washing of his hands after the trial of Jesus is taken as an expression of his supposed innocence. A physical act of cleansing is symbolically turned into a moral act of purification. Studies show that such behavior is widespread. In one study, participants were asked to think about a moral or an immoral act they had committed in the past. At the end of the study, they could choose a thank-you gift, either a pencil or a pack of antiseptic wipes. The group that had to think of an immoral act was significantly more likely to choose the wipes. In another study, participants were asked to lie. One group had to tell the story of the lie and the other had to write it down. At the end, a choice between different hygiene products was available as a gift. Those who had to tell a story were significantly more likely to choose a mouthwash, while those who had to write down a story were significantly more likely to choose hand soap. "Moral pollution" can apparently be alleviated with surprisingly concrete physical measures, arguing for the close neurological connection between moral and physical disgust.

What are the possible implications of these findings for economic decision theory?

- A first aspect worth noting is that the findings on the link between bodily and moral disgust call into question any notion of autonomous decision-making. As we have seen, people can be manipulated quite easily by eliciting moral disgust. Contextual variables such as the smell of a room have the potential to alter individual behavior and moral evaluations of other people's behavior, and people are unaware of the true reasons for their evaluations. These findings do not challenge the idea of rationality as consistent choice behavior, but they do challenge the idea that preferences are somehow the result of a consistent process of opinion formation. Such an assumption is not part of mainstream economics, but our willingness to accept the more restrictive idea of instrumental rationality depends at least in part on the implicit assumption that preferences are formed in a reasonable way.
- Conversely, the findings on disgust and political sentiment lead us to a debate about legitimate and illegitimate motives for action that is excluded from traditional rational-choice theories of decision-making. Some of the behaviors associated with moral disgust are considered unacceptable from an overarching ethical perspective when committed to ideas such as universal human rights and universal values because they are discriminatory. Especially since the European Enlightenment, principles such as universalism and impartiality have been considered core values. What research on disgust shows, however, is that intuitive moral judgments are not the result of a process of rational deliberation but are sometimes the result of confabulation that rationalizes gut feelings.

11.2.3.4 Oxytocin

Dopamine was one example of approach and disgust and fear two examples of avoid systems. The next example plays an ambiguous role in this regard. It is the hormone/neuropeptin oxytocin. The perception of the role of oxytocin has had a very interesting history. Initially, studies suggested that this hormone increases cooperation, reduces anxiety, and strengthens bonding, for example, between parent and child or partners. It also lowers blood pressure and cortisol levels, has a calming effect, and can lead to improved wound healing. Oxytocin is considered capable of alleviating the effects of negative stress. In mothers and fathers, it increases the desire to care for their children. However, the effects also apply to couple bonding. Higher levels of oxytocin lead to greater perceived attractiveness of the partner, more synchronous behavior, and long-lasting bonds. Artificially increasing oxytocin levels (by administering a nasal spray) leads to more positive communication and a reduction in stress hormones during conflict. It also plays a role in bonding between people and their dogs. Oxytocin has an inhibitory effect on the amygdala, which reduces anxiety and fear, and activates the parasympathetic nervous system, which calms the body and mind. At the perceptual level, it manifests as a sense of security. In experiments with rodents, it has been shown to reduce aggression. This is accompanied by a positive effect on cooperative and altruistic behavior in economic games.

Up to this point, one might get the impression that oxytocin could be a magic bullet to reduce social conflict and increase individual well-being. However, as with other hormones/neurotransmitters, the effect is context-dependent, and research shows that this is also the case here: oxytocin produces the described effects on cooperative and prosocial behavior only in interactions with members of one's own group, with people who share important aspects of one's social identity.

Research on *ingroup–outgroup* behavior has its origins in social psychology. An important finding from the so-called *social-identity theory* is that cooperative behavior among participants can be increased in experiments by inducing an (arbitrary) group identity. However, the cooperation-enhancing effect was only evident when there were other participants in the experiment who belonged to a different, alternative group. When all individuals were assigned the same social identity, no behavioral effects could be measured. And it is not difficult to create a sense of belonging to a group. The *minimal-group* paradigm is a methodology based on the robust finding that even seemingly arbitrary and volatile group identities have effects on behavior. Even when participants in experiments are assigned arbitrary markers of group identity, such as the color of a shirt, these markers trigger a tendency to cooperate with members of the same group at the expense of others.

This type of behavior is also known as *parochial altruism*: people automatically seek markers that allow them to identify with a group, and they are willing to act altruistically towards other group members. However, the other group is needed to activate ingroup cooperation. Thus, group identities help to solve both coordination and cooperation problems (see Chap. 9) within a group. However, with respect to members of other groups, the results are mixed. Some experiments have shown that explicitly harmful behavior towards members of other groups can occur, even if at a cost to the individual. Other experiments found more neutral behavior towards outsiders.

Here are a few examples of the effects of parochial altruism on behavior: in studies of white and black participants in the USA, white individuals regularly assume that blacks are less sensitive to pain than whites. This type of discrimination is also detectable in measures of activity in the corresponding brain regions. Another study was able to show that participants in image-recognition tests were significantly more likely to confuse harmless objects with weapons or to see weapons where there were none if they had previously been unconsciously confronted with the image of a black rather than a white child. Clearly, unconscious mechanisms of discrimination are at work here. In a study of mixed groups (blacks and whites) matched for similarity of group members in attitudes and beliefs, it was found that participants consciously expressed no preference for members of their own group. At the same time, discrimination by skin color was measurable at a subconscious, emotional level. This suggests a conflict between the emotional and cognitive experience of a situation: many people do not perceive themselves as discriminating, but on an emotional level they are.

It is plausible to start from the assumption that parochial altruism evolved because people survived and evolved in groups, creating a complex structure of inter- and intra-group conflict. In evolutionary biology, inter-group conflict is typically used to explain the evolution of cooperative behavior that goes beyond kinship (and thus genetic similarity) because overcoming selfish behavior can be critical for survival when groups compete for scarce resources or hunting large game. In the absence of intense inter-group conflict, however, intra-group conflict over scarce resources and status becomes relatively more important, explaining why the existence of a rival group is essential to trigger intra-group cooperation.

How is this type of cooperative behavior encoded in our bodies and brains? And oxytocin seems to play an important role in answering this question. In a series of experiments, parochial-altruistic behavior has been shown to increase with the amount of oxytocin administered to participants. The oxytocin chain begins in the hypothalamus, which is part of the brain's limbic system, implying that oxytocin-induced parochial altruism is an autonomic response. However, the ability to reason allows the tendency to discriminate to be attenuated or overridden. In a repeated group prisoner's dilemma experiment, one group of participants had to solve a mentally demanding task and the other group a simple cognitive task. Parochial-altruistic behavior was more prevalent in the mentally stressed group, which appeared to be unable to regulate its behavior at will.

The question of whether and under what circumstances parochial altruism leads to behavior that actively harms outsiders is still unresolved. However, there are several findings. (1) There appears to be heterogeneity among individuals; some are more inclined to harm outsiders unnecessarily, while others are more restrained. However, because attitudes towards members of an outgroup are not influenced by oxytocin alone, the effect cannot be clearly attributed to individual differences in oxytocin sensitivity. (2) Harmful behavior occurs when it is the only way to signal membership in a group. (3) Willingness to harm outsiders depends on whether one is the aggressor or the defender in a conflict. The defensive group acts more aggressively against members of the aggressor group than vice versa.

What are the possible implications of these findings for economic decision theory?

- Based on the findings on harmful behavior, the results show that the specific context seems to be crucial for the behavior. Usually, this context has a narrative form (e.g., the answer to the question "Who is the aggressor?" can sometimes be hotly contested), and the crucial, behaviorally relevant variables of this context are sometimes difficult to predict. The importance of context will prove to be a recurring theme as we bring the various mechanisms together at the end of this chapter. From the perspective of standard decision theory, the importance of context challenges the notion that preferences are fixed and, in that sense, context independent. The assumption of context independence is nowhere made explicit, but the way decision theory is applied suggests that this is the common understanding.
- The role of oxytocin explains (group-) altruistic behavior, as discussed in Chap. 10. Humans evolved in groups, and our perception and behavior reflect this point. Even more, altruistic behavior has a dark side in the sense that it can also mean harming outsiders.

- This observation leads back to the previous section's discussion of legitimate and illegitimate motives for action. Parochial altruism is incompatible with universalist notions of justice, impartiality, and nondiscrimination. However, our moral gut instincts have evolved differently.
- In evolutionary contexts, group membership was largely predetermined and fixed. In modern societies, everyone has multiple identities that can have different visibilities (salience) depending on context; gender, religion, occupation, ethnicity, nationality, soccer club, the list is long. Skin color and gender still play an important role because of their salience. But the social meaning of these possible identities is culturally constructed. This observation has two implications. First, it takes us back to the problem of context sensitivity mentioned above, because behavior depends on the specific identity that is salient at a given moment. And second, these identities are socially constructed and therefore part of the larger narrative of a culture, even though people may not be aware of this fact. The normative problem that accompanies this observation is the question of why preferences that are a result of such conventions should be normatively justified. Acting according to group norms may be an expression of a deeper form of injustice and unfreedom, especially for members of minority groups.

11.2.3.5 Testosterone

Research on testosterone is interesting because it challenges our everyday understanding of the role of this hormone and reinforces some of the more general findings we have already noted.

In men, testosterone is secreted by the testes, while in women it is secreted by the ovaries (albeit to a lesser extent). Contrary to its public image, testosterone does not play a direct role in explaining (male) aggression (more testosterone = more aggressive behavior); rather, it plays a central role in determining group hierarchies. The *challenge hypothesis* states that testosterone makes people more aggressive only when there is a threat to their position in the status hierarchy of their peer group. In this case, the body responds by releasing testosterone at two points in time: before the challenge and after it has been won. This is also true for symbolic rank struggles as in sports and even without own participation in the competition (e.g., as a fan).

The most important finding, however, is that testosterone does not make people more aggressive *per se*, but that it triggers any behavior necessary to defend, increase, or stabilize rank and status in a situation. This finding is consistent with the context sensitivity of behavior mentioned earlier. In one experiment, subjects had to play an economic ultimatum game in which it paid to be nice. Being nice was a high-status trait in the experiment. Consistent with the challenge hypothesis, artificially increasing participants' testosterone levels led them to make more generous offers. The effects of testosterone are thus a result of the social context of a person. Other studies also support the challenge hypothesis. In one study, participants' status was associated with honesty of behavior, and testosterone led to an increase in honesty. In a similar study, participants could donate money to a common pool, which increased status, and testosterone increased donations for most participants.

The overall effect, however, is even more complex. In the former study, a control group was unknowingly injected with saline instead of testosterone. Those who mistakenly believed they had increased testosterone behaved less generously. What is going on here? As stated earlier, most people hold the (false) belief that testosterone is associated with aggressive, reckless behavior. A likely explanation, therefore, is that the belief in the hormone's effects, combined with the belief that one has elevated levels, influences behavior to conform to the theoretical belief. It is plausible to assume that people try to identify and then exhibit the correct behavior in social contexts. This includes belief in the effects of testosterone. One is not a slave to one's hormones, but one can actively intervene. And this realization is double-edged. In this experiment, it turned out that the theoretical assumption about the effect of testosterone, and not the hormone itself, dominated behavior.

But how does the widespread idea that testosterone has something to do with aggression come about? Sapolsky (2017, p. 107) summarizes the state of research as follows: "Testosterone makes us more willing to do what it takes to attain and maintain status. And the key point is what it takes. Engineer the right social circumstances and boosting testosterone levels during a challenge would make people compete like crazy to do the most acts of random kindness. In our world riddled with male violence, the problem isn't that testosterone can increase levels of aggression. The problem is the frequency with which we reward aggression."

What are the possible implications of these findings for economic decision theory?

- Sapolsky's summary presents the first challenge: as the example of testosterone shows, behavior and preferences are shaped by a complex interplay of biochemical mechanisms, social conventions, perceived realities, and so on. If one infers normatively relevant preferences from observed behaviors, one blinds oneself to the underlying social processes that produce those preferences. If one shares the normative principle that violence—symbolic, physical, or whatever—is bad, the basic conventions and narratives that link aggressive and violent behavior to rank and status are part of the problem, not part of the solution. The goal then would be to change the basic rules of the status game to make it more socially acceptable and perhaps even productive. Such a perspective is impossible if preferences are taken at face value. (We have discussed status in market contexts in Chap. 6.)
- In this context, the results show how important the basic narratives, values, and norms of a society are for identities and behavior. With norms and narratives that tie rank and status to peaceful conflict resolution and cooperative behavior, testosterone can be put at the service of a peaceful and efficient society. At the same time, it is naïve to believe that narratives, values, and norms can simply be "designed." Preferences do not exist in a vacuum; they are shaped by the fundamental ideas, norms, and narratives of a society. The role of testosterone for behavior is only one piece of the puzzle that this view reveals. Modern decision theory leaves no room for embedding preferences in culture and thus implicitly declares these connections normatively irrelevant.

11.2.4 Cognitive and Metacognitive Adaptation

Like the terms emotion, feeling, and affect, the term cognition is used inconsistently in the literature. We use the term *cognition* to refer to conscious processes, and the term *metacognition* to refer to situations in which one consciously thinks about cognition. Cognition and metacognition are not independent and self-sufficient; rather, they are embedded in other mechanisms such as emotional responses. The brain is selective in choosing which phenomena become conscious. And consciousness is activated by unconscious responses to the environment and other processes in the body. Many activities of the environment, the body, and the brain remain unconscious.

Most scholars agree that we consciously perceive reality in narrative form: “We seem to have no other way of describing ‘lived time’ save in the form of a narrative." (Bruner, 2004). And narratives are *by definition* social in nature. We construct stories from the narrative material that surrounds us. This refers both to the specific language with its syntax and semantics and to the pre-existing stories that a society uses. These narratives are the quarry from which we draw when we try to make sense of the world and our position in it. It is not surprising, then, that the experience of reality is to some degree specific to a particular culture.

11.2.4.1 Confabulation

The way we develop narratives is complex. The default mode seems to be *confabulation*, that is, the tendency to tell stories and arrange arguments in ways that serve our interests and are consistent with our gut feelings or our affective perception of a situation. The term was originally used in clinical contexts to describe memory deficits in people suffering from, e.g., dementia or brain lesions who make up stories about aspects of their past that they believe to be true but cannot recall due to their illness. More recently, it is becoming more and more clear that confabulation is the default mode of human storytelling: “Rather than being merely an odd neurological phenomenon, the existence of confabulation may be telling us something important about the human mind and about human nature. [. . .] Once one forms a concept of confabulation from seeing it in the clinic or reading about it in the neuropsychological literature, one starts to see mild versions of it in people. We are all familiar with people who seem to be unable to say the words ‘I don’t know’, and will quickly produce some sort of plausible-sounding response to whatever they are asked.” (Hirstein 2005).

In order to act and plan consciously, we need coherent interpretations of reality that have a narrative form. So we make up stories, even in situations where we are clueless. From an evolutionary point of view, “truth” has an adaptive advantage only if it serves survival. Despite this fact, most people are *naïve realists* and think that their perception of reality and reality coincide, they are usually unaware that they are confabulating.

The role of rationality in the process of creating narrative consciousness is controversial. Some authors argue that it is mostly a more or less arbitrary form of confabulation, while others attach greater importance to rationality. Metacognition is the ability to think about cognitive processes and thereby become aware of them, creating the ability not to act blindly according to affects and confabulated stories. However, this requires a conscious effort to break through naïve realism.

Digression 11.2 (Confabulation and the *Iowa gambling task*)
The *Iowa gambling task* is an experiment that provides evidence for the process of confabulation and the relationship between conscious and unconscious processes. In this experiment, participants had to select cards from four different decks. The different decks had different average winning probabilities, which were unknown to the participants at the beginning. They had to choose 100 times in a row, and their electrical skin-conductance rate was monitored. The task was interrupted at various points to check whether the participants consciously understood the situation. The results were as follows:

- Participants' skin conductance responded to the situation before and after card selection, indicating that their emotional mechanisms responded to the situation.
- After about ten rounds, participants began to show anticipatory changes in skin conductance in the 5-second window before selecting a card, indicating stress while considering bad decks and positive emotions while considering good decks. At this time, they had no conscious knowledge of what was going on.
- After about 30 rounds, participants began to develop behavioral preferences for the good decks. At this point, they still had no conscious understanding of the situation.
- Over time, they developed a conscious sense of good and bad decks without being able to adequately explain why.
- After about 50–80 rounds, they had developed a conscious model of the game and understood what was going on.
- When confronted with their change in behavior during the time before they had developed a conscious understanding of the situation, participants began to confabulate. Some of them even reacted aggressively when they learned that their behavior had changed, even though they had not consciously initiated the changes.

The results have a number of important implications. First, behavior is not necessarily the result of conscious deliberation about the best way to act. Second, unconscious emotional responses can be very effective and adaptive mechanisms for triggering behavior. They guide behavior in the right direction and are faster learners than the brain's conscious processes. And third,

(continued)

Digression 11.2 (continued)
emotional comes before conscious learning and narrative explanations. In the first stage of conscious understanding, people confabulate when asked what they do and why they are doing it. One of the authors of the study argues very aptly that our conscious brain does not trigger behavior but engages in after-the-fact rationalization or confabulation most of the time.

If the narratives we construct are sense-making tools that allow us to act and plan, we can better understand the tendency to confabulate. Confabulation, however, does not mean that there are no constraints imposed on the stories we tell. For example, if one believes that one can walk on water, there is tremendous selection pressure against that story. Narratives, like organisms, can only survive if they are adaptive. This observation allows us to bridge to cognitive and affective biases discussed in Chap. 10. Here are a few examples.

- The *self-serving bias* is the tendency to distort cognitive and perceptual processes in ways that maintain and enhance self-esteem.
- The *availability bias* is the tendency to overestimate the probability of events that are more accessible to memory. For example, availability correlates with the affective charge of an event.
- The *confirmation bias* is the tendency to seek and interpret information that is consistent with one's own prejudices and interests.
- *Illusion of control* is the tendency to overestimate one's influence on events.
- The *stereotypical bias* is the tendency to bias memories towards stereotypes (such as race and gender).

Many more examples could be given to illustrate that narratives do not tend to be "true." We do not look at and talk about the world from an impartial perspective, but in a self-serving way. This tendency becomes more pronounced when one or more of the following three conditions are met.

- When there is a long time lag between the stories we tell and their consequences, one is not immediately punished for narratives that conflict with important aspects of physical reality. If one denies the existence of a poisonous snake on the road ahead, the genetic experiment may soon be over. But if one denies anthropogenic climate change, nothing bad happens in the short term. There may even be short-term negative consequences to accepting climate change, because one may have to change behavior.
- Humans are social creatures, and their survival depends on their membership and position in a social group. In evolutionary times, it was almost tantamount to a death sentence if someone was cast out of a group, which explains the pronounced tendency to conform and accept group norms. Thus, there is always

the possibility of conflicting narratives: if there is a group norm denying the existence of poisonous snakes, it is not clear which is worse: to submit to the group norm and risk being bitten by a snake, or to break with the group norm, with all the possible consequences for group status and membership. And if the "truth rent" is not paid out immediately, but with a long delay (as with climate change), the balance tilts even more towards conformity to group norms, even if it is dysfunctional in the long run.

- Third, things become even more complicated when we look at social conventions. According to Searle (2010) , social conventions have a subjective ontology; they exist when people agree that they exist, and they do not exist otherwise (see Chap. 2). They arise from mutual acceptance of the narratives that underlie them. The truth of social conventions is ambivalent from the beginning; today's lie may be tomorrow's truth and vice versa. Therefore, there is an even stronger tendency to bow to group norms.

Digression 11.3 (Confabulation and Political Leanings)
The ubiquity of confabulation was demonstrated in an experiment by Hall et al. (2013), who confronted participants with statements such as "Israel's violent actions in the conflict with Hamas are morally defensible, despite civilian deaths among Palestinians." A contrary statement declared the action as morally indefensible. Participants had to adopt a position and then read it aloud. This was followed by all sorts of distracting questions, as is common in such experiments. Without the study participants noticing, their answers were exchanged, and in the further course of the experiment, they had to justify their (now exchanged) answers. 69% of the participants did not notice the swap; rather, they justified an opinion that they had not initially communicated. Interestingly, their justified opinion even had long-term persistence, as found in a follow-up study in which participants disproportionately retained the opinion they had to justify (but had not initially communicated). It is plausible that this result was due to the fact that they (students at a Swedish university) did not have strong and informed opinions about these statements from the beginning. The same study in Israel would likely have yielded a different result. Nevertheless, the results show, first, that confabulation can be induced quite easily, and second, that opinions can be easily distorted when confabulation plays a role: even if the opinion was completely arbitrary at the beginning, it can become a "true" opinion through skillful manipulation.

11.2.4.2 The Narrative Self

Since we are concerned with the homo oeconomicus model, which places the individual at the normative and explanatory center of economic theories, we will now be concerned with the narratives that form the "self." How is this *narrative self* created? Narration seems to take the form of "incongruent framing" in which the infinite variety of sensory impressions is brought into some meaningful order by creating a simplified model of the world. This model takes the form of a story. The act of storytelling is thus a way of making sense of the world and one's existence in it. The process of autobiographical storytelling is selective in terms of the events integrated into the self and their meaning for the individual. The main purpose is to create meaning and ultimately *agency*. And since stories are identity generating and produce agency, a double relatedness results: "Narrative imitates life, life imitates narrative." (Bruner, 2004).

Many self-narratives common in Western societies have either a redemption or a contamination structure. A story that follows a redemption structure begins badly and ends well. The opposite is true for a story with a contamination structure. And such life stories have a systematic impact on life satisfaction. It has been shown that people who tend to think in terms of redemption have better mental health than people who think in terms of contamination. Furthermore, issues such as agency and community are important for life satisfaction. People who tell their stories as autonomous but socially integrated individuals with agency are more satisfied than others. There also appears to be a positive correlation between perceived agency and empathy. For example, people whose stories emphasize agency and autonomy and who downplay the influence of other people, institutions, and luck on their own success have a different view of normative issues of inequality.

The narrative self, however, does not exist in the form of a unified, consistent, or possibly even linear story in which all sensory impressions are congruently embedded. Rather, the self is a multiplicity of stories and narratives that overlap, diverge, or even contradict each other, even if a person has a particular view of him- or herself that he/she believes to be valid. These different stories often correspond to different areas of life, such as work, family, or faith. They are unstable over time, leading to changes in the life story even though they appear to be stable. The reasons for instability and incongruence are varied, ranging from fallible memories to narrative construction errors. Kahneman (2011) writes "Narrative fallacies inevitably arise from our continuous attempt to make sense of the world. The explanatory stories that people find compelling are simple; are concrete rather than abstract; assign a greater role to talent, stupidity, and intentions than to luck; and focus on a few striking events that happen rather than on the countless events that failed to happen." To understand this point, it is important to keep in mind that from an evolutionary perspective, the main purpose of a life story is not factual accuracy, but to create a sense of agency by generating meaning and causality. In this process, the life story evolves as a dynamic unfolding of situational stories in different contexts and in front of different audiences.

However, to make a story a life story and embed situational experiences into it requires an autobiographical component: central experiences must be identified and lessons for one's life derived and integrated into it. This process also offers the possibility of giving negative experiences a positive meaning by interpreting them as important or even necessary impulses for the growth of one's personality. It has been shown that people who can positively embed negative events in a larger context have a more complex conception of the self and exhibit higher life satisfaction.

The individual life story corresponds to the social environment in several ways: (1) it generates an important part of the experiences that make up life stories. (2) Life stories are adapted to the expectations of the audience and the social context in which one tells them. (3) They are rehearsed, modulated, and reshaped so that they gradually override and replace memories. In this process, the (affective) meaning of events is sharpened and normative ambiguities are eliminated. (4) They are assembled from a culturally predetermined stock of building blocks. This cultural stock is generated in a dynamic process that turns the past into individual stories of the present. The building blocks are enriched with individual details. They influence the way people think about possible ways of living. It is at this level that culture has its greatest influence, for it is the source of the narrative self. Some authors even argue that many memories that are integrated into the self are in fact shared cultural conventions about possible and legitimate ways of living.

Digression 11.4 (Self-narratives and Health)
Advertising and marketing are good examples to illustrate the impact of narratives on health and well-being. Marketing campaigns for products develop narratives that offer identities that suggest that a certain ideal image of the product can be transferred to the person consuming it. Levant et al. (2015) show that there is a positive association between the consumption of energy drinks such as Monster or Red Bull, a certain idea of masculinity, and sleep disorders. This association had a negative correlation with age and was limited to white males (it was a US study). The authors interpret their findings as further evidence of the potential negative health effects of marketing campaigns that appeal to stereotypical (narrative) gender identities, particularly during the formative years of adolescence.

This study, which focuses on the relationship between male narrative role models and health, is only the tip of the iceberg. There is extensive evidence for the existence of a robust relationship between advertising and media consumption on the one hand and subjective well-being and health on the other. In a meta-study of the relationship between eating disorders and media consumption, Spettigue and Henderson (2004) found that the media develop and communicate a model of femininity that leads to unrealistic and dysfunctional normative ideals about beauty and slenderness that cause women to suffer. The general challenge for such campaigns is to credibly communicate the following message: (1) physical appearance is important, (2) individuals are deficient according to the ideal norm, and (3) consumption of certain products can (partially and temporarily) solve the problem (Wolf 1990, Kilbourne, 1994; Thomsen et al., 2001). From the perspective of affective experience, it is critical to establish a standard of normalcy that most people cannot meet. Narratives are narratives of deficiency, and consumption is a way out. The state of normalcy becomes what is called *normative discontent*

(continued)

Digression 11.4 (continued)
in psychology (Oliver-Pyatt, 2003): suffering. Kilbourne (1994) asked 11- to 17-year-old girls what they would wish for if they had one wish and found that the most common wish was permanent weight loss. The question, of course, is whether the media are tapping into something that is already there, or whether they are creating these self-images. A so-called *natural experiment* to test these hypotheses was the introduction of television in Fiji. Becker et al. (2002) were able to show that adolescent girls developed significantly higher rates of eating disorders after the introduction of television, and other studies show similar effects (Stice et al., 1994; Stice & Shaw, 1994; Utter et al., 2003).

What is evident here is that socially dominant self-narratives have an impact on individual self-narratives and that these narratives have an impact on behavior, subjective well-being, and health. This connection illustrates two things. To the extent that self-narratives influence behavior, they also influence "preferences." But even if behavior were unchanged, different self-narratives may have different consequences for subjective well-being. The stories we listen to can be nourishing or toxic, just as physical food can be nourishing or toxic. Communication is much more than just transmitting information.

11.2.4.3 Concluding Remarks and Implications for Economics

As we have seen, narratives from which people build their social identities are part of the culture of a society. The construction and implications of the narrative role models remain invisible to most people most of the time, as long as their normative legitimacy is not called into question: it has normative force because reality and perceived reality are seen as one. And the fact that these stories become an important part of one's consciousness over time has a stabilizing effect on the dominant culture: questioning and criticizing the stories necessarily imply that the conscious self is also criticized, and one additionally risks loss of status in or exclusion from a group. To be able to critique, the conscious narrative self, in addition, presupposes that one is aware in principle that it is culturally dependent and to some extent arbitrary (that it is a convention).

Therefore, role models for the narrative self reflect and stabilize power within a society. The concept of gender is one example of this, but "nationality," "race," or "class" are other examples of elements of a society's overarching narrative. The effects of the embodiment of narratives on the individual have been analyzed in sociology. A key concept to understand the social impact of narrative conventions is *symbolic power*. According to Pierre Bourdieu, symbolic power is "a gentle violence, imperceptible and invisible even to its victims, exerted for the most part through the purely symbolic channels of communication and cognition (more precisely, misrecognition), recognition, or even feeling". This definition points to the fact that narratives become deeply embedded and shape affective landscapes, a conjecture that has found support by findings from affective neuroscience over the last years. This process is mostly unplanned and self-emergent: "[L]egitimation of the social world is not, as some believe, the product of a deliberate and purposive action of propaganda or symbolic imposition; it results, rather, from the fact that agents apply to the objective structures of the social world structures of perception and appreciation which are issued out of these very structures and which tend to picture the world as evident." (Bourdieu, 1989)

Some patterns became visible in this section which have consequences for economics:

- First of all, important aspects of what we call "the conscious self" are based on a more or less unconscious pattern of narratives that exist in a culture. In this sense, the narrative self is arbitrary; in a different culture, and in a different position within society, one would have different stories from which to assemble a self. And these narratives are far less individual than one might think; they are permutations of the culturally dominant templates that become individual selves in a complex back and forth between group expectations and individual experiences.
- If the narrative self is the result of cultural processes, it is not clear why it is plausible to use such a self, the "individual," as the exclusive normative center of gravity in economics. There is a danger of ignoring too many aspects of the complex relationship between individual and society that are of potential normative relevance. Building on Bourdieu's concept of symbolic power, *gender theory* has argued that there may be social fields in which the very set of permissible narratives from which we construct our selves is normatively problematic.
- Following on from this, mainstream economics' clear distinction between ends (preference satisfaction) and means (everything else) also allows for a clear distinction between instrumental rationality (which is what economics is about) and value rationality, which questions preferences and places them in a larger context (which goes beyond economics). But when narratives influence behavior and establish the self, there is no longer a meaningful means–ends distinction. The narrative self (as end) becomes the entity that evaluates narratives (as means) but is, at the same time, manufactured from the very same stories. This creates a circularity that calls the means–ends distinction into question. Bruner (2004) highlighted the problems that arise from this reflexivity: "[T]he reflexivity of self-narrative poses problems of a deep and serious order—problems beyond those of verification, beyond the issue of indeterminacy (that the very telling of the self-story distorts what we have in mind to tell), beyond 'rationalization'. [. . .] Given their constructed nature and their dependence upon the cultural conventions and language usage, life narratives obviously reflect the prevailing theories about 'possible lives' that are part of one's culture. Indeed, one important way of characterizing a culture is by the narrative models it makes available for describing the course of a life. [. . .] I believe that the ways of telling and the ways of conceptualizing that go with them become so habitual that they finally become recipes for structuring experience itself, for laying down routes into memory, for not only guiding the life narrative up to the present but directing it into the future.

> [...] [E]ventually the culturally shaped cognitive and linguistic processes that guide the self-telling of life narratives achieve the power to structure perceptual experience, to organize memory, to segment and purpose-build the very 'events' of a life. In the end, we become the autobiographical narratives by which we 'tell about' our lives. And given the cultural shaping to which I referred, we also become variants of the cultures' canonical forms."

11.3 Where Do We Stand?

It is now time to pause and look back to see if a pattern is emerging in terms of an empirically based model of man and how it relates to the homo oeconomicus conception of man used in economics. And the pattern that is becoming visible is more complex, but also much more fascinating, than homo oeconomicus. What are the core elements?

- First, humans are constantly adapting their behavioral repertoire and specific behaviors. This type of learning occurs at multiple levels, from epigenetic effects to emotional responses to cognitive narratives, and this learning has implications for conscious perception of reality. Learning occurs automatically and mostly unconsciously, and it manifests itself in the form of habits and personalities (as bundles of habits). However, even if habits are already present, adaptation continues and also modifies or replaces older habits. Moreover, individuals can actively influence the processes of habit formation by choosing the kinds of experiences they seek. These findings contrast with the assumption of exogenous and time-invariant preferences in economics. This need not be problematic from a positive perspective, as long as the predictions that can be made with the simple preference-maximization model are empirically correct. What is less clear, however, is what the results imply from a normative perspective, because even if individuals had changing but at any point in time stable preferences, the normative significance of them for measuring well-being is unclear. Moreover, if one takes seriously the possibility of maladaptation, these short-term preferences could be an expression of an underlying problem that the individual or society should address, rather than an expression of genuine self-interest. This possibility becomes particularly pressing when we consider that our brains learn not only from direct experiences but also from "mediated" experiences, e.g., through the media.
- Second, we have seen that perception and behavior are influenced by many emotional mechanisms, and it is *ex ante* unclear which of them will prove dominant in a given situation. Herein lies one source of the *framing* and *anchoring* effects discussed in Chap. 10. We illustrate the implications using the example of risk preferences, a concept discussed in Chaps. 8 and 10. Mainstream theory (including behavioral economics, see *prospect theory* from Chap. 8) conceptualizes risk behavior as an at least locally stable pattern of behavior that can be represented by, e.g., an expected-utility function and measured by the

curvature of the indifference curves of the Bernoulli utility function. Is there evidence for the validity of this approach? If we summarize the findings from this chapter, the picture becomes more fragmented, as we have seen that the specifics of the situation and the way it is perceived are crucial for behavior. Risk behavior is sensitive to a number of factors. Therefore, the traditional approach can lead down a wrong track. The avoid systems, which are responsible for emotions such as fear, anxiety, or disgust, tend to promote risk-averse behavior unless a fight response seems to be the only alternative. In contrast, the dopamine system promotes risk-seeking behavior. To further complicate the picture, testosterone responds to status threats. Whether this implies risk-averse or risk-seeking behavior depends on the specific status of narratives within a society and thus on the narrative level of the self and society. Because our brains are constantly searching for cues regarding the safety of the environment, the evaluation of a situation can quickly change from a perception of safety (approach) to a threat (avoid), and we can therefore expect risk behavior to be highly context-dependent. The interpretive context of a situation is critical to behavior. Therefore, even without adaptation or learning, we should expect less stability in behavior than implied by the standard approach.

- Third, the specific functioning of different emotional mechanisms makes it plausible to reconsider the normative position of identifying well-being with preference satisfaction. The dopamine system, as a very important approach mechanism, rewards what is called *positive surprisal* and thereby threatens to lead to a hedonic treadmill in which people constantly seek novelty (as long as the avoid mechanisms do not get the upper hand) without ever reaching a point of satisfaction. And both oxytocin-induced ingroup–outgroup behavior and the complex relationship between physical and moral disgust make it seem at least reasonable to ponder whether all types of behavior and motives for action are equally acceptable in a society. The role of narratives, with their influence on identities, further complicates these questions. Both mechanisms supported the survival of our ancestors in evolutionary times, but this fact does not normatively justify behavior. And the rapid rate of change in modern societies makes it likely that some of these traits are no longer adaptive adjustments to contemporary challenges. Conversely, the role of testosterone in competitions for status requires a reassessment of the basic status-related narratives we find in our societies. The traditional preference model does not question the normative legitimacy of behavior. This sounds like a laudable expression of tolerance but turns out to be a self-imposed blindness to morally problematic behavior and the structural reasons for its existence.
- This last point is further strengthened when one considers, fourth, that most people are more or less ignorant of the underlying factors that explain their narrative perception of reality and their behavior. A culture that views preferences as the ultimate and legitimate goal of behavior and the fulfillment of preferences as happiness and a good life is blind to the deeper reasons that explain how these preferences come into existence. What we know today about the functioning of emotional mechanisms (as in the high road–low road model), the relationship

between conscious and unconscious decision-making, and the tendency towards confabulation calls into question the notion of autonomous decision-making. At the same time, this knowledge allows us to reevaluate the idea of freedom of choice. Traditional economics assumes that freedom means getting what one wants and that life satisfaction has to do with the circumstances of our lives. The insights we have presented here paint a very different picture, namely that life satisfaction arises in no small part from the way we develop our habits and personality, from our willingness to examine and change the way we feel and think.

- Fifth, the inescapable importance of safety and security and of belonging to other well-meaning people for a successful life indicates that these two areas should occupy a central position in the normative discourses of any society. Belonging and security are existential needs for human beings.

11.3.1 Virtue Ethics and the Creation of Good Habits

The conception of humanity that became visible bears striking resemblance to a class of very old theories from ethics called *virtue ethics* (see Chap. 5). We will present the basic elements of the model of man underlying these traditions. One of the key points of virtue ethics is that a good life requires an active influence on the process of habit formation. The risks and rewards of the processes of habit formation are obvious: if habits necessarily form over the course of life, without an understanding of the processes that lead to them and their role in life, habits may result that are dysfunctional or detrimental to happiness. Virtue ethics are ethical theories in a broad sense; they ask not only what the individual owes to other individuals, but more importantly, what they owe to themselves. They are about the right way to live. And the formation of good habits plays a central role in these theories. Virtue ethics as a concept of the good life also emphasizes that the good, flourishing life is possible only if one actively participates in community life and respects and internalizes norms of justice and morality. For Aristotle, for example, justice was the most important virtue. A good life is not possible in a society that suffers from injustice.

Virtue ethics must be used in the plural because many variants have arisen in different cultures over the ages. They all assume that an individual's character, personality, and perception are shaped by past experiences. These experiences can be influenced to some extent by the individual, and not all character and personality traits and perceptions are equally conducive to a good life. The good, or as it is also called, *eudaimonic*
indexEudaimonia life, is one in which the individual develops a certain kind of character. Different virtue ethics are unified by the following two criteria:

- The theory establishes the social and environmental conditions that support human flourishing and the good life.

- The theory specifies how the human mind and/or brain and/or body must be structured to lead a good life.

With these criteria, we get a large class of theories to be considered virtue ethics, ranging from Aristotelian and other ancient Greek concepts to Daoism, Confucianism, Buddhism, or the yogic traditions of Hinduism. One can also see why virtue ethics resonates with the previous model and the results presented; they are built on a view of humanity that places development at its center. And the character traits to be developed are in principle no different from other skills: "The expert pianist plays in a way not dependent on conscious input, but the result is not mindless routine but rather playing infused with and expressing the pianist's thoughts about the piece. [. . .] The analogy [of virtue] with practical skill, then, enables us to see how virtue can be a disposition requiring habituation without becoming mere routine." (Annas, 2011, p. 13f). Modern insights from neuroscience, psychology, and evolutionary biology can help modernize virtue-ethical concepts of the good life by providing empirical evidence about the behavioral and perceptual effects of experiences and habits. For example, understanding the dopamine system allows us to better understand our own desire for novelty. Understanding the role of disgust allows us to question our perception of others, etc. It can also provide clues to the long-term consequences of behavior, allowing us to assess whether one wants to become that type of person.

This understanding and examination of one's life is an important step in the process of attaining *autonomy*, a form of freedom we will now look at in more detail. Central to such theories of the good life is the idea that individuals can and must develop autonomy, inner freedom. As we have seen in the previous sections, affective and cognitive perceptions of reality are dynamic processes that reflect past experiences, culture, and so on. Therefore, the way the individual perceives and reacts to situations at any given moment is a preliminary and more or less arbitrary endpoint of this process of adaptation. We have also seen that cognition has a tendency to confabulate. In this sense, emotions and narratives are real because they are what an individual experiences in a given situation, but at the same time arbitrary because an individual with a different history of experience would have arrived at differently calibrated affects and different narratives, including narratives of the self. This is where the idea of autonomy comes into play. Autonomy is the ability to distance oneself from one's own feelings and narratives and to critically reflect and act independently of immanent impulses. Actions have two purposes in this regard. The first is to solve an immediate problem (such as buying an apple or a candy bar), and the other is to willfully shape habits over time so that they are as consistent as possible with a model of the good life. It is generally agreed that a life in which the individual is a "slave to its passions" is not a eudaimonic life, and metaphors of surprising similarity are found in various cultures to illustrate this point. Plato used the metaphor of the charioteer and the two horses. The charioteer represents reason, one horse represents the rational and moral impulses (the positive side of our affective nature), while the other represents our irrational passions. The challenge is to train the horses to run harmoniously in the direction dictated by reason. In Daoism, there is the metaphor of the shepherd (reason) and the ox (e.g., affects), which illustrates the stages of a practitioner's progress towards the cultivation of virtues. And in Buddhism, there is the metaphor of the rider (reason) and the elephant (e.g., affects). The harmonious, eudaimonic, and examined life is that in which affect and reason are not only in harmony, but in which reason is also free from false perceptions.

The above arguments suggest that there is no distinction between habits, virtues, character, and eudaimonia in virtue-ethical conceptions of the good life. One does not ultimately develop virtues in order to become eudaimonic; they are not a means to an end. Eudaimonia is expressed in a specific attitude towards life: "Possibly the most significant problem about virtue's relation to happiness imported by thinking of the latter in terms of pleasant feelings or satisfaction is that it leads us to confuse the circumstances of a life with the living of it. [...] Given that so much in contemporary work on happiness searches for happiness in the circumstances of our lives, it bears repeating that money, health, beauty, even relationships don't make us happy; our happiness comes in part from the way we do or don't actively live our lives, doing something with them or acting in relation to them." (Annas, 2011, pp. 149). Eudaimonia is thus itself a practice that begins with a willingness to see affective and narrative reality for what it is: an arbitrary and temporary endpoint of an ongoing process of habit formation within the framework of our genetic and epigenetic inheritance.

A virtue-ethical concept of man and the good life stands in sharp contrast to homo oeconomicus. Stocker (1976, p. 457) develops this point using the example of hedonism: "Hedonistic egoists take their own pleasure to be the sole justification of acts, activities, ways of life; they should recognize that love, friendship, affection, fellow feeling, and community are among the greatest (sources of) personal pleasures. Thus, they have good reason, on their own grounds, to enter such relations. But they cannot act in the ways required to get those pleasures, those great goods, if they act on their motive of pleasure-for-self. They cannot act for the sake of the intended beloved, friend, and so on; thus, they cannot love, be or have a friend, and so on. To achieve these great personal goods, they have to abandon that egoistical motive. They cannot embody their reason in their motive. Their reasons and motives make their moral lives schizophrenic. [...] We mistake the effect for the cause and when the cause-seen-as-effect fails to result from the effect-seen-as-cause, we devalue the former, relegating it, at best, to good as a means and embrace the latter, wondering why our chosen goods are so hollow, bitter, and inhumane. [...] But what must also be looked at is what it does to us—taken individually and in groups as small as a couple and as large as society—to view and treat others externally, as essentially replaceable, as mere instruments or repositories of general and non-specific value; and what it does to us to be treated, or believe we are treated, in these ways. At the very least, these ways are dehumanizing."

11.3.2 Implications for an Economy that Promotes the Good Life

What are the possible consequences of these findings for the economy and society? To answer this question, one cannot build on a body of established research comparable to mainstream economics. However, there are some patterns consistent with some of the so-called heterodox schools of economics.

In general, a virtue-ethical theory of the relationship between the individual and the state, whose goal is to promote eudaimonic well-being, starts from the observation that the development of individual habits and character traits depends on and is intertwined with the rules of society. Thus, the normative perspective on rules is quite different from that found in mainstream economics. There, rules are *by definition* not mechanisms that can change preferences, habits, or a person's character. When individuals have exogenous preferences, the reason for rules is to create incentives. This methodology was discussed in Chaps. 4 and 7. In contrast, in a view of human beings based on a virtue-ethical conception of the good life, first, the interdependencies among rules, habits, and personalities become the main component of a normative theory of economics or society. This position is exemplified by Aristotle, who wrote "Lawgivers make the citizens good by training them in habits of right action. It is in this that a good constitution differs from a bad one." (Aristotle 2002 [350 BCE], cited in Bowles, 2014). This normative foundation does not necessarily establish the state as a paternalistic agent, but rather it is an acceptance of the fact that habit formation will occur no matter what. Such a perspective on the state differs from the incentive view of modern economics. And if the underlying model of man is correct, the next step is, second, to ask whether one can find common ground regarding how to distinguish good habits and narratives from bad ones and how to encourage the development of the good ones.

We have seen that safety, security, belonging, positive personal development, and thus freedom are key elements for human flourishing.

- Safety and security have two dimensions. The first is economic: a certain level of material well-being and insurance against risk is a necessary condition for safety and security. The implication is an economy that guarantees a minimum income and insurance against elementary life risks, for example, through a social-security system. The other dimension relates to the absence of violence and crime and to the development of healthy forms of competition. Security is also linked to the dimension of sustainability.
- A sense of belonging partly overlaps with security but has a more complex meaning. People who are small cogs in the immensely complex machinery of global capitalism are unable to develop two important dimensions of their potential as human beings. As noted by Adam Smith, specialization allows for increased production but has potentially negative side effects in the form of alienation (see Chap. 2). It is difficult to find meaning in life when one does not understand one's role in a complex process of production and consumption, lacks agency, and is faced with monotonous and boring activities most of the

time. The latter also encourages the development of habits in which people fall short of their potential because creativity, spontaneity, etc. cannot develop sufficiently. In addition, a sense of belonging depends on knowing and engaging with one's surroundings and stable, meaningful relationships with other people. A side effect of the absence of such a sense of belonging is that people lose their moral compass because the consequences of behavior remain abstract. This moral blindness is not necessarily caused by selfishness or even malice but is a result of creating contexts in which moral behavior is impossible. In the long run, however, such an environment breeds selfishness, since empathy and compassion are character traits that, like others, must be learned and trained.

- Which brings us to positive personality development in general. We will look at two aspects of this complex topic.
  - To be able to develop a eudaimonic personality, freedom and autonomy are essential. In the homo oeconomicus model, freedom is freedom of choice. This is a form of external freedom, the ability to impose one's will on the external world. In virtue ethics, however, freedom has another meaning: autonomy, the ability to understand and control one's impulses and to develop one's personality by acquiring good habits. This concept of freedom was the dominant one among early modern philosophers such as John Stuart Mill and Adam Smith, who invented important aspects of our understanding of a democratic, market-based society and capitalism.

    For Mill, external freedom (political and economic) was necessary, but not sufficient for the very goal of autonomy: to become autonomous, and to develop self-determination and good habits, one needs some degree of external freedom, but the ultimate goal is autonomy. Therefore, a state that unnecessarily restricts external freedom is harmful in two ways. It creates citizens who act out of fear of punishment or other negative consequences of deviant behavior, which is contrary to eudaimonia. And the restrictions make it difficult for citizens to experience themselves as individuals with agency who can determine their own destiny by becoming autonomous.

    Smith, on the other hand, distinguished between two normative guides to action, rules and virtues. Rules control certain detestable behaviors and create a framework of shared expectations in a society. They limit external freedom insofar as they are prescribed as social norms or laws. They make people who are not fully virtuous act with a modicum of decency. And, acting as normative anchors, they make it harder for everyone else to justify their selfish behavior. Virtues, however, require more than following rules; through them we internalize right behavior by developing the necessary habits. And we develop a deeper understanding of the appropriateness of behavior. The virtuous person does not need rules to constrain behavior because she or he has internalized them and understands their meaning. So good rules no longer restrict the freedom of the virtuous person because she/he has internalized them. In Aristotelian virtue ethics, this is called *phronesis*, practical wisdom, the ability to act in accordance with the needs of a situation. For Smith, building on Aristotle, virtue is constitutive of a good life. The good state, therefore, provides its citizens with sufficient external freedom while creating the necessary rules in a way that facilitates the development of good habits.

– The second central element of personality development is education. Virtue ethics necessarily focuses on aspects of human development and thus on the role of education. Education, according to this view, is more than the teaching of skills or vocational training. The idea of education is the development of personality in a comprehensive sense. An example of this ideal is Wilhelm von Humboldt's model of higher education. In a letter to the Prussian king, he laid out the cornerstones of his vision: "There are undeniably certain kinds of knowledge which must be of a general nature, and, more importantly, a certain cultivation of the mind and character, without which no one can afford to be. People, of course, cannot be good craftsmen, merchants, soldiers, or businessmen unless, whatever their profession, they are good, upright, and—according to their circumstances—well-informed people and citizens. If this foundation is laid by school education, professional skills are easily acquired later, and man is always free to change from one profession to another, as so often happens in life." (Humboldt, quoted in Günther, 1988, p. 132). The term "cultivation of the mind" refers to Humboldt's virtue-ethical position with its ideal of autonomy and self-determination through the development of inner freedom and good habits.

Minimum income and insurance that guarantee both security and external freedom, comprehensive education as a form of personal development, meaningful activities as vocation and not just a job, all these elements point in the direction of a society with strong egalitarian tendencies that is nevertheless based on the principles of external freedom, agency, and individual responsibility. In order to facilitate the creation of responsibility and belonging, the economy has to be regional, sustainable, and decentralized.

There is still one missing piece that we need to consider to complete this sketch. The insights from this chapter also show that eudaimonic happiness and flourishing are not necessarily linked to progress in the materialistic sense. Material well-being is important as long as it contributes to the above aspects of security, education, etc., but not beyond that. On the contrary, a materialistic society can be based on narratives and role models of success and prosperity that can hinder eudaimonic growth and that are ecologically unsustainable. Moreover, the accumulation of material wealth can divert time from the development of autonomy. Conversely, a life that strives for autonomy is almost the opposite of a life that strives for convenience and is characterized by consumerism and a naïve notion of individualism. It understands that examining one's way of life takes a lot of work but is essential to living well.

Digression 11.5 (The Capabilities Approach)
The most prominent example of an economic theory that can be grounded in virtue ethics is Amartya Sen's *capabilities approach*. It has become quite influential in practice as the *Human Development Index* published by the United Nations since 1990 as an alternative to measuring economic development by the concept of *Gross National Income* is based on it.

The capabilities approach is an example of measuring development based on a concept of universalizable human needs, needs that everyone has regardless of preferences or economic and social position in life. Another example is John Rawls' concept of primary goods in his theory of justice as fairness (which, however, is not based on a virtue-ethical model of man). Theories like these are called *perfectionist* because they require an objective conception of what makes life meaningful, fulfilling, and good: "[A perfectionist] moral theory starts from an account of the good life, or the intrinsically desirable life. And it characterizes this life in a distinctive way. Certain properties, it says, constitute human nature or are definitive of humanity—they make humans human. The good life, it then says, develops these properties to a high degree or realizes what is central to human nature." (Hurka, 1993).

Sen's basic insight has been that there is a distinction between goods and what goods can do for people. For example, income has no value in itself. It is valuable, according to Sen, in that it allows people to

- stay/become healthy,
- be adequately nourished,
- be mobile,
- have self-respect,
- participate in community life, and
- and be happy.

Sen calls the various items on the list *functionings*, and they represent the specific objective list of human needs on which his theory is based. Moreover, he emphasizes the importance of freedom for human flourishing. His normative ideal is that *ceteris paribus*, for example, income should be distributed in such a way that the functionings that persons can achieve are equally distributed. Assuming that these can be measured on an ordinal scale, any combination of functionings can be represented by a vector. For example, people can convert income into vectors of functionings, and the set of functionings from which an individual can choose is called her or his capability set. He emphasizes that the ability to choose from a large capability set is a value in itself.

We have discussed the capabilities approach as an example of a normative economic theory that is compatible with a virtue-ethical model of man. It

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Digression 11.5 (continued)
focuses on the conditions for flourishing to be possible. However, there are two differences worth noting. First, the findings from neuroscience, psychology, and evolutionary biology presented in this chapter provide a naturalistic account of human development by gathering scientific evidence supporting a specific normative view of human flourishing. And it is argued that these findings have normative consequences for how one should think about individual behavior and the role of the economy/society. The capabilities approach uses functionings as normative ends without providing psychological or neurological evidence for the specific role that these functionings play for human development. Second, while the capabilities approach mentions human development, it does not develop a detailed account of character formation and the relationship between individual behavior and economic and social rules. A comprehensive economic theory built on a naturalistic concept of human flourishing would therefore go deeper than the capabilities approach.

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Part IV

Firm Behavior and Industrial Organization

12 Costs

This chapter covers · · ·

- the importance of cost functions and their role in managerial decision-making,
- the relationship between a firm's production technology and its cost function, and
- different types of costs and their relevance.

12.1 What Are Costs, and Why Are They Important?

Two roads diverged in a yellow wood,
And sorry I could not travel both
And be one traveler, long I stood
And looked down one as far as I could
To where it bent in the undergrowth.
(Robert Frost, The Road Not Taken)

If one goes shopping and buys a new pair of sneakers, the cost for one's sneakers is the price that one pays for them. The monetary price of a good is, however, only part of the story economists tell when they talk about costs. As covered in Chap. 1, scarcity implies that one's decision to go *this* way makes it impossible to go *the other* way; that all activities have opportunity costs. The opportunity cost of choosing one alternative is the value that one attaches to the next-best alternative foregone. The implication for the sneakers example is that the total costs of the sneakers are, in general, higher than the price one pays, because one has to invest time and effort to find and buy them. If one could have used one's time otherwise, then one has to take the opportunity costs of time into consideration to get a correct measure of the costs one has to incur to get hold of a new pair of sneakers. To give another example, opportunity costs are the reason why it may be silly to drive the extra mile to refuel your car, only because the gas station is a cent cheaper.

M. Kolmar, *Principles of Microeconomics*, Classroom Companion: Economics,
https://doi.org/10.1007/978-3-030-78167-5_12

However, the true costs of sneakers are only higher than the monetary costs *in general*. It may be that one actually enjoys going shopping, which implies that the opportunity costs of time are negative, subtracting from the monetary costs. Moreover, to make things even more involved, the value that one attaches to the price sticker may depend on one's situation in life and one's expectations. If one assumes that there will be considerable inflation the next day, reducing one's purchasing power substantially, one will most likely do one's best to get rid of one's money *that day*. Thus, all costs are ultimately opportunity costs, which are psychological and subjective concepts of value that are related, but not identical, to market prices.

The fact that the relevant costs are opportunity costs may be interesting in and of itself, but the real importance of this observation becomes apparent if one considers the implications for decision-making. Here is an example: assume one wants to make some extra money parallel to one's studies by offering tutoring services to other students, but one is not sure whether this is a good idea, because one does not fully oversee all the consequences of this decision. In order to get a better idea, one makes a business plan to identify the costs and benefits of one's decision. To keep the analysis simple, assume that one can help one student at a time (class size is one) and that the only things one needs to get one's business going are one's time and a room that one has to rent. Furthermore, assume that one can teach up to 20 h per month. The monthly rent for the room is CHF 500, and one can charge students CHF 50 for an hour of tutoring. A first back-of-the-envelope calculation reveals that one has to teach for 10 h per month to cover one's monetary costs (this is called the *break-even point*). If one teaches for the entire 20 h, one ends up with a monetary profit of 20 · CHF 50 - CHF 500 = CHF 500. Given this calculation, the question is if one is willing to enter the tutoring business. Based on the above calculation, one should enter the tutoring business because of the positive monetary profit.

If, however, one does not feel completely happy with starting the business based on this calculation, the reason must be that one puts this number into a different context. What could that context be? For example, the next-best alternative on the job market could be to work as a barista in a café, at an hourly wage of CHF 30 (including tips). Thus, working 20 h, one could earn CHF 600 per month. Even though the hourly wage is much smaller than the one that one could earn for tutoring, the income exceeds the profits from tuition, because one does not need to pay the rent. Therefore, compared to the barista job, one would *loose* CHF 100 by opening one's business. Hence, one should somehow take these opportunity costs explicitly into consideration.

Now, one could argue that tutoring is a more meaningful way to spend time for one than brewing coffee is. If this is the case, one should also include these psychological rewards and costs into one's calculation. Working may not just be about making money, but also about doing something that one finds meaningful, which implies that there is a difference between costs and expenditures. Assume that one assesses the intrinsic pleasure that one gains from tutoring by CHF 30 and the intrinsic pleasure that one gains from brewing coffee by CHF 20 per hour. In that case, these psychological benefits sum up to opportunity costs of brewing coffee of CHF 20 · CHF 30 − 20 · CHF 20 = CHF 200, which would tip the balance towards opening one's tutorial business.

Table 12.1 Optimal decisions depend on opportunity costs

	Tutor	Barista	Exam
Rental costs	500	0	0
Wages	1000	600	0
Net	500	**600**	0
Intrinsic pleasure	600	400	500
Net	**1100**	1000	500
Future income	0	0	1000
Net	1100	1000	**1500**

One can elaborate on one more aspect of the problem of getting the business plan straight before summarizing it. Assume that the alternative to opening one's business is not working as a barista, but studying for one's exams. In that case, there are no direct monetary opportunity costs that can be taken into consideration. However, even in this case, one has to figure out how much the additional 20 h of studying would be worth. These benefits might be completely functional, driven by the effect that one's grades get better and one is, therefore, more likely to qualify for better programs and jobs. On the other hand, they might be purely intrinsic, measuring the pleasure that one derives from learning. Regardless of how one evaluates one's own situation, the theory suggests that one should be able to attach some monetary value to these alternatives in order to be able to make the right decision. Table 12.1 gives an overview of the example. It is assumed that one can attach a monetary value of CHF 500 to the intrinsic pleasure of learning and a monetary value of CHF 1000 to the better job prospects.

What the above example has illustrated is that costs are a tool that can help one to make smart decisions. However, in order to be able to support your decisions in a rational way, one has to think about costs in terms of opportunity costs. If the costs are calculated incorrectly, then one's decisions will not be smart.

One may wonder if it is always possible to attach a meaningful monetary value to psychological opportunity costs. Numerous psychological studies have shown that, for different reasons, people have trouble specifying their valuations of alternatives in a reasonable way. How reliable is the figure that one attaches to the value of 20 h of additional learning? Will one really use the time to learn? Can one anticipate how much fun it will be to help other students? People are very bad in what is called *affectual forecasting*, i.e., anticipating how they will feel in the future. Is one's perception of the psychological costs and the benefits context-dependent? There is also evidence that people have a tendency to rationalize their gut feelings by developing narratives that selectively focus on aspects that support their "guts." The term *narrative fallacy* describes how flawed stories of the past influence one's perception of the present and future. People have an innate urge to develop a coherent story about the events that shape their lives and simplicity and coherence often more important than accuracy. The mind is a sense-making organ and the narratives it cooks up reduce the anxiety that one would experience if one faced the complexity and unpredictability of life. This may help one in one's life, but it is not the same as descriptive accuracy.

Nevertheless, if one has ample reason to scrutinize the numbers that one assigns to psychological opportunity costs, would it not be better to abandon the idea altogether? This would throw out the baby with the bathwater, because one has to decide somehow and decisions that take all the relevant opportunity costs into consideration are, in expectation, better than decisions that neglect some of the trade-offs. An awareness of the flaws and biases that exist when one thinks about psychological opportunity costs can help one to put the concept into perspective and to cope with the idiosyncrasies of one's mind.

The following three examples will illustrate how one can proceed in assigning opportunity costs. Assume that a firm produces a good using capital and labor. Profits are revenues minus costs. What are the costs and revenues that are associated with this activity?

- **Case 1, all costs monetary:** The firm borrows capital from capital markets, rents labor from labor markets, and sells the good on a goods market. In this case, the revenues of the firm are the market price times the produced and sold quantity of the good (assume revenues are CHF 1000). The firm's costs are the sum of interest payments for rented capital (CHF 400) and wage payments for hired labor (CHF 500). All relevant costs and revenues are monetary, because they involve market transactions. An accounting system that includes ("takes into account") all three costs and benefits makes the business appear profitable.
- **Case 2, goods not sold:** The firm borrows capital from capital markets and rents labor from labor markets, but the owner of the firm consumes the goods directly. The costs of the firm are, again, the sum of interest payments (CHF 400) for rented capital and wage payments for hired labor (CHF 500). However, it has no monetary revenues. A system of accounting that considers only monetary payments would support the decision to shut down the business, because it would show a deficit of CHF 900. There is no monetary equivalent for the satisfaction or utility of the owner from consuming the goods (again CHF 1000). Hence, economically meaningful decisions can only be supported by an accounting system that attaches a monetary value to the satisfaction or utility of the owner.
- **Case 3, owner self-employed:** The firm borrows capital from capital markets and sells the good on a goods market, but the owner works himself/herself. In this case, the firm's revenues are, again, the market price times the produced and sold quantity of the good (for example, CHF 800 this time). The firm's monetary costs are the interest payments for rented capital (CHF 400). Without incorporating labor costs into the equation, the business appears profitable. However, this calculation would lead to the wrong decision. Assume the owner would make CHF 500, if he/she worked somewhere else. These opportunity costs should be taken into account to support the right decision. The business now appears deficient and, compared to the next-best alternative, it actually is: if the owner were to shut down the firm, he/she would earn CHF 500. Staying in business gives a monetary profit of CHF 400, so he/she actually loses CHF 100 compared to the next-best alternative.

What are the consequences of the idea that costs and revenues have to incorporate non-monetary opportunity costs? First of all, it can serve as a guideline for the design of managerial accounting systems. One of the primary reasons for the existence of accounting systems is that they can support decisions. However, as one has seen, decisions are only accurate according to some objective (profits, in this example) of the firm, if the accounting system that supports decisions incorporates all opportunity costs. These opportunity costs are sometimes referred to as *imputed interest* or *calculatory entrepreneur's salary*.

Management accounting, however, has to be distinguished from *financial reporting*. The primary purpose of the latter is to communicate a company's financial situation to the outside world. These statements are subject to legal constraints and regulations that are sometimes incompatible with the idea of opportunity costs. The so-called *imputed costs* are a good example of opportunity costs that are, in general, considered in management accounting, but are not allowed to be considered in financial statements. It is, for example, possible to activate interest payments on debt capital but not imputed interest payments on equity. Imputed interest payments on equity are opportunity costs, because they are equal to the interest payments one would have received, if the capital had been lent to someone else.

Digression 12.1 (Opportunity Costs and Maximization)
The idea that rational decisions are based on the correct identification, evaluation, and comparison of opportunity costs is closely related to the idea of *maximization*. An individual is a maximizer, if he/she consistently chooses the best (according to his/her subjective standard) alternative among the available alternatives. There is a lot of evidence that people are rarely maximizers in this sense. One is seldom in a position to know and precisely evaluate all the alternatives, because of uncertainties regarding the relevant probabilities and cognitive limitations. Hence, a lot of people are not aiming for the best, but for a good enough alternative. Think of your decision to meet a friend for dinner. Most people browse their directory and call the first friend with whom it seems sufficiently interesting to spend the evening with. Simon (1957) called this type of behavior *satisficing*. The idea is that individuals have certain aspiration levels and choose the first alternative that meets these standards. Because of that, the resulting choices are, in general, less than optimal. There may have been friends in your directory with whom you could have spent an even better evening.

At first glance, satisficing seems to contradict the idea of maximization and thereby the concept that one should start by identifying and evaluating all opportunity costs. However, advocates of the maximization approach have argued that the opposite is the case: satisficing is optimization where all opportunity costs, including the costs of processing information and optimization, are considered. Looking for the best friend to spend the evening

(continued)

Digression 12.1 (continued)
with may be so complicated and time consuming that, in the end, one has dinner alone. It is disputed, however, whether this is a legitimate defense of the idea of maximization. It brings the whole concept close to a tautology, because it comes with the risk of explaining every type of behavior by identifying arbitrary and non-falsifiable opportunity costs.

What studies with monozygotic and dizygotic twins have shown is that the tendency to satisfice or to maximize has a strong genetic component and that people can be categorized into "maximizers" and "satisficers." Interestingly, maximizers tend to make better decisions than satisficers but are less happy with them. One explanation for this apparent paradox is that even maximizers tend to fail to identify the best alternative in complex environments but are more aware of the fact that they may have failed to achieve their goals. Hence, they often feel regretful when they evaluate their choices. Therefore, in the end, the satisficer goes to the first ok-looking restaurant with the first ok-looking friend and spends a happy evening, whereas the maximizer continuously questions whether sushi with Sasha would have been better than pizza with Paul.

12.2 A Systematic Treatment of Costs

One is now in a position to define costs in a systematic way. In the easiest case of factor costs that are linear in factor inputs, costs are the sum of factor inputs evaluated by their prices (be they monetary or opportunity costs). If there is only one input whose quantity is denoted by q and that can be purchased at a price (per unit) of r. In this case, costs are simply $\mathcal{K}_{al}(q, r) = q \cdot r$ (the subscript refers to the fact that it is additive and linear). If there are $i = 1, \ldots, m$ different inputs with quantities denoted by q_i and prices by r_i, the *cost equation* can be defined as

$$\mathcal{K}_{al}(q_1, \ldots, q_m, r_1, \ldots, r_m) = \sum_{i=1}^{m} q_i \cdot r_i .$$

The cost equation is easy to specify, but it is not particularly interesting for economic decision-making. What one would like to understand is the relationship between *output* and *costs* or, more precisely, between output and the *minimum costs* that are necessary to produce this output. This information is given by the *cost function*.

Definition 12.1 Cost Function A cost function $C(y_i)$ assigns the minimum costs to the production of y_i units of a good i.

Factor costs that are linear in factor inputs are a natural starting point if factor markets are perfectly competitive and function in the same way as perfectly competitive goods markets. This assumption builds a close link between the technology of production and the structure of the cost function. However, it simplifies the underlying structure of contracts in a way that may be an oversimplification in a number of cases. Assume for example that one can rent office space on a daily (you come to the office building in the morning and pay for the day) or on a monthly basis (you sign a rental agreement that is fixed for the next month). The difference between these two contracts are the relevant opportunity costs (even if monthly total costs are identical if you rent all days). In the first case, you decide and pay each and every day, which makes daily rental costs part of the relevant daily opportunity costs. In the second case, you decide and pay at the beginning of the month, which implies that the daily opportunity costs of office space are zero after you have signed the contract (you cannot avoid them). As we will see, this difference will also make a difference with respect to economic decision-making. This is why we also use a more general definition of the cost equation, $\mathcal{K}(q_1, \ldots, q_m)$, that does not have to be additive and linear in factor inputs but that is (weakly) increasing in factor inputs:

$$\mathcal{K}(q_1, \ldots, \hat{q}_i, \ldots, q_m) \geq \mathcal{K}(q_1, \ldots, \bar{q}_i, \ldots, q_m) \quad \forall \quad \hat{q}_i \geq \bar{q}_i, i = 1, \ldots m.$$

In principle, it would be possible to define certain properties of cost functions and see what they imply for the behavior of firms in different market contexts. Economists, however, usually take a detour and establish a causal link between the cost equation and the cost function, because it allows them to see how the cost function relates to the physical properties of production. This is important for assessing, for example, the effects of technological change on market behavior or market structure, and so on.

Production is, first of all, a physical activity that transforms matter from one state into another, generally more desirable state. The rules of transformation are summarized by the so-called *technology of production*. It is the set of all technologically feasible input–output combinations and is—mathematically speaking—a set. The boundary, or "outer hull," of this set is the subset of all productively efficient input–output combinations because at a point along the outer hull it is (for given quantities of inputs) only possible to increase the production of one good by lowering the production of some other good. This outer hull is called the *production-possibility frontier*. It can—under certain conditions—be represented by a function that one calls the *production function*.

▶ **Definition 12.2 Production Function** A production function relates the output of a production process to the necessary inputs. It assigns the productively efficient output to any combination of inputs.

Digression 12.2 (Firms as Production Functions and Firms as Organizations: How Efficient can One Possibly be?)
At this point, it is important to scrutinize the basic assumption that a point along the production function can actually be reached. Underlying this assumption is the view that firms are able to organize economic activities within the firm in a perfectly efficient way. Historically, economists were not particularly interested in the management structures of firms and treated the firm as a black box that entered their analysis as a production function. This simplification might be useful, if the primary focus of the analysis is the interaction of supply and demand on markets. As one knows from the short introduction into the philosophy of science (Chap. 1), every scientific theory has to make simplifying assumptions; the question is if the simplifications are useful.

The firm-as-production-function view was challenged when economists started to realize that they cannot explain the existence of firms as subsets of transactions that replace decentralized market transactions with more centralized forms of governance. Since then, a large body of literature on the internal organization of firms and the boundaries between firms and markets has emerged that allows one to better understand under what conditions and with what kind of organizational structure companies can get to or close to the production function. This issue boils down to understanding if firms can organize economic activities in a way that all interdependencies, which are internal to the firm, are internalized (i.e., no firm-internal externalities exist). The strands of the literature that focus on these problems are called *principal-agent theory*, *contract theory*, or merely *theory of the firm*. The important point is that one has to conceptually distinguish between the production function and the relationship between inputs and outputs, which exists given the (possibly imperfect) way economic activities are organized within a firm.

Economists and business economists are usually no experts in the physical laws of production. Nevertheless, they have to be able to communicate with engineers and scientists (who are experts in respect of these laws of production) in order to understand how the production process influences the structure of the cost function. The idea is relatively straightforward and can be exemplified by means of a (hypothetical) production technology that transforms one input, labor (l), into one output, apples (y). The input price is equal to the market wage (w). The production function can then be defined as $y = Y(l)$, and the structure of the function $Y(.)$ summarizes the “laws” for transforming labor into the number of apples picked. A potentially interesting question is by how much the number of apples picked is increased by one additional unit of labor.

▶ **Definition 12.3 Marginal Product** The marginal product of a production function measures the change in production y that is caused by an additional unit of an input l.

In order to access the powerful toolbox of Calculus, one has to assume that infinitesimal changes in inputs and outputs are possible and that the production function is continuously differentiable. These assumptions allow one to approximate the marginal product by taking the partial derivatives of the production function. Formally, let dl be a change in labor input and dy the associated change in output. With only one input and a marginal change in l, $dl \to 0$, the marginal product is given by

$$\frac{dy}{dl} = Y'(l),$$

where $Y'(.)$ is the partial derivative of $Y(.)$. If several inputs $q_1, \ldots, q_m$ are needed for production, the production function can be denoted as $Y(q_1, \ldots, q_m)$, and the marginal product for an infinitesimal change in input i, dq_i, is given by

$$\frac{dy}{dq_i} = \frac{\partial Y(q_1, \ldots, q_m)}{\partial q_i}.$$

The marginal product will be useful later on in the analysis.

Figure 12.1 gives a graphical illustration of a production function for the case of $Y(l) = \sqrt{l}$. The factor input (l) is drawn along the abscissa and the output (y) is drawn along the ordinate. The root function implies that additional labor input increases the output, but at a decreasing rate.

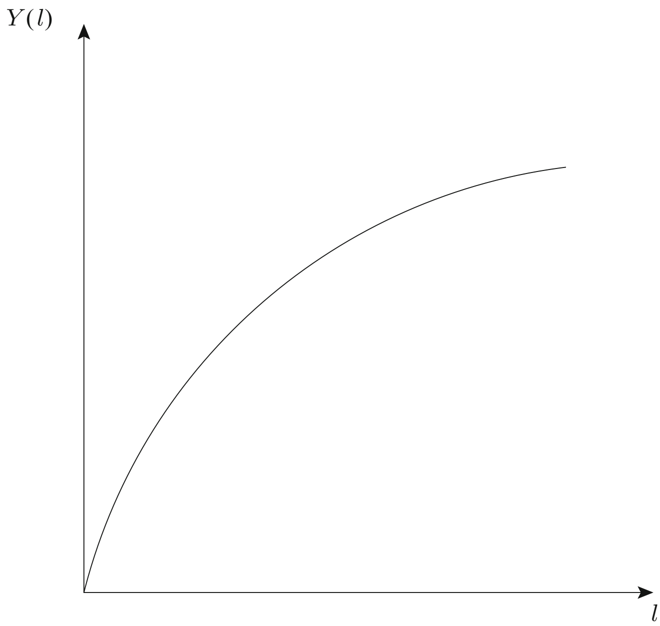

Fig. 12.1 The graph of the production function $Y(l) = \sqrt{l}$

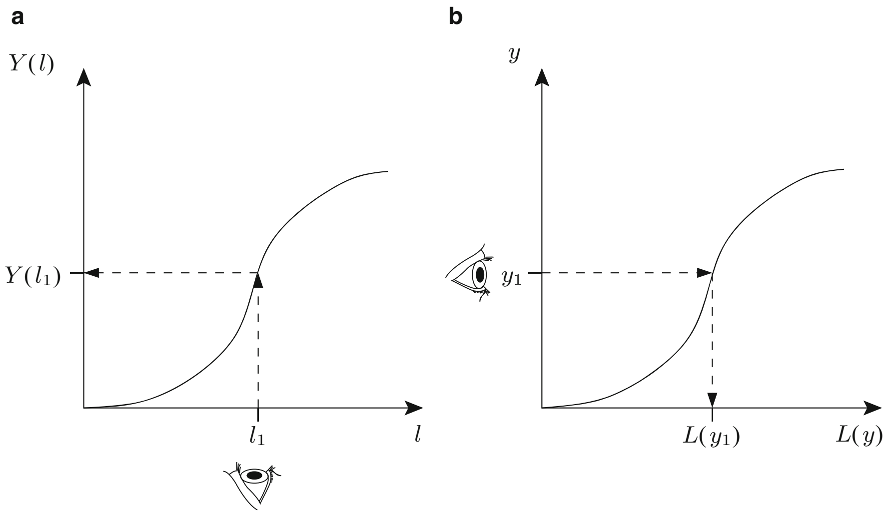

Fig. 12.2 Looking at graphs from two different angles: (**a**) production function and (**b**) cost function ($w - 1$)

Costs in the simplified case $\mathcal{K}_{al}$ are inputs evaluated by input prices. The production function establishes a link between inputs and outputs. If one had the opposite link between output and input, one would be close to the solution of the problem: if one could associate a level of input with each level of output, the only thing that one would have to do is to multiply the input by the input price to get the cost function. However, the opposite link can be readily established as the *inverse function* of the production function. It gives an answer to the question of how much input one needs for a given output. Multiply this input by the factor price and you have the cost function. More formally, assume the production function is monotonically increasing (i.e., more input generates more output), and let $\mathcal{L}$ be the set of all possible inputs and $\mathcal{Y}$ be the set of all possible outputs. The production function is a mapping from $\mathcal{L}$ to $\mathcal{Y}$, $Y : \mathcal{L} \to \mathcal{Y}$. Denote by $L(y)$ the inverse function of the production function, $L(y) = Y^{-1}(y)$. It is a mapping from $\mathcal{Y}$ to $\mathcal{L}$, $L : \mathcal{Y} \to \mathcal{L}$. Figure 12.2 illustrates.

This figure displays the relationship between labor input (l, along the abscissa) and output (y, along the ordinate). People are used to following the convention of interpreting the variable on the abscissa as the explanatory variable and the one on the ordinate as the explained variable. This is the interpretation as a production function: how much output can be produced with l units of labor input? Graphically speaking, one looks at the figure from the abscissa to the ordinate, indicated by the stylized eye in Fig. 12.2a. One can, of course, also look at the figure from another angle. In Fig. 12.2b, the stylized eye indicates that one interprets y as the explanatory and l as the explained variable. The question that one asks then is how much labor input one needs, if one wants to produce y units of output. The answer to this question is given by the inverse of the production function.

Definition 12.4 Cost Function for One Output–One Input Technologies The cost function $C(y)$ for a production function $y = Y(l)$ is given by $C(y) = L(y) \cdot w = Y^{-1}(y) \cdot w$.

Figure 12.3 gives a graphical illustration of the inverse production function $L(y) = y^2$ and the cost function $C(y) = y^2 \cdot w$, which results if $Y(l) = \sqrt{l}$. I have used $w = 2$ in the graph.

Now, output (y) is drawn along the abscissa and input (l) along the ordinate. The cost function (see upper graph) is a multiple of the inverse production function (see lower graph).

This link between the production and the cost function allows one to understand for the linear case $\mathcal{K}_{al}$ how cost functions are related to production technologies. Two qualifying remarks have to be made in order to get the bigger picture.

First, the assumption that the firm can rent or buy inputs at given input prices reveals the implicit assumption that factor markets are perfectly competitive. If the firm has market power on some input market (for example, if it is the only major employer in the region), then the relationship between costs and technology is no

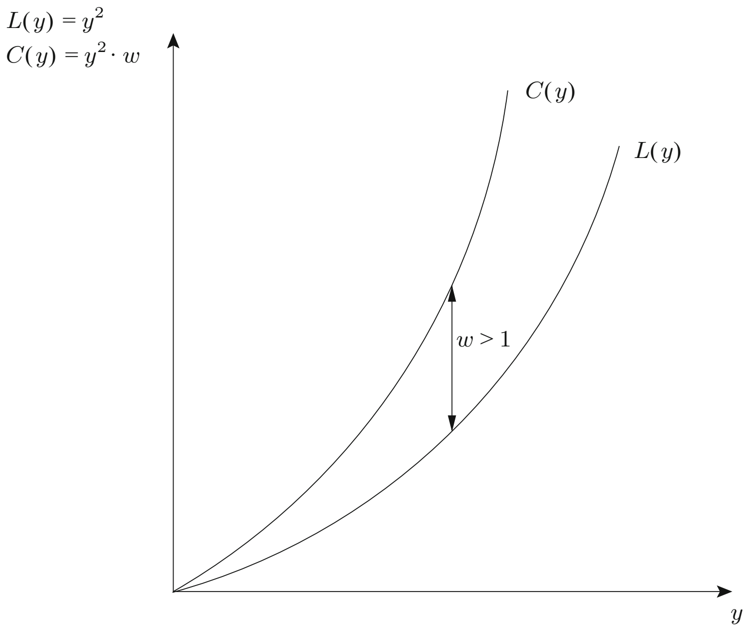

Fig. 12.3 Inverse production function and cost function

longer so straightforward and is also determined by the power of the firm to set wages as a function of labor input.

Second, it is, of course, a completely unrealistic assumption that production requires only one input. Some production processes lead to co-production, such as when crude oil is separated into its different marketable components. Multi-input production gives rise to the more complex question of how to determine the optimal mix of inputs. This optimal mix is influenced by the technologically determined degree to which the different inputs can be substituted for each other and the input prices. Manufacturing, for example, can be relatively capital-intensive or relatively labor-intensive, and the capital–labor ratio depends on the relative prices of capital and labor. In order to determine the cost function, in this case, one has to solve what is called a *cost-minimization problem*. We solve this problem for the case of two factors 1 and 2 with quantities q_1 and q_2. In this case, the cost equation is $\mathcal{K}_{al}(q_1, q_2, r_1, r_2) = r_1 q_1 + r_2 q_2$, and the production function is $Y(q_1, q_2)$. In order to be able to link output y with costs, one holds y fixed and looks for the pair of inputs q_1 and q_2 that minimizes costs at given input prices r_1 and r_2. This yields the following minimization problem:

$$\min_{q_1, q_2} (r_1 \cdot q_1 + r_2 \cdot q_2) \quad \text{s.t.} \quad Y(q_1, q_2) = y.$$

Let λ be the Lagrange multiplier, we can set up the following Lagrange function:

$$\mathcal{L}(q_1, q_2, \lambda) = (r_1 \cdot q_1 + r_2 \cdot q_2) - \lambda \cdot (Y(q_1, q_2) - y),$$

and we get the following three first-order conditions:

$$\frac{\partial \mathcal{L}(q_1, q_2, \lambda)}{\partial q_1} = r_1 - \lambda \cdot \frac{\partial Y(q_1, q_2)}{\partial q_1} = 0,$$
$$\frac{\partial \mathcal{L}(q_1, q_2, \lambda)}{\partial q_2} = r_2 - \lambda \cdot \frac{\partial Y(q_1, q_2)}{\partial q_2} = 0,$$
$$\frac{\partial \mathcal{L}(q_1, q_2, \lambda)}{\partial \lambda} = Y(q_1, q_2) - y = 0.$$

The third condition guarantees that y is in fact produced. The first and second conditions determine the optimal combination of factor inputs and can be combined to yield

$$\frac{\partial Y(q_1, q_2)/\partial q_1}{\partial Y(q_1, q_2)/\partial q_2} = \frac{r_2}{r_1}.$$

The term on the left-hand side is called the *marginal rate of technical substitution* ($MRTS$). The interpretation is similar to the interpretation of the marginal rate of substitution (MRS) in Chap. 7. It is again an expression of the idea of opportunity costs in the context of a firm's decision problem: if one takes a little bit of one factor away, how much of the other factor does one need to add in order to get the same output? The condition on the right-hand side measures the relative price of the two factors, which is the ratio at which they can be exchanged on the market. Hence, at a cost minimum, the technological exchange rate has to be equal to the market exchange rate. Why is this condition economically meaningful? The following example may be helpful: assume that the relative price of input 1 in terms of input 2 is 2 and that the $MRTS$ of resource 1 in terms of resource 2 is 4 at some point. In a situation like this, the firm could give away four units of input 2 for an additional unit of input 1 and still produce the same amount of the good. However, given the market rate of exchange, the firm has to give away two units. Hence, it can be wise to reduce costs by using more of input 1 at the expense of input 2. This logic applies to all input bundles for which the $MRTS$ differs from the market rate of exchange (the relative price). Hence, only input bundles for which the marginal rate of technical substitution equals the relative price are consistent with the assumption of cost minimization.

The solution to this problem are the so-called *conditional factor-demand functions* $q_1(r_1, r_2, y)$ and $q_2(r_1, r_2, y)$. They are called *conditional* because they depend on the level of output y. If one inserts these functions into the cost equation $\mathcal{K}_{al}$, one gets a cost function $C(r_1, r_2, y) = r_1 \cdot q_1(r_1, r_2, y) + r_2 \cdot q_2(r_1, r_2, y)$. Because one is usually interested in the relationship between costs and output, the two factor prices are suppressed in general, $C(y)$.

We can illustrate the cost-minimization problem with the following so-called *Cobb–Douglas* production function $Y(q_1, q_2) = \sqrt{q_1} \cdot \sqrt{q_2}$. The cost-minimization problem with this function is

$$\min_{q_1, q_2} (r_1 \cdot q_1 + r_2 \cdot q_2) \quad \text{s.t.} \quad \sqrt{q_1} \cdot \sqrt{q_2} = y,$$

and the Lagrange function becomes

$$\mathcal{L}(q_1, q_2, \lambda) = (r_1 \cdot q_1 + r_2 \cdot q_2) - \lambda \cdot \left(\sqrt{q_1} \cdot \sqrt{q_2} - y\right).$$

The first-order conditions are $\partial\mathcal{L}/\partial q_1 = r_1 - \lambda \cdot 0.5 \cdot \sqrt{q_2/q_1} = 0$, $\partial\mathcal{L}/\partial q_2 = r_2 - \lambda \cdot 0.5 \cdot \sqrt{q_1/q_2} = 0$, and $\sqrt{q_1} \cdot \sqrt{q_2} = y$, which gives rise to the following $MRTS$-equals-factor-price condition:

$$\frac{q_1}{q_2} = \frac{r_2}{r_1}.$$

If we use the additional condition $\sqrt{q_1} \cdot \sqrt{q_2} = y$, we can determine the conditional factor-demand functions as follows:

$$q_1(r_1, r_2, y) = \sqrt{\frac{r_2}{r_1}} \cdot y, \quad q_2(r_1, r_2, y) = \sqrt{\frac{r_1}{r_2}} \cdot y.$$

And if we insert these into the cost equation, we get the cost function

$$C(r_1, r_2, y) = \sqrt{r_1 \cdot r_2} \cdot y.$$

The conditional factor-demand functions have intuitive properties: (1) they are increasing in y, which means you need more inputs to produce more output. (2) They are increasing in the price of the other input and decreasing in the price of the own input, which means that you are willing to substitute for the cheaper input. The cost function is increasing in input prices, and it is linear in output. This latter property is a result of the fact that the Cobb–Douglas function is homogenous of degree one.

With this understanding of a cost function, one can now move on and use it as an explanatory tool for different theories of firm behavior in markets. As one will see throughout the following chapters, different types of costs will turn out to be important explanatory factors. Therefore, this subchapter will introduce them now, filling the toolbox with additional tools that one will use later on. As we have argued before, the above analysis is a special case of an additive and linear cost equation $\mathcal{K}_{al}$. The more general cost equation $\mathcal{K}$ gives rise to a more general cost function $C(y)$. We will define the different types of costs with respect to this general function, holding in mind that they apply accordingly to the special case $C_{al}(y)$.

If one takes total costs and distributes them equally among all the units that one produces, one gets the average costs of production:

Definition 12.5 Average Costs The average costs of production equal the total costs of production divided by the quantity produced, $AC(y) = C(y)/y$.

Some costs vary with, and some are independent of the quantity produced. Take computer software or cars as examples. Before one can sell a new product, one has to incur development costs. These costs are independent of the number of licenses or vehicles that one produces and sells; they are a prerequisite for their production. The reason why these costs do not vary with the volume produced is technological. But there are other contractual reasons for costs that are independent of production. It is, for example, possible that the market offers only annual rental agreements for office space. In this case, irrespective of the amount of time that you actually need the office, you can either rent it for one year or not. In a situation like this, rental costs are zero before you sign the contract and jump to the specified price thereafter.

Both examples have the property that, from an *ex ante* perspective (before one makes the investment decision), they are zero, but immediately "jump up," if one decides to develop and sell the new product. One calls these costs *fixed costs*.

Definition 12.6 Fixed Costs The fixed costs of production are the costs that occur once a firm starts production and they are independent of the volume of production,

$$FC(y) = \begin{cases} 0, & y = 0 \\ FC, & y > 0. \end{cases}$$

In case of the additive-linear cost equation $\mathcal{K}_{al}$, fixed costs are in general a consequence of the technology of production because the implicit assumption was that one can freely determine the quantity of the input at the given market price. However, if one allows for more complex (and more realistic) contracts and the resulting cost equation $\mathcal{K}$, fixed costs can also be a result of contracts that deviate from the above structure. Another example is labor contracts. In some countries with limited unemployment protection (like the United States of America) and some industries, the labor market works on a daily hire-and-fire basis (this is sometimes called a *spot market*). This gives rise to labor costs that are approximately equal to $w \cdot l$. In countries with extensive unemployment protection, however, labor costs are very different. They are zero before signing the employment contract and fixed for a certain amount of time thereafter. Costs are related to contracts, and contracts exist within an institutional framework as part of a contract. This is why costs can sometimes be independent of production volume and sometimes not, even though the underlying production technology is the same.

Now assume that there are fixed costs and that you have signed the relevant contract. In that case, the costs cannot be recovered, even if one decides to produce nothing. There is an asymmetry between the *ex ante* perspective before you sign the contract and the *ex post* perspective after you have signed the contract. *Ex ante*, costs can be avoided by not signing the contract and staying out of business. *Ex post*, this is no longer the case. This asymmetry gives rise to the following definition:

▶ **Definition 12.7 Sunk Costs** Sunk costs are costs that have already been incurred at a given point in time and thus cannot be recovered.

It can be argued that *ex ante* fixed costs are *ex post* sunk costs. The wording, despite being suggestive and widely used, is, however, misleading: if all costs are opportunity costs, then sunk costs are not "proper" costs at all, because they refer to events in the past and are, therefore, irrelevant for decisions. Remember that opportunity costs refer to comparisons between different alternatives. If "sunk costs" change the evaluation of every admissible alternative in the same way, they cannot change the relative evaluation of these alternatives, which is why they are no opportunity costs to begin with.

The costs that vary with production are called variable costs. If one is in the fruit-picking business and one hires fruit pickers every morning, then labor costs are variable on a daily basis.

▶ **Definition 12.8 Variable Costs** The variable costs of production are the costs that vary with the quantity produced: $VC(y) = C(y) - FC$.

One can now look for averages in fixed and variable costs, which motivates the following two definitions:

▶ **Definition 12.9 Average Fixed Costs** The average fixed costs of production equal the fixed costs of production divided by the quantity produced: $AFC(y) = FC/y$.

▶ **Definition 12.10 Average Variable Costs** The average variable costs of production equal the variable costs of production divided by the quantity produced: $AVC(y) = VC(y)/y$.

Last, but not least, one might be interested in the costs that result if one produces an additional unit of output.

▶ **Definition 12.11 Marginal Costs** The marginal costs of production are the costs that result from the production of an additional unit of output: $MC(y) = dC(y)/dy$.

Marginal costs *MC*(*y*) are approximately equal to the partial derivative of the cost function $C'(y)$, if one allows for infinitesimal changes in inputs and outputs. Marginal costs are a key concept in mainstream economics, because they play a prominent role in determining the behavior of firms, which seek to maximize their profits.

Thus, the question of which inputs contribute to fixed costs and which to variable costs depends on the contract and the contract may be culture specific. In countries with extensive employment-protection laws, it is difficult to fire employees on short notice, so one gets a certain downward rigidity. In countries with hire-and-fire cultures, it is much easier to adjust one's workforce on short notice. The same is true for capital, where one needs to understand the contracts in order to know whether rental agreements, etc., contribute to fixed or variable costs. If one follows this line of reasoning, it becomes clear that the question whether costs vary with output or not also has a temporal component. If the minimum duration of a contract cannot be freely determined but is pre-specified by law or for other reasons, one is only free to decide to invest the costs or not at those points in time when the contracts have to be renewed.

Here are two examples. (1) Let us assume that the labor market is a spot market but the capital market is not and that it has a contract duration of one year. In that case, *ex post*, after one made a capital investment, only labor costs are flexible within the next 12 months. Capital costs, on the other hand, are sunk. (2) Alternatively, let us assume that the capital market is a spot market but the labor market is not and that it one has unemployment protection for one year. In that case, *ex post*, after one hired a person, only capital costs are flexible for the next 12 months. Labor costs, on the other hand, are sunk.

It is easy to imagine that these inflexibilities have an impact on optimal economic behavior and that this behavior depends on the planning horizon. This is why one distinguishes between the so-called *short run* and the so-called *long run*. The short run is defined as a period of time in which some of the contractural obligations are binding. The long run is defined as a period of time that is sufficiently long such that none of the contractural obligations are binding. Hence, in the short run, some of the costs are sunk, whereas in the long run, none of the costs are sunk. We will see the relevance of this distinction in the next chapter.

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13 Firm Behavior Under Perfect Competition

This chapter covers …

- how profit-maximizing firms behave in competitive markets (behavioral foundation of the supply function).
- how the supply function is related to marginal and average cost functions and what this says about the informational demands and effective organization of firms.
- the technological prerequisites for the functioning of competitive markets.
- how competition drives profits to zero and why this is not bad.

13.1 Introduction

> The natural price or the price of free competition … is the lowest which can be taken. [It] is the lowest which the sellers can commonly afford to take, and at the same time continue their business. (Adam Smith, The Wealth of Nations (1776/1991), Book I, Chapter VII)

This chapter will take a closer look at the supply decision of a firm that sells in a market with perfect competition. To make the problem manageable, one has to specify the objective of the firm and say a few words about its ownership structure as well as its internal organization.

The standard assumption in the literature is that firms seek to *maximize profits*. If p is the price of some good produced by the firm, y is the quantity produced, and $C(y)$ are the costs of production, then the profits are $\pi(y) = p \cdot y - C(y) = R(y) - C(y)$, where $R(y)$ stands for revenues. One way to think about this objective function is in terms of the interests of the owners. Assume that a single person owns the firm and uses it as a vehicle to maximize her income. What objective would she try to give the firm in order to pursue her goal? Obviously, the increase in income that the owner can extract from the firm is equal to the firm's profit: the owner deploys capital and labor, which costs her $C(y)$ for y units of output, and she gets the revenues

M. Kolmar, *Principles of Microeconomics*, Classroom Companion: Economics,
https://doi.org/10.1007/978-3-030-78167-5_13

of the firm, $p \cdot y$. Therefore, the surplus or the increase in income is equal to the firm's profit. Hence, if income-maximizing owners invest in firms, it is in their best interest that the firms maximize profits. If owners invest in firms because they want to reach something else, then the imputed objective may be different. Nevertheless, it is a good starting point to conjecture that most shareholders invest in corporations because they want to make money.

Digression 13.1 (The Limits of Profit Maximization: Information, Contracts, and the Organization of Firms)
The idea that income-maximizing owners would like to make sure that the managers of the firm maximize profits is simple and powerful. However, it is the source of a lot of controversy for both normative and positive reasons. From the positive point of view, it is sometimes argued that firms do not, in fact, maximize their profits. Deviations from this objective may have several reasons. They can be a result of imperfect information about costs and revenues. Limited information is definitely a relevant problem and it may lead to decisions that are apparently not in line with profit maximization. Nevertheless, it does not falsify the objective *per se*. As previous chapters have shown, it is the purpose of managerial accounting to provide information to support decisions. If the information is bad, the decisions are bad, and the first impulse should be to develop a better accounting system, not to abandon profit maximization.

Another important reason for deviations from profit maximization results from the fact that firms are usually complex networks of individuals with their own objectives. The key question then becomes whether it is possible to align the interests of the owners with the interests of the workers. Take the CEO of a firm that is not managed by the owner, and assume further that both, the owner and the manager, want to maximize their incomes. The income of the manager depends on the contract, so it becomes a problem of contract design whether the owner's and the manager's income maximizations coincide. (One can think of such a contract as an incentive mechanism. An optimal contract is one that creates no externalities between manager and owner.) The key question is, therefore, how such a contract has to be designed to make sure that the manager internalizes the interests of the owner. If the contract is ill-designed, the manager will use her discretionary power to maximize her own income, which is not compatible with the owner's income maximization and, therefore, is in conflict with profit maximization. An example might be a contract with bonus payments that incentivizes short-term profits, despite the fact that they are in conflict with the long-term interests of the firm.

To simplify things, one assumes that owners want to maximize income, that contracts perfectly align owners' and managers' interests, and that the accounting system is sufficiently precise to allow for a realistic view of costs and revenues. Hence, firms maximize profits. This case acts like a benchmark. If one understands the benchmark, one can get a better understanding of the effects of deviations from it.

It makes sense to state the objective function explicitly. The firm maximizes profits by the choice of the quantity of the good produced. Formally, it is expressed as follows:

$$\max_{y} p \cdot y - C(y).$$

The assumption of perfect competition enters the above choice problem, because the price is treated as a parameter, which means that the firm takes it as given. The above formulation also assumes that both the quantity produced and the quantity sold are identical and that firms do not produce for or sell from stocks.

The concept of marginal revenues will be helpful in understanding optimal firm decisions.

▶ **Definition 13.1 Marginal Revenues** The marginal revenue of production is the revenue the firm makes by an additional unit of production: $MR(y) = dR(y)/dy$.

What are the implications of the assumption of profit maximization for the supply decision of the firm? The following thought experiment allows one to gain a better understanding. Assume that the firm produces a quantity such that marginal revenue is larger than marginal cost and marginal costs are strictly positive. What would the effect on profits of an increase in production by one unit be? Given that profit is revenues minus costs, profit must increase if marginal revenues exceed marginal costs. So it would be rational to increase production, because the firm would make more money with the additional unit than it would cost. Next, assume that the firm produces a quantity such that the marginal revenues are smaller than the marginal costs. In this case, profit would go down, because the next unit of production costs more than the firm would get for it on the market. Therefore, it would be rational to reduce production. These two observations pin down the profit-maximizing behavior of a firm: the optimal quantity is the one where marginal revenues are equal to marginal costs.

This condition can also be derived analytically, by setting the first derivative of the profit function equal to zero. Given that the price is fixed for a firm on a competitive market (the firm is a price taker), the marginal revenues are equal to the price of the good, $MR(y) = p$, and one gets

$$\pi'(y) = p - C'(y) = p - MC(y) = 0.$$

Denote the quantity of the good that fulfills this condition by y^*. This result is a very important finding in the theory of firm behavior: a profit-maximizing firm on a competitive market produces according to the "price-equals-marginal-costs" rule, because marginal revenue is equal to the price under perfect competition. This rule has several implications that the following paragraphs will discuss. Its applicability also depends on several factors that one has to make explicit for an in-depth understanding of its role in the theory of firm behavior. I will start with the implications.

The first and most important implication, for an economist, is the link between the cost and supply functions. The condition $p = MC(y)$ formally establishes a relationship between price p and quantity y. The supply function of a firm establishes the same type of relationship with $y = y(p)$. It maps each price onto a quantity produced by the firm. If one looks at the inverse of the marginal-cost function, one gets $y = MC^{-1}(p)$. But this mapping has prices as domain and quantities as codomain. This mapping described by the supply function has quantities as its domain and prices as its codomain. The implication of this is that these two mappings are inverse to each other and that a competitive firm's supply function is identical to its inverse marginal-cost function. When one observes a firm's market behavior, one can "look through" the supply decision and get information about the firm's marginal costs.

This finding also allows for a more in-depth understanding of the willingness-to-sell concept, which Chap. 5 introduced: I have argued that one can interpret a point along the supply function as the minimum price the producer has to get in order to be willing to sell an additional unit of the good. This price, as we have seen, is equal to the marginal costs of producing this unit, which makes perfect sense: marginal costs measure how much it costs to produce an additional unit of the good. If one is paid more than that, one makes a profit with this unit, and if one is paid less, one takes a loss. Therefore, one is indifferent between selling and not selling, if one gets exactly one's marginal costs.

The "price-equals-marginal-costs" rule also has important managerial implications: in order to be able to behave in accordance with this rule, a manager needs information about the market price and the marginal-cost function. This has implications for the organization of her company: in addition to the factory that produces the goods that the firm sells, the firm needs an accounting system that collects information about costs as well as current (and maybe also expected future) market prices. The organization of a competitive firm is not very complicated. However, getting the accounting right is crucial for the firm, because the quality of decisions depends on the accuracy of the information about marginal costs.

Unfortunately, life on competitive markets, as either a manager or an economist, is not as simple as the above rule suggests. Next, one has to put the "price-equals-marginal-costs" rule into perspective. I will discuss three aspects in the following subchapter: technological conditions under which perfect competition works, short-versus long-run decisions, and the relationship between firm and market supply.

13.2 Production Technology and Market Structure

As this chapter has already shown, the profit-maximizing production decision of a firm can be characterized by the condition:

$$\pi'(y^*) = p - C'(y^*) = p - MC(y^*) = 0.$$

I will scrutinize this approach from a purely technical point of view and discuss the economic implications thereafter. This approach illustrates how a back-and-forth between economic thinking and mathematical reasoning can improve one's understanding of the economy.

One may remember, from one's mathematics classes in high school, that the so-called first-order conditions are necessary, but not sufficient, for the characterization of a maximum. The only thing that a first derivative of zero guarantees is that the function has a "flat" point, which can be a maximum, a minimum, or a point of inflection. In order to make sure that one characterizes a maximum, one has to check the so-called second-order condition, i.e., one has to check if

$$\pi''(y) = -C''(y)$$

fulfills a certain property at the potential optimum. The second-order condition says something about the curvature of the function. In order to make sure that the first-order condition characterizes a maximum, one has to make sure that the profit function is "hump shaped" or, more technically, strictly concave. (In addition, one has to make sure that there is an interior optimum. A technical condition that guarantees this is $p > MC(0)$ and $p < \lim_{y \to \infty} MC(y)$.) This is guaranteed if the second derivative of the profit function is negative,

$$\pi''(y) = -C''(y) < 0 \Leftrightarrow C''(y) > 0.$$

Figure 13.1 illustrates this case.

The upper part of Fig. 13.1 shows the profit of a firm for all possible production levels. It is inversely U-shaped. The first-order condition identifies the quantity where the slope of the function is zero, which characterizes the maximum profit. The lower part of Fig. 13.1 disentangles the profit into revenues and costs. The straight line represents revenues as a function of y. Revenues are linear in production, because it is the product of an exogenous price and the endogenous quantity of the good. Costs increase disproportionally. Profit in Fig. 13.1 is equal to the *vertical* difference between the revenue and the cost curve. What the firm tries to do is to identify the output where this vertical difference is at its maximum. This point is at the place where both functions have the same slope. The slope of the revenue function is p and the slope of the cost function is $MC(y)$.

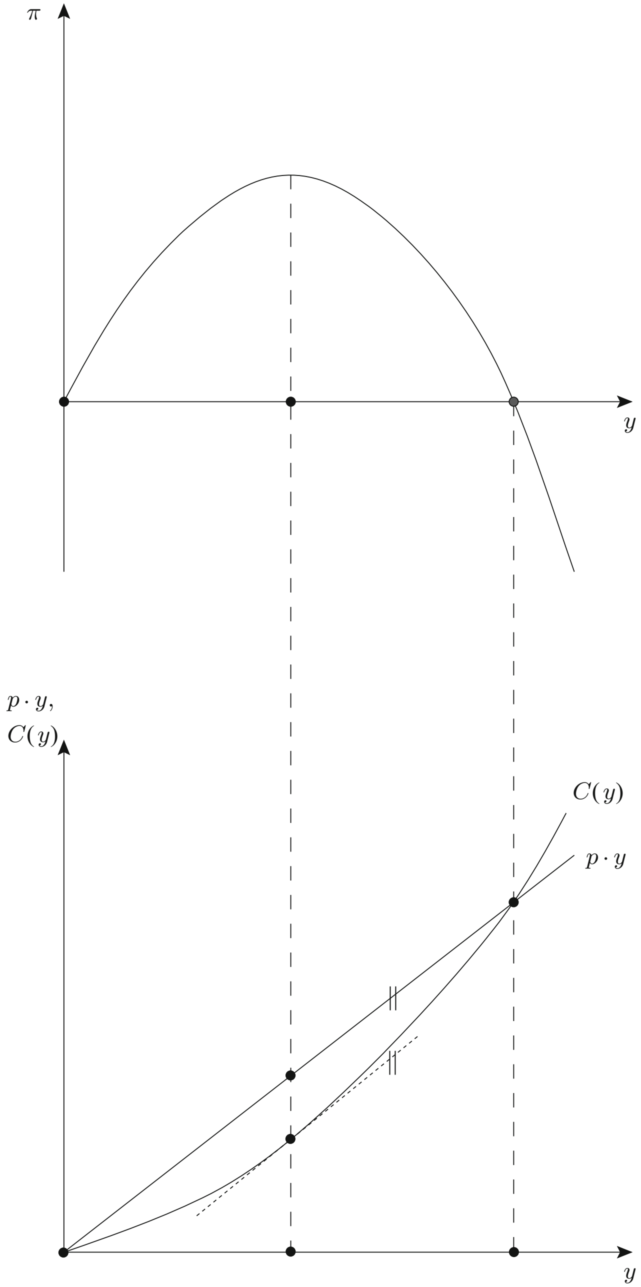

Fig. 13.1 Profits as a function of output

In concluding that purely technical argument, is there anything one can learn from this condition as an economist? First of all, one can see that the condition restricts the class of admissible cost functions to those that increase overproportionally in production. Hence, the marginal costs of production increase in the quantity produced. Here is an example: assume that one invests time to study for the final exam. The more time one spends, the better one's expected grade becomes. It is relatively easy to pass, but it becomes more and more difficult to get the best possible grade. This property is nicely reflected by an application of the so-called 80–20 rule (also called the Pareto principle), which states that, for many events, 80% of the effects come from 20% of the causes. Applied to the example, it would say that one gets 80% of the output in 20% of the time, and the additional 20% of output in the remaining 80% of the time. This principle applies to a large number of production processes, and intellectual or physical skills are only one example. If one exploits natural resources, it is usually relatively easy at the beginning and gets increasingly difficult, when the source becomes depleted. Increasing the crop on a given piece of land is relatively easy at the beginning, but, the larger the crop, the more difficult it gets to further increase it, and so on.

The above arguments used technological explanations for increasing marginal costs, and this is exactly one of the reasons why I have linked costs with production functions. Given that input markets are competitive, the structure of the cost function is determined by the structure of the production function, because they are, in the one-factor example (up to a scaling factor, which is determined by input prices), inverse to each other. Increasing marginal costs exist, if the marginal product decreases, i.e., if it gets more difficult to increase production the more one is already producing.

Assume that marginal costs are decreasing. In this case, the first-order condition characterizes a minimum. What are the economic implications of this finding? Figure 13.2 illustrates this case.

Figure 13.2 shows revenues (straight line) and costs (curved line) as functions of output. What one can see is that the output level, where price equals marginal costs, now characterizes the profit minimum and the marginal-cost curve is downward sloping. At this point, the firm basically has two strategies. It can leave the market and make zero profits (arrow to the left) at $y = 0$, or it can try to grow as large as possible (arrow to the right). If the firm is successful in growing beyond the point y^{be}, it starts making profits. However, the firm should not stop here; the figure reveals that the difference between revenues and costs gets larger the more the firm produces. Therefore, it is the best strategy for the firm to grow as large as possible. However, this strategy is incompatible with the assumption that the firm takes prices as given because of its smallness relative to the rest of the market. If a firm gets so large that it can serve the whole market, then it is able to influence the market price. The assumptions of perfect competition and decreasing marginal costs are logically incompatible.

The implication of this inconsistency is that perfectly competitive markets are no one-size-fits-all institution that can be used to organize economic activities. If costs $\mathcal{K}$ are linear in factor inputs, such markets can only sustain themselves if the

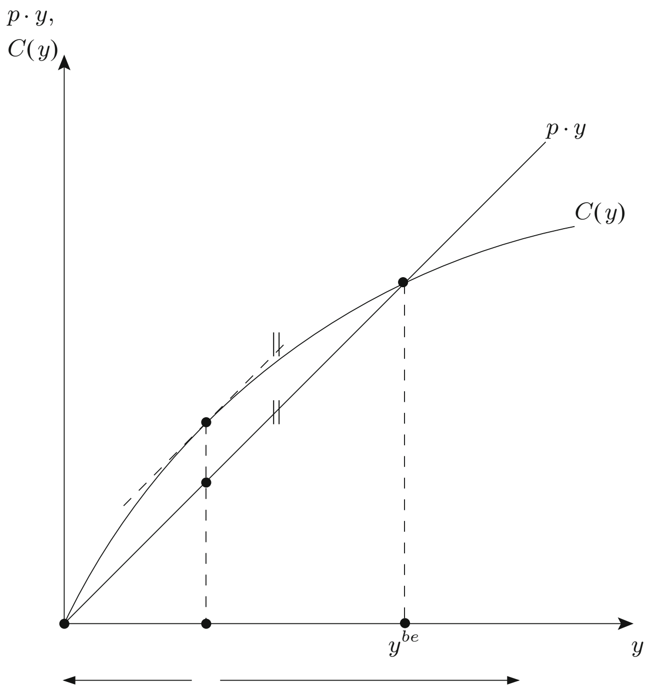

Fig. 13.2 Costs and revenues, if costs increase disproportionally with output

industry produces with the "right" type of technology, and an important number of industries does not fit into this picture.

The intermediate case, of constant marginal costs, deserves some attention, as well. Figure 13.3 shows revenues and costs as functions of output.

Constant marginal costs imply that the cost function is linear. One can denote it as $C(y) = c \cdot y$ with $c > 0$. There are three possible cases: the cost function is steeper than the revenue function, $c > p$, flatter, $c < p$, or both have the same slope. The economic implications of these scenarios are straightforward: the best the firm can do, if $c > p$, is to shut down its business and to leave the market. If $c < p$, however, the opposite is the case. The firm should grow indefinitely, which is in conflict with the assumption of perfect competition. Thus, there is only one case left, where perfect competition is compatible with constant marginal costs: $c = p$. In this case, the firm is indifferent between all production levels, because it makes zero profits irrespective of how much it produces. (At some other point, I explain in detail why zero profits do not imply zero gains from trade. Zero profits imply that equity owners cannot expect a rate of return that exceeds the market interest rate for a similar investment. Hence, one can assume that the firm continues to produce, even with zero profits.)

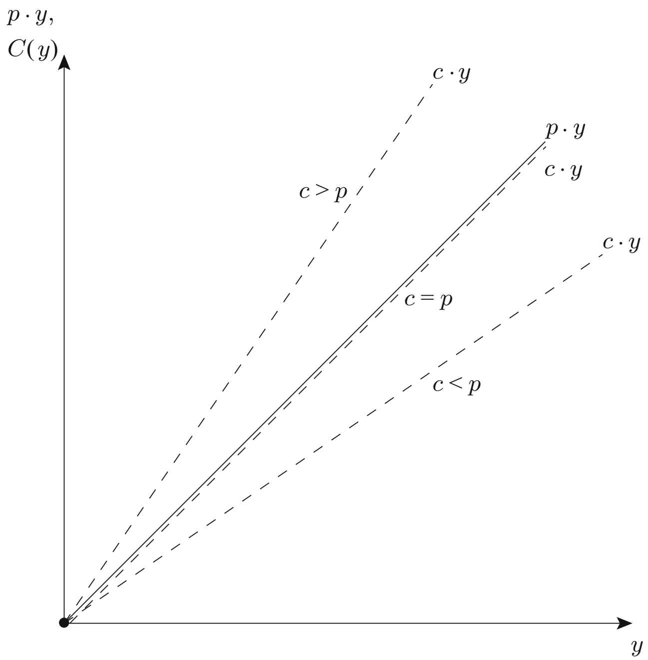

Fig. 13.3 Costs and revenues, if costs increase proportionally with output

13.3 The Short Versus the Long Run

I have argued in Chap. 12 that, depending on the time frame and the term structure of contracts, some costs of the firm can be avoided by producing a quantity of 0 and some cannot. The "price-equals-marginal-costs" rule made the implicit assumption that the firm is active on the market. However, it can always decide to leave the market and this may be a wise decision, if the losses that occur when leaving the market are smaller than the losses would be, if it stays. This statement may sound dubious at first, so one has to dig a little deeper to understand what exactly is meant by it.

Assume that a firm produces with fixed costs $FC > 0$ and variable costs:

$$C(y) = \begin{cases} 0, & \text{for } y = 0 \\ VC(y) + FC, & \text{for } y > 0, \end{cases}$$

and further assume that marginal costs are increasing. This situation is depicted in Fig. 13.4 with the example of a variable cost function being $VC(y) = 0.5 \cdot y^2$. Please note that this function implies that the marginal costs $MC(y) = y$ for all $y > 0$.

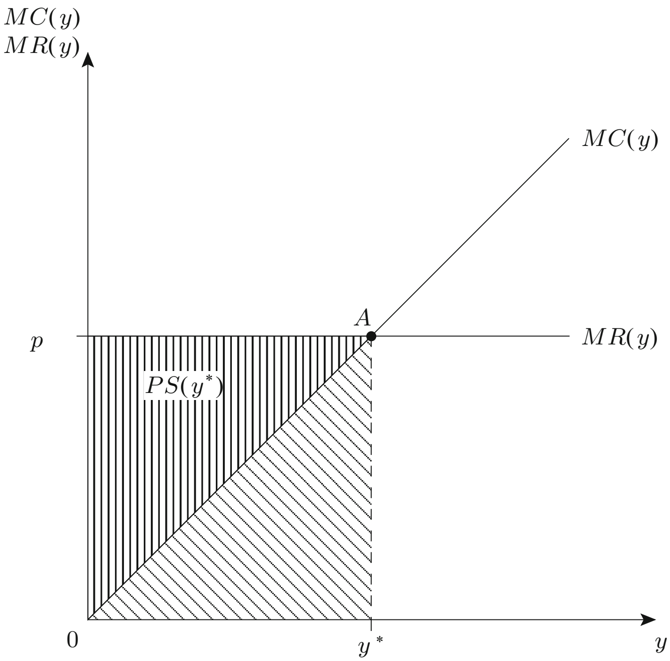

Fig. 13.4 Revenues and variable costs

The horizontal line (p) is the market price, and the linear monotonic line represents the marginal costs. If the firm decides to stay in the market, it will choose the quantity that equals price and marginal costs, indicated by y^* in the figure. Total revenues for an output of y^* are $p \cdot y^*$ and can be represented by the rectangular area $0pAy^*0$. Given that marginal costs are the first derivative of the variable-cost function, the triangular area $0Ay^*0$, under the marginal-cost curve, represents the variable costs. Hence, the producer surplus, $PS(y^*)$, is given by the triangular area $0pA0$ and is equal to revenues minus variable costs.

This is a general property. One may have wondered why the measure for the gains from trade of a firm is called producer surplus instead of profit. The reason is that the profit includes fixed costs, whereas the producer surplus does not. One can establish the following relationship between profit and producer surplus:

$$\pi(y) = PS(y) - FC.$$

It follows that producer surplus and profits coincide, if fixed costs are zero, $FC = 0$. In this case, the area $0pA0$ is also the profit of the firm. However, if production requires upfront investments, then the profit is lower than the producer surplus.

The easiest way to see how fixed costs influence profits is by adding the average-cost curve to the picture. It is equal to

$$AC(y) = \frac{VC(y)}{y} + \frac{FC}{y} = 0.5 \cdot y + \frac{FC}{y},$$

if $y > 0$. A closer look at the expression reveals that it is U-shaped: the first term is a linear increasing function, whereas the second term is hyperbolic. Hence, the sum must be U-shaped. Is there anything else that one can say about the average-cost curve? Yes, it intersects with the marginal-cost curve at the minimum of the average costs. To understand this intuitively, think of the range over which the average-cost curve is declining. Within this range, marginal costs must be smaller than average costs: if the average is declining at a given point, then the cost of the last unit needs to be below the average costs up to this point. By the same token, if the average-cost curve is increasing, then the costs of the last unit must be higher than the average costs at any given point, because otherwise marginal costs would not have sufficient "leverage" to bring up average costs.

To see this algebraically, note that, applying the quotient rule, a necessary condition for the minimum m of the average-cost curve is

$$AC'(y^m) = 0 \Leftrightarrow \frac{C'(y^m) \cdot y^m - C(y^m)}{(y^m)^2} = 0.$$

For $y^m > 0$, this condition can be simplified to

$$C'(y^m) \cdot y^m - C(y^m) = 0,$$

if one multiplies by $(y^m)^2$ (which is possible because $y^m > 0$). Dividing by y^m and rearranging terms give the desired result:

$$C'(y^m) = \frac{C(y^m)}{y^m} \Leftrightarrow MC(y^m) = AC(y^m).$$

(The same calculation can be carried out for average variable costs.) To illustrate, Fig. 13.5 shows the marginal-cost curve and the average-cost curve for $FC = 10$.

Note that $AC(y) = C(y)/y$, or $C(y) = AC(y) \cdot y$, which means that total costs for any output y can be measured by the rectangular area $0ABy0$.

With this prerequisite, one can return to the relationship between producer surplus and profit or the role of avoidable fixed costs in firm behavior. Different levels of fixed costs give rise to a family of average-cost curves, where higher curves correspond to higher fixed costs.

Figure 13.6 shows the marginal-cost curve and the family of average-cost curves for different values of FC.

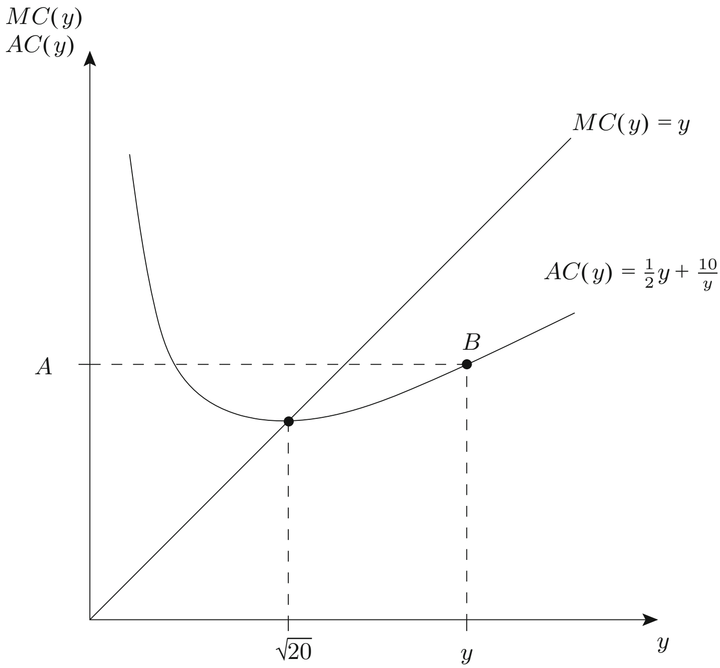

Fig. 13.5 Marginal and average costs

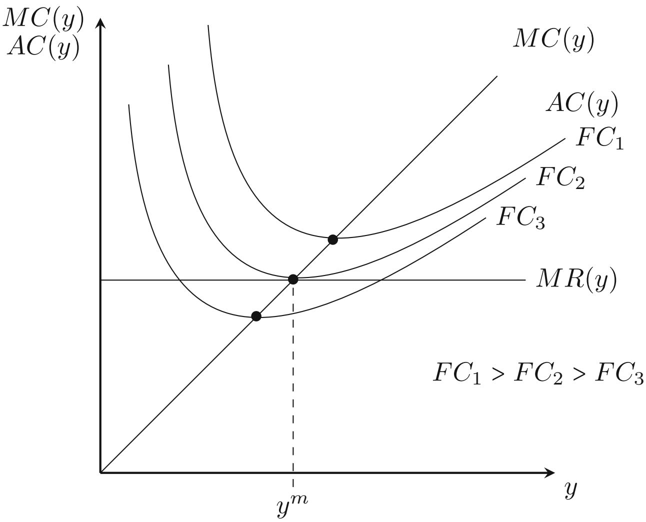

Fig. 13.6 A family of average-cost curves

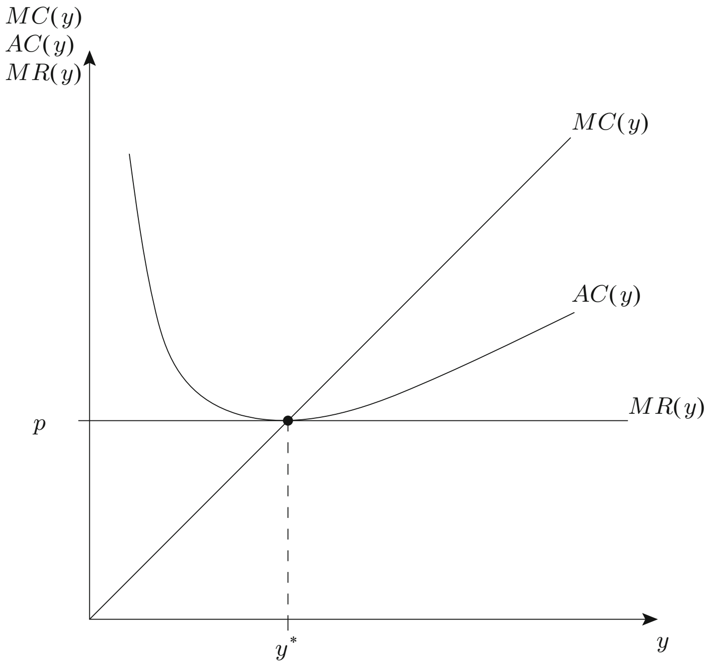

Fig. 13.7 Average costs such that profits are equal to zero

There is one average-cost curve that is of particular interest: the one that intersects with the marginal-cost curve exactly where price equals marginal costs. Call this level of fixed costs FC'. This situation is represented in Fig. 13.7.

One already knows that total revenues are equal to $0pAy^*0$ at y^* and that producer surplus is equal to $0pA0$. What one knows, in addition, is that total costs are $0pAy^*0$ at y^*, so total profits are equal to zero. What is happening here is that the producer surplus is sufficient to cover the fixed costs. If fixed costs are lower, the firm stays in business and makes a profit. What happens, however, if fixed costs are higher? In this case, the firm would end up with a negative profit or loss. Is there anything the firm can do about this loss? Yes, given that one is talking about avoidable fixed costs, it can *ex ante* (before it starts the development process), anticipate that the producer surplus will be insufficient to cover the fixed costs, at the expected market price, and stay out of business. At this *ex ante* stage, the total profit from staying out of business is 0, which is better than the loss that results from entering the market. This finding leads to an important modification of the optimal supply decision. In the long run, when all costs can be avoided by not entering or leaving the market, the optimal strategy of a competitive firm is to determine the optimal quantity, according to the price-equals-marginal-costs-rule, if the market price is (weakly) above the average costs, and to stay out of the market

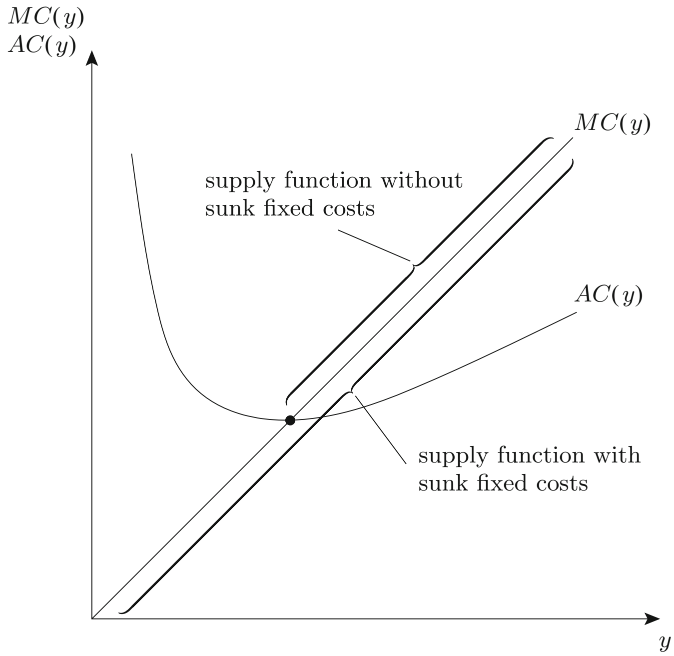

Fig. 13.8 Supply functions with and without sunk fixed costs

otherwise. The individual supply function is, therefore, identical to the inverse of the marginal-cost function, if the price is (weakly) larger than average costs.

One can now turn to a slightly modified case. Contrary to the above example, assume that the firm has already entered a contractual arrangement that turns the fixed into sunk costs, i.e., "costs" that cannot be avoided by shutting down the business. In this case, the same analysis as in Fig. 13.7 applies, but the economic consequences are different. For all levels of fixed costs $FC > FC'$, the firm makes a loss, but this loss cannot be avoided by going out of business. Hence, the best the firm can do is to minimize losses, which means sticking to the price-equals-marginal-costs rule. This rule will lead to losses in the end, but they are smaller than the losses that would occur with any other strategy, including going out of business. Figure 13.8 compares the two scenarios.

The upward-sloping function is the marginal-cost curve, and the U-shaped function is the average-cost curve. The supply curve equals the section of the marginal-cost curve above the average-cost curve, if fixed costs are not yet sunk, and it equals the complete marginal-cost function, if fixed costs are sunk.

The above example carved out the implications of the difference between avoidable fixed and sunk costs. Contractual fixed costs can, however, also exist in situations where the technology requires no upfront investments. Assume, for example, that a farmer has a cherry orchard with a given number of trees. The only additional input that he needs at harvest time is labor. Assume also that the quantity of cherries picked is increasing in the number of hours fruits are picked, but that the increase is declining (it gets harder and harder to pick additional cherries). At a given market wage, this "picking technology" creates increasing marginal costs of fruit picking. If the farmer can hire fruit pickers on a daily spot market, this assumption turns wage payments into variable costs. Assume, on the contrary, that a union of fruit pickers negotiated a 3 months dismissal protection. In this case, labor costs become fixed and sunk once the employment contract is signed. The analysis of situations like this is qualitatively identical to the analysis above, and the basic understanding is simple: *costs that the firm cannot influence have no significance for the optimal behavior of the firm.* Alternatively, to put it shortly: *sunk costs are sunk.*

At this point, a remark is in order about the role that sunk costs play in standard economics. It is a generally accepted view that rational decision makers ignore sunk costs in their decisions: if one cannot influence them, they should be irrelevant for one's decisions. This is the *sunk-cost principle*. Generally, it is a wise and important normative principle: one should not care about the past, if one wants to make rational decisions (but one should have a look at the digression below). However, it is less clear that its predictive power in positive theory is very high. In a number of cases, people care about sunk costs, even if they should not, according to the sunk-cost principle.

An example is the empirical phenomenon of *mental accounting* that describes the tendency of individuals to keep different financial titles in different "mental accounts" and to evaluate the performance of the different titles separately, despite of the fact that a rational decision maker should aggregate them and evaluate the performance of the whole portfolio. For example, assume that someone made equal investments in two stocks. If he sold them today, stock A would have gained CHF 5000 and stock B would have lost CHF 5000. Assume that he has to sell a stock because he needs some extra liquidity. A rational person would only take the past performance of stocks into consideration, if he thinks that past performance is correlated with future performance, such that one can learn from the past. Otherwise, past gains and losses should be irrelevant for one's decision to sell stock A or stock B. However, empirical evidence shows that most people have a preference for selling the winning stock A, which could only be rationalized, if the good past performance is an indicator for bad future performance. Much more likely is the explanation that they hold both stocks in different mental accounts and react emotionally to realized losses and gains. Capitalizing the gains from selling stock A gives one pleasure, and, at the same time, it allows one to avoid the confrontation with the pain of realizing the losses of stock B. These emotional predispositions may influence one's behavior and make it incompatible with the sunk-cost principle. The tendency to invest additional resources into losing accounts or to "throw good money after bad" is sometimes also called the *sunk-cost fallacy*.

Digression 13.2 (Evolution, Emotions, and Sunk Costs: When Caring About Sunk Costs Can Be Beneficial)
It appears that deviations from the sunk-cost principle are always bad. However, if this were the case, one may wonder why human brains evolved in a way that makes us vulnerable to the sunk-cost fallacy. Recent research in evolutionary biology challenges the theory that such behavior is necessarily bad. Take the so-called ultimatum game as an example. In this game, two players have to decide how to divide a sum of money. The first player can propose how to split the sum between the two players and the other player can then accept or reject the offer. If she accepts, the money will be split according to the proposal; if she rejects, neither player receives anything. According to the sunk-cost principle, the second player should accept any positive amount, because the proposal of the first player is in the past and cannot be influenced. Nevertheless, with this logic, a selfish player 1 should offer the minimum amount possible. Hence, the sunk-cost principle guarantees that player 2 gets almost nothing.

This prediction has been consistently tested and falsified in the laboratory. It turns out that subjects in the role of player 2 very often reject small offers, because they find them unfair or even outrageous. However, rejecting positive offers violates the sunk-cost principle. In the end, one walks home without any money when one could at least have had some. From an evolutionary point of view, however, the apparently dysfunctional emotions of anger, frustration, or rage that lead one to turn down flimsy offers may play a very functional role. Within a community, reputation takes on a vital role in human interaction, because it is not unlikely for one to be in a position to do business with the same person more than once or with people who have heard about one's previous business dealings. Thus, player 2 would like to commit to a strategy that turns down bad offers because, if player 1 knows that bad offers will be turned down, he has an incentive to make better ones. The problem is, of course, how to make such an announcement credible. An important role emotions seem to be playing in regulating human interactions is exactly this: to make credible commitments possible. Assume player 2 reacts with anger and frustration to bad offers, so that he happily rejects them and player 1 knows this (either by introspection or because he knows player 2). This knowledge would motivate player 1 to make a better offer, with the consequence that the resulting allocation is more egalitarian, which gives an "emotional" player 2 a fitness advantage over a purely "rational" player 2. What this example shows is that one's behavioral dispositions and emotional reactions evolved over a long period of time and that they are usually functional adaptations to certain environments. In different environments, however, they may become dysfunctional. This is why it would be completely premature to classify the sunk-cost principle as the only rational way to make decisions; it all depends on the context.

13.4 Firm and Market Supply

This chapter has, up until this point, concentrated on the behavior of an individual firm. It has also shown that one can interpret the individual supply function as the inverse of the marginal-cost function, if the market price exceeds a certain benchmark, which is defined by the relevant average costs of the firm. It has neglected, thus far, to cover the relationship between individual and market supply. The assumption that firms seek to maximize profits allows one to say a little bit more than one already knows.

Up until now we have worked under the assumption that there is a given number of firms l in each market i. In this case, market supply for a good j was defined as

$$y_i(p_i, r, w) = \sum_{j=1}^{l} y_i^j(p_i, r, w).$$

Depending on market prices, fixed and sunk costs, the optimal policy of a firm can lead to positive profits, zero profits, or even losses (during a period of time when contractual obligations restrain firms). Assume now that, for the given number of firms l, profits are strictly positive. Under certain conditions, such a situation is unsustainable in the long run if firms maximize profits, because positive profits in a market attract additional firms to enter the market.

A good example is Lidl and Aldi, two German grocery stores that entered the Swiss market a few years ago. The old situation, in which two major incumbents, Coop and Migros, divided the lion's share of the Swiss market, was no longer sustainable after Switzerland signed the Bilateral Agreements II with the European Union, which became relevant for the food industry in 2004. These treaties opened the Swiss market for new entrants from the European Union and the relatively high profit margins, in fact, encouraged Aldi (in 2005) and Lidl (in 2009) to enter.

As the example shows, there may be legal impediments to entering a market, but there may be technological ones as well: for example, if one has to invest in an infrastructure for the distribution of one's products, whose value depreciates if one leaves the market again. The loss in value is like a barrier to entering the market, because it defines a minimum producer surplus below which market entry is not profitable.

There may not only be barriers to enter but also barriers to exit a market. Most of them are related to unfinished contractual obligations, which create financial liabilities even after leaving the market, as seen in the sunk-costs example above. However, there may also be technological closure costs, like shipping costs of equipment. With positive exit costs, a firm might be forced to stay in the market because the costs of leaving are higher than the operative loss.

I will focus on the extreme case, where entry and exit costs are zero, because it allows one to derive a very strong conclusion about the effects of competition. If the number of firms is fixed, profits can be positive, if the price exceeds average costs. Therefore, without market entry, it may be possible that profits are positive. Without entry and exit costs, these profits will encourage other firms to enter the market. This process will continue until they drive profits down to zero. Any other solution would be incompatible with the assumption of profit maximization. However, this is only possible if the market price is equal to the average costs of the firm, which is the situation that Fig. 13.7 illustrates.

This equilibrium is bad news for the owners of firms and good news for the general public. It is bad news for owners, because any expectation about positive profits will ultimately be discouraged, because market forces drive them down to zero. This finding illustrates Adam Smith's quote from the beginning of this chapter.

Zero profit does not mean that being in business is meaningless, as one can see from the cost equation. I will focus on two factors, capital K and labor L, for simplicity. Zero profit means that revenues $p \cdot y$ equal costs $\mathcal{K}(K, L, r, w) = r \cdot K + w \cdot L$. Assume the owner provides all the capital and works himself. In this case, zero profit means that he cannot expect a compensation for the capital and labor that exceeds the market interest rate r and the market wage w, because all the revenues of the firm are completely used for factor payments, whose opportunity costs are evaluated at the input prices. Therefore, the owner is indifferent between investing in her own firm, renting out the capital at an interest rate r and working for his own firm or working for someone else for a wage w. Zero profit, in other words, does not mean that there are no gains from trade; it only implies that the owners of a company do not get rents larger than the current market rates.

From the point of view of the general public, zero profits are good news: they imply that production takes place at minimum average costs, because marginal costs intersect with average costs at the minimum of the average costs. As long as profits are positive or negative, the average costs of production are not at their minimum. The allocation is efficient, given the number of firms in the market, but the number of firms (or factories) is not yet optimal. Free entry and exit imply that, in the long run, even the number of firms adjusts such that goods are produced in the cheapest possible way.

Digression 13.3 (The Ethics of Profit Maximization)

> Profit is useful if it serves as a means towards an end that provides a sense both of how to produce it and how to make good use of it. Once profit becomes the exclusive goal, if it is produced by improper means and without the common good as its ultimate end, it risks destroying wealth and creating poverty. (Benedict XVI 2009, Caritas in Veritate)

One of the most intensely scrutinized assumptions of mainstream economics is profit maximization. Most people find it unethical, or even morally offensive, and claim that profit maximization is a major source of the problems of capitalist societies. The idea of *corporate social responsibility* (CSR) is seen

(continued)

Digression 13.3 (continued)
as an alternative to profit maximization, which helps firms to better align their behavior with society's interests.

The debate about ethical and moral standards in business is probably as old as business itself. One of the oldest deciphered writings of significant length in the world, the Code of Hammurabi (1700s B.C.), lays down the rules of commerce and prescribes prices and tariffs, as well as penalties for noncompliance.

According to the 2001 Greenbook by the European Union, CSR is a "concept whereby companies integrate social and environmental concerns in their business operations and in their interaction with their stakeholders on a voluntary basis." In addition, since 2011, the European Union defines CSR as "the responsibility of enterprises for their impacts on society." This concept goes far beyond the narrow idea of profit maximization, which was put forward by Milton Friedman (1970): "In [a free economy] there is one and only one social responsibility of business—to use its resources and engage in activities designed to increase its profits so long as it stays within the rules of the game." This quote nicely expresses the mainstream view that normative concerns should, and can be, addressed at the level of the foundational institutions of society: the "rules of the game." One has seen examples for this approach in the preceding chapters: externalities should be internalized by the design of property rights, contract law, taxes, regulations, and so on, but not by appealing to firms to voluntarily internalize them by non-profit-maximizing business practices.

Given these opposing views, is it possible to bridge them? For starters, one gets a lot of support for the so-called *Friedman doctrine* from the model of firm behavior under perfect competition, which was developed in this chapter. First, note that the existence of a complete set of competitive markets implies an ideal institutional framework, which, in the language of Milton Friedman, could be understood as the perfect rules of the game. This is expressed in the First Theorem of Welfare Economics. Second, with free entry and exit, competition has the tendency to drive profits to zero. However, if profits are zero at the maximum, firms do not have much choice but to maximize them. Paying higher wages to employees or selling at lower prices simply drives firms out of business. The only exceptions to this rule are short-run profits, or a situation where entry and exit are restricted, such that profits are positive even in the long run. However, in this case, advocates of free markets would argue that one should first try to reduce the entry and exit barriers to the largest extent possible, in this case. Like it or not, under perfect competition, there is not much room for anything but profit maximization.

A lot of firms voluntarily choose ethically sound business practices. One has to be careful to judge these practices correctly, though. Their existence

(continued)

Digression 13.3 (continued)

does not necessarily imply that firms incorporate other objectives than simply profits into their business models. There are a number of cases where a more comprehensive understanding of the factors that influence the adoption of these practices is necessary. For example, there are apparently cases in which ethical practices are profit maximizing in a long time horizon. Paying decent wages may motivate employees to work harder and to be loyal to the firm, thereby increasing profits. Sustainability standards may lead to higher prices, if consumers have a willingness to pay for sustainable production, and so on. In fact, a lot of proponents of CSR reduce the concept to this “enlightened self-interest” of the firm, the argument being that a lot of potential conflicts of interest between the owners and managers of firms (“shareholders”) and other groups in society (“stakeholders”) result from a too-narrow perspective of the shareholders. This view implicitly accepts the profit motive but aligns it with social interests by declaring them compatible. The approach could also be called *responsible profit maximization*.

However, this is not the end of the story. One has seen that perfect competition depends on technological prerequisites, which are not always fulfilled, and that externalities may make an equilibrium inefficient. In situations like these, there is room for discussion about the adequate way to address inefficiencies and problems of sustainability, as well as distributive justice on the firm level. Here is an example: one of the major challenges of globalization is exactly the lack of a consistent global regulatory framework—the rules of the game—that create a perfectly level playing field, and institutions like the WTO or OECD are too weak to fill the holes and gaps in the playground. (Nevertheless, CSR goes beyond the problems imposed by globalization.) Nation states even enter into race-to-the-bottom types of international competition, where they reduce taxes and social standards to attract internationally mobile capital. This type of competition can, in principle, be beneficial, if it is primarily utilized as a disciplinary device for nation states to provide public services more efficiently, but it often drives standards below the efficient level. Especially large multinational corporations can profit from these developments, and, for the foreseeable future, there is no other institutional actor able to address the ethical issues that result from these developments other than the corporations themselves. Again, like it or not, if they do not care, no one will.

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Firm Behavior in Monopolistic Markets

14

This chapter covers . . .

- cognitive, technological, and regulative prerequisites for the existence of monopolies.
- how firms can use their monopoly to develop basic and sophisticated pricing strategies.
- the role of price discrimination in markets with imperfect information about the willingness to pay of the customers, and why the findings help to better understand pricing behavior in, for example, airline, software, and hardware markets.
- the role of price discrimination between market segments and why the findings help to understand the debate about international price differences.
- how the informational demand for optimal pricing strategies is related to the optimal organization of firms.
- the economic-policy consequences of the above pricing models.

14.1 Introduction

> Like many businessmen of genius he learned that free competition was wasteful, monopoly efficient. And so he simply set about achieving that efficient monopoly. (Mario Puzo 1969, The Godfather)

The model of firm behavior under perfect competition has shown how a firm's supply is determined, if it takes prices as given. If it produces a positive quantity, a firm's optimal policy is generally determined by the condition "marginal revenues equal marginal costs," which simplifies to "price-equals-marginal-costs," because marginal revenues and prices are identical under perfect competition. Therefore, the firm's supply function is the inverse of its marginal-costs function. The fact that it

M. Kolmar, *Principles of Microeconomics*, Classroom Companion: Economics,
https://doi.org/10.1007/978-3-030-78167-5_14

is willing to sell at marginal costs is also a prerequisite for the Pareto-efficiency of a competitive market.

However, the model has also shown that not all goods can be traded under conditions of perfect competition. One prerequisite is that there are many perfect substitutes for the good a firm produces. Another prerequisite is that the firm's production technology has to guarantee that the (long-run) marginal costs are non-decreasing. For different reasons, both conditions cannot be taken for granted. Consequently, one has to ask how markets function, if there is no perfect competition and keep one's focus on imperfect competition on the supply side. A similar logic applies to imperfect competition on the demand side as is, for example, frequently observed in regional labor markets, when there are only a few firms and labor has a low mobility. Another example is public procurement with firms that specialize in public projects. However, because imperfect competition on the supply side is the more commonly analyzed case, I will derive the implications of a supply-side monopoly for the functioning of markets.

One can start by analyzing a situation in which a firm has a monopoly for the supply of some good. The definition of a monopoly as a market with only one supplier of a good seems pretty obvious. However, this definition is not very operational, because it is unclear what exactly is meant by the idea that there is only one supplier. Hence, one first has to get to grips with a more operational understanding of what it takes for a firm to have a monopoly. Then one studies the optimal policy for a monopolist and analyzes what this implies for the functioning of markets.

14.2 Conditions for the Existence of a Monopoly

Assume that one wants to bake a cake and needs flour. If one compares different retailers, one will find that each of them has different brands. In this sense, for example Migros is a monopolist for flour sold as “M-Budget Haushaltsmehl” (M-Budget flour), because Migros is the only supplier of this brand in the world. However, does this mean that Migros has a monopoly on “M-Budget Haushaltsmehl” in any meaningful economic sense? This question cannot be answered without further information. The reason is that two conditions have to be met in order to leverage the unique characteristics of a brand onto a monopoly position.

1. The customers have to be able to differentiate the product from other products, and this ability to differentiate is reflected in the fact that alternative goods are not perceived as perfect substitutes. If consumers of flour are aware that there are different brands, but if this fact does not influence their decision which one to buy (because, for example, all they care for is the price of the flour), then flour is a homogeneous good sold by different suppliers, irrespective of the different brands. The fact that no other firm sells “M-Budget Haushaltsmehl” does not translate into the ability of Migros to raise prices above those of its competitors. However, if the customers consider the different brands to stand

for non-homogeneous goods, then firms can use this willingness to differentiate between brands to charge brand-specific prices and optimal pricing becomes an integral aspect of the optimal firm policy. Indeed, flour seems to be a homogenous good to most customers and one may thus conjecture that the market for flour is, in fact, competitive. However, it is important to note that homogeneity of goods has nothing to do with the good's *physical* characteristics or the brand name *per se*. It is the customers' willingness and ability to differentiate between goods of different suppliers that is a necessary prerequisite for a monopoly.

The willingness to differentiate can be assessed empirically by estimating the price and cross-price elasticities of demand. Intuitively, elasticities measure the percentage change of a variable that is caused by a one percent change in some other variable. If demand is ordinary and very price elastic, then it reacts strongly to price changes and there is no leeway to set prices actively. Similarly, the cross-price elasticity describes how demand changes, if the price of another good changes. If this elasticity is very large (in absolute terms) and the goods are close substitutes, then there is, again, little scope for price setting. An introduction to the concept of elasticities can be found in the mathematical appendix in Chap. 17.

If the existence of a monopoly position depends on the customers' ability and willingness to differentiate between products, then it must be an integral element of corporate communications and marketing to define and communicate relevant differences to other firms' products or to create them in the first place. From this point of view, even an ordinary product like flour becomes interesting: In recent years, the market has displayed increasingly differentiated products. For example, wheat flour has been differentiated by cultivation method (organic vs. conventional), origin (local vs. from somewhere else), etc. This differentiation has the purpose of transforming a formerly homogeneous product into a set of heterogeneous products for which—if the efforts are successful—differences in the willingness to pay exist that can be exploited by the firms. Two other examples are denim jeans and coffee.

- Denim jeans do not fundamentally differ in their functionality: They protect from weather, have pockets to store and carry small items, and so on. The physical characteristics of jeans seem to suggest that they are a fairly homogeneous product, which is sold on competitive markets. However, this reasoning does not take into account that producers of jeans can use advertising campaigns in an effort to create a specific brand image that adds additional "cultural" content to the product, from which customers can benefit: Jeans do not only protect from weather, but customers send a specific social message by wearing a specific brand. The brand's image is transferred onto the customer, allowing the customer to perform a specific societal role; to belong to a specific group whose values are implicitly communicated by the brand name. In our societies, jeans and many other products are sophisticated mediums of communication and the communicative function often dominates, or even replaces, the primary, utilitarian one (think of intentionally ripped jeans). This is why firms often produce cultural narratives in which their products play an important role. If successful, there are many differentiated products with their own differentiated markets, like the markets for Levi's jeans, Diesel jeans, Wrangler jeans, and so on, and the firms have more or less extensive leeway to set prices. One can, for example, buy a pair of H&M jeans for $9.95 and a pair of Tom Ford Jeans for $3250 (winter 2020).

- For many firms in the food industry, the wine market is *the* reference point for the development of marketing strategies because, for parts of the population, it is fashionable to be a "wine connoisseur." A plethora of differentiated products exist, such that producers are, to some degree, able to exploit the customers' ability and willingness to differentiate by charging higher prices (which, *ceteris paribus*, translates into larger profits).

  Currently, coffee is probably one of the more interesting products in the food industry, because many producers—inspired by the market for wine—try to escape the dead end of the homogeneous-good market by "educating" the customer to distinguish different types of coffee. Historically, the lion's share of the market sold homogenous quality and customers were very price-sensitive, which implied a high degree of competition between suppliers. The central elements of the "third wave of coffee culture," as it is called, are referencing the origin of the coffee all the way back to the farm where it was cropped: an accentuation of the varieties of tastes of coffee and differences in cultivation methods, from the coffee cherry to the final beverage. This includes the introduction of quality standards, like the "Cup of Excellence" seal, and the training of customers with respect to the flavors and brewing methods. On top of this, the emergence of the third wave as a subcultural phenomenon in Portland, Chicago, and San Francisco gives third-wave coffee specific cultural overtones, which makes it an attractive symbol for certain groups of customers (as in the jeans example) and which is important for the evolution of a niche product into the (profitable) mainstream.

2. If the demand for some product is not perfectly elastic (the market demand curve is not flat), then the potential for a firm to create a monopoly exists. However, a somewhat inelastic demand function is not sufficient, but merely necessary for a monopoly. In addition, it has to be impossible for other firms to undercut the privileged position by simply imitating the first firm's products. There are different reasons for why imitation might not be a possibility.

   - The producer has exclusive control over some necessary resource. For example, the "De Beers diamond monopoly" existed because De Beers controlled a large share of raw diamond mines.
   - The producer is a technology leader, such that other firms are not able to imitate the product, because of a lack of skills. A good example is the US-American telecommunications company AT&T. It became the first long-distance telephone network in the USA and made huge investments in research and development that allowed it to acquire crucial inventions. As a

result, the company obtained near-monopoly power on long-distance phone services.

- The state regulates market entry by creating public monopolies or by patents and trademarks. An example for high profit margins that are protected by patents and trademarks was the Nespresso capsule system (most patents have expired by now). A slightly awkward example for a public monopoly was the German monopoly for safety matches (Zündwarenmonopol) from 1930, which granted exclusive rights to distribute safety matches within the borders of the German Empire to a monopolist (Deutsche Zündwaren-Monopolgesellschaft). It ended in 1983. Historically, most countries had public monopolies in the post and telecommunications industries, as well as for rail transportation. A lot of these industries were, at least partially, privatized and opened up for competition in the 1980s and 1990s.
- One has already seen that competitive markets cannot function, if either or both marginal and average costs are decreasing. In industries with such technologies, firms with larger market shares have an advantage, because they can produce at lower marginal and average costs and, hence, can sell at lower prices compared to their smaller competitors. Therefore, a large market share protects firms to some extent against competition. I have already discussed a special case of such a technology in Chap. 6, where I argued that club goods are sometimes called natural monopolies, because they imply decreasing average costs by increasing the number of users.
- Some products are characterized by the fact that the utility and, therefore, the customers' willingness to pay is increasing with the number of customers. This phenomenon is called a positive "network externality." Examples include telephones, word processing software, and social media like Facebook and Twitter. Positive network externalities benefit firms with large market shares. Market share protects, to some degree, against market entries and competition, because a competitor with a smaller market share offers a *ceteris paribus* less attractive product.

If one or more of the above conditions hold, then the customers' willingness to differentiate translates into a (possibly temporary) monopoly position. The next subchapter analyzes how firms can make use of such a position.

14.3 Profit Maximization in Monopolistic Markets

The problem of a monopolistic firm is quite complex. As the previous subchapter explained, it has to decide about brand management and product development, needs to develop pricing strategies, and has to take into account the political environment to protect and further its interests. In the following subchapter, I will reduce this complexity by focusing on the pricing aspect. Thus, the following analysis will assume that a firm has a monopoly in an already existing market with an established product. To understand optimal pricing policies, different cases have to be distinguished:

- The firm is not able to discriminate prices between customers; each customer buys at the same price. This is the standard model of monopoly theory. It will allow one to understand the important elements of an optimal pricing strategy better. We will first analyze the case of a one-product monopoly selling a good in one market. As an extension, we will then generalize this model to include so-called two-sided or multi-sided markets. In this case, the monopolist sells two or more goods or services in different markets, and the distinctive feature is the existence of interdependencies between the markets. This rather abstract sounding description is of great importance to understand the pricing logic of the digital economy.

  However, the absence of price differentiation is not very realistic, as companies will usually try to differentiate prices between customers, so this basic model alone cannot give us a sufficiently accurate picture of monopoly behavior. Hence, the standard model alone cannot give one an appropriate picture of monopolistic behavior. The fact that price discrimination is an important tool of a firm's policy will become clear during the analysis.
- The firm is able to discriminate prices.
  - Perfect *(first degree) price discrimination* is possible. This is a theoretical benchmark, where the firm is able to set individualistic prices for each customer and can, in addition, discriminate by the quantity demanded. This model helps one to understand the consequences of price discrimination by bringing it to its extreme. It is, however, not particularly realistic, because it assumes that firms have all the relevant information about their customers and that a legal environment exists that allows them to use this information to charge different customers different prices. The availability of "big data" and the development of sophisticated algorithms that analyze the behavior of individuals on the internet may, however, allow them to move closer in the direction of perfect price discrimination in the future.
  - Price discrimination according to the quantity, quality, or time demanded (*second-degree price discrimination*). A firm often knows that there are different "types" of customers, who differ in their willingness to pay. From its market research, it may also know the different demand functions of these types. However, it does not know the willingness to pay of a specific customer. Therefore, the firm cannot condition the price on the customer's type directly, but needs to find alternative, indirect ways to skim off the different types' willingnesses to pay by appropriately designing products and prices. Examples are economy- and business-class airline tickets. Flexibility regarding the altering of the booking, leg space, and service on board are important quality dimensions and airlines have an incentive to play with these variables to optimize profits.
  - Price discrimination according to specific customer attributes or customer segments (*third degree price discrimination*). The monopolist is able to

discriminate between groups of customers, but cannot discriminate within groups. An example is price discrimination of multinational firms between countries.

We will discuss these cases in the following sections.

14.4 Monopoly Without Price Discrimination

14.4.1 The Single-Product Monopoly

The most studied case is the non-price-discriminating monopolist. Before discussing the circumstances under which it may be optimal to dispense with price discrimination, one should analyze how such a market functions. Assume the monopolist acts as a profit maximizer and produces with a technology that leads to a cost function $C(y)$.

A firm's market-research department estimates a market demand function $x = X(p)$ for one of the firm's products. This function shows the amount of the good or service that can be sold at a given price p. In perfectly competitive markets, the perceived demand function is perfectly price elastic at the market price. This implies that the only information necessary to determine the optimal output is the existing or expected market price. However, this is no longer the case for a monopoly, where the firm needs to estimate the market demand function with as much precision as possible. The organization of the firm is hence more complex: While in perfectly competitive markets, firms only need managerial accounting to determine marginal and average costs, but a firm in a monopoly market also needs a market-research unit to estimate the demand function, because it is no longer a price taker.

Digression 14.1 (Measuring Willingness to Pay)
This chapter's analysis shows that an understanding of the likely responses of potential buyers to price changes is of considerable importance for firms. Despite this fact and despite the advances in pricing research, many firms price and develop products without an adequate knowledge of their customers' willingness to pay. Research has shown that only 8–15% of all companies use pricing strategies that are based on empirical assessments of buyer responses (Monroe and Cox, 2001), despite the fact that there is empirical evidence that even minor changes in prices can have important effects on profits (Marn et al., 2003). A lot of firms would rather use a strategy that may be dubbed "intuitive" pricing.

Marketing research offers a large variety of different techniques for measuring the willingness to pay. Broadly speaking, they fall into two different categories: "revealed" and "stated" preference models. Revealed-preference

(continued)

Digression 14.1 (continued)
techniques infer a customer's willingness to pay from observed data. This can be market data, data that is generated while browsing the internet or data generated in experiments. Stated-preference techniques are based on surveys that are designed to elicit information about the willingness to pay. Examples of these include, among others, expert or customer surveys, and conjoint analysis. Conjoint analysis is a statistical technique where a product is partitioned into different attributes that together generate value for the customer (in the case of a car, these attributes might be mobility, versatility, status, etc.). Customers are then asked to rank or rate different bundles of these attributes. The results are used for the design and pricing of future products.

The different techniques to measure one's willingness to pay have their own strengths and weaknesses, and it depends on the specific product and the available budget of the market-research department which method is applied.

At this point, one has to make a decision. One can assume that the monopolist sets a price and passively adjusts the produced quantity, $X(p)$, or one can alternatively assume that the monopolist decides on the quantity and demand determines the price at which the market clears. Both approaches lead to the same result but, since the second is somewhat simpler, it is the one that is usually applied. In order to do so, however, one has to infer the so-called inverse demand function from $X(p)$, knowing that, for any price (p), the quantity (x) that can be sold is given by $x = X(p)$. Taking the inverse function of this demand function yields $p = X^{-1}(x)$, which determines the price that clears the market for any quantity offered by the firm. The convention from the previous chapters is to denote demand by x and supply by y. Given that one is analyzing the problem from the position of the monopolist who decides how much to supply, it makes sense, therefore, to replace x by y in the inverse-demand function that one denotes as $p = P(y)$.

If π denotes the firm's profit, then one can use this information to express it as revenues minus costs:

$$\pi(y) = P(y) \cdot y - C(y).$$

The problem faced by the firm's manager is to determine the quantity that maximizes profits. This quantity is implicitly defined by the necessary ("first-order") condition $\pi'(y) = 0$. (Assume in the rest of the book that this condition characterizes the global profit maximum. This is guaranteed, for example, if the second derivative of the profit function is globally negative, has a positive slope at $y = 0$, and has a negative slope for $y \to \infty$.) This yields

$$P'(y) \cdot y + P(y) \cdot 1 - C'(y) = 0.$$

This condition has a straightforward economic interpretation: The first two terms represent the marginal revenues of an additional unit of the good, which can be decomposed into a price effect (first term) and a quantity effect (second term). The quantity effect is known from perfectly competitive markets. It measures by how much revenues increase, if an additional (marginal) unit is sold and the price stays constant. For infinitesimal changes, it is equal to the good's price. The price effect is new, however, and measures the loss in revenues of the firm, if it wants to sell another unit. To be able to sell another unit, the firm has to lower its price a bit to gain more customers. Since price discrimination is not possible, the firm also has to lower the price for those customers who would have paid a higher price. This "loss" can be interpreted as an opportunity cost and is measured by the price effect. The third term represents marginal costs and hence the "marginal revenues = marginal costs" rule holds.

The first-order condition can be transformed into an easy rule of thumb, which is of great relevance in the management and pricing literature. Simple manipulations of the first-order condition show

$$\begin{aligned} P'(y) \cdot y + P(y) &= C'(y) \\ \Leftrightarrow P(y) \cdot \left(P'(y) \cdot \frac{y}{P(y)} + 1 \right) &= C'(y) \\ \Leftrightarrow p \cdot \left(\frac{1}{X'(p) \cdot \frac{p}{X(p)}} + 1 \right) &= C'(y) \\ \Leftrightarrow p \cdot \left(\frac{1}{\epsilon_p^X(p)} + 1 \right) &= C'(y). \end{aligned}$$

The transformation from the second to the third row follows from the definition of the inverse-demand function and the fact that demand is denoted by x. The manipulation between the third and fourth row follows from the definition of the price elasticity of demand: $\epsilon_p^x(p)$.

One can start by making a short plausibility check: when the market demand function has a negative slope, the price elasticity of demand is negative. Hence, the expression in brackets is smaller than one. Therefore, the condition can only hold if the price exceeds marginal costs. If there are perfect substitutes for the good, then the price elasticity converges to $-\infty$, such that the expression in brackets converges to 1, which leads to an intuitive conclusion: To comply with the above condition the price has to be equal to marginal costs, which is, of course, the case in perfect competition.

If the price elasticity is finite, however, then the optimal price exceeds marginal costs. The difference between price and marginal costs is called the "markup", and this rule of thumb is called "cost-plus pricing." In general, the more inelastic market demand reacts to price changes, the higher the optimal markup. Thus, a manager who wants to set the optimal price needs information about two things: the marginal costs and the price elasticity of demand.

To further illustrate the optimal pricing decision of a monopolist, I derive the solution for the special case of a linear demand function $p(y) = a - b \cdot y$ and constant marginal costs $MC(y) = c$. In this case, revenues are equal to $R(y) = a \cdot y - b \cdot y^2$, with marginal revenues being $MR(y) = a - 2 \cdot b \cdot y$. Equating marginal revenues and marginal costs and solving for y yield the optimal solution $y^* = (a - c)/(2 \cdot b)$ and a price of $p^* = (a + c)/2$.

The demand function $x(p) = a/b - (1/b) \cdot p$ has a price elasticity of demand:

$$\epsilon_p^x(p) = -\frac{1}{b} \cdot \frac{p}{a/b - (1/b) \cdot p} = -\frac{p}{a - p}.$$

Thus, the absolute value of the price elasticity of demand is equal to

$$|\epsilon_p^x(p^*)| = \frac{p^*}{a - p^*} = \frac{a + c}{a - c} \geq 1.$$

The fact that the optimal quantity and price are in the elastic part of the demand function is no coincidence: If demand is inelastic, then the monopolist can increase revenues by reducing output, because a 1% decrease in output increases the price by more than 1%. However, in this case, the initial level of output could not have been profit maximizing, since reducing output also reduces costs.

Figure 14.1 shows the graphical solution to the profit-maximization problem of the monopolist. The optimum is given at the quantity where the marginal-revenue and the marginal-cost curves intersect. The associated price is defined by the value of the demand function for that quantity.

The solution to the linear model looks abstract, but is, in fact, rather intuitive. Assume for the moment that $c = 0$. In this case, profit maximization boils down to revenue maximization and revenues $p(y) \cdot y$ are the rectangular area under the demand function for any output y. Hence, the monopolist maximizes the size of this area. The optimal output is, therefore, given at $y = a/(2 \cdot b)$. If costs are positive, one has to restrict attention to the area where gains from trade are positive. $(a - c)$ are the maximum gains from trade of the customer with the highest willingness to pay, in this case. Thus, what one effectively gets is a "truncated" demand function $\bar{p}(y) = \bar{a} - b \cdot y$ with $\bar{a} = a - c$. The same argument as was used in the case of zero marginal costs also applies to this truncated function.

Digression 14.2 (What Factors Determine Price Elasticities?)
There are two factors that determine the price elasticity of demand: The customer's purchasing power (when the good becomes more expensive, customers can *ceteris paribus* afford less of it) and the willingness and

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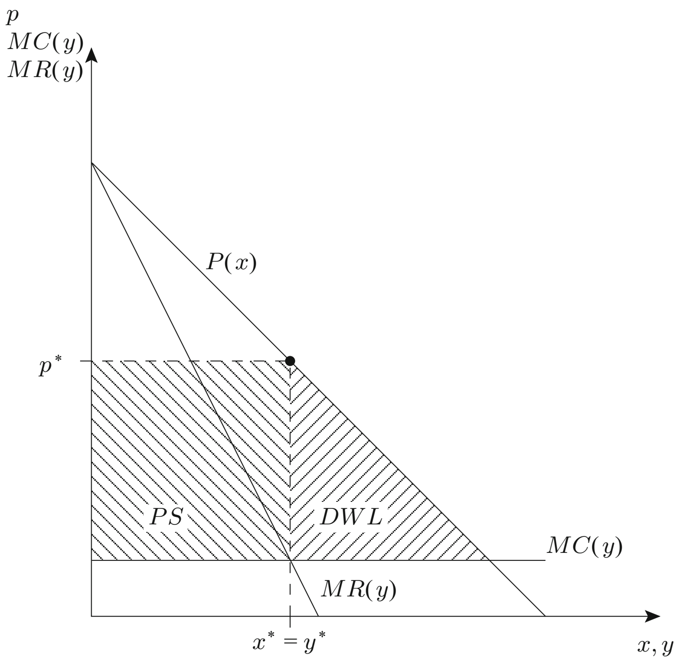

Fig. 14.1 The supply of a monopolist without price discrimination

Digression 14.2 (continued)
possibility to substitute the good with another one. This second determinant makes the model applicable to markets with close but imperfect substitutes, e.g., different brands of jeans. The model's implication for markets with close substitutes is that markups have to be relatively moderate. The markup rule also gives one a first clue about how firms should invest in advertising and public relations: Cost-plus pricing indicates that the markup in a market is negatively related to the price elasticity of demand. A marketing campaign should hence aim at making demand less elastic. In order to determine the optimal advertising budget, the firm needs to know the marginal revenues and marginal costs of advertising. The marginal revenues are determined by the change of the price elasticity of demand that is induced by another unit of advertising.

The monopolist's optimal price policy has interesting implications for economic policy: Since the optimal price exceeds marginal costs, unexploited gains from trade will remain. There are still customers who are willing to pay a price that exceeds the firm's marginal costs, but at which the monopolist is not willing to sell.

Consequently, the sum of consumer and producer surplus is below its maximum and the market is inefficient, a situation that is also called "market failure." The reason for this market failure is easy to grasp: If the monopolist wants to sell another unit of the good, he needs to lower the price a bit. However, because price differentiation is not possible, the price needs to be lowered for all: not only for the marginal customers, but also for those who would buy the product at higher prices. If the firm wants to sell at marginal costs, the decrease in revenues due to the price effect exceeds the increase due to the quantity effect; therefore, the monopolist prefers to constrain the quantity to keep the price high. The inefficiency is given by the triangular area *DWL* in Fig. 14.1. *DWL* stands for *deadweight-loss* and is a measure for the inefficiency of the allocation.

Before one can discuss the implications for economic policy, one needs to have a better understanding of the causes of this inefficiency. Hence, the next analysis is a monopolist's optimal pricing policy, if price discrimination is possible.

14.4.2 Two- or Multi-Sided Markets

Two- or multi-sided markets are intermediation platforms that provide goods and services to two or many different groups of customers. What distinguishes them from traditional multi-product businesses is the presence of interdependencies in terms of profits from trade between the different groups (see Chap. 6). These interdependencies can be positive or negative. Facebook, for example, has two main groups of customers, users (side 2) and online advertisers placing targeted ads (side 1). Facebook collects data about its users that allows it to place ads more effectively. Thus, the willingness of online advertisers to pay for the placement of ads depends on the number of users that can be reached and the effectiveness of the targeting strategy, which creates a positive interdependency from side 2 to side 1. At the same time, there may be a negative interdependency in the opposite direction if users do not like being exposed to too many ads.

Interdependencies between different customer groups can occur basically anywhere in the economy. They can be found in traditional industries (e.g., credit card companies connecting cardholders and merchants, shopping malls connecting customers and merchants, or organizations like alumni clubs, AIESEC, etc.). But they are particularly relevant in the digital economy, where some of the largest and most profitable companies in the world act as intermediaries or platforms. Examples include Facebook, Google, Baidu, eBay, Amazon, Microsoft, Apple, Taobao, and many others. As an example, consider Apple's digital application platform. In this case, application developers and users form the two groups of customers. The goal of application developers is to sell their applications to iPhone, iPad, or Mac users. These users are willing to buy and install these applications. Apple has integrated this platform into its hardware and software ecosystem to bring these groups together, for which fees are charged.

Two-sided markets generally benefit from many of the factors (such as network externalities) that explain the existence and persistence of monopolies. They also have very interesting and, at first glance, potentially counterintuitive consequences for optimal pricing, which will be the focus of this section. One is that many of the services offered to one side of the market are free (have prices of zero). Facebook users do not pay a membership fee, nor do users of search engines such as Google. From the isolated perspective of this market, such a business model looks strange to say the least, although it is probably efficient since the marginal cost of an additional Facebook user or Google search is close to zero (although the fixed costs are significant). The rationality of this pricing strategy only becomes clear if you look at both sides of the market at the same time. There is the saying "If you don't pay, you are the product," which nicely illustrates for example Facebook's business model. The mass of user data that Facebook collects is invaluable to online advertisers because it allows them to target users with ads and messages and is more likely to get their attention because they know their preferences well. So Facebook is free to users (side 1) because its business model is to collect data and provide advertisers (side 2) with guidance on how to identify and target their preferred customers. This service is not free, and the prices that can be charged depend on the number of users, the time they spend on the platform, and the quality of the algorithms that analyze the data and turn it into profitable information. What we can learn from this is that because of the interdependencies that exist in two-sided markets, optimal pricing is also interdependent. A profit-maximizing firm should not focus on each side of the market separately, but should see pricing as a task encompassing both sides of the market, the goal of which is to internalize the interdependencies as best as possible. As we will see later, such a strategy can explain prices of zero and even prices below marginal cost on one side of the market.

Digression 14.3 (User Fees: An Alternative Business Model for Facebook?) One could argue that an aggressive placement of ads on platforms reduces user experience, so a user-fee-based business model with ad-free service (and no data collection) could be a viable alternative. And some platforms like Spotify do indeed offer so-called premium services as an option. Whether this strategy can work depends on the specific services the platform offers. Facebook, at least so far, has always insisted on offering a free service for its users. An interesting thought experiment is to ask what user fee Facebook would have to charge to be indifferent between its current business model and a user fee-based alternative. In 2017, Facebook's average revenue per user in North America was 84.41 U.S. dollars. To replace that revenue with an ad-free service, Facebook would need to charge each user at least that amount. A recent survey of US Facebook users found that less than 10% would be willing to pay such a user fee for an ad-free service. Taking this figure at face value, the community would collapse dramatically. This would have two negative effects for the remaining users. First, due to the importance of network externalities, they would perceive Facebook as less attractive. And

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Digression 14.3 (continued)
second, maintaining Facebook's revenue would mean that user fees would also have to increase dramatically, which would likely drive away even more users.

In what follows, we restrict ourselves to two-sided markets and present a simple model that allows us to develop some of the main ideas. A monopolist (the intermediary) offers goods and services in two markets (the sides) 1 and 2. The difference with the standard model is an interdependency between the quantity supplied in market 2 (e.g., Facebook users) and the willingness to pay of customers in market 1 (e.g., online advertisers that buy information from Facebook). The monopolist's profit function is

$$\pi(y) = P_1(y_1, y_2) \cdot y_1 + P_2(y_2) \cdot y_2 - C_1(y_1) - C_2(y_2),$$

and we obtain the following first-order conditions characterizing the profit maximum:

$$\frac{\partial P_1(y_1, y_2)}{\partial y_1} \cdot y_1 + P_1(y_1, y_2) - \frac{\partial C_1(y_1)}{\partial y_1} = 0.$$

$$\frac{\partial P_2(y_2)}{\partial y_2} \cdot y_2 + P_2(y_2) + \frac{\partial P_1(y_1, y_2)}{\partial y_2} \cdot y_1 - \frac{\partial C_2(y_2)}{\partial y_2} = 0.$$

The first-order condition can be transformed into two markup rules similar to those we already know. We denote by $\epsilon_1^{X_1}$ and $\epsilon_2^{X_1}$ the price and cross-price elasticities of demand for good 1 and by $\epsilon_2^{X_2}$ the price elasticity of demand for good 2:

$$p_1 \cdot \left(\frac{1}{\epsilon_1^{X_1}} + 1 \right) = \frac{\partial C_1(y_1)}{\partial y_1},$$

$$p_2 \cdot \left(\frac{1}{\epsilon_2^{X_2}} + 1 \right) = \frac{\partial C_2(y_2)}{\partial y_2} - p_1 \cdot \frac{y_1}{y_2} \cdot \epsilon_2^{X_1}.$$

The first markup rule is qualitatively identical to the one we already know. However, the second markup rule is new and takes into account the interdependency between market 2 and market 1 (thus internalizing it from the monopolist's point of view). Two cases can be distinguished:

- **Negative interdependency:** If $\epsilon_2^{X_1} < 0$, the markup on market 2 is higher than on independent markets. The fact that more demand on market 2 reduces demand on market 1 is accounted for by a higher markup on market 2 compared to the standard case.

- **Positive interdependency:** If $\epsilon_2^{X_1} > 0$, the markup on market 2 will be lower than for independent markets. The fact that more demand on market 2 increases demand on market 1 is accounted for by a lower markup on market 2. It may be that the price charged is below marginal cost, equal to zero, or even negative.

Charging prices below marginal cost may be attractive if the positive interdependency with the other market is strong enough to offset the associated losses. It is said that game companies like Sony sell their consoles at a loss to achieve a large market share, which makes it attractive to develop software for their consoles. Sony then receives royalties for this software when it is used on their consoles.

Here is an example with linear demand functions and marginal costs of zero: The inverse demand for good 1 is given by $P_1(y_1, y_2) = 100 - y_1 + d \cdot y_2$, where $d \leq 1$ is a parameter that measures the interdependency between market 2 and market 1. The inverse demand for good 2 is given by $P_2(y_2) = (100 - y_2)$. This yields the following profit function:

$$\pi(y_1, y_2) = (100 - y_1 + dy_2) \cdot y_1 + (100 - y_2) \cdot y_2.$$

The example is useful because it allows us to immediately see the optimal solution for the case without (or with neglected) interdependency ($d = 0$): $y_1^* = y_2^* = 50$, and therefore $p_1^* = p_2^* = 50$. The solution is shown in Fig. 14.2a, where one can see the inverse demand functions in both markets and the resulting profit-maximizing quantities and prices. The square areas are the profits $y_i^* \cdot p_i^* = 2,500$, $i = 1, 2$. The solution without interdependence is also the solution that would result if the firm neglected the interdependency and maximized profits in both markets separately.

With $d \neq 0$, the solution is the following:

$$\frac{\partial \pi(y_1, y_2)}{\partial y_1} = 0 \Leftrightarrow y_1 = 50 + \frac{d}{2} \cdot y_2, \quad \frac{\partial \pi(y_1, y_2)}{\partial y_2} = 0 \Leftrightarrow y_1 = -\frac{100}{d} + \frac{2}{d} \cdot y_2.$$

Solving both equations leads to the following profit-maximizing quantities and prices:

$$y_1^* = y_2^* = \frac{100}{2-d}, \quad p_1^* = \frac{100}{2-d}, \quad p_2^* = \frac{100 \cdot (1-d)}{2-d}.$$

Thus, when d is strictly positive (strictly negative), the price in market 1 is larger (smaller) than the price in market 2, which is consistent with our intuition derived from the modified markup rule. When $d = 1$, the optimal price in market 2 is $p_2^* = 0$. The case $d = 1$ is shown in Fig. 14.2b. The inverse demand function in market 1 is obtained when $p_2^* = 0$, $y_2^* = 100$ is inserted. The profit is equal to $y_1^* \cdot p_i^* = 10{,}000$, and $y_2^* \cdot p_2^* = 0$. It is easy to see that internalizing the interdependency

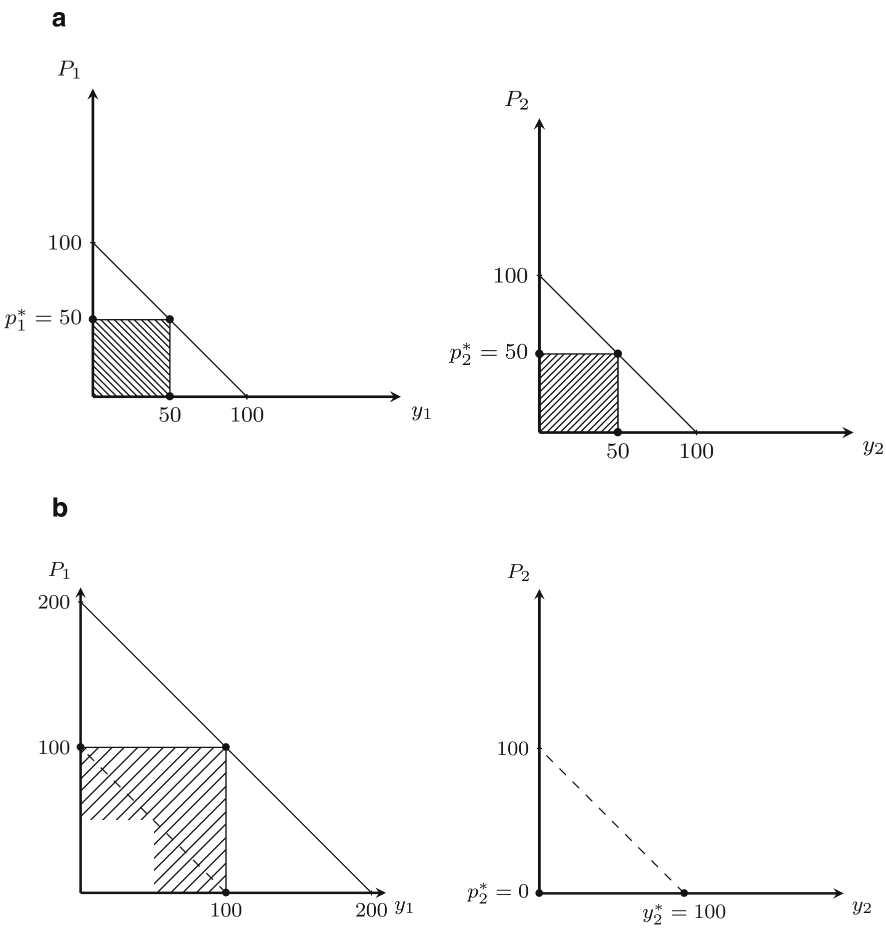

Fig. 14.2 Optimal pricing in two-sided markets. (**a**) Optimal pricing if interdependency is ignored. (**b**) Optimal pricing if interdependency is internalized

between the two markets in this case doubles the total profit. The gray area in the left part of Fig. 14.2b denotes the increase in profits and the gray area in the right part of Fig. 14.2a denotes the decrease in profits compared to the non-internalized solution.

14.5 Monopoly with Price Discrimination

Reasonable charges
Plus some little extras on the side!
Charge 'em for the lice, extra for the mice
Two percent for looking in the mirror twice

Here a little slice, there a little cut
Three percent for sleeping with the window shut
When it comes to fixing prices
There are a lot of tricks he knows
How it all increases, all them bits and pieces
Jesus! It's amazing how it grows!
(Alain Boublil (2013), Les Miserables (based on the novel by Victor Hugo))

14.5.1 First-Degree Price Discrimination

This subchapter covers the problem of a monopolist who is able to discriminate prices perfectly. Although this is not a very realistic assumption, as firms are usually unable to get all the relevant information, it is a useful theoretical benchmark and allows one to better understand the reasons for the above-mentioned inefficiency as well as current trends in firms' pricing strategies.

Perfect price discrimination is easy to analyze. In order to be able to pursue this strategy, the monopolist needs to know the willingness to pay of each individual customer. If this information is available, the firm will charge individualized prices for each customer, which equal that customer's willingness to pay. (It may be necessary to lower the price a bit to induce customers to actually buy the product. The remainder of this book will assume that indifferent customers behave in the interest of the firm. This assumption is innocuous with respect to its implications and simplifies the analysis.) Hence, in such a market, there is no uniform price, but a price function that is exactly equal to the inverse-demand function.

What is the minimal price at which the monopolist will supply the good? His profit increases as long as the price of the last unit exceeds the marginal costs of that unit. Hence, he will expand his supply up until the point where price equals marginal costs. This brings about a surprising result: The resulting market equilibrium is Pareto-efficient and the sum of consumer and producer surpluses are maximized. However, contrary to the case of perfect competition, gains from trade are not shared between the producer and the customers. Instead, the monopolist is able to skim off all the surplus in the market (see Fig. 14.3).

What are the consequences of this discovery for economic policy and the regulation of monopoly markets? If one compares the case of a non-price-discriminating monopolist with that of a perfectly price-discriminating one, one can see that the monopolist will always choose to discriminate prices, if he can. Hence, the inefficiency in the market with a non-price-discriminating monopolist is caused by the inability to discriminate prices. There are three reasons why this instrument may be infeasible:

1. Price discrimination is illegal. The monopolist is then forced to charge the same price for any customer. In this case, it is the regulation of the market that causes the inefficiency. Market failure is not a result of some inherent tendency of the monopolist to be inefficient, but of a failed regulation of the monopoly (if the objective of regulation is to achieve efficiency).

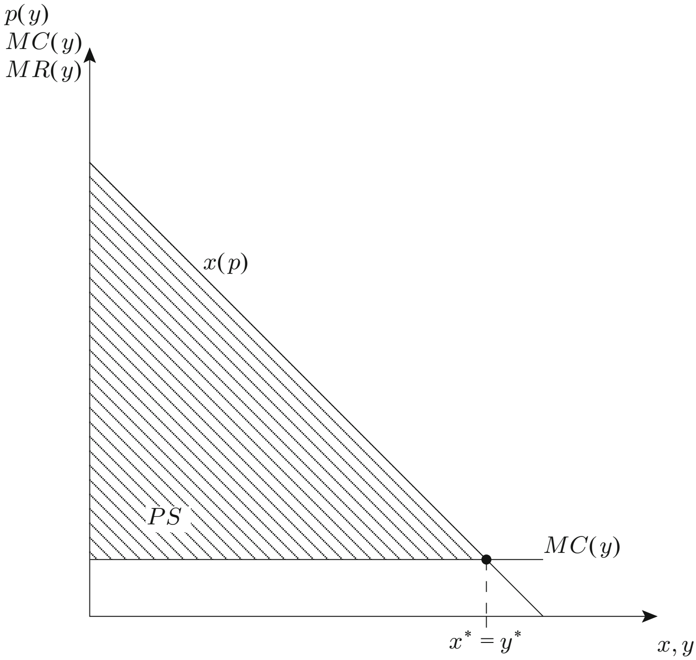

Fig. 14.3 Supply of the efficient quantity with first-degree price discrimination

An example for efforts to impede price discrimination by legal action is the "Robinson Patman Act," specifically Title 15, Chapter 1 §13 of the United States Code titled "Discrimination in price, services, or facilities." It is worthwhile studying the first paragraph of the act. "It shall be unlawful for any person engaged in commerce, in the course of such commerce, either directly or indirectly, to discriminate in price between different purchasers of commodities of like grade and quality, where either or any of the purchases involved in such discrimination are in commerce, where such commodities are sold for use, consumption, or resale within the United States or any Territory thereof or the District of Columbia or any insular possession or other place under the jurisdiction of the United States, and where the effect of such discrimination may be substantially to lessen competition or tend to create a monopoly in any line of commerce, or to injure, destroy, or prevent competition with any person who either grants or knowingly receives the benefit of such discrimination, or with customers of either of them: Provided, That nothing herein contained shall prevent differentials which make only due allowance for differences in the cost of manufacture, sale, or delivery resulting from the differing methods or quantities in which such commodities are to such purchasers sold or delivered: Provided, however, That the Federal Trade Commission may, after due investigation and hearing to all interested parties, fix and establish quantity limits, and revise the same as it finds necessary, as to particular commodities or classes of commodities, where it finds that available purchasers in greater quantities are so few as to render differentials on account thereof unjustly discriminatory or promotive of monopoly in any line of commerce; and the foregoing shall then not be construed to permit differentials based on differences in quantities greater than those so fixed and established: And provided further, That nothing herein contained shall prevent persons engaged in selling goods, wares, or merchandise in commerce from selecting their own customers in bona fide transactions and not in restraint of trade: And provided further, That nothing herein contained shall prevent price changes from time to time where in response to changing conditions affecting the market for or the marketability of the goods concerned, such as but not limited to actual or imminent deterioration of perishable goods, obsolescence of seasonal goods, distress sales under court process, or sales in good faith in discontinuance of business in the goods concerned."

2. The monopolist cannot prevent the resale of his products. In this case, resale markets evolve and so-called arbitrageurs specialize in buying and reselling the monopolist's products. For example, if there are two customers and one of them can buy at a high price only while the other can buy at a low price, it is worthwhile for both to trade at a price that is somewhere in between the two monopoly prices. Under ideal conditions, this process continues until only a uniform price prevails in the market.

   Why should a monopolist be unable to prevent the emergence of resale markets? To answer this question one needs to take a closer look at the types of contracts a monopolist can use because, from a legal perspective, the sale of a product or service is a transfer of a bundle of rights that is (explicitly or implicitly) specified in the underlying contract. If the monopolist can freely choose and constrain these rights, he can prohibit the resale of his products. He grants his customers the right of usage, but not the right of resale. The formation of resale markets can be precluded, if such contracts are legal and enforceable. However, in reality, it is often the case that courts do not enforce such contracts. They are sometimes legal in insurance markets, where insurance policies cannot be traded freely whereas, in traditional, consumption-goods markets, such contracts are usually illegal (for example in the European Union). However, the picture is more complicated for digital products, where complicated arrangements exist that regulate user rights. If resale were possible, then one would have to conclude that the source of market failure is, once again, an inefficient regulation of the market.

3. The monopolist does not have the information that is necessary to discriminate prices. The next chapter will cover the implications for the monopolist's profit maximization in more detail.

Digression 14.4 (Price Discrimination in the Digital Age)
Compared to second- and third-degree price discrimination, first-degree price discrimination has long been seen as a theoretical benchmark without much practical relevance, because the need for customer-specific information that is necessary to charge personalized prices was considered too extensive. On the other hand, moving in the direction of perfect price discrimination is extremely tempting for firms, because of its obvious consequences for profits. It should therefore not come as a surprise that e-commerce sites experiment heavily with pricing strategies that are based on the tracks people leave while browsing the internet.

A Executive Office President of the United States (2015) report for the attention of the President of the USA concludes that "the combination of differential pricing and big data raises concerns that some customers can be made worse off, and have very little knowledge why. [...] [M]any companies already use big data for targeted marketing, and some are experimenting with personalized pricing, though examples of personalized pricing remain fairly limited. [...] [P]roviding consumers with increased transparency into how companies use and trade their data would promote more competition and better informed consumer choice."

Hannak (2014) analyzed the search results of 300 people who visited 16 online retailers and travel agencies from the USA. They found that customers were shown different prices or different results for the same searches on nine of these 16 sites. For example, the online-travel company Expedia discriminates prices according to the browsing history stored on the customers' computers. It is unclear, however, which type of browsing history triggers high prices. Another travel-agency, Travelocity, offered hotel rooms that were $15 a night cheaper if viewed from an iPhone or iPad. Home Depot displays higher prices and pricier products for smartphone users than for customers using desktops. In 2012, Wall Street Journal found that Staples discriminated prices according to the location of the device, and Orbitz discriminated prices between Mac and PC users, because data analysis revealed that Mac users are willing to pay higher prices for hotels.

These attempts to discriminate prices are still relatively crude, but the availability of more information and better algorithms may soon change the picture. Calo (2013) concludes that big data and better algorithms will enable companies to profile customers and deliver advertisements in a much more personalized way, also making use of the limited rationality of individuals. For example, Apple and Microsoft have filed patents for the so-called mood-based advertising, and Amazon is developing algorithms that tell them what the customers are likely to want before they place an order. This information is crucial for price discrimination, because it allows them to adjust prices or tweak choices while the customer is still searching. Google, for example,

(continued)

Digression 14.4 (continued)
is filing a patent for an algorithm that can decide if a customer is likely to buy something and then to display a high price, while lowering the price for customers who have a low likelihood of buying.

Shiller (2014) studies the effects of including more information into pricing strategies on profits in the case of Netflix. He found that, compared to standard second-degree price discrimination, using the full set of information about web-browsing behavior increases variable profits by 1.39%, compared to 0.15% if pricing strategies are based on demographics alone. This may not sound like much but, compared to net profit margins of 2.34% in the US online retail industry, it makes a big difference.

The preliminary conclusion that one can draw at this stage is somewhat surprising, because one cannot make a case against monopolies that is based on efficiency arguments. In light of the two models that have already been covered, one has to conclude that market inefficiencies are a result of an insufficient regulation of the market, not of the monopoly as such. This conclusion is, however, at odds with the intuitive feeling that most people and also most economists share, which states that monopolists are inherently inefficient. There are two ways to align this idea with the realizations discussed above:

First, it is, indeed, possible that perfect price discrimination of a monopolist can lead to an efficient market outcome. Still, society might have goals that go further than efficiency. For example, distributive justice is a goal that many societies pursue. However, since monopolies are owned by individuals, who are also customers, customers will, in the end, receive the monopolist's profits. Therefore, one cannot judge the distributive properties of monopoly markets without further knowledge of the distribution of property shares among the population. However, there is empirical data about asset ownership in different countries. The demand for products and services is usually widely scattered, whereas property is concentrated in the hands of relatively few, rich individuals such that, from a more egalitarian point of view, a trade-off between efficiency and distributive justice can exist. This may explain why some inefficiency is seen as the necessary price for a more egalitarian society. However, then the question arises of why the problem of distributive justice is not addressed more directly, for example by redistributive taxation.

Digression 14.5 (Pricing and Bounded Rationality)
Finding ways to more effectively discriminate prices is a key topic in many industries. Strategies to discriminate go under names such as "dynamic pricing," "power pricing," or "yield management." The basic problem behind

(continued)

Digression 14.5 (continued)
all of these strategies is the same: How can a firm segment its customers into groups, which differ in their willingness to pay, and charge group-specific prices? Such strategies can actually lead to win-win situations between firms and customers, if there are close substitutes to the offered products (customers do not have to accept the offer, which is why they have to be better off if they accept it) and customers economize on search costs (e.g., finding an appropriate hotel for the planned trip to Vienna).

A related problem has to do with irrational or boundedly rational behavior. Based on findings from behavioral economics, some legal scholars criticize pricing strategies that systematically exploit customers' behavioral biases. Research in this field is still in its infancy.

Here is an example: Assume a health club or gym uses a two-part tariff with an upfront-payment of L and a per-visit charge of p. If p equals marginal costs and L contributes to the financing of the club's fixed costs, then the contract is efficient. There is a lot of evidence, however, that customers overestimate the number of times that they will go to the club. This form of irrationality can be used by the club by charging p below its marginal costs and increasing L, which widens the gap between the surplus that the customer expects to receive from accepting the contract and what she actually receives. The customer finds this contract more appealing, but may end up with a negative consumer surplus.

Another example is a pricing strategy that is based on the *anchoring effect*. The rule of thumb on how to sell a good, for which customers have an unclear willingness to pay, is to place it right next to a similar, but much more expensive good. Williams-Sonoma added a $429 breadmaker next to their $279 model. The consequence was that sales of the cheaper model doubled, even though practically nobody bought the $429 machine (Ariely, 2008): In this case, the expensive option acted as a price anchor.

A similar effect occurred in a study on purchasing patterns for beer (Poundstone, 2011). In the first test, subjects had the choice between a regular beer for $1.80 and a premium beer for $2.50; 80% chose the premium beer. In the next test, a smaller and cheaper ($1.60) option was added. No one chose the cheap option, but orders for the premium beer dropped to 20%. In the final test, the cheap option was replaced by a large, expensive ($3.40) option. In this case, orders for the premium beer rocketed to 85%. This experiment shows that customers react to the pricing brackets in which products are displayed. Most people go for the "middle" option, which gives firms a lot of leeway in manipulating choices by developing adequate contexts for their products.

It might also be the case that the intuitive problems many people have with monopolies are not adequately grasped by the model. It is possible that the reason for a lack of efficiency of a monopoly is inherently dynamic, for example, because an ironclad monopoly position decreases the incentives to innovate. Such an argument, however, suggests that a completely different model is necessary to tackle the problem.

14.5.2 Second-Degree Price Discrimination

One central problem a monopolist faces when trying to discriminate prices is his lack of information about customers. There are two ways to solve this problem: investing in better information or using the given information to discriminate prices with maximum possible effectiveness. This subchapter will analyze the latter strategy.

In order to keep the problem simple and manageable, assume that there are two groups of customers, which can be differentiated by their willingness to pay. The firm knows each group's willingness to pay and also the respective group sizes, but cannot identify a customer as a member of one group or the other. An example for this situation is an airline that offers a flight from Zurich to Frankfurt, which is frequented by both business and leisure travelers. Business travelers have a higher willingness to pay for the flight and, in particular, for altering bookings flexibly. The airline knows the respective willingness to pay, as well as the groups' relative sizes, but cannot distinguish between individuals at the ticket counter (or on their homepage for that matter).

If the firm had all the relevant information, it would charge each customer according to his or her willingness to pay, such that both groups would receive their respective optimal offers, as in the case of first-degree price discrimination. From the point of view of the firm, the problem with asymmetric information is that a customer with a high willingness to pay may prefer the offer that is being provided for customers with a low willingness to pay. Their "own" offer gives the customer zero consumer surplus, whereas the offer provided for the other group not only differs in the quantity or quality of the good but is also sold at a different price (both lower). Hence, buying a lower quality or quantity at a lower price might be profitable for the customer, if the lower price compensates for the loss in quality or quantity. In that case, all customers choose the offer that was designed for the group with the lower willingness to pay and the other offer remains a shelf warmer. This observation begs the question of what a firm's optimal reaction should be.

In order to answer the question, one should give the problem a more formal structure and analyze it graphically. In the following figures, one can see the quantity or quality of a good along the abscissa and the customers' willingness to pay along the ordinate. "Quantity" or "quality" can thereby be interpreted as an attribute, for which there are differences in the willingness to pay. In the airline example, quality can be interpreted as the flexibility to alter a booking, how much leg space there is or the level of service provided. If the good is a printer, quantity could refer to the number of pages the printer can print per minute. Depending on the specific context,

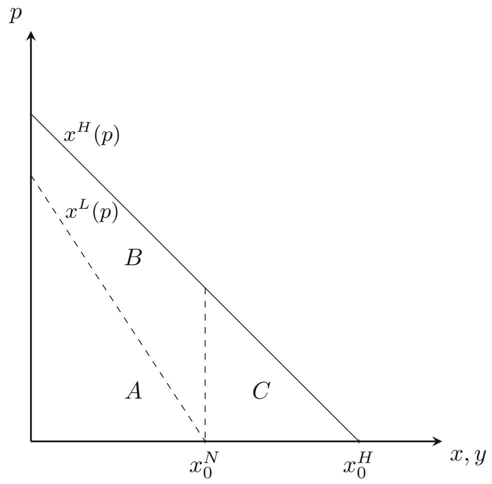

Fig. 14.4 Two types of customers, L (dashed line) and H (solid line)

it may be hard to distinguish between the quantity and the quality of a product. I will use the convention to talk about quantity in the following example.

In Fig. 14.4, one can see the inverse demand functions $p^H(x)$ and $p^L(x)$ of an individual with a high (H-type, solid line) and low (L-type, dashed line) willingness to pay. In order to simplify matters, assume that there are as many H-types as there are L-types and that there is only one individual of each type. The monopolist has marginal costs of zero, such that the efficient quantities supplied are equal to the maximum demand levels x_o^H and x_o^L. An individual's aggregate willingness to pay for a quantity x is equal to the area under the demand function, $P^H(x) = \int_0^x p^H(x)dx$, $P^L(x) = \int_0^x p^L(x)dx$. Her respective willingness to pay for the efficient quantity is, therefore, given by the areas $P^L(x_o^L) = A$ and $P^H(x_o^H) = A + B + C$.

In the preceding chapters, one has implicitly assumed that a firm sets a price per unit of the good and the customers choose how much to buy. For effective price discrimination with asymmetric information, the firm needs to restrict the customers' sovereignty by offering pre-specified quantity-price bundles. For example, $\{y, P^H(y)\}$ is a possible offer where the monopolist offers quantity y at the maximum price the H-type is willing to pay. An arbitrary pair $\{y, P\}$ is also called a "contract." P is the price for y units, not for one unit of the good, as it was before.

It is immediately clear that, with perfect information and, therefore, price discrimination, the monopolist will offer the efficient contracts, $\{x^L, P^L(x^L)\} = \{x_o^L, A\}$, $\{x^H, P^H(x^H)\} = \{x_o^H, A + B + C\}$. (In the following analysis, assume that a customer is willing to purchase a contract, if she is indifferent between buying and not buying, and that she is also willing to purchase the contract designed for her in case that she is indifferent between two contracts. This assumption simplifies the analysis and is without relevance for the qualitative results.) The monopolist's profit is then $2A + B + C$, and the consumer surplus is zero, $CS^H(x_o^H, P^H(x_o^H)) = CS^L(x_o^L, P^L(x_o^L)) = 0$.

However, with asymmetric information, these contracts are not enforceable. A H-type individual would prefer to buy the contract of the L-type, because it leads to a higher consumer surplus of B. The L-type would never buy the H-contract, because she has no willingness to pay for the additional quantity and, therefore, has no willingness to pay the higher price.

How will the firm react to this problem? In order to answer this question, one first needs to understand whether it is possible to change the contracts in a way that increases profits. If nobody buys the H-contract, because the H-types prefer the L-contract, then the firm's profits are $2A$. In order to induce the H-type to buy "his" contract, the firm can decrease the price of the H-contract until the H-type is indifferent between the two. Because his consumer surplus is B, this is achieved when the H-contract is $\{x_o^H, A + C\}$ (see Fig. 14.4). Because altering the contract in that way increases profits to $2A + C$, it is always profitable. The profit is smaller than it would be with perfect price discrimination, but larger than $2A$.

Is this the profit-maximizing pair of contracts? The answer is no, because the firm has another policy parameter that it can use to increase the effectiveness of price discrimination, namely the quantity of the product. If it is reduced in the L-contract, then both types' willingness to pay for this contract decreases. Therefore, the firm has to complement this change with a decrease in the price for this contract in order to be able to sell it. This seems like a bad idea, because it decreases the profit from the L-contract. The fact that a change of the contract in this direction can increase overall profits can be seen once one takes into account that the H-type has a higher marginal willingness to pay for additional quantity; he is willing to pay more for the last unit than the L-type is. This fact has the following consequence: The reduction of the quantity that is offered in the L-contract does not only decrease the profit from selling to the L-type, but can also be used to increase the price for the H-contract. The H-type's implicit "threat" to choose the L-contract becomes weaker given that $\{x^H, P^H(x^H)\} = \{x_o^H, A + C\}$. The L-contract becomes less attractive for both, but this effect is stronger for the H-type, whose willingness to pay for additional quality is higher than that of the L type. Thus, this quantity reduction can be used as an instrument for type selection. In the limit, as the L-contract's quantity goes to zero at a price of zero, it becomes possible to increase the H-contract's price to $A + B + C$ again.

Contracts that make the H-type indifferent between both contracts fulfill the so-called *self-selection constraint*. Figure 14.5 shows the possible and necessary price adjustments accompanying a change of the quantity of the L-contract from x_o^L to $x_o^L - dx_o^L$.

The adjustment of the contract stops when the marginal increase in profits, due to the increase in the price for the H-contract, equals the marginal loss in profits caused by the reduction of the price for the L-contract. Graphically, this means that the line segment between the H-type's and the L-type's demand functions has to be of equal length as the line segment between the L-type's demand function and the abscissa. This situation is depicted in Fig. 14.6.

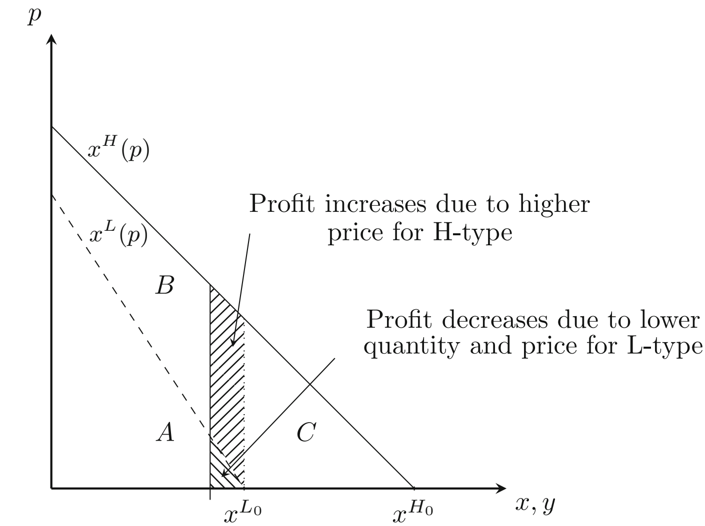

Fig. 14.5 Effect of a reduction in *L*-quantity

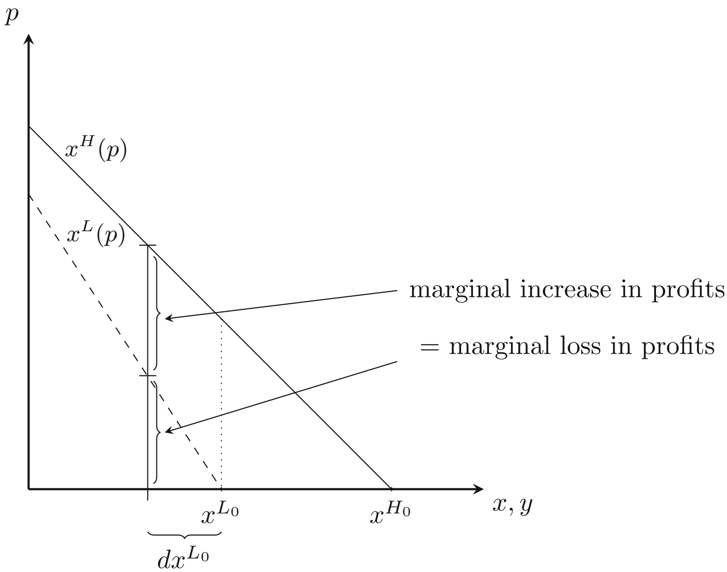

Fig. 14.6 In the optimum, the marginal decrease equals the marginal increase in profits

(In Fig. 14.6, both contracts offer positive amounts of the good. This finding results from the assumption that both types have equal frequencies in the population and the specific demand functions. If there are either very few *L*-types, or their willingness to pay differs significantly from the *H*-type's, then it can be the case that the monopolist prefers not to sell to the *L*-types at all.)

The previous analysis has revealed some general characteristics of optimal price discrimination with asymmetric information.

- The H-type always consumes the optimal quantity, unlike the L-type. This property is also called *no distortion at the top*, because it is a general property of models with asymmetric information to not distort the allocation of the "best" type.
- With such contracts, the H-type always receives positive consumer surplus, if the L-quantity is positive. The L-type always gets a surplus of zero.

While these characteristics of optimal contracts sound quite abstract, they are very useful for understanding real-world pricing decisions. In the aforementioned example of airline pricing, business travelers usually have a higher willingness to pay for flexibility than leisure travelers do. In order to apply the model, one can interpret x as a variable that measures the flexibility of a ticket. The results of the model can then be interpreted in the following way: The airline should discriminate between the two groups of customers by offering economy and business class tickets. Business class tickets offer the optimal flexibility and comfort to business travelers, but economy tickets come with less flexibility and comfort than economy customers would like (and are willing to pay for). This reduced flexibility and comfort of economy tickets is the reason that business travelers choose "their" higher-priced tickets, because they get a larger surplus from doing so. This can lead to strange incentives for airlines that may, for example, make economy seating purposely uncomfortable.

This logic can be applied to many other markets, for example ones in which customers can be grouped as "professional" and "private" users (software, computer hardware, ...). The strategy to play around with product quantity and quality in a way that makes sure that market segments are kept separate, in order to prevent demand spillover from high-priced segments to low-priced segments, is also called *price fencing*. Price fences are very important for effective market segmentation and, therefore, for profit maximization. As in the above example, they are designed such that customers who can afford and are willing to pay higher prices are not tempted by the lower-priced versions.

Sometimes, firms even have an incentive to incur costs to make products worse. Manufacturers of printers, for example, standardly equip their printers with soft- and hardware that is designed for fast printing speed and then equip a series of these printers with (costly) additional hardware and software to slow them down and sell them at a lower price. Thus, if a private user wonders at times why firms do not offer the perfect products for her needs, this may be the answer: From the point of view of a firm, the marginal costs of production are not the only ones it has to take into consideration. Additionally, there are opportunity costs that exist because customers from a different group may buy a version of the product that is not designed for them. These opportunity costs are relevant for the firm, but not for society, which is why there are externalities in the resulting equilibrium.

A related strategy for profit-maximizing firms, which should briefly be mentioned, is called *bundling*. The underlying problem for a firm is to decide on the number of characteristics or features of a product. A car manufacturer can, for example, include features like electronic safety features in the standard package, or sell them separately. A flower shop can sell bouquets or separate flowers, a computer can come with word processor, spreadsheet and presentation program, or the soft- and hardware can be sold separately, and so on.

If one thinks of different features of a complex product as separate, simpler products, then the problem of bundling is to determine which products should be included in a bundle and which ones should be sold separately. There are several rationales for bundling. There could, for example, be complementarities between products, which is why shoes are usually sold as pairs. Alternatively, bundling might economize on costs, because bundles are more efficient to produce or distribute.

A subtler reason for bundling results from the fact that it allows the producer to skim off the willingness to pay in situations where it would otherwise be impossible to do so. This is why it makes sense to discuss bundling in the context of asymmetric information and second-degree price discrimination.

Here is an example. Assume there are two types of customers in the market, who are interested in two different products: word-processing (*WP*) and spreadsheet (*SS*) software. One type of customer has a high willingness to pay for *WP* and a low willingness to pay for *SS* (say, a novelist, *N*), and the other has a high willingness to pay for *SS* and a low willingness to pay for *WP* (an accountant, *A*). Table 14.1 gives an example for the two types of customers' willingness to pay for the two different products. Type *N* is willing to pay up to CHF 120 for *WP* and CHF 100 for *SS*, and type *A* is willing to pay up to CHF 100 for *WP* and CHF 120 for *SS*. Hence, the total willingness to pay for both products is CHF 220 for both types.

Assume that the firm that sells the software knows that these two types of customers exist (one of each type), but that it cannot verify the identity of a customer when she buys the software. Assume further that the marginal costs of an additional software license are zero. Now, consider two pricing strategies for the firm: the unbundled and bundled selling of the two products.

What happens if the firm sells both products separately? I start with *WP* and denote its price by p^{WP}. If $p^{WP} \leq 100$, the firm can sell two licenses. If $p^{WP} \in (100, 120]$, it can sell one license and, for all prices $p^{WP} > 120$, the number of licenses sold drops to zero. Hence, the profit-maximizing price is $p^{WP} = 100$, yielding a profit of $\pi = 200$. The same calculation applies for *SS*. Therefore, total firm profits with unbundled selling are $\pi = 400$.

What happens if the firm decides to bundle the products? Denote the price of a bundle by p^B. Demand for each bundle is two, if $p^B \leq 220$, and drops to zero

Table 14.1 An example for product bundling

Customer type	*WP*	*SS*	Sum
N	120	100	220
A	100	120	220

for higher prices. Hence, the profit-maximizing price for each bundle is equal to $p^B = 220$, yielding profits of $\pi = 440$.

Compared to the unbundled selling, bundling increases profits by $40 = 440 - 400$. What has happened? The underlying rationale is that differences in the willingness to pay "average out" by bundling. If the licenses are sold separately, the minimum willingness to pay becomes decisive in the example. This effect cancels out, if the two products are bundled and sold as a "package."

This result is robust and especially relevant for digital products that are produced at almost zero marginal costs: Bundling large numbers of unrelated goods makes it easier to predict the customers' valuations for a bundle than their valuation for an individual good does when it is sold separately. This "predictive value of bundling" makes it possible to increase sales and profits. Examples are cable television, an internet site's content (e.g., the New York Times), or copyrighted music (for example Spotify).

To conclude this subchapter, it is important to note that the above findings also have implications for the optimal organization of firms. As seen, there are different contracts for different groups of customers. The two dimensions of the optimal contracts, which are price and—depending on the specific interpretation—quantity or quality, are not independent from each other, but can only be understood in combination. Hence, to take these important interdependencies into account, the responsibility for the different customer groups should not be given to different, independent product managers whose responsibility is to maximize profits for their departments (profit centers). This system ignores the fact that modifications of the contracts cause externalities in the other departments thereby leading to a situation where each manager maximizes the profits of his profit center, but not the total firm profits.

14.5.3 Third-Degree Price Discrimination

The last case is third-degree price discrimination. This variant is characterized by the firm's ability to discriminate between different segments of customers, but not within each segment. A prominent example is price discrimination between national markets, which is often practiced by internationally operating firms. Especially the pharmaceutical industry repeatedly makes it into the headlines for selling the same active ingredients at higher prices in Switzerland than in, for example, the European Union. According to the Swiss price supervisor (Preisüberwacher), the prices for generic drugs are on average more than twice as high than in comparable other countries (2020). However, prices for ordinary consumption goods are also discriminated in this way and Swiss customers quite often pay more for a good than others do. There are many other forms of third-degree price discrimination, for example according to age group or status (student or senior discounts, discounts for military members in the USA) or according to gender ("Ladies' night" in nightclubs or at the dry cleaners, which typically charge higher prices for women's clothes).

Assume that a firm produces a given product at a given production facility (say in China) and sells it to two countries, Switzerland (country 1) and France (country 2). The respective quantities are y^1 and y^2, and the production and logistics costs depend on the total quantity produced, $C(y^1 + y^2)$. The market-research department estimates the demand functions in the two countries as $P^1(y^1)$ and $P^2(y^2)$. Consequently, total profits are given by

$$\pi(y^1, y^2) = P^1(y^1) \cdot y^1 + P^2(y^2) \cdot y^2 - C(y^1 + y^2).$$

From the manager's point of view, the problem is to choose the quantities supplied to the different markets in order to maximize profits. The optimal decision is characterized by the following necessary conditions:

$$\frac{\partial \pi(y^1, y^2)}{\partial y^1} = \frac{\partial P^1(y^1)}{\partial y^1} \cdot y^1 + P^1(y^1) \cdot 1 - \frac{\partial C(y^1 + y^2)}{\partial y^1} = 0,$$
$$\frac{\partial \pi(y^1, y^2)}{\partial y^2} = \frac{\partial P^2(y^2)}{\partial y^2} \cdot y^2 + P^2(y^2) \cdot 1 - \frac{\partial C(y^1 + y^2)}{\partial y^2} = 0.$$

If one looks at the two conditions in isolation, the result is not very surprising: As in the model without price discrimination, the firm chooses the quantity that equalizes marginal revenues with marginal costs for each market. Only if one takes into account the fact that marginal costs are identical irrespective of the market where the products are sold (production takes place in the same factory) can one learn something new. Then one can establish the following relationship between the two markets:

$$\frac{\partial P^1(y^1)}{\partial y^1} \cdot y^1 + P^1(y^1) = \frac{\partial P^2(y^2)}{\partial y^2} \cdot y^2 + P^2(y^2).$$

Thus far, the above condition only states that marginal revenues are equal in both markets. However, rewriting the equation to transform it into the rule of thumb that was developed before, one gets

$$p^1 \cdot \left(\frac{1}{\epsilon_{p^1}^{y^1}(p^1)} + 1 \right) = p^2 \cdot \left(\frac{1}{\epsilon_{p^2}^{y^2}(p^2)} + 1 \right).$$

Further assuming that demand is falling with respect to price in both markets (which implies that the elasticities are negative), one ends up with:

$$p^1 \cdot \left(1 - \frac{1}{|\epsilon_{p^1}^{y^1}(p^1)|} \right) = p^2 \cdot \left(1 - \frac{1}{|\epsilon_{p^2}^{y^2}(p^2)|} \right).$$

In order to understand the economic reasoning underlying this condition, assume that the price elasticity in market 1 (Switzerland) is lower than the price elasticity in market 2 (France), $|\epsilon^{y^1}_{p^1}(p^1)| < |\epsilon^{y^2}_{p^2}(p^2)|$ (Swiss demand is less elastic). This implies that the expression in brackets is smaller in market 1 than in market 2. Hence, the condition can only be fulfilled if $p^1 > p^2$: The good is sold at a lower price in the market with the higher price elasticity.

To further illustrate this condition, assume that demand in both markets is linear, $p^i(y^i) = a^i - b^i \cdot y^i, i = 1, 2$, and that marginal costs are constant and equal to $c > 0$. In this case, one knows from above that

$$y^{i*} = \frac{a^i - c}{2 \cdot b^i}, \quad p^{i*} = \frac{a^i + c}{2}, \quad \epsilon^{y^i}_{p^i}(p^{i*}) = \frac{a^i + c}{a^i - c}, \quad i = 1, 2.$$

Comparing the elasticities between both markets reveals that

$$\epsilon^{y^1}_{p^1}(p^{1*}) > \epsilon^{y^2}_{p^2}(p^{2*}) \Leftrightarrow \frac{a^1 + c}{a^1 - c} > \frac{a^2 + c}{a^2 - c} \Leftrightarrow a^1 > a^2.$$

However, this is the case if and only if $p^{1*} = \frac{a^1+c}{2} > \frac{a^2+c}{2} = p^{2*}$: The price on the less elastic (in equilibrium) market is higher.

This result gives an important hint as to why a lot of prices in Switzerland are generally higher than abroad: The willingness to pay (as reflected by a low price elasticity) is higher in Switzerland than elsewhere, which implies that firms sell their products at higher prices. One can use this theoretical result to test the theory empirically. All one needs to do is to estimate the price elasticities in different markets and compare them with prices. If the hypothesis of the model cannot be rejected, then one has a valid explanation for an important empirical phenomenon.

Without going into the analytical details, it is time to contemplate the consequences of a regulation that forbids price discrimination between markets. Such a regulation might, for example, prevent price discrimination directly, or it might allow the emergence of resale markets that make profit out of price arbitrage between markets. Such a "single-price philosophy" can, for example, be found in the European Union with its "Single European Market," which is enforced by the European Commission.

Taking the theoretical results from above as a point of departure, the monopolist, who is no longer in a position to discriminate prices, needs to determine the new, aggregate demand function for the joint market. This new demand function results from adding up the individual market demand functions, $X(p) = x^1(p) + x^2(p)$, and it follows that the new inverse demand function is $P(x) = X^{-1}(x)$. The resulting problem is equivalent to the problem of a monopolist who cannot discriminate prices. Hence, even without a formal analysis of the situation, one can determine the differences between the new and the old situations. There are three different constellations possible:

1. The demand structure is similar in both countries and markets are of approximately the same size. The monopolist will sell to customers in both markets, and the new price will be in between the prices that would be charged with price discrimination. The redistributive consequences between the customers in both markets are easy to determine: customers in the previously high-price market profit, because they can buy at lower prices (and more customers buy) while those in the previously low-price market lose, because they are paying higher prices (and fewer customers buy).
2. The country with less elastic demand is relatively large or the price difference between countries is large, or both. In this case, it can happen that the monopolist will not serve the smaller market anymore. The reason is that, in order to sell to the smaller market, he must lower the price in the larger market to an extent that makes it rational to not serve the more elastic, or smaller market, at all. The effect is that nothing changes for the large country, but the situation in the smaller market deteriorates, because its customers are excluded from the consumption of the product. Therefore, prohibiting price discrimination in different markets may lead to inefficiency and exclude customers from consumption.
3. The country with higher prices is relatively small or the price difference is relatively small, or both. In this case, the price in the more expensive country might decrease almost to the level of the other country. There is no change for the formerly low-price country, whereas customers in the formerly high-price country benefit.

This qualitative analysis shows that no clear prediction about the consequences of market integration can be made without further information about the relative size of the markets and the relative willingness to pay in each market. Only if this kind of information is available, it is possible to make a reliable prognosis about the effects of such a policy change.

Digression 14.6. Parallel Imports in the European Union (EU)
Firms that sell in different markets have an incentive to discriminate prices according to the market-specific elasticities of demand. However, the creation of a common market within the EU has made it possible for parallel imports to move freely across the EU. Parallel imports are sales by authorized or unauthorized distributors to another country without the permission of the initial property owner.

Parallel importers use price differences between markets to make a profit out of price arbitrage. This puts pressure on high prices and, thereby, creates a tendency towards uniform prices within a common market. The only

(continued)

industry-specific exemption from the general competition principles is the automotive industry. The purpose of the so-called block exemptions is to restrict competition between car dealers. Nevertheless, even with these special agreements, EU rules require the car dealers to sell their products to any EU citizen regardless of where they live.

This regulation is, of course, a thorn in the side of car manufacturers, who try to find ways to limit competition due to parallel imports. The European Commission fined Volkswagen an amount of €102 million (later reduced to €90 million) for preventing Austrian and German customers from buying cars in Italy. It also fined PSA Peugeot Citroën €49.5 million. Peugeot Netherlands tried, for example, to incentivize its franchise dealers to restrict sales to other countries by withholding bonus payments and limiting the supply of Peugeot cars.

14.6 Monopolistic Competition

I have argued that the models of monopolistic behavior apply to situations where a firm faces a demand function that is not perfectly elastic. This situation allows the firm to charge prices that are above marginal costs. The associated producer surplus is higher than in a situation of perfect competition. This has two consequences.

First, if production involves fixed costs, the firm can stay profitable in situations where firms in competitive markets would have to leave the market, as long as prices are above average costs. Such a situation is illustrated in Fig. 14.7, where it is assumed that the monopolist cannot discriminate prices.

In this figure, average costs are above marginal costs, but below the price of a non-price-discriminating monopolist. This leads to a situation where a competitive firm makes a loss equal to area A, whereas a monopolist makes a profit that is equal to area B.

Second, positive profits in a monopolistic market, as in Fig. 14.7, make it attractive for other firms to develop similar products. Even if these firms are legally or otherwise prevented from simply imitating the profitable product, they can try to develop and sell similar ones. Such a situation is called *monopolistic competition* and there are several examples for such industries:

- Cars of a given type from different manufacturers (like SUVs from Audi, Mercedes, BMW, Volkswagen, etc.).
- Books or music that are variations of the same topic (romantic novels or textbooks in economics) or style (Jazz, Pop, Classical Music).
- Smartphones, tablets, or notebooks from different manufacturers.
- Pubs and restaurants in a city.

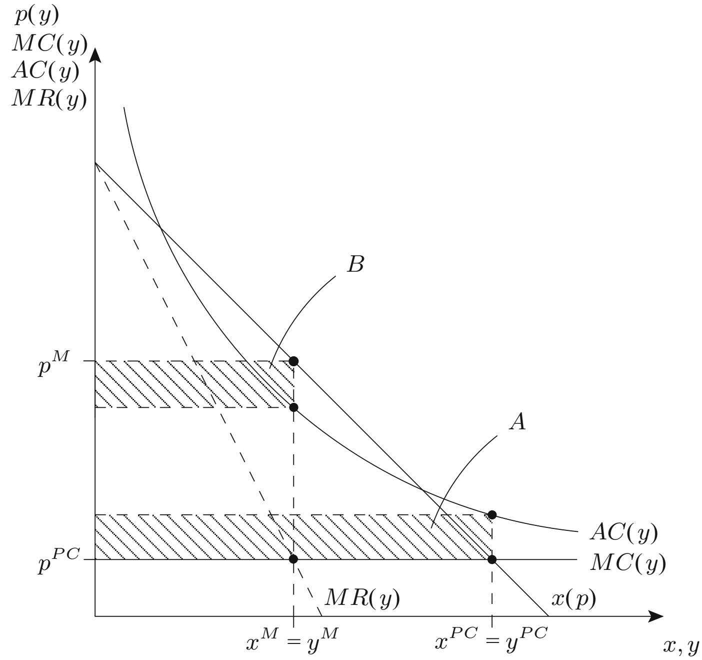

Fig. 14.7 Profits in monopolistic and perfectly competitive markets with fixed costs

The above list illustrates that monopolistic competition is a very prominent market structure, especially in an economy where brands are important for customers (which is the same as saying that they are willing to pay for a specific brand). This is why it makes sense to understand the functioning of this type of a market. The different varieties of similar goods are called *differentiated products*.

The main question is about the number of similar products that exist in such an industry. When one compares the total number of different SUVs with the total number of different romantic novels, one sees that there are huge differences. Are there any patterns that allow one to explain why some industries produce a relatively small number of variants, whereas others produce far more?

The basic idea for answering this question is to blend the analysis of a single monopoly with the idea of market entry: Assume there is free market entry and exit and that a monopolist makes a profit with a product, say an SUV from a given manufacturer *A*. Profits exist, if the price exceeds the average costs, $p^A > AC^A(y^A)$.

These profits encourage another firm, *B*, to enter the market and to sell a similar product. The availability of this additional product increases the choice of the customers. They still consider the products to be different, but the existence of another model in the SUV market makes the first one less exclusive and manufacturers *A* and *B* have to somehow share the market. The effect is that the demand for SUV *A* is likely to shift leftward and to become more price elastic,

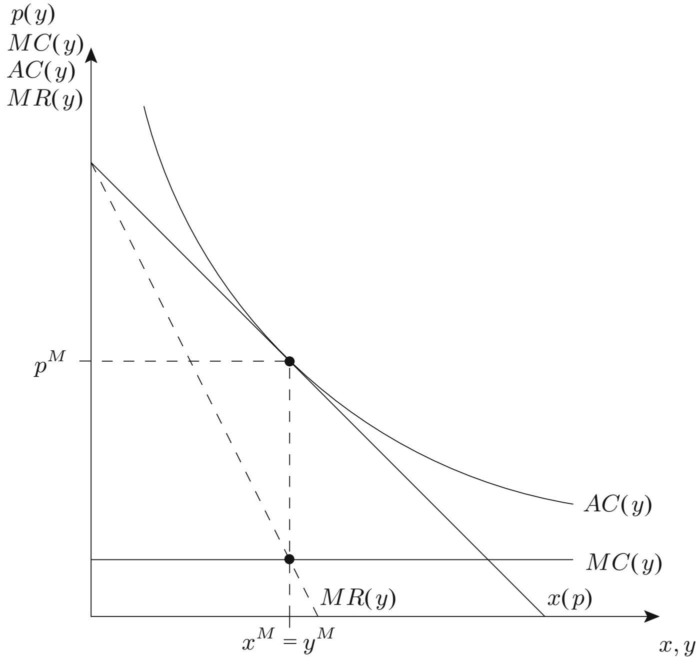

Fig. 14.8 Long-run equilibrium in a market with monopolistic competition with free entry and exit

which reduces profits. With free entry and exit, additional firms will enter the market as long as profits are still positive.

By the same token, if the number of different products is so large that the firms (for example i) are making losses, $p^i < AC^i(y^i)$, some of them will have to leave the market. The effect is that the number of products from which the customers can choose decreases. This effect likely shifts the demand rightward and makes it less price elastic.

The long-run equilibrium must, therefore, be a situation where the prices of the products equal average costs, $p^i = AC^i(y^i)$, because at this point firms make zero profits. This situation is illustrated in Fig. 14.8.

This is the situation where no further competitor is willing to sell another similar product and no existing competitor is willing to leave the market. The figure reveals two properties of the long-run equilibrium in such a market.

First, if firms can develop similar products, there is no escape from the zero-profit equilibrium in the long run. As in the case of perfect competition, competitors will react to positive profits by entering the market with differentiated products.

Second, even though long-run profits are zero, the resulting allocation is not Pareto-efficient. The single firm is still facing a downward-sloping demand function for its product, so prices in this industry will be above marginal costs.

In addition, one can say something about the number of differentiated products that can survive in such an industry. Figure 14.7 shows a situation where the monopolist has profits π_M. Profits depend on the relationship between the demand and the average-cost curve. The bigger the difference is, the higher the profits are. Now, assume that this firm is the first one to sell a new type of product (the first SUV), such that Fig. 14.7 refers to a situation where no other firm has entered the market with a similar product.

Profits depend on fixed costs. An increase in fixed costs shifts the average-cost curve upwards, which implies that profits decline. In the extreme case, profits are equal to zero without any competition from differentiated products. If a second firm enters the market with a similar product, any leftward shift of the demand function that is caused by market entry implies losses for the firm. If profits had been positive but relatively small, the shift in the demand function reduces them, but not necessarily to zero, which would imply that there is room for a second firm selling a similar product. The pattern that becomes visible here is a general one: The more fixed-cost-intensive the production of the product is, the fewer firms can succeed in the market; the number of differentiated products is inversely related to the fixed costs of production.

The above argument was pretty loose, so it makes sense to develop it formally. In order to do so, assume that there are n differentiated products in a market and that demand for a single product is given by the demand function $y^i = Y(1/n - b(p^i - \bar{p}))$, where $\bar{p} = \sum_{j=1}^{n} p^j/n$ is the average price level and $Y = \sum_{j=1}^{n} y^j$ is the total output in the industry. Here, b represents the responsiveness of a firm's output to its price. The demand function implies that the n different firms share the market equally, if they charge identical prices: $p^i = \bar{p}$ implies $y^i = Y/n$. When we solve the model we will see that this function implies that individual and market demand are not absolutely fixed so that we have a degree of freedom in determining the equilibrium. Assume further that all firms produce with identical cost functions $C(y^i) = c \cdot y^i + FC$ and maximize profits. These assumptions may not be particularly realistic, but they simplify the analysis considerably without changing the qualitative insights.

From the point of view of a single firm, the inverse demand function is given as $P(y^i) = 1/(b \cdot n) + \bar{p} - y^i/(b \cdot Y)$, which leads to profits as a function of output:

$$\pi(y^i) = P(y^i) \cdot y^i - c \cdot y^i - FC = \left(\frac{1}{b \cdot n} + \bar{p} - \frac{y^i}{b \cdot Y}\right) \cdot y^i - c \cdot y^i - FC.$$

The profit-maximizing output of firm i is, again, characterized by the first-order condition of the profit function. (In general, Y and $\bar{p}$ are functions of y^i. Assume that the firm neglects this effect.) If one does the math, one ends up with the following price and output of product variant i:

$$y^{i*} = \frac{b \cdot Y \cdot (1/(b \cdot n) + \bar{p} - c)}{2}, \quad p^{i*} = \frac{1/(b \cdot n) + \bar{p} + c}{2}.$$

The solution has intuitive economic properties: The profit-maximizing output and price of variant i are decreasing as the number of variants n increases. This property illustrates the effect of competition on the market for product variant i: The larger the number of similar products, the fewer the number of products of a given variant that can be sold and the lower the price level for this variant.

What is even more interesting is if one can say something about the number of differentiated products that can be supplied in this market. In order to gain insight into this question, assume that all firms charge equal prices in equilibrium, $p^{i*} = \bar{p} = p^*$. If one uses this assumption, one can solve for the equilibrium price level in this industry for a given number of differentiated products n:

$$p^* = \frac{1/(b \cdot n) + p^* + c}{2} \quad \Leftrightarrow \quad p^* = \frac{1}{b \cdot n} + c.$$

This finding nicely illustrates that the markup rule still applies: The firm is able to sell the variant above marginal costs c, but the markup is the lower, the higher the competitive pressure is that results from the number of similar products n.

If we use the information that all prices in the industry are the same, we get back to the above-mentioned property that individual and market demand are not fixed in absolute terms such that we have a degree of freedom that we can use to fix one of these variables and solve the rest of the model relative to it. We use $y^{i*} = 1$ as normalization because it is easy to solve, but any other convention would work as well:

$$y^{i*} = \frac{b \cdot Y \cdot (1/(b \cdot n) + 1/(b \cdot n) + c - c)}{2} = \frac{Y}{n} = 1.$$

Hence, the total supply of variant i is equal to 1, and industry output is, therefore, equal to n, the number of firms in the industry. One last step is missing to determine how many differentiated products exist in the long run. Given the equilibrium outputs and prices, profits of an arbitrary firm i are equal to

$$\pi^{i*} = \left(\frac{1}{b \cdot n} + c\right) \cdot 1 - c \cdot 1 - FC.$$

This equation, again, shows the effects of competition: Equilibrium profits are decreasing with an increasing number of differentiated products.

One knows that free entry and exit into this industry drive profits down to zero,

$$\left(\frac{1}{b \cdot n} + c\right) \cdot 1 - c \cdot 1 - FC = 0.$$

This information can be used to finally determine the long-run number of differentiated products:

$$\left(\frac{1}{b \cdot n} + c\right) \cdot 1 - c \cdot 1 - FC = 0 \quad \Leftrightarrow \quad n = \frac{1}{b \cdot FC}.$$

The result confirms the intuitive conclusion that I have discussed before: There is a negative relationship between the fixed costs of an industry and the number of differentiated products that exist in a long-run equilibrium. This result sheds light on the question of why there are fewer SUVs than romantic novels on the market: Product categories differ with respect to fixed costs. Writing a beach novel is far less expensive than developing a new car. (Both, the costs of writing the novel and the development costs, are part of fixed costs, because they occur independently of the number of copies or cars sold.)

The result also contains an important message for managers in an industry with differentiated products, because profits for a given number of competitors and the long-run number of competitors allows estimations as to whether market entry is still profitable and how many variants of a product can survive in the long run.

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Firm Behavior in Oligopolistic Markets 15

This chapter covers …

- how to apply techniques from game theory towards understanding firm behavior and equilibria in oligopolistic markets.
- the difference between the significance of price and quantity competition on oligopolistic markets.
- how models of oligopolistic behavior can help one to better understand markets for oil, gas, etc.
- the logic of collusive behavior and the role of regulation in oligopolistic markets.
- how firms have to be organized that compete in such markets.

15.1 Introduction

> A horse never runs so fast as when he has other horses to catch up and outpace. (Ovid, 2002, Ars Amatoria)

Models of markets with perfect competition and monopolistic markets pinpoint extreme cases. They illustrate and help to understand how markets work. However, the stylized nature of these models makes it necessary for them to abstract from aspects of reality that may be relevant for understanding some markets. One such aspect—strategic interdependence of firm decisions—will be the topic of this chapter.

This chapter starts with a short summary of the central results from the theory of competitive and monopolistic markets:

- **Perfect competition:** There are many suppliers of an identical product and each seller assumes that she cannot influence the market price with her decisions. Under certain conditions, price-taking behavior leads to the "price-equals-marginal-costs" rule for the profit-maximizing choice of output and, at the same

M. Kolmar, *Principles of Microeconomics*, Classroom Companion: Economics,
https://doi.org/10.1007/978-3-030-78167-5_15

time, to the Pareto efficiency of this type of market, because all potential gains from trade are exploited. Two additional conditions, however, have to be met to make this rule rational. On the one hand, producer surplus has to exceed the relevant fixed costs. On the other hand, the production technology has to induce increasing or constant long-run marginal costs. If competitive markets work, then market entry and exit will drive profits to zero because positive (negative) profits encourage entry (force exits).

  The managerial implications of these findings point towards the crucial importance of having an effective accounting system: marginal and average costs of production have to be precisely reflected in the relevant indicators. In addition, given that profits are approximately zero with constant returns to scale or in the long run, the return on equity cannot exceed the return on debt, owners cannot expect larger profits from their investments than they would get in the capital market.

- **Monopoly:** Only one supplier of a product exists, which implies that customers see a relevant difference between this product and the closest substitute and that other firms cannot imitate it. Compared to competitive markets, a monopolist generates a higher producer surplus, such that it can sustain itself, even if fixed costs would drive competitive firms out of the market (if they are not too high). The efficiency of such a market depends on the monopolist's ability to discriminate prices. The closer the monopolist gets to the ideal of perfect price discrimination, the more efficient the market becomes. However, there is a tension between the efficiency of monopolistic markets and the distribution of rents between the firm and the consumers, because in the efficient solution, the monopolist is able to transform all rents into producer surplus.

  In order to implement the optimal policy, the firm needs more information than under perfect competition. In addition to an accounting system, it needs a market-research department that estimates price elasticities and helps to segment demand into different groups that are targeted individually.

These findings give some mileage in understanding firm behavior and the functioning of markets, but the important topic of the strategic interdependence of firms' decision-making has been left out of the picture. Strategic interdependence does not play any role in a monopolistic market, by definition, and it does not play a role in competitive markets, because each single firm is too small to influence aggregates. It becomes important, however, if there is more than one firm that is sufficiently large to influence the market price, such a decision made by one firm can influence the profit of another. This direct interdependency between firms' objectives follows the same logic as the one analyzed in Chap. 6 and can therefore, in principle, be analyzed with the same toolbox of property rights and transaction costs. A direct interdependency can occur if several firms sell homogenous goods, but also if they sell differentiated goods that are closely linked (which happens, if cross-price elasticities between the goods are non-zero).

The latter situation is, to some extent, always present for a monopolist, but it is usually left out of the analysis to avoid additional complexities. This chapter will also neglect the analysis of several monopolists whose profits are interdependent, because they sell similar products. Instead, it focuses on oligopoly markets in which few sellers supply a homogenous good. The assumption that the goods are perfect substitutes, from the consumers' point of view, simplifies the analysis and allows it to isolate the pure effect of strategic interdependence.

The central tool for understanding strategic interdependence is game theory and the definition of a game and a Nash equilibrium will be used to analyze the functioning of oligopolistic markets. Firms have, in principle, two instruments to maximize profits, if they are selling a given product. Both instruments are, however, not independent, because they are linked by the market demand function. This is why it is irrelevant, for the monopolist, whether he sets a price and lets quantities adjust passively or sets a quantity and lets the price adjust passively; both approaches lead to the same solution. This equivalence is lost in an oligopolistic market. As the following analysis will show, predictions for the functioning of an oligopoly market with price- and quantity-setting firms differ sharply. In order to understand the deeper reasons for this difference, one has to start by building models of price and quantity setting and then see what predictions they make.

The model of quantity setting is called the *Cournot model* and the model of price setting is called the *Bertrand model*, named after the French mathematicians Antoine Augustin Cournot, who developed his model as early as 1838, and Joseph Louis François Bertrand, who reworked the model by using prices in 1883. It is fascinating that Cournot's analysis anticipated a lot of concepts from economics and game theory, like supply and demand as functions of prices, the use of graphs to analyze supply and demand, reaction functions, and the concept of a Nash equilibrium (limited to the oligopoly context).

Digression 15.1 (The Stackelberg Model and the Value of Commitment)

> I can resist everything except temptation. (Oscar Wilde, 1892)

There is a third model of oligopolistic decision-making that goes back to Heinrich Freiherr von Stackelberg (1934). He returned to Cournot's original analysis but assumed that two firms determine their quantities sequentially instead of simultaneously, as Cournot had assumed. This model will not be covered in this chapter, but I would like to focus attention on a figure of thought that emerged from this model and that proved to be of primary importance for economics and other social sciences: the idea of *commitment*.

It turns out that the firm that sets its quantity first (the "leader") has an advantage over the other firm (the "follower"), in comparison to the Cournot model. However, if this were the case, both firms would like to be the leader

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Digression 15.1 (continued)
and the factors that determine leadership are not obvious. Both firms would do whatever they could to be able to choose their strategy first. What is necessary is the existence of some mechanism or device to be available to one firm, but not to the other, which allows the firm to make its leadership position credible. Such a mechanism is called a *commitment device*.

The appreciation of the economic role and value of such a device offer an important new perspective on a number of social phenomena. One can interpret them as reactions to commitment problems. According to Dubner and Levitt (2005), a commitment device is "a means with which to lock yourself into a course of action that you might not otherwise choose but that produces a desired result."

The ultimate commitment device can be found in Homer's Odyssey, where Ulysses puts wax in his men's ears so that they could not hear and had them tie him to the mast so that he could not jump into the sea, to make sure that he does not fall prey to the song of the sirens. (Franz Kafka, 1931, sees this as "[p]roof that inadequate, even childish measures, may serve to rescue one from peril.")

Commitment problems exist on the individual as well as on the social level. Fitness goals are a good example of an individual commitment problem. Most people would like to exercise a little more, drink less alcohol, or eat healthier food. However, if it is time for a run, a friend asks if one is ready for a second glass of wine, or one has the choice between chocolate cake and broccoli, one can resist everything other than the temptation to give in. What would be needed in these situations is a device that forces one to stick to one's resolutions. Some argue that emotions, like shame and embarrassment, can be interpreted as such a device: assume that one publicly announces a fitness goal ("I will run the Berlin Marathon next year"). If one makes such a public announcement and fails to stick to one's goals, one's friends will ridicule one and one will feel ashamed, which helps one's future self persevere. These emotions make deviations from one's plans costly (in this case, in a purely psychological sense), which is the most important property of a credible commitment device: if one wants to stick to a savings plan, sign a long-term contract that is costly to cancel; if one wants to prepare for an exam, lock oneself into a room without internet access and give the key to a friend, who will be away for the weekend; and so on.

The prisoner's dilemma is the main example of a social commitment problem: both players would profit from a device that makes the cooperative strategy credible. If the dilemma is used as a metaphor for social interactions in general (a mainstream view since Thomas Hobbes claimed that life before organized, civil societies was solitary, poor, nasty, brutish, and short), then the state can be interpreted as one big attempt to make cooperation credible. This idea can refer to institutions like the rule of law, property rights, and their

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enforcement by means of material sanctions and punishments, but it can also refer to culture in general, where credibility stems from "softer" sanctions like feelings of guilt and shame.

Commitment problems have also been shown to be at the heart of phenomena like inflation and taxation. The phenomenon is also known as the *time inconsistency* of decision-making. For the case of monetary policy, politicians have an interest in promising low inflation for the future, in order to control the expectations of the people. However, once tomorrow comes, increasing inflation can have positive, short-run effects, like increasing employment. Hence, the announcement of a low-inflation goal may not be credible, if the government cannot commit to it, leading the economy into a high-inflation equilibrium. Independent central banks with high degrees of discretion in monetary policies are widely seen as a commitment device that can solve this problem. If the central banker's objective is a zero-inflation policy, then taking away discretion from politicians can, in the end, help them in achieving their goals. The same is true for taxation. If a government wants to encourage investment, then it should announce very low rates of capital taxes but, once the investments are sunk and the factories are built, the corporations are locked in and it is rational for the politician to increase taxes again. If this incentive is anticipated, then firms will not invest in the first place. One of the reasons why Switzerland is considered an attractive place for investments is because it managed to establish a reputation for not falling prey to this incentive. A lack of such a reputation can be a serious impediment to economic development.

The above-mentioned firms are "locked in" with their investments. This *lock-in effect* is a widely used business practice that helps firms to make profits. Software standards are a good example. In order to be able to use software, one usually has to make large investments of time and effort. These investments lock one into a standard because, *ex post*, after one has made the investments, the opportunity costs of switching to another standard (called *switching costs*) are higher than *ex ante*, before one committed to it. This asymmetry in opportunity costs can be exploited by firms for setting higher prices, and so on.

Evolutionary biologists have used commitment problems to explain the evolution of moral sentiments, by arguing that the evolution of emotions that make cooperation rational (not in a material, but in a psychological sense) has a positive effect for the survival of groups.

A problem with any credible commitment device is that they reduce flexibility. If the future can be perfectly foreseen, then commitment incurs no additional costs but the more uncertain the future becomes, the more risky it is to constrain one's choices. What would have happened to the epic poem "Odyssey" if Ulysses, tied to the mast, had drowned because of an unforeseen storm that hit his ship before he passed the island of the sirens? He would not

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be remembered for his brilliance and cunning intelligence, but for his ability to drown himself in an attempt to control his virility. That is not exactly the type of story that would be remembered forever.

15.2 Cournot Duopoly Model

In the Cournot duopoly model, it is assumed that two profit-maximizing firms, U_1 and U_2, simultaneously plan the quantities y_1 and y_2 of a homogenous good that they want to sell in a given period of time. Quantities are chosen from the set of positive real numbers (including zero). They produce with a technology that, for given factor prices, leads to convex cost functions, $C_1(y_1)$ and $C_2(y_2)$. Furthermore, there is an inverse demand function, $P(y_1 + y_2)$, that gives the market price for market supply, $y_1 + y_2$ (customers see both goods as perfect substitutes). In order to keep the analysis simple, assume that all firms are completely informed about all the cost functions and the inverse demand function, and that all of this is common knowledge.

If the profits of the firms are denoted by π_1 and π_2, they can be written as

$$\pi_1(y_1, y_2) = P(y_1 + y_2) \cdot y_1 - C_1(y_1), \quad \pi_2(y_1, y_2) = P(y_1 + y_2) \cdot y_2 - C_2(y_2).$$

From the managers' points of view, the problem is that profits depend not only on the firm's own strategy, but also on the strategy chosen by the other firm, because the market price is a function of total quantity. In order to solve this problem, assume that manager 1 (2) expects that the other firm will supply a quantity y_2^e (y_1^e). The managers determine the optimal quantities given these expectations. The first-order conditions for the profit-maximizing strategies are

$$\frac{\partial \pi_1(y_1, y_2^e)}{\partial y_1} = \underbrace{\frac{\partial P(y_1 + y_2^e)}{\partial y_1} \cdot y_1 + P(y_1 + y_2^e) \cdot 1}_{=MR_1(y_1, y_2^e)} - \frac{\partial C_1(y_1)}{\partial y_1} = 0$$

for firm 1 and

$$\frac{\partial \pi_2(y_1^e, y_2)}{\partial y_2} = \underbrace{\frac{\partial P(y_1^e + y_2)}{\partial y_2} \cdot y_2 + P(y_1^e + y_2) \cdot 1}_{=MR_2(y_1^e, y_2)} - \frac{\partial C_2(y_2)}{\partial y_2} = 0$$

for firm 2.

Both conditions have a simple economic interpretation: for an expected production level of the competitor, a firm chooses its quantity such that the marginal revenue of the last unit produced equals the unit's marginal costs. This condition corresponds to the condition of a non-price-discriminating monopolist with the exception that marginal revenues depend on the expectations of the other firm's production decision.

If one solves the first-order conditions for the respective decision variables, y_1 and y_2, one gets two functions $Y_1(y_2^e)$ and $Y_2(y_1^e)$, which determine the optimal quantity for one firm for a given expected supply of the other firm. These are the so-called *reaction functions* of the two firms.

Points on the reaction functions imply that firms behave optimally for any given expectation of the other firm's strategy. However, plans do not have to be mutually consistent. There can be situations where both firms start with expectations, y_2^e and y_1^e, choose their strategies optimally, but end up with quantities that deviate from the expectations of the other firm, $Y_1(y_2^e) \neq y_1^e$ or $Y_2(y_1^e) \neq y_2^e$. In order to guarantee consistency, one has to require that expectations and actual behavior coincide, $Y_2(Y_1(y_2^e)) = y_2^e \wedge Y_1(Y_2(y_1^e)) = y_1^e$: The best response of firm 2 to the best response of firm 1, at an expected quantity of y_2^e, is equal to the expected quantity y_2^e, and the best response of firm 1 to the best response of firm 2, at an expected quantity of y_1^e, is equal to the expected quantity y_1^e.

This is another way to say that one is looking for a Nash equilibrium in the game. Formally, a Nash equilibrium of a Cournot duopoly model is completely characterized by $Y_2(Y_1(y_2^e)) = y_2^e \wedge Y_1(Y_2(y_1^e)) = y_1^e$.

The general characterization of the Nash equilibrium does not contain anything interesting from an economic point of view, because it is just a formal way to say that firms follow their objectives rationally and that their behavior is mutually consistent. In order to gain more economic understanding, this chapter will proceed by assuming that the demand function is linear and that the cost functions are identical and linear, $p(y_1 + y_2) = a - b \cdot (y_1 + y_2)$, $C_1(y_1) = c \cdot y_1$, $C_2(y_2) = c \cdot y_2$ with $a > c > 0$ and $b > 0$. These functional specifications are called the *linear model*. A lot of the understanding that one can get from this model carry over to more general models with nonlinear functions for either demand, cost, or both. The model is illustrated in Fig. 15.1. In the figure, $y_1 + y_2$ is plotted along the abscissa and demand, as well as the marginal-cost functions are plotted along the ordinate. The marginal-cost function intercepts the ordinate at c; the demand function interrupts at a and has a slope of $-b$.

From a mathematical point of view, there are a lot of different ways to determine the equilibrium. This subchapter will cover a long and rather complicated way for the purpose of exercise, by first computing the profit functions (in order to have a lean notation, one can skip the explicit mention of expected values):

$$\pi_1(y_1, y_2) = (a - b \cdot (y_1 + y_2)) \cdot y_1 - c \cdot y_1,$$

$$\pi_2(y_1, y_2) = (a - b \cdot (y_1 + y_2)) \cdot y_2 - c \cdot y_2.$$

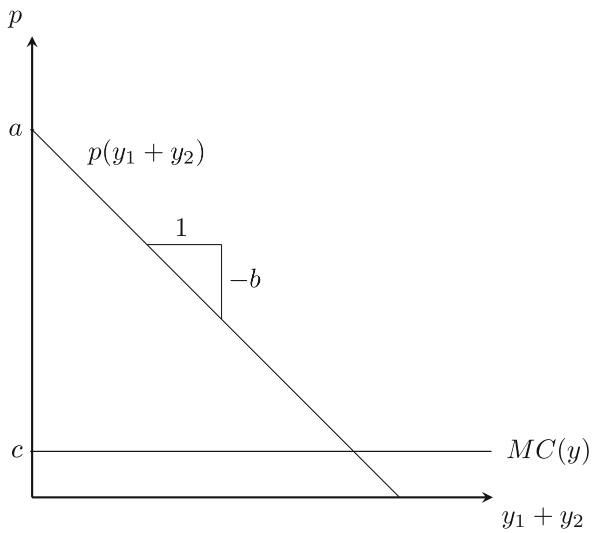

Fig. 15.1 The linear model

They can be simplified to

$$\pi_1(y_1, y_2) = (a - c - b \cdot y_2) \cdot y_1 - b \cdot y_1^2,$$
$$\pi_2(y_1, y_2) = (a - c - b \cdot y_1) \cdot y_2 - b \cdot y_2^2.$$

The next step is to determine the first-order conditions:

$$\frac{\partial \pi_1(y_1, y_2)}{\partial y_1} = (a - c - b \cdot y_2) - 2 \cdot b \cdot y_1 = 0$$

and

$$\frac{\partial \pi_2(y_1, y_2)}{\partial y_2} = (a - c - b \cdot y_1) - 2 \cdot b \cdot y_2 = 0.$$

Firm 1's first-order condition is depicted in the left panel of Fig. 15.2. Marginal costs are constant at c. Marginal revenues intersect the ordinate at $a - b \cdot y_2$ and have a slope of $-2 \cdot b$. They are falling with the supply of the other firm. A comparison with the monopoly case is illustrative: the marginal revenues of a non-price-discriminating monopolist have the same slope, $-2 \cdot b$, but they intersect the ordinate at a. One can, therefore, think of a Cournot duopolist i as a monopolist with

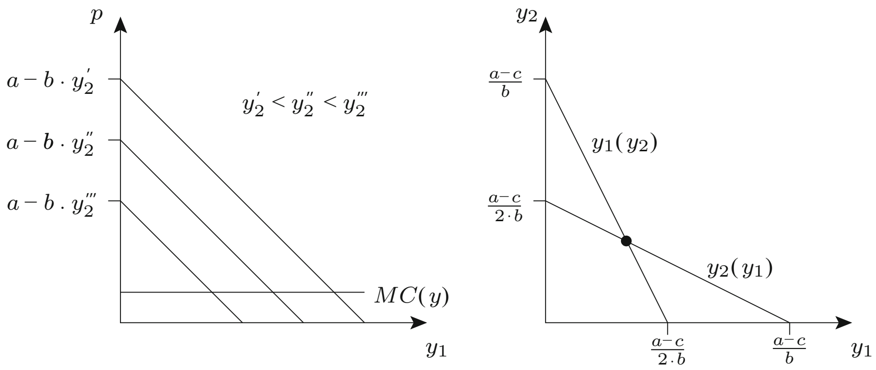

Fig. 15.2 Marginal revenues and marginal costs of the oligopolists (*left*) and reaction functions (*right*)

a "curtailed" demand function $\tilde{a} = a - b \cdot y_j$. If one solves both conditions for the respective decision parameters, one ends up with the reaction functions:

$$Y_1(y_2) = \begin{cases} (a - c - b \cdot y_2)/(2 \cdot b), & \text{if } \ y_2 \leq (a - c)/b \\ 0 & \text{if } \ y_2 > (a - c)/b \end{cases},$$

$$Y_2(y_1) = \begin{cases} (a - c - b \cdot y_1)/(2 \cdot b), & \text{if } \ y_1 \leq (a - c)/b \\ 0 & \text{if } \ y_1 > (a - c)/b \end{cases}.$$

They are illustrated in Fig. 15.2 where y_1 is plotted along the abscissa and y_2 along the ordinate. Given that firm 1's reaction function has y_2 and firm 2's reaction function has y_1 as explanatory variable, one has to look from the abscissa and ordinate simultaneously to understand the figure. The "flatter" graph is firm 2's reaction function, which has the traditional orientation. The "steeper" graph is firm 1's reaction function, which is symmetric to firm 2's, but with the opposite orientation.

The figure reveals the following: (1) $Y_1(0) = Y_2(0) = (a - c)/(2 \cdot b)$: thus, if the other firm produces nothing, the remaining duopolist behaves like a monopolist. (2) The profit-maximizing quantity of a firm falls with an increase in the quantity of the competitor. (3) The Nash equilibrium is given by the intersection of both reaction functions. Only at that point are the actual and expected supplies of the firms consistent with each other.

Formally, one can find the Nash equilibrium by inserting the reaction functions into one another, $Y_1(y_2) = (a - c - b \cdot y_2)/(2 \cdot b)$ and $Y_2(y_1) = (a - c - b \cdot y_1)/(2 \cdot b)$. A solution to these equations is given by

$$y_1^* = \frac{a - c}{3 \cdot b}, \quad y_2^* = \frac{a - c}{3 \cdot b}$$

for the individual equilibrium supplies and

$$y^{CN} = y_1^* + y_2^* \times \frac{2 \cdot (a - c)}{3 \cdot b}$$

for the equilibrium market supply.

Compare this solution to the monopoly solution, $y^M = \frac{a-c}{2 \cdot b}$, and to the solution under perfect competition, $y^{PC} = \frac{a-c}{b}$. (One can obtain this number from the "price equals marginal costs" rule, which implies for the linear model that $a - b \cdot y = c$. Solving for y gives the result.) It follows that $y^M < y^{CN} < y^{PC}$, which reveals a lot about the effects of competition: comparing a monopoly with a duopoly and this, in turn, with perfect competition shows that competition reduces inefficiency. However, with only two firms, the competitive forces are not strong enough to enforce the solution under perfect competition. Accordingly, the equilibrium price in a duopolistic market lies between the price in a monopolistic market and the price under perfect competition, because the demand function is monotonically decreasing. The different prices can be determined as markups on marginal costs:

$$p^{PC} = c < p^{CN} = c + \frac{a - c}{3} < p^M = c + \frac{a - c}{2}.$$

These markups play an important role as "rules of thumb" in the management literature, because they allow it to quickly assess the profitability of a market. They depend on the elasticity of demand, which is, in and of itself, a function based on the customers' tastes and incomes (as reflected in a and b), as well as the competitiveness of the market, expressed by the number of firms. The markup under perfect competition is zero and it is smaller in a Cournot duopoly than in a monopoly.

15.3 The Linear Cournot Model with *n* Firms

The above analysis suggests that the Cournot model builds a bridge between the model of non-price-discriminating monopolies and the model of perfect competition. In order to define this insight more precisely, it makes sense to analyze the equilibrium of an oligopolistic market with an arbitrary number of firms, to see how the number of competitors influences the outcome. The following paragraphs will determine the Nash equilibrium for the linear model with n firms in the market. For this purpose, some additional notations are needed. Denote the supply of any firm i by y_i and the supply sum of all firms, except for firm i, by y_{-i}. Then, firm i's profit equation is

$$\pi_i(y_i, y_{-i}) = (a - b \cdot (y_i + y_{-i})) \cdot y_i - c \cdot y_i, \quad i = 1, \dots, n.$$

Given the quantity supplied by all other firms, firm *i*'s profit-maximizing supply can be determined by the first-order condition:

$$\frac{\partial \pi_i(y_i, y_{-i})}{\partial y_i} = (a - c - b \cdot y_{-i}) - 2 \cdot b \cdot y_i = 0, \quad i = 1, \ldots, n.$$

In general, there are n first-order conditions and n unknown variables $y_1, \ldots, y_n$. If one assumes that identical firms behave identically in equilibrium, i.e., for any two firms i and j $y_i = y_j$, one can replace y_i with y and $y_{-extiti}$ with $(n - 1) \cdot y$. This substitution reduces the system of equations to one:

$$(a - c - b \cdot (n - 1) \cdot y) - 2 \cdot b \cdot y = 0.$$

If one solves this equation for y, one obtains the Nash equilibrium quantity of a representative firm as $y^* = (a - c)/((n + 1) \cdot b)$. Market supply $n \cdot y^*$ is then given by $n/(n + 1) \cdot (a - c)/b$. To understand this result, compare it to the one under perfect competition, which was determined as $(a - c)/b$. Then carry out the comparative-static analysis with respect to n by treating n as a continuous variable (which it is not, but the assumption facilitates the analysis):

$$\frac{\partial y^*}{\partial n} < 0, \quad \frac{\partial (n \cdot y^*)}{\partial n} > 0.$$

Two implications follow: first, individual supply is falling due to the number of firms; the more competitors there are, the less each single firm produces. Second, market supply is increasing due to the number of competitors. Even though each single firm produces less, if more competitors are on the market, this effect is overcompensated by the sheer number of firms. Now let the number of firms become very large, such that one obtains $\lim_{n \to \infty} n/(n + 1) \cdot (a - c)/b = (a - c)/b$ in the limit: the market tends towards the equilibrium under perfect competition, if the number of firms gets very large. The other extreme is a monopolistic market ($n = 1$). In this case, the optimal quantity is $(a - c)/(2 \cdot b)$: the result from the monopoly model.

Alternatively, one can look at the markup the firms can charge. The equilibrium price is given by $p^* = a - b \cdot n \cdot y^*$, which is equal to $p^* = c + (a - c)/(n + 1)$. It follows that the markup is decreasing in the number of firms and converges to zero, if n becomes very large. Hence, the Cournot model provides a theoretical foundation for the idea that competition drives a market towards efficiency: the more competitors there are, the smaller the individual firm's influence is on the outcome of the market. If the number of firms becomes arbitrarily large, then the influence of a firm completely disappears and it behaves as a price taker and sells according to the efficient "price-equals-marginal-costs" rule.

15.4 The Bertrand Duopoly Model

In order to see how price—instead of quantity setting—influences the behavior in such a market, assume that the duopolists choose the prices p_1 and p_2 instead of quantities. All other assumptions from the previous model persist and prices are assumed to be positive, real numbers (including zero). The only exception is that one directly assumes constant and identical marginal costs for both firms, $C_1(y_1) = c \cdot y_1, C_2(y_2) = c \cdot y_2$. Price competition with more general cost functions is very difficult to analyze, and the fundamental ideas of price competition are contained in the simplified model.

The firms' profits are analogous to the previous model, but with the exception that, this time, prices are the strategic variables. Customers are confronted with two prices and they will choose their preferred firm and their optimal demand accordingly. Hence, $x_1(p_1, p_2)$ and $x_2(p_1, p_2)$ are the demand functions relevant for the two firms, for any given pair of prices p_1 and p_2. The profit functions become

$$\pi_1(p_1, p_2) = p_1 \cdot x_1(p_1, p_2) - c \cdot x_1(p_1, p_2),$$
$$\pi_2(p_1, p_2) = p_2 \cdot x_2(p_1, p_2) - c \cdot x_2(p_1, p_2).$$

Both firms set prices simultaneously and independently. In order to be able to do so, they have to form expectations about the other firm's price p_1^e, p_2^e. A Bertrand–Nash equilibrium is a pair of prices, p_1^* and p_2^*, such that both firms maximize their profits given price expectations for the other firm, and these expectations are correct, $p_1^e = p_1^*, p_2^e = p_2^*$.

The maximization problems are non-standard, because the profit functions are not continuous in prices. Both goods are perfect substitutes from the point of view of the customers, so they will always buy the cheaper one. Assume that one firm charges a price that is a little bit higher than the price of the competitor. In that case, no one will buy from this firm. If the firm lowers the price just a little bit to undercut its competitor's price, then all customers will change their minds and now buy from this firm instead. The firm can meet this demand, because it can produce with constant marginal costs and without any capacity constraint. Hence, demand is non-continuous at this point.

An example is two neighboring bakeries that are on the way to work for a number of people. If one bakery sets a higher price for a croissant than the other bakery, then no one will buy there (one abstains from queuing or transaction costs of queuing). Hence, demand as a function of both prices can be written as follows. Let $X(p_i), i = 1, 2$ be the market demand function:

$$x_1(p_1, p_2) = \begin{cases} X(p_1), & p_1 < p_2 \\ 0.5 \cdot X(p_1), & p_1 = p_2 \\ 0 & p_1 > p_2 \end{cases},$$

$$x_2(p_1, p_2) = \begin{cases} X(p_2), & p_1 > p_2 \\ 0.5 \cdot X(p_2), & p_1 = p_2 \\ 0 & p_1 < p_2 \end{cases},$$

using the convention that consumers will be split up equally between the two firms, if prices are identical.

The non-continuity of the profit functions implies that one cannot characterize the best-response functions using partial derivatives of the profit functions. The non-continuity occurs at $p_1 = p_2$ because, at this point, demand switches from one firm to the other. To characterize best responses, the following paragraphs will focus on firm 1. A similar argument holds for firm 2 because of the symmetry of the problem.

If the purpose is to characterize just one equilibrium, then the task is simple: start with the conjecture that both firms offer a price that equals marginal costs, $p_1 = p_2 = c$. Market demand splits equally between the firms for this pair of strategies and both firms make zero profits. If a firm sets a higher price, it loses the demand and still makes zero profits. If it sets a lower price, it wins over all the customers, but sells at a price that is lower than its marginal costs, so it incurs losses. In other words, it cannot improve its profits by deviating to another price, which is the definition of a Nash equilibrium. Therefore, $p_1^* = p_2^* = c$ is a Bertrand–Nash equilibrium.

It is slightly more complex to prove that the equilibrium is unique. In order to show uniqueness, start with the scenario in which at least one firm sets a price below marginal costs. This price leads to losses for at least one firm (the one with the lower price). This firm can avoid these losses by increasing its price above that of its competitor. (If both firms set equal prices, the same logic applies.) Now, assume that at least one firm sets a price that is strictly larger than its marginal costs. If the other firm sets a price below marginal costs, then one is back at the case analyzed above. Thus, assume that the other firm sets a price above or equal to its marginal costs. If they are equal to marginal costs, both firms make a profit of zero, because one of them has no customers and the other is selling at marginal costs. The firm that is selling at marginal costs can increase its profits by increasing its price a little bit, making sure that it is above marginal costs, but below the price of the competitor. If the price is larger than marginal costs, but smaller than the competitor's price, it wins the whole market and also makes a profit. However, it is not rational for the competitor to stick to the higher price. She can increase his profits by slightly undercutting the other price, making sure that it is still above marginal costs. In this case, he wins over the market, which increases profits from zero to something strictly positive. Last, but not least, one has to focus on situations in which both firms set equal prices above marginal costs. In this case, they share the market equally, making positive profits. Denote the prices by $p > c$. Formally, this leads to $\pi_1(p, p) = 0.5 \cdot X(p) \cdot (p - c) > 0$. What happens if firm 1 deviates to a price $p_1 = p - \epsilon$, where ϵ is a small positive number, $\epsilon > 0, \epsilon \to 0$? Given that all customers buy from firm 1 now, profits become $\pi_1(p-\epsilon, p) = X(p-\epsilon) \cdot (p-\epsilon-c)$. Given that the firm wins half of the market by this change, there exists an ϵ that is small enough such that profits go up.

To summarize, the above line of reasoning has shown that the equilibrium is, in fact, unique. The model of Bertrand price competition has a stark implication:

price competition drives prices all the way down to marginal costs. This result is remarkable: even with only two firms, the market behaves as if it were perfectly competitive. This result has an important implication for competition policy: the number of firms in a market is, in general, a poor indicator for the functioning of the market. No conclusive evidence about the intensity of competition can be drawn from the number of firms alone. Further information about the type of competition is necessary.

This result has been derived under very specific assumptions, especially regarding the absence of capacity constraints and identical marginal costs. In order to figure out how robust the results are, one must start with an analysis of the consequences of different marginal costs, $c_1 < c_2$. In this case, setting prices equal to marginal costs leads to different prices and only the low-cost firm 1 is able to sell its products. However, it no longer has an incentive to stick to a price that equals marginal costs, because it can still serve the whole market at higher prices, as long as it sets a price below firm 2's marginal costs (which define the lower limit for the price of this other firm). The exact strategy of firm 1 depends on the difference between both firms' marginal costs. Let p_1^M be the price that firm 1 would set, if it had a monopoly.

- If $c_2 > p_1^M$, then firm 1 is able to set the monopoly price without being threatened by firm 2. Due to a sufficiently large cost differential, firm 1 has a *de facto* monopoly, even though another firm exists that could enter the market. Firm 1 is protected against market entries, due to its cost leadership.
- If $c_2 < p_1^M$, then firm 1 cannot enforce the monopoly price, because it would encourage market entry by firm 2. This case is not only interesting because of its economic implications, but also because it shows a tension between economic intuition and mathematical modeling, where one has to ask which source is more trustworthy: one's intuition or the results from the theoretical model. Here is the problem: intuitively one would expect that the low-cost firm would set the highest price it can that is still lower than the marginal costs of the competitor, i.e., $p_1 = c_2 - \epsilon$ with $\epsilon > 0, \epsilon \to 0$. Such a price keeps firm 2 out of the market and is, at the same time, as close to the monopoly price as possible. Such a strategy does not exist from a mathematical point of view, however, because the set $p_1 < c_2$ is an open set (the boundary $p_1 = c_2$ does not belong to it). Hence, for each price, $p_1 = c_2 - \epsilon$, there exists a larger price, $\tilde{p}_1 < c_2 - 0.5\epsilon$, that leads to higher profits, which follows from the denseness of real numbers. The implication of the denseness of real numbers is that firm 1 has no optimal strategy, which in turn implies that there is no Nash equilibrium. This result is highly unsatisfactory, because intuition tells one that this is highly unlikely; that this problem is merely an artifact of an abstract property of real numbers.

  One way to bring intuition in line with the mathematical model is to impose a certain "granularity" on the set of admissible prices. If one assumes that prices are elements of a finely structured set of possible prices (the smallest change in prices could, for example, be 1/10 of a Rappen), then an equilibrium exists where firm 1 chooses the highest price lower than the marginal costs of the second firm (provided that it is higher than its own marginal costs).

If the granularity of prices solves the problem, one may ask why this assumption was not used right from the beginning. The reason is twofold. First of all, the necessary notation would be more complex. Second of all, discrete price changes have unintended side effects of their own. For example, in the case of identical marginal costs, one would get the potential for multiple equilibria or positive profits in the equilibrium. These problems illustrate the role mathematics plays in economics: there is no deeper truth behind the mathematical formalism used in most theories. Mathematics helps one to understand the logical structure of arguments: it does no more nor less.

15.5 Conclusion and Extensions

The Cournot and Bertrand models lead to radically different predictions about the functioning of oligopolistic markets. The natural question then becomes which model is more adequate to describe oligopolistic behavior. Unfortunately, the answer to this question is not that simple. The Cournot and Bertrand models are only the tip of the iceberg of models of oligopolistic behavior that have been developed over the years and that focus on different aspects of firm strategies in such a market environment. Firms can, for example, also compete in the positioning of their products, technological innovations, marketing, or reputation. It depends on the specific industry, maybe on the exact period of time, as well as on other factors that are hard to predict whether a market is more adequately described by quantity or by price competition. While both models are useful, a metatheory that explains and clarifies the conditions under which each model is more adequate is still missing.

In a nutshell, it can be argued that the Bertrand model is useful for the analysis of price wars. It shows that the results of the model of perfect competition may also hold in markets with few firms. This has important methodological consequences, because it implies that the much easier model of perfect competition can also be used to analyze industries with few competitors, as long as there is evidence that they engage in price competition.

The Cournot model is useful for the analysis of firms' behavior in less competitive situations. It builds a bridge between the monopoly model and the model of perfect competition, because it predicts a continuous adjustment from the monopolistic to the perfectly competitive equilibrium as the number of firms increases.

Economists have tried to develop a "unified" approach to the Cournot–Bertrand problem. An interesting one is to disentangle the problem of an oligopolist into two stages. The idea is to assume that a firm's production capacity has to be planned at a relatively early stage (stage 1) when there is still uncertainty regarding demand and that the firm is then committed to produce within the chosen capacity constraint. The production decision (stage 2) takes place under conditions of price competition. Interestingly, such a two-stage game is able to predict Bertrand-type price competition in periods of low demand and overcapacity (capacity constraints are not binding). At the same time, the market transforms into Cournot competition if capacity constraints are binding. Given that firms try to avoid overcapacities (they are costly), Cournot competition can therefore be regarded as the normal case if demand is relatively predictable. However, if demand fluctuates widely over time, there will be periods of Bertrand competition again and again.

Independently of whether one is confronted with price or quantity competition, firms have a strong incentive for coordinated or collusive behavior. The reason is that the joint industry profits are maximal, if the firms coordinate on the monopolistic solution and share the profits equally. To see this assume, on the contrary, that industry profits would be maximized in the oligopolistic equilibrium. If this were the case, the monopolist could imitate the oligopolists and choose the Cournot or Bertrand solution instead. The fact that a profit-maximizing monopolist prefers another solution shows that he must be better off. Thus, it is in the interest of the oligopolists to collude and constrain their production in an attempt to move closer to the monopolistic outcome, which creates a tension between profits and efficiency of the market. Different strategies are possible to achieve this goal:

- Firms can try to make explicit price-fixing agreements. However, this is illegal in most countries, exactly because it would make the market less efficient. Hence, firms have developed more subtle strategies to coordinate their outputs.
- One way of reducing competition is through a merger or an acquisition (M&A). These measures usually have to be approved by the national or supranational competition authorities. However, even if M&As are not an option, in practice it is sometimes possible to gain control over some other firm's strategies by complicated cross-ownership or holding structures.
- It is also possible to reach implicit agreements on prices or quantities that fly below the radar of the competition authorities. These agreements are relatively easy to achieve, because of the limited number of firms that all operate in the same industry but, at the same time, difficult to enforce. However, enforcement is crucial, because every single firm has an incentive to break the agreement and sell a little more at a lower price. The reason is that the monopoly solution is not a Nash equilibrium, so every single firm can profit from unilaterally deviating from a non-equilibrium strategy. Coordination in an oligopolistic market has the structure of a prisoner's dilemma. A way out of this dilemma opens, if firms compete repeatedly. If firms compete not only today, but also in the future, then trust can build and they can, in principle, punish deviations from cooperative behavior over time. The exact conditions under which cooperation can be stabilized, by repeated interactions, are complicated to characterize, but an important factor is how forward-looking firms are. If they focus heavily on

the present, then future gains and losses are of only secondary importance, which makes the enforcement of cooperative behavior difficult.

Digression 15.2 (The Prisoner's Dilemma and Frames of Reference)
From the point of view of the competing firms, Cournot and Bertrand equilibria have the character of the prisoner's dilemma: both firms could be better off by coordinating on the monopoly solution, but individual rationality leads them to a different outcome.

At this point, one could argue that, as with the prisoners in their interrogation rooms, this solution is no dilemma at all, because the general public profits from the inability of the firms or prisoners to cooperate. The prisoners are guilty and end up in jail and the outcome of oligopolistic competition is closer to the Pareto optimum than the monopolistic one is.

What this discussion shows is that the perception of a problem depends on the frame of reference. Oligopolistic competition is a cooperation problem from the point of view of the firms, but not from the point of view of society. On the contrary, society can make use of the dilemma structure between the firms to make markets more efficient.

Thus, the existence of a cooperation problem does not automatically imply that society should do something about it. It depends on the frame of reference (the most adequate one from a normative perspective), whether a cooperation problem is perceived as a vice or as a virtue.

Empirical industry studies usually identify many factors that influence market behavior, but that change rather frequently, which makes it very difficult to empirically identify and control, *ceteris paribus*, experiments to test the theory. One way out of this dilemma is to test the theories in the lab by means of market experiments. The advantage of this approach is that the researcher can control a lot of the relevant factors by the design of the experiment. However, the validity of experiments is limited, because participants are aware that they are not in real markets, but in the lab. There is an extensive debate about the so-called *external validity* of experiments that this chapter will not cover. Instead, this subchapter will briefly summarize the main findings from the literature on experimental oligopoly theory.

In experiments about Cournot quantity competition studies find a lot of support for the predictions of the model, if the experiment is run for a single round and subjects are anonymous and cannot communicate with each other. Repeated interaction and the possibility to communicate reduce the intensity of competition and collusive behavior becomes more likely. However, collusion is fragile and depends on the number of firms (players) in the experiment. In a duopoly, collusive behavior can be frequently observed, but it breaks down quickly, if the number of players increases. With four firms (players), the intensity of competition is generally higher in experiments than is predicted by the theory and the solution converges very quickly to the competitive equilibrium. The Bertrand model has also been experimentally tested, and the experimental findings are in line with the theoretical predictions.

Digression 15.3 (The Three *C*s of Economics)
Chapter 9 concluded with the conjecture that games can be interpreted as structural metaphors that allow one to gain insight into the logic of individual decision-making and collective outcomes. It asserts that society has to overcome two types of challenges, if it wants to alleviate scarcity, cooperation problems, and coordination problems. At the beginning of this chapter, the argument is brought that a third type of problem exists: commitment. Commitment problems lie at the heart of the solution to cooperation, as to coordination problems. To see why, take a prisoner's dilemma as an example. In this cooperation problem, players would like to mutually coordinate on the cooperative strategy, but individual rationality makes cooperation not credible. Hence, what is missing is a commitment device that allows them to overcome the credibility problem. Coordination problems have a different logic, but commitment mechanisms play a crucial role as well. If all players could publicly commit to a specific strategy, the equilibrium-selection problem would be solved.

Hence, coordination, cooperation, and commitment problems define the structural landscape of economics. This is why they can be called the three *C*s of economics.

Such a structural approach to economics has two main advantages:

- First, the simplicity of the three *C*s approach gives one a frame of reference for the interpretation and understanding of societal problems. Is it a coordination problem or a cooperation problem? What kind of commitment device might help to overcome it? Additionally, if there is no problem, then what kind of commitment mechanism is in the background that helps in stabilizing the efficient outcome?

  Here are two examples that illustrate this approach: Chap. 14 demonstrated that externalities can be interpreted as unresolved cooperation problems. Hence, the next step is to think about commitment mechanisms that help in internalizing them. On the other hand, previous chapters have argued that a complete set of competitive markets leads to efficiency under certain assumptions. The commitment device in the background is a system of perfectly enforced property rights. But is this the end of the story? Who enforces the property rights and is it in the interest of this person to do so? Does one have to dig deeper to identify commitment mechanisms for law enforcers? etc.

(continued)

Digression 15.3 (continued)

- Second, the three *C*s are a tool for future studies. When one begins to study more elaborate and advanced economic theories, it is easy to lose track of the basic story underlying the theory. Yet most, if not all, theories are variations of coordination or cooperation problems, plus some more or less elaborate ideas on commitment. Approaching these theories with a three-*C*s perspective helps one to make sense of them. It also helps one to scrutinize the basic ideas of these theories. Is the problem at hand adequately described as a coordination or cooperation problem? Are the institutions the theory focuses upon convincing, in the sense that they are credible commitment devices and, if not, why?

Part III of this book gave an introduction into the functioning of different prototypical markets. The following table summarizes the main findings from those chapters.

Overview of market structures (long run)	Sellers	Buyers	Price	Profits	Efficiency
Perfect competition	Many (homogeneous goods)	Many	$p = MC$, in the long run $p = \min AC$	$\pi = 0$	Efficient
Bertrand oligopoly	Few (same cost structure)	Many	$p_B = MC$	$\pi_B = 0$	Efficient
Cournot oligopoly	Few	Many	$p_C > MC$	$\pi_C > 0$	Inefficient
Monopoly (no price discrimination)	One	Many	$p_M > p_C > MC$	$\pi_M > \pi_C > 0$	Inefficient
Monopoly (1st degree price discrimination)	One	Many	$p_M^j =$ individual j's willingness to pay	$\pi_M =$ maximum sum of CS and PS $> \pi_M > \pi_C > 0$	Efficient
Monopolistic competition	Many (heterogeneous goods)	Many	$p = MC + \mu = AC$, $\mu =$ markup	$\pi = 0$	Inefficient

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Part V

Appendix

A Case Study

16

This chapter covers …

- how to apply the theoretical insights from the last chapters in order to gain a better understanding of a specific market or industry.
- how legal, technological, and economic aspects of an industry work hand in hand in determining the functioning of markets.
- how to interweave empirical facts with economic theory to thereby build a case.
- some facts about the European aviation industry.
- how all these facts influenced Swissair in the years before its grounding.

16.1 The Grounding of Swissair

> Swissair's collapse this week stranded thousands of passengers world-wide; saw its planes blocked in London; and left fliers holding potentially worthless tickets. A widespread feeling in Switzerland is that the airline that was the national pride was finished off by the banks that embody its national character of reliable, no-nonsense business. Yet its undoing may have been something very un-Swiss: bad management. [. . .] The plunge in air traffic after the Sept. 11 terrorist attacks in the U.S. pushed Swissair over the edge, but it has been flirting with collapse for months. [. . .] The nightmare began as a grand plan for growth. Like scores of other companies from this small, land-locked country, Swissair grew into a global player. 'An inflexible regulatory environment and some poor investments' crippled Swissair, says Damien Horth, an airline analyst at ABN-Amro in London. 'Poor management by Swissair in terms of its acquisitions and not controlling its associates well' proved fatal. (The Wall Street Journal, October 02, 2001)

We have covered a lot of ground in the last chapters and one should, by now, have a decent understanding of the functioning of prototypical markets, how they contribute to welfare and their weaknesses. We have also devoted a lot of pages putting the theories into perspective and applying them towards getting a better understanding of the societal phenomena that are characteristics for today's

M. Kolmar, *Principles of Microeconomics*, Classroom Companion: Economics,
https://doi.org/10.1007/978-3-030-78167-5_16

societies. The case studies have been relatively short, however, and have been tailored to specific theories, or even to specific aspects of a theory. What is still missing is a case study of sufficient complexity that it allows one to bring different theories together and to discuss the adequacy of the different theories for gaining an understanding of complex economic and social issues.

This chapter is an attempt at filling this gap and at illustrating how economic theories can be used to analyze and to better understand developments in markets and industries. The case that I am analyzing is the spectacular grounding of Swissair, a former Swiss airline. In order to be able to do so, one has to combine insights from different chapters. As one will see, a narrow economic focus is not sufficient to get a grip on this case. Rather, one has to embed economic analysis into the integrative approach that is fostered in this book, in order to gain a better understanding of the different factors that contributed to the insolvency of this once proud airline. One will see that legal, political, managerial, and cultural aspects played important roles in this case. However, this analysis will also mention the limitations of the theoretical framework that has been developed in this book. Some aspects of the aviation industry require more elaborate market models, and I will briefly show how one can use the theories presented in this book to address these issues and to develop the theories in the directions necessary to understand these more complex aspects.

The market structure of an industry reflects the technology of production, the size of the market, as well as the legal and regulatory framework in which the firms operate. Changes in any of these factors can trigger deep, structural changes that impact on the number of competitors in a market, as well as the way competition works. Some of the reasons for the grounding of Swissair cannot be understood, if one does not take these factors into consideration. In the following pages, I will briefly summarize the most important theoretical insights from the preceding chapters that are relevant for a better understanding of the airline industry and apply them to the Swissair case. They provide one with a toolkit that allows one to better understand some of the key factors that determine the functioning of the airline industry. If one is still familiar with them, one can skip this subchapter. However, there are some additional properties of the industry that have to be taken into consideration for a comprehensive understanding, which require more advanced theories and therefore have to be left out of consideration. The main purpose of the following case study is, therefore, twofold:

1. It should help one to see how economic theories can be used in order to better understand real-world phenomena, how to select the most adequate theories, and how to use one's insights to gain an understanding of the case. The fact that one has to conduct a thought experiment under "laboratory conditions," which leave out some important aspects of the problem, does not compromise this approach but instead creates a relatively accessible foundation. Hence, one is not aiming to present a "full-scaled" report on the case, but rather a version that allows one to apply and restrict one's attention to the theories that one has learned throughout the previous chapters.

2. It illustrates how economics, law, and management can and should work hand in hand to better understand the logic of social phenomena. In the end, good political and managerial decisions become more likely, if they are built on such an integrative approach.

16.2 Some Facts About the Aviation Industry in Europe

On March 31, 2002, after 71 years of service, Swissair ceased operation. This was the official endpoint of an economic downturn that led a once major international airline into bankruptcy. The airline prospered well into the 1980s, when it was one of the five major airlines in Europe. It was known as the "Flying Bank," due to its financial stability, and it was considered a national icon in Switzerland. How is it possible that a "Flying Bank" can turn into a money burner within 20 years? Which factors contributed to the demise of this airline?

A major event like the grounding of an airline can never be traced back to only a few causal factors. Reality is messy and one should shy away from oversimplifications. An economic analysis of the European aviation industry sheds at least some light on the case and makes some of the aspects that contributed to the grounding more transparent. However, an economic analysis of the case only gets one so far. In the end, the interplay between legal, technological, and institutional factors created an environment in which managers had to act and define strategies for their firms. This environment may have been relatively hostile towards an airline like Swissair, but there is no direct causal chain from the changing economic logic of the industry to the demise of Swissair.

After World War 2, air traffic increased rapidly and many airlines profited from the political regulation of the markets that created national, *de facto*, monopolies. During the 1960s and 1970s, Swissair was considered one of the best airlines of the world and made huge profits. Things began to change in the 1980s when the European Community started a process of liberalization of the community air transport market, to which the member states committed themselves in 1986, and that also became relevant for Switzerland. In order to create a single market for air transport, the EU liberalized its air transport sector in three stages, called "packages." This process culminated in the third package, adopted in 1993 and extended in 1997. It introduced the freedom for any airline of a member state to provide services within the EU and the freedom to provide "cabotage," the right for an airline of one member state to operate a route within another member state. This single market was extended to Norway, Iceland, and Switzerland in the following years.

This process of liberalization gradually changed the market structure from a system of regionally partitioned monopolies into a system of interregional competition, leading to a period of "cutthroat" competition in a market with too many, too small airlines, i.e., a form of competition where it is clear that some firms will be forced to leave the market. The following analysis will show that it was clear from the onset that this change in the political regulation of the industry would eventually lead to a consolidation and concentration of airlines. Different airlines began from different starting positions in this process of predatory competition. The "Flying Bank" Swissair had a head start, because of its large asset holdings and huge liquidity. However, the fact that Switzerland rejected taking part in the European Economic Area in 1992 was a huge disservice to Swissair, because the emerging common airline market was, for that reason, not a level playing field. Here are a few examples of the obstacles that confronted them: Swissair planes were not allowed to take up passengers during intermediate landings in EEA countries and Swissair was not allowed to sell tickets for sections within EEA member countries.

16.3 Applying Economic Theory

Now, one can lay down some principles that govern optimal firm behavior in a monopolized aviation industry. One should focus one's attention on two different technological characteristics that are of major importance: the technology-induced cost structure of an airline and the bundling problem that results from the network structure of the product. These factors influence the pricing strategies of the airlines and, thereby, its profits. The network of flights offered by an airline determines its portfolio of different products, which implies that all airlines offer a different product portfolio, even if there may be some routes for which they compete directly.

Digression 16.1 (Additional Aspects)
This analysis gives only a very broad concept about airline pricing. There are at least three additional aspects in reality that complicate pricing, but that also make pricing in this industry intellectually fascinating: (1) There is no spot market for flights, so demand for a specific flight drops more or less stochastically over time before the flight. This implies that there is no single price on such a "dynamic" market, but a time-dependent price function. Prices may vary over time, depending on load factors, and so on. (2) Each flight has a given capacity, which implies that the marginal costs of an additional passenger are very small before and very large after the capacity threshold is reached (one would have to change the aircraft). Hence, any cost-plus pricing rule would discriminate prices at this point. The resulting problem is known as *peak-load pricing* in the literature. (3) An airline offers a network of different connections, which implies that there are complementary, as well as substitutive, edges in each network and airlines also compete with respect to their network structures.

In order to be able to analyze the effect of liberalization on the industry, remember that the model of oligopolistic quantity setting (Cournot competition) includes the case of perfect competition (and thereby also Bertrand competition) as a special case, with a perfectly elastic demand function. Hence, one can restrict one's attention to a short repetition of this model in order to be able to distill the main messages for the Swissair case.

16.3.1 Costs

Chapter 7 explained that a firm's total costs, $C(y)$, are the sum of fixed costs, FC, and variable costs, $VC(y)$, the last of which depend on the quantity produced, y. In the airline context, y may be, for example, the number of passengers transported from A to B or the frequency of flights offered. Hence, one can describe the total costs as

$$C(y) = VC(y) + FC.$$

One important characteristic of the aviation industry is the structure of the airlines' cost functions: fixed costs are a significant share of total costs because the logistic infrastructure is, at least in the short run, largely independent of the occupancy rate. Fixed costs do not influence the pricing policy of a firm but are relevant for profits and for determining whether a firm stays in a market or has to exit it.

Fixed costs are, to a large degree, capacity costs: that is, the depreciation and financing costs of the aircraft fleet and its maintenance, the costs of the supporting infrastructure, as well as the costs of landing rights and the handling of passengers at airports (contracts are usually longer term).

An airline's variable costs, for a given flight, encompass gasoline, onboard services like free drinks and meals (if they exist), and so on. If one breaks down costs to a single passenger, not even gasoline costs are variable. Hence, depending on the level of aggregation, variable costs are relatively unimportant in this industry. This leads to the following observation: the average total costs of a firm are

$$AC(y) = \frac{C(y)}{y} = \frac{VC(y)}{y} + \frac{FC}{y}.$$

Average costs are decreasing over a given range when y is small and, depending on the structure of the variable costs, they might even be decreasing for all y. In order to see this, note that $VC(0) = 0$ by definition. Because fixed costs are large, the average costs decrease over a significant range of y and decrease over the whole range (for all y), if marginal costs are constant or decreasing. Assume, for simplicity, that variable costs are linear,

$$VC(y) = c \cdot y, \qquad c > 0,$$

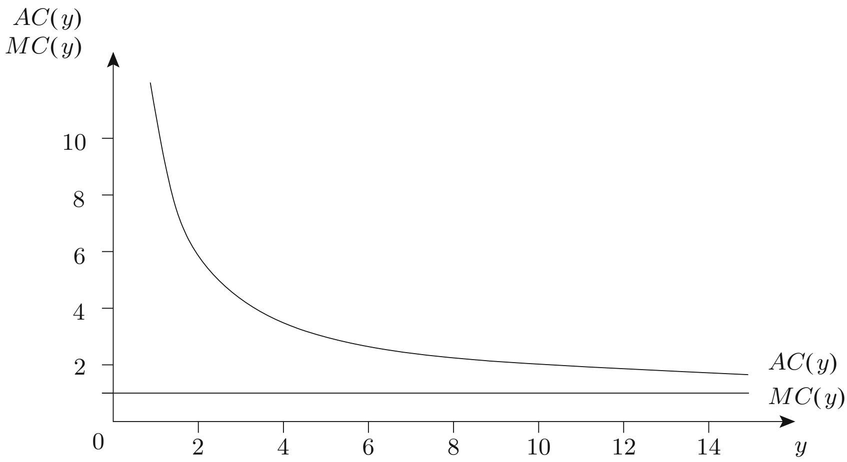


Fig. 16.1 Average and marginal costs

which implies that marginal costs are constant and equal to c. Hence, the average-cost function is

$$AC(y) = c + \frac{FC}{y}.$$

Average costs decrease strictly for all y and converge to c as y grows large, because $AC'(y) = -FC/(y^2) < 0$ and $\lim AC(y)|_{y\to\infty} = c$. In Fig. 16.1, one can see this relationship in the special case of $FC = 10$ and $c = 1$.

What are the implications of this type of cost structure for the functioning of the industry? First, a single firm can operate a given network more efficiently than two competing firms can that share the market:

$$C(y) = FC + c \cdot y < 2 \cdot C(y/2) = 2\left(FC + \frac{1}{2} \cdot y\right) = 2 \cdot FC + c \cdot y.$$

There are size effects, because an increase in output decreases average costs. Because of this property, industries like the aviation industry have a tendency for concentration, because fixed costs limit the number of competitors that can profitably operate in the market. However, it indicates that the number of firms, for which this is the case, is rather limited. Hence, starting from a situation with a large number of protected airlines, it is very likely the case that competition leads to concentration; some airlines will not be able to survive the process of market liberalization, as soon as they start to compete on some segments of the networks. Airlines were forced to play musical chairs when the European Community decided to liberalize the market. However, to the extent that average costs are downward sloping, the process of market concentration is potentially efficiency-enhancing, because it reduces the total costs of production.

16.3.2 The Linear Cournot Model with *n* Firms

In the following subchapter, assume that the effect of an increase in competition can be captured by the Cournot model of oligopolistic competition. Taken literally, the model could only be applied to flights for which airlines directly compete (e.g., Zurich–Frankfurt), because the products have to be perfect substitutes. The assumption of Cournot competition is, however, innocuous insofar as that the qualitative results do not depend on this specific market model. The assumption of monopolistic or Bertrand competition would lead to similar conclusions. Also, more elaborate pricing strategies, or more complicated models of network competition, with imperfect substitutability, would also leave the qualitative results unchanged. If the qualitative results are robust in this sense, one can—remember the epistemic status of positive theories that was discussed in Chap. 1—go for a simple model.

In order to be able to understand the effects of competition, one can determine the Nash equilibrium for a linear Cournot model, with n airlines that compete in (some segment of) the market. I follow the notation from Chap. 15. (If one is still familiar with the n-firm model from Chap. 15, then one can skip the derivation of the Nash equilibrium and jump immediately to the conclusions.)

Assume, for simplicity's sake, that the demand for the services of a given airline is linear and has the following form:

$$p = a - b \cdot Y,$$

where Y is the market supply, $a > c$ denotes the maximal willingness to pay in the market, and b quantifies how price-sensitive the market is. Denote by y_i the supply of a single airline i, and by y_{-i} the supply sum of all airlines except i. Then, airline i's profit equation is

$$\pi_i(y_i, y_{-i}) = (a - b \cdot (y_i + y_{-i})) \cdot y_i - c \cdot y_i - FC, \quad i = 1, \ldots, n.$$

Given the quantity supplied by all other firms, firm i's profit-maximizing supply can be determined by the first-order condition, which establishes the well-known "marginal-revenues-equals-marginal-costs" rule:

$$\frac{\partial \pi_i(y_i, y_{-i})}{\partial y_i} = (a - c - b \cdot y_{-i}) - 2 \cdot b \cdot y_i = 0, \quad i = 1, \ldots, n.$$

A single airline, i, behaves like a monopolist on a "curtailed" market with a market demand function of $p = a' - b \cdot y_i$, where $a' = a - b \cdot y_{-i}$. Figure 16.2 depicts this situation for a curtailed demand function, $p = 11 - y$, and cost function, $C(y) = y + 10$. In this situation, the airline's optimal output is $y^M = 5$, with a corresponding price of $p^M = 6$. Per-unit profit would be $p^M - AC(y^M) = 6 - 3 = 3 > 0$. (Remember that this result need not be a Nash equilibrium: declaring it as such would require specifying all the parameters to make sure that all the other airlines are on their reaction functions, as well.)

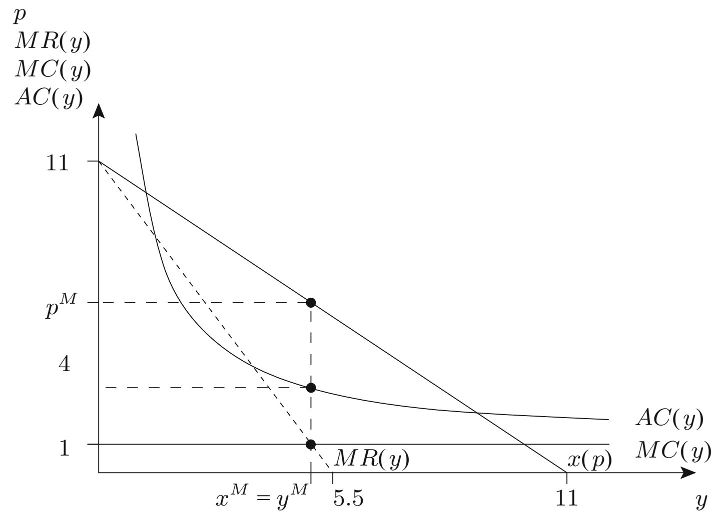


Fig. 16.2 The airline's optimal policy for a given curtailed demand function

This formulation reveals that the relevant demand function for a single airline, $p = a' - b \cdot y_i$, depends on the total quantity supplied by all other airlines, which captures the effect of competition in this model: an increase in y_{-i} shifts the curtailed demand function inwards; an increase in the total supply of the competitors has the same consequences as a reduction in the demand for aviation services does. In the example displayed in the figure, the price is above average costs, which implies that the airline makes positive profits. If competition has the effect of shifting the curtailed demand function inwards, it is easy to see that there is a point at which price equals average costs, such that the airline can no longer operate profitably. This is the point at which the airline is forced out of the market, if it cannot cut costs or make its services more attractive to the customer.

If one assumes that all other airlines supply the same quantity, $y_{-i} = (n-1)y$, it becomes apparent that this downward shift in the curtailed demand function may be a result of an increase in the quantity supplied by the competitors, holding the number of competitors constant, or the result of new airlines competing in the market. The model, therefore, makes very sharp predictions about the effect of market liberalization on a single airline: as soon as new airlines start to compete with the formerly monopolistic network of, for example, Swissair, this increase in competition "steals" part of the demand from Swissair, which eventually reduces profits to zero. How long it takes before an airline starts making losses depends on its fixed and variable costs.

In order to derive more detailed results, one has to solve for the Nash equilibrium. In general, the first-order conditions specify a system of n equations and n unknowns, $y_1, \ldots, y_n$. If one assumes that identical firms behave identical in equilibrium so that, for any two firms i and j, $y_i = y_j$ holds, one can replace y_i

with y and y_{-i} by $(n-1) \cdot y$. One ends up with one equation and one unknown variable:

$$(a - c - b \cdot (n-1) \cdot y) - 2 \cdot b \cdot y = 0.$$

If one solves this equation for y, one obtains the equilibrium quantity of a firm as $y^* = (a-c)/((n+1) \cdot b)$ and market supply $n \cdot y^*$ is $n/(n+1) \cdot (a-c)/b$. One can also derive the market price, as well as the airline's profits:

$$p^* = \frac{a + nc}{n+1}, \tag{16.1}$$

$$\pi^* = \frac{(a-c)^2}{(n+1)^2 b} - FC. \tag{16.2}$$

These findings allow a more detailed analysis of the effect of competition (which one can interpret as an increase in the number of competitors n in the market). First, looking at equilibrium prices, one finds that $\partial p^*/\partial n < 0$: an increase in competition brings prices down and, given that demand and prices are inversely related, leads to an increase in total demand.

Reliable data for this effect exists for the US market. Figure 16.3 demonstrates the potential empirical magnitude of this effect for a single route, the Baltimore

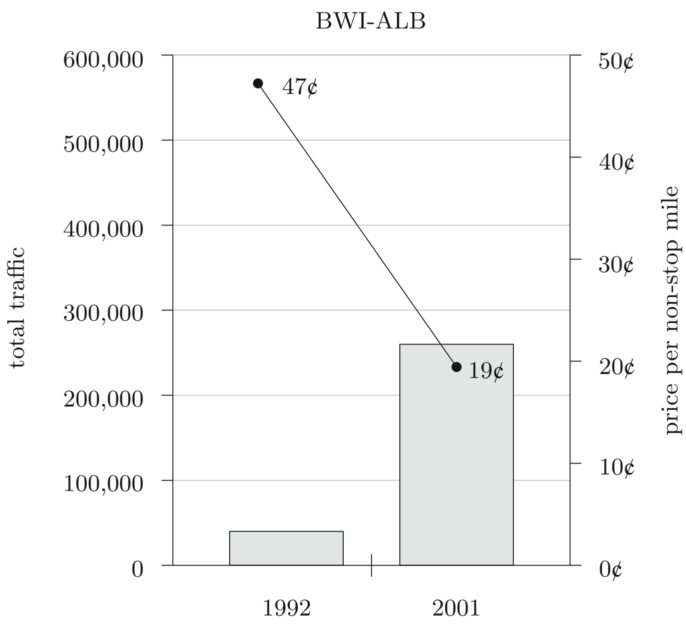


Fig. 16.3 Prices and demand after market entry

(BWI) to Albany (ALB) market for the 1992–2001 period. The entry of Southwest Airlines into the market decreased the average fare by 61%, causing passenger demand to increase by 641%.

The downward pressure on prices, which is caused by competition, is, in and of itself, no problem; on the contrary, it can be argued that it makes the market more efficient, because it brings the equilibrium closer to a Pareto-efficient allocation. However, a look at profits reveals that competitive pressure can lead to deeper structural changes in the market. The first term in the profit condition is revenues minus variable costs. It defines the gross margin that an airline can use to cover its fixed costs. This gross margin decreases as the number of competitors increases, which implies that a number of competitors exist, due to which airlines start to make losses. Denote this number by $\bar{n}$. It can be determined from (16.3) by setting profits equal to zero:

$$\pi^* = \frac{(a-c)^2}{(\bar{n}+1)^2 \cdot b} - FC = 0 \Leftrightarrow \bar{n} = \frac{a-c}{\sqrt{b \cdot FC}} - 1. \tag{16.3}$$

If, for example, $b = 1, c = 1, a = 2001$ and $FC = 1{,}000{,}000$, then the maximum number of firms that can exist without taking losses is $\bar{n} = 2$. Of course, given that market liberalization heats up competition and competition brings down profits, the maximum number of airlines that can survive in a regulated, quasi-monopolized market exceeds the number of airlines that can survive on a liberalized market. Hence, if the number of airlines that operate in the regulated market, $\hat{n}$, exceeds $\bar{n}$, then cutthroat competition sets in. This was exactly the situation European airlines were confronted with at the beginning of market liberalization.

If cutthroat competition is the effect of market liberalization, one may ask why airlines were willing to enter new, formerly protected markets. The answer to this question follows the logic of Cournot competition and the market-entry game. Assume that an airline does not offer a direct flight from A to B before market liberalization and that it considers opening this route. The incumbent had a monopoly before liberalization and will suffer from market entry. However, even if total market profits fall after market entry, because of competition, it is still profitable to enter, as long as profits are positive. The fact that the incumbent is worse off is irrelevant for the entry decision (one is facing a cooperation problem).

It could also be argued that the picture painted above is incomplete, because an airline like Swissair could compensate the loss in profits in its formerly protected markets (routes) by entering other markets (routes); competition is not a one-way street. In order to see why this logic is flawed, one has to remember that monopoly profits exceed the sum of oligopoly profits in a market. Hence, if two former monopolists on markets A and B start competing with each other on both markets, total profits are reduced. Therefore, the additional profits from entering new markets cannot compensate the loss in profits in one's former monopoly market. The only case where it is, theoretically, possible that an airline can increase its total profits is a situation with asymmetric competition, where the airline enters more new markets that there are competitors entering its formerly monopolized market.

(In this example, this effect would trivially occur, if the airline operating market B decides not to enter market A, but the airline operating market A enters market B.) As this chapter already suggested, Swissair was not able to compete on a par with other European airlines because it did not belong to the EEA. Hence, it was much more difficult for Swissair to compensate for losses in the home market by entering new ones than it was for its competitors from the EEA.

The managers of the airlines could have known that market competition would eventually lead to market concentration by either insolvencies of some carriers, mergers and acquisitions, or strategic alliances. What was not clear from the outset, however, was whether Swissair would be among those airlines that survived this process, despite its handicap.

16.3.3 Extensions

The effect of market liberalization was, of course, that airlines started to operate flights on routes that had previously been monopolized. Any new route has an effect on the network structure of an airline and this network structure is such an important factor for an understanding of the functioning of the market that one has to devote some time and energy to this fact so that one can fully appreciate it. In order to do so, one can use the models in the toolbox gained from previous chapters as heuristics so one can develop an understanding of more complex technological and market structures.

Its network structure is an important element for the success of an airline. An airline's network is the collection of routes or connections that it offers. This network structure is important for at least two reasons. First, it is an important determinant of the airline's total costs. Depending on the size and structure of the network, costs may differ and it is, therefore, of great importance to develop and structure the network efficiently. Second, the size and structure of the network influences demand, because it influences the potential customer's willingness to pay.

The second argument can be illustrated by means of the following example. Assume an airline offers a flight between two cities, A and B, and considers extending its network by offering a new connection between cities B and C. The first effect is, of course, that this new flight creates demand from those passengers who want to travel from B to C. However, there is a second, indirect effect, because the new connection creates additional demand by those passengers who want to travel from A to C, who can now be served by this airline. Hence, from the airline's point of view, the value of network $A-B-C$ exceeds the sum of values of sub-networks $A-B$ and $B-C$, which is a simple form of a positive network effect. The fact that network effects imply that the total is more than the sum of its parts has implications for the optimal network structure, from the point of view of the demand side: the network should be extended by including additional routes, if the additional revenues from an additional route (including network externalities) exceed the additional costs (airport charges, direct operating costs of the flight, etc.).

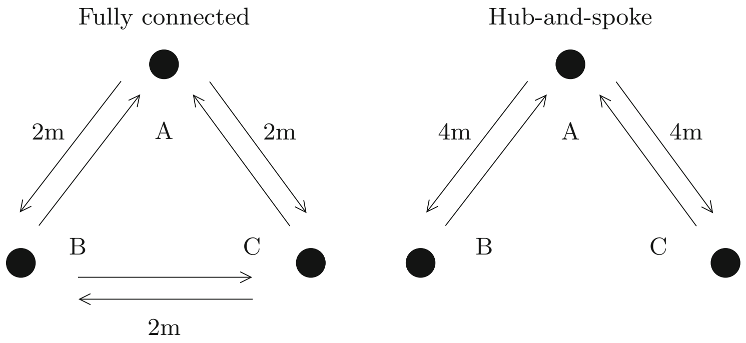


Fig. 16.4 Different network structures, fully connected and hub-and-spoke

The first, cost-saving argument can be illustrated by the same three-city model with cities *A*, *B*, and *C*. Assume that, for given prices *m*, passengers want to travel from any city to either of the others (*A* to *B*, *B* to *A*, *A* to *C*, *C* to *A*, *B* to *C*, and *C* to *B*). An airline has, basically, two options at its disposal. The first is to offer the full set of connections (*FCN*, fully connected network): that is, to offer the capacity to accommodate demand for each route. The second is to use one of the cities, say *A*, as a hub that is connected to both other cities, but to not connect the others directly with each other. Passengers who want to fly from *B* to *C*, or vice versa, need to fly via *A*. This structure is called a hub-and-spoke (*HSN*) network. Figure 16.4 shows the two network types and the corresponding traffic flows on each route.

In order to illustrate how network structures influence costs, I introduce a simplified model that illustrates how network structure influences an airline's costs. For simplicity, the study only encompasses a single airline, but the general message remains valid in a competitive environment. The three different routes are denoted by *AB*, *BC*, and *CA*. Demand is $2 \cdot m$ for each route, m for each direction. The airline's total costs are a function of the number of routes it operates and of the number of passengers on each route. There are fixed costs for operating a route, *F*, and variable costs on each route, *i*, are a function of the total number of passengers, *k*, transported on that route times marginal costs, *c*, so:

$$VC_i(k_i) = c \cdot k_i^{\alpha},$$

where $\alpha \geq 1$ is a parameter that determines whether marginal costs increase ($\alpha > 1$) or are constant ($\alpha = 1$). Note that k is not necessarily equal to $2 \cdot m$ because, if the *HS* network is chosen, nobody flies on *BC*, but all the *BC* passengers have to take a detour *via A*, and analogously for all passengers who want to go from *C* to *B*. In that case, $k_{AB} = k_{CA} = 4 \cdot m$. If the airline offers a fully connected network, $k_i = 2 \cdot m$, then the total costs are

$$TC^{FCN} = 3 \cdot c \cdot (2 \cdot m)^{\alpha} + 3 \cdot FC = 3 \cdot c \cdot 2^{\alpha} \cdot m^{\alpha} + 3 \cdot FC.$$

If the airline decides to operate a *HS* network instead, then the total costs are

$$TC^{HSN} = 2 \cdot c \cdot (4 \cdot m)^{\alpha} + 2 \cdot FC = 2 \cdot c \cdot 4^{\alpha} \cdot m^{\alpha} + 2 \cdot FC.$$

HS is more cost efficient for the airline than *FC*, if and only if

$$TC^{HSN} < TC^{FCN} \Leftrightarrow m < \left(\frac{FC}{c \cdot (2 \cdot 4^{\alpha} - 3 \cdot 2^{\alpha})} \right)^{\frac{1}{\alpha}}.$$

In the case of constant marginal costs, $\alpha = 1$, the above condition simplifies to

$$m < FC/(2 \cdot c).$$

Hence, the relationship between the demand for a given route and the fixed-to-variable-costs ratio is crucial for the optimality of a network structure. Large fixed costs make it, *ceteris paribus*, more likely that a *HSN* is more cost efficient. This relation is depicted in Fig. 16.5.

Cost efficiency, however, is not the only factor an airline has to take into consideration when it optimizes its network for a given set of possible connections. From the point of view of a customer, it may make a difference whether she flies directly from Zurich to Copenhagen or whether she has to change planes in

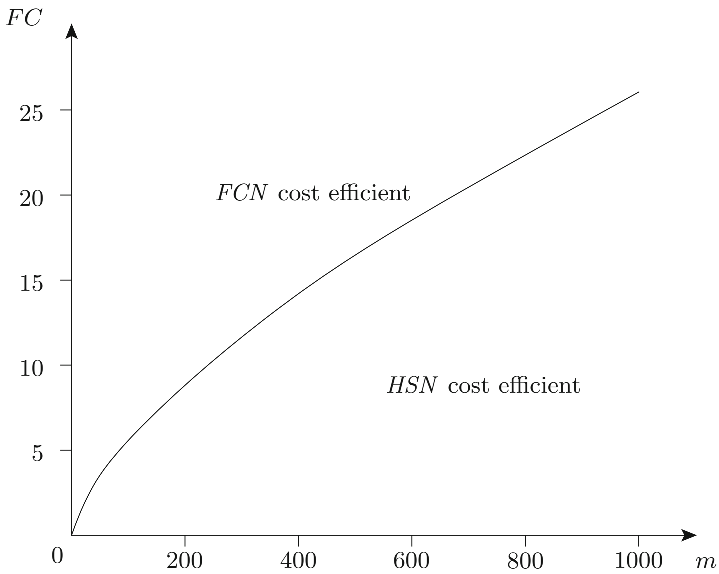


Fig. 16.5 The function describes the locus on which the total costs of operating the different networks are equal, given $\alpha = 3/2$ and $c = 1$. Below the graph is the area in which a *HSN* type would be cost efficient; above is the area in which a *FCN* would be cost efficient

Frankfurt. Usually, the willingness to pay is lower in the latter case. The optimal network structure, therefore, reflects an optimal compromise between cost efficiency and the willingness to pay.

At the point in time at which the European market started to liberalize, experience from the liberalization of the US market (which went through a similar process more than a decade earlier) already suggested that a *HSN* is superior to a *FCN* and most European airlines adopted a *HSN* structure (Air France with a hub in Paris, Lufthansa with a hub in Frankfurt, KLM with a hub in Amsterdam,. . .). Swissair, however, resisted that trend and maintained three, large-scale airports in Zurich, Basel, and Geneva. In fact, Swissair operated a network that was neither purely *FCN* nor *HSN* but, given the size of the Swiss market, it was closer to a *FCN*. While this decentralized structure did not really make the available network more attractive for travelers, because the geographic distance between the three cities is negligible by international standards and the local market is too small to justify such a network, it was (and is) costly to maintain. The additional costs were estimated to be in the high double-digit million Swiss Francs per year.

The decision to maintain three, comparably large, international airports in a small country like Switzerland was, to a great extent, political. Especially keeping the airport in Geneva was a political decision to manifest the equality between the French and German speaking parts of the country. However, political decisions that do not follow the logic of markets have their price and, in the case of Swissair, that price was substantial. The cost-inefficient network structure further reduced the airline's profits over a period of time when increased competition was already driving fares down and cutting back profits.

The analysis up until this point has shown that the effects of liberalization of the airline market are rather complex. First, opening a new route in a formerly protected market has the competitive effects analyzed before. Airlines will start opening new routes, if they can increase their profits by doing so, even if the overall effect is that industry profits go down. For this isolated effect, strategic alliances, mergers, and acquisitions are forms of collusive behavior that can increase the airline, as well as the industry profits by coordinating the strategies of the airlines. Hence, the analysis predicts that there is a strong tendency to move in the direction of a more concentrated industry, but the overall welfare effects of concentration are unclear, because concentration allows the airlines to move closer in the direction of a monopolistic solution. Second, opening new routes may have positive network externalities, as well as cost-saving effects, if the extended network can be organized in a more cost efficient way. There are two ways to achieve such a goal: either by an extension of an airline's own network (internal growth), by the formation of strategic alliances, or by mergers and acquisitions (external growth). Both strategic options have their own advantages and disadvantages and it would be beyond the purpose of this case study to analyze them in detail.

16.4 How About Swissair?

The analysis of the last sections has shown that market liberalization was likely to erode profits by intensifying competition and that decreasing average costs could easily make airlines unprofitable. Internal, as well as external, growth strategies (alliance formation, mergers, and acquisitions) were key to managing profits during a period of time when the whole industry was likely to consolidate. It is, therefore, no surprise that the world's first and largest global alliance, Star Alliance, was founded in 1997.

European market liberalization was more of a challenge than an opportunity for Swissair, because the vote against the ratification of the EEA Treaty in 1992 implied that Switzerland had to renegotiate the restrictive, bilateral air service agreements with every single EU member state. Additionally, equal access for Switzerland-based airlines to the EU market was granted only in combination with the Agreement on Free Movement of Persons, which was not fully in force before 2004. Table 16.1 gives an overview of the main factors that contributed to Swissair's demise.

Given the above arguments, and despite of the impediments that resulted from the non-membership in EEA, it seems straightforward that Swissair had its own growth strategy, the Hunter strategy, with the objective to reach a 20% market share in Europe. Its aim was to increase its market share by the acquisition of smaller airlines instead of entering into alliance agreements. (In 1989, however, Swissair was the first European airline to seal a partnership agreement with the overseas carrier, Delta Airlines. Part of the arrangement was a mutual 5% equity swap. One year later, a similar deal was made with Singapore Airlines.) These airlines created the so-called Qualifier Group. Table 16.2 gives an overview of the acquisitions, as of 2000.

As can be seen, the Hunter strategy exclusively targeted airlines from smaller European countries like Belgium, Austria, Finland, Hungary, Poland, Portugal, and Ireland and, thereby, bypassed the more important and mature markets in Italy, Germany, and France.

The idea was to funnel traffic from the accessed markets through Zurich and Brussels to establish two principal hubs within Europe. One key problem with this strategy was, however, a lack of network externalities and cost synergies, because the different networks did not fit together well. On top of that, the strategy diluted

Table 16.1 Main political, legal, and economic factors that contributed to Swissair's problems

	Cause	Effect
Political factors	Inefficient network structure within Switzerland	Inefficient cost structure
Economic factors	Importance of fixed costs	Limits the number of competitors
	Increased competition on routes	Pressure on prices and quantities
Legal factors	Non-membership in EEA	Inefficient cost and route structure

Table 16.2 Holdings of Swissair as of 2000

Airline	Equity stakes
Air Europe	49.0
Volare Air	49.0
Air Littoral	49.0
Austrian Airlines	10.0
AOM France	49.5
Balair/CTA Leisure	100.0
Crossair	70.5
Cargolux	33.7
LOT Polish	37.6
LTU Group	49.9
Portugalia	42.0
South African Airways	20.0
Sabena	49.5
Ukraine International Airlines	5.6
TAP Air Portugal	34.0

the company's valuable brand, because of the lower quality standards of the acquired carriers (effectively only carriers that had been shunned by the other alliances). The dilution of the brand further undermined Swissair's ability to extract premium fares from its passengers.

16.5 Concluding Remarks

Economic analysis is not like a crime novel where, in the end, the detective manages to perfectly solve the case and to identify the culprit. In economics, there is usually no single culprit and the best an economist can hope for is to identify some of the more important contributing factors, which are related to the industry, regulatory, and, ultimately, market context in which Swissair was embedded. Management failure may have played another important role, upon which economists can only speculate without further information. Nevertheless, as the above analysis has shown, management happens within a political, legal, and regulatory, as well as economic context that, together, created a huge handicap for Swissair.

1. Increasing competition drove profits down and created a situation of cutthroat competition in which some carriers could not survive.
2. The decision not to ratify the EEA Treaty made it difficult for Swissair to get a foothold in the profitable EEA markets.
3. Growth strategies had to take this strategic disadvantage into consideration and Swissair had to acquire what was left on the market. The resulting network structure was far from optimal. Market share alone was not a good objective.

The purpose of this case study was not to develop a detailed analysis of the economics of aviation industry in general, or the insolvency of Swissair in particular, but to illustrate how different economic theories, combined with empirical facts about politics and law, can be used to better understand certain aspects of reality.

17 Mathematical Appendix

This chapter covers . . .

- an introduction into functions with several variables.
- an introduction into linear equations.
- the concept of elasticities.

17.1 General Remarks

> If I were again beginning my studies, I would follow the advice of Plato and start with mathematics. (Galileo Galilei)

> (1) Use mathematics as shorthand language, rather than as an engine of inquiry. (2) Keep to them till you have done. (3) Translate into English. (4) Then illustrate by examples that are important in real life. (5) Burn the mathematics. (6) If you can't succeed in 4, burn 3. This I do often. (Alfred Marshall)

The purpose of scientific theories is to develop hypotheses about causal relationships and to test them empirically. This is why the mathematical concept of a *function* is very important in both the natural and social sciences. A function is a mapping from a set of explanatory variables onto a set of explained variables. One should know simple functions from high school: in order to define a function, it is usually assumed that a variable x, which is an element of some set X, and a variable y, which is an element of some set Y, exist and that y is related to x by some mapping $f : X \to Y$. Such a function is the easiest representation of a causal mechanism. If one states that $y = f(x)$, one means that some "state" y is caused by some "state" x and the function $f(.)$ represents this causal relationship between x and y. One calls x the *explanatory* and y the *explained* variable, because y is caused or "explained" by x via the function $f(.)$. Look at the following example: an individual demand function $x(p)$ assumes a relationship between a market price p and a quantity x that

M. Kolmar, *Principles of Microeconomics*, Classroom Companion: Economics,
https://doi.org/10.1007/978-3-030-78167-5_17

the consumer is willing to buy at this price. This is a causal relationship that is represented by the function $x(.)$ and for which the price, p, is the explanatory and the quantity, x, is the explained variable.

The simple, one-explanatory–one-explained-variable function is convenient, but often too simplistic to appropriately cope with economic phenomena. In social systems there are usually several factors that causally determine some outcome. In the case of individual or market demand for some good, i, for example, it is not only the price of this good, p_i, that determines demand, but also the prices for other goods, as well as the income of the individual. With n goods, one would, therefore, have prices, $p_1, \ldots, p_i, \ldots, p_n$, and income, b, that explain demand, x_i, and one has to denote this by means of a demand function that depends on all these variables, $x_i(p_1, \ldots, p_i, \ldots, p_n, b)$. Otherwise, one would not be able to fully understand the causal mechanisms at work.

There are two important fields of application for functions that represent causal mechanisms. First, it might be important to understand how the change in one explanatory variable changes the explained variable because, in empirical tests, it is often possible to measure changes in some variables, but not their absolute values. In order to describe those changes one can use the concept of the partial derivative of a function. The next subchapter introduces and works with partial derivatives.

Second, there are important cases in which a causal system is described by several functions. In markets, for example, both supply, $y(p)$, and demand, $x(p)$, are of importance. Supply and demand are mappings from explanatory to explained variables. In such situations, it is a standard problem to analyze whether it is possible to find values of the explanatory variables that are consistent with some constraints on the explained variables. In the case of supply and demand, such a constraint is the condition that supply equals demand, $x(p) = y(p)$ (equilibrium). If one asks if a price exists such that supply equals demand, one asks, from a mathematical point of view, if a value p exists such that $x(p) - y(p) = 0$. In other words, one is looking for the root of the equation $x(p) - y(p)$. This will be done in the subchapter after the next.

Functions are rather abstract and complicated tools. In order to avoid complications, assume throughout this book that the domain, as well as the codomain, of all functions are the set of real numbers and that all functions are continuous and have no "kinks." Why this is important, as well as more general properties of functions, will be discussed in math class.

17.2 Functions with Several Explanatory Variables

This subchapter now leaves the demand and supply context behind to talk about functions more generally. Most people are familiar with the $y = f(x)$ notation of functions. (y no longer stands for supply, but for an arbitrary explained variable, x no longer stands for demand, but for an arbitrary explanatory variable, from now on.) For a function with only one explanatory variable, it is possible to use a very lean notation in order to be able to describe a change in the explained variable that is caused by a (small, infinitesimal) change in the explanatory variable: $f'(x)$. For example, the derivative of $f(x) = x^2$ is denoted as $f'(x) = 2 \cdot x$. There is nothing wrong with this notation, but it is not sufficiently precise, if one faces a problem with several explanatory variables. Assume that there are two explanatory variables x_1 and x_2, and denote by $y = f(x_1, x_2)$ the causal relationship. If one denotes derivatives as $f'(x_1, x_2)$, one cannot distinguish between changes in x_1 or x_2. One, therefore, has to introduce a way to denote derivatives that solve this problem. In principle, there are several ways to do so. For example, one could use the notation $f^1(x_1, x_2)$, $f^2(x_1, x_2)$ for the derivatives with respect to x_1 and x_2. However, this is not the usual convention.

Let $x_1, \ldots, x_n$ be the explanatory variables. One is interested in the changes of the function f evaluated at some point $a_1, \ldots, a_n$, which is caused by some infinitesimal change in x_i, holding all other explanatory variables constant (comparative statics). The most common notation for these so-called *partial derivatives* is given by

$$\frac{\partial f(a_1, \ldots, a_n)}{\partial x_i}, i = 1, \ldots, n.$$

The notation $f(a_1, \ldots, a_n)$ reminds one that one is looking for the derivative of the function at a specific point $(a_1, \ldots, a_n)$. The "∂"-sign is pronounced as "del" and is reminiscent of the definition of partial derivatives by means of the difference coefficient,

$$\frac{\partial f(a_1, \ldots, a_n)}{\partial x_i} = \lim_{dx_i \to 0} \frac{\overbrace{f(a_1, \ldots, a_i + dx_i, \ldots, a_n) - f(a_1, \ldots, a_n)}^{=df(a_1, \ldots, a_n)}}{dx_i},$$

$i = 1, \ldots, n$.

The notation "d" represents a discrete change in x_i and $f(.)$, respectively, and ∂ indicates the limit of this change, if dx_i becomes arbitrarily small (converges to zero).

In order to be able to work with partial derivatives, one has to generalize the rules of differentiation. Here are the most important ones:

Additive Functions Let $f(x_1, \ldots, x_n) = g(x_1, \ldots, x_n) + h(x_1, \ldots, x_n)$; then

$$\frac{\partial f(a_1, \ldots, a_n)}{\partial x_i} = \frac{\partial g(a_1, \ldots, a_n)}{\partial x_i} + \frac{\partial h(a_1, \ldots, a_n)}{\partial x_i},$$

$i = 1, \ldots, n$.

Product Rule Let $f(x_1, \ldots, x_n) = g(x_1, \ldots, x_n) \cdot h(x_1, \ldots, x_n)$; then

$$\frac{\partial f(a_1, \ldots, a_n)}{\partial x_i} = \frac{\partial g(a_1, \ldots, a_n)}{\partial x_i} \cdot h(a_1, \ldots, a_n) + g(a_1, \ldots, a_n) \cdot \frac{\partial h(a_1, \ldots, a_n)}{\partial x_i},$$

$i = 1, \ldots, n$.

Quotient Rule Let $f(x_1, \ldots, x_n) = g(x_1, \ldots, x_n)/h(x_1, \ldots, x_n)$; then

$$\frac{\partial f(a_1, \ldots, a_n)}{\partial x_i} = \frac{\frac{\partial g(a_1, \ldots, a_n)}{\partial x_i} \cdot h(a_1, \ldots, a_n) - g(a_1, \ldots, a_n) \cdot \frac{\partial h(a_1, \ldots, a_n)}{\partial x_i}}{(h(a_1, \ldots, a_n))^2},$$

$i = 1, \ldots, n.$

Chain Rule For a number of scientific problems, the causal chain between the explanatory and explained variables is more complex, because the effect of some explanatory on the explained variable is mediated by some "intermediate" variable. For example, it could be that some variable, x_i, has an influence on the intermediary variable z, $z = g(x_i)$, and z has an influence on y, $y = \tilde{f}(x_1, \ldots x_{i-1}, z, x_{i+1}, x_n)$. (For simplicity, assume that there is no direct effect of x_i on y, which will generalize the analysis in the next section. One calls this function $\tilde{f}(.)$, because it is a function of z and one has to be able to distinguish it from $f(.)$, which is a function of x_i. One can denote this structure as $y = f(x_1, \ldots x_{i-1}, x_i, x_{i+1}, x_n) = \tilde{f}(x_1, \ldots x_{i-1}, g(x_i), x_{i+1}, x_n)$.

The individual demand function can be used as an example. One has assumed that individual demand is a function of prices and income, b. If one further assumes that income is, itself, determined by some other factors, like qualification, then one gets a chain of causal effects: qualification determines income and income determines demand.

In a situation like this, one gets the following rule for the differentiation of $f(.)$ with respect to x_i:

$$\frac{\partial f(a_1, \ldots, a_n)}{\partial x_i} = \frac{\partial \tilde{f}(a_1, \ldots, a_n)}{\partial z} \cdot \frac{\partial g(a_i)}{\partial x_i}.$$

The above expression is intuitive: x_i has an influence on z. This effect is captured by the second term of the product. The induced change in z, in turn, influences y. This is captured by the first term.

If x_i has an additional direct effect on y, one gets a function $y = \tilde{f}(x_1, \ldots x_{i-1}, x_i, x_{i+1}, x_n, z)$. The derivative with respect to x_i must, therefore, also include this direct effect:

$$\frac{\partial f(a_1, \ldots, a_n)}{\partial x_i} = \frac{\partial \tilde{f}(a_1, \ldots, a_n, z)}{\partial x_i} + \frac{\partial \tilde{f}(a_1, \ldots, a_n, z)}{\partial z} \cdot \frac{\partial g(a_i)}{\partial x_i}.$$

A frequent application of partial derivatives is to estimate the effect of a discrete change, or simultaneous changes, in the explanatory variables on the explained variable (e.g., because only discrete changes can be measured empirically). This can be done by means of the total differential.

Total Differential Take $f(x_1, \ldots, x_n)$ and consider a simultaneous change in the explanatory variables dx_i. Then, the total effect is given as

$$df(a_1, \ldots, a_n) = \frac{\partial f(a_1, \ldots, a_n)}{\partial x_1} dx_1 + \ldots + \frac{\partial f(a_1, \ldots, a_n)}{\partial x_n} dx_n.$$

In order to understand this expression, assume that all changes are zero except for x_i. Then, the total differential simplifies to

$$df(a_1, \ldots, a_n) = \frac{\partial f(a_1, \ldots, a_n)}{\partial x_i} dx_i.$$

The right-hand side is a *linear* function of x_i, because the partial derivative is evaluated at a given point $a_1, \ldots, a_n$. However, this means that one can estimate the effect of an explanatory variable on y by means of a linear approximation, which is sometimes also called the *linear form*. Figure 17.1 illustrates this method.

Graphically speaking, the slope of the tangent line is equal to the partial derivative of the function at a given point. As can be seen, for discrete changes in x_i there is a gap between the true effect on y and the effect that is measured by the linear approximation: the linear approximation overestimates the true effect, in this example. However, if dx_i becomes very small, the "error" becomes arbitrarily small and vanishes in the limit for an infinitesimal change in x_i. One of the reasons why linear approximations are popular is that linear systems can be analyzed by means of linear algebra, which is powerful and simplifies the analysis considerably.

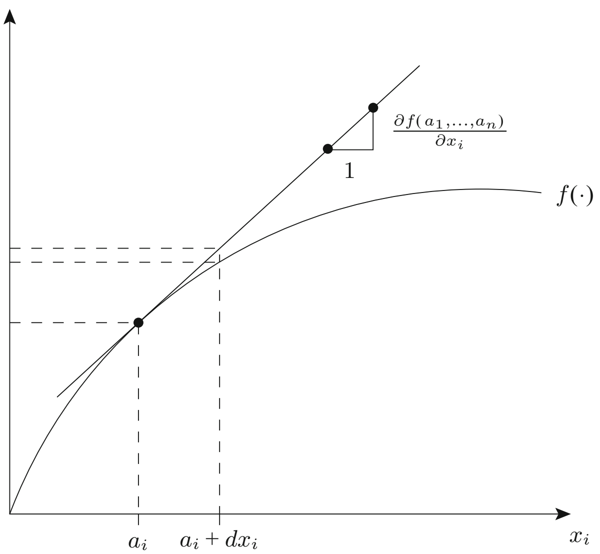


Fig. 17.1 Linear approximation of a function at a point a_i

The following will reveal how the above rules can be used to determine derivatives of specific functions.

Example 1 Let $f(x_1, x_2) = x_1^2 + x_2$; then

$$\frac{\partial f(x_1, x_2)}{\partial x_1} = 2 \cdot x_1, \quad \frac{\partial f(x_1, x_2)}{\partial x_2} = 1.$$

The additive structure of the function implies that the different variables do not influence each other. As a consequence, the partial derivatives are independent of the other variable.

Example 2 Let $f(x_1, x_2) = x_1^2 \cdot x_2$; then

$$\frac{\partial f(x_1, x_2)}{\partial x_1} = 2 \cdot x_1 \cdot x_2, \quad \frac{\partial f(x_1, x_2)}{\partial x_2} = x_1^2.$$

The multiplicative structure implies that the partial derivatives, with respect to one variable, also depend on the other variable. However, in order to determine the derivative, the other variable can be treated as a number, because it is, in fact, a number, given that the partial derivative is an exercise in comparative statics (which means that all other variables are treated as constants).

Example 3 Let $f(x_1, x_2) = x_1^2/x_2$; then

$$\frac{\partial f(x_1, x_2)}{\partial x_1} = \frac{2 \cdot x_1 \cdot x_2 - x_1^2 \cdot 0}{(x_2)^2} = \frac{2 \cdot x_1}{x_2},$$

because of the quotient rule.

All other rules that one has learned in school remain applicable to this generalized problem. If, for example, the problem is to determine the derivative of $f(x) = 10 \cdot \ln[x]$, with respect to x, it follows that $f'(x) = 10/x$. One can use this function to generalize the rules in the direction of functions with more than one variable. In order to do so, recognize that the above function has multiple variables already, because it is a function of x as well as 10, $f(x, 10)$, because 10 influences the result. Now, assume that one is not only interested in the partial derivative of this function at 10, but also at $9, 11, \ldots$. In this case, either one can determine the derivative for each case separately, or one can replace the specific number 10 by a dummy variable. If one redefines x by x_1 and calls the dummy variable x_2, one ends up with a new function $f(x_1, x_2) = x_2 \cdot \ln[x_1]$. However, now one has crossed the border from standard to *multivariate analysis*. The partial derivative of this function, with respect to x_1, can now be determined:

$$\frac{\partial f(x_1, x_2)}{\partial x_1} = \frac{x_2}{x_1}.$$

It is time for a quick plausibility check: if $x_2 = 10$, one gets $10/x_1$, which is reassuring. What one sees, from this example, is that one treats all the explanatory variables that stay constant in the same way as one has always treated numbers and the reason is that they are, in fact, numbers. The only difference is that they are written in an abstract way. In addition, one can, of course, also analyze the effect of a change of x_2 on y:

$$\frac{\partial f(x_1, x_2)}{\partial x_2} = \ln x_1.$$

17.3 Solution to Systems of Equations

Economists are interested in equilibria, because they tell them something about the logical consistency of the assumptions of a model. As already stated, an equilibrium exists, if there is a price such that supply equals demand. Supply and demand, however, are both functions, which implies that the previous chapters have implicitly talked about a property of mathematical objects (functions). If $x(p)$ and $y(p)$ are the market demand and market-supply functions, an equilibrium is a price p^*, such that $x(p^*) = y(p^*)$. One can, alternatively, rearrange this condition to get $x(p^*) - y(p^*) = 0$: excess demand has to be equal to zero. If one looks at the problem from this perspective, one can see that the economic problem of the existence of an equilibrium is equivalent to the mathematical problem of the existence of a root of a function, the excess-demand function $ED(p) := x(p) - y(p)$.

Most students will have touched the problem of the existence of roots in high school: a function has a maximum or minimum, if its first derivative is zero. The intermediate-value theorem is useful, in this respect, because it specifies sufficient conditions that guarantee the existence of a root of a function $ED(p)$: $ED(.)$'s domain has to be closed, $ED(.)$ has to be continuous, and at least two prices, p and p', exist, such that $ED(p) < 0 < ED(p')$.

In order to be able to analyze problems like the one above, one needs a little knowledge about how to solve functions. The above problem is very simple, because it only has one equation in one explanatory variable: $ED(p) = 0$. In a number of more realistic situations, the problem is more complex, however. Assume, for example, that there is not one, but two markets, with goods 1 and 2, and one wants to know if prices exist that equilibrate both markets simultaneously. The mathematical problem becomes

$$ED_1(p_1, p_2) = 0 \wedge ED_2(p_1, p_2) = 0,$$

with $ED_1(.)$, $ED_2(.)$ being the excess-demand functions for both markets, which are functions of both prices, p_1 and p_2. The mathematical problem is to find a solution to a system of two equations and two unknowns.

In reality, there are many more goods and services that are simultaneously traded in markets, such that one has to specify n markets with excess-demand functions and an equilibrium exists, if the system of n equations in n unknowns has a solution. This is a rather involved problem, which is why I restrict my attention to, at most, two equations and two unknowns and one also restricts one's attention to linear functions, most of the time in this book. Here, I denote the explanatory variables by x_1, x_2, the explained variables by y_1, y_2, and the causal mechanisms by $y_1 = f_1(x_1, x_2), y_2 = f_2(x_1, x_2)$.

Assume that one has to identify a pair of explanatory variables, x_1^* and x_2^*, that set both functions equal to zero, $f_1(x_1^*, x_2^*) = 0 \wedge f_2(x_1^*, x_2^*) = 0$. As can be conjectured from the intermediate-value theorem, it is not guaranteed that such a solution exists for general functions. However, if both equations are linear, one can use methods from *linear algebra* to identify the solution. Let

$$f_1(x_1, x_2) = a_1 + b_1 \cdot x_1 + c_1 \cdot x_2, \quad f_2(x_1, x_2) = a_2 + b_2 \cdot x_1 + c_2 \cdot x_2$$

be a linear system of equation with $a_1, b_1, c_1, a_2, b_2, c_2$ as the exogenous parameters of the equations. (a_1, a_2) are the intercepts and the other parameters measure the respective slopes. The problem of finding a zero is then given as

$$a_1 + b_1 \cdot x_1^* + c_1 \cdot x_2^* = 0 \wedge a_2 + b_2 \cdot x_1^* + c_2 \cdot x_2^* = 0.$$

This problem has a unique solution, if the two equations are not parallel:

$$x_1^* = \frac{a_1 \cdot c_2 - a_2 \cdot c_1}{b_2 \cdot c_1 - b_1 \cdot c_2}, \quad x_2^* = \frac{a_1 \cdot b_2 - a_2 \cdot b_1}{b_2 \cdot c_1 - b_1 \cdot c_2}.$$

These formulas give one the general solution to the problem. In order to make sure that the denominator does not become zero, one has to, in addition, assume that $b_2 \cdot c_1 - b_1 \cdot c_2 = 0$ is excluded. If one inserts specific numbers, one can see what the general solution implies.

One can calculate the above solution with a little effort by, for example, solving the first equation for x_1, which yields $x_1 = -a_1/b_1 - c_1/b_1 x_2$. This equation is an intermediate step that can be used to eliminate x_1 in the second equation, $a_2 + b_2 \cdot (-a_1/b_1 - c_1/b_1 x_2) + c_2 \cdot x_2 = 0$. Now, one is left with only one equation with one unknown variable that can be solved for x_2.

This approach comes to an end, if one is confronted with a problem with more than two variables and unknowns. In such a case, one can use techniques from matrix algebra to characterize a solution.

Another problem may exist, if the equations are not linear. It would be far beyond the scope of this textbook to dig deeper into the solution of systems of nonlinear equations.

17.4 Optimization Under Constraints

For a number of optimization problems one does not search for the unconstrained optimum of a function $f(x_1, \ldots, x_n)$ (the objective function), but for the optimum relative to certain constraints. As an example, consider a utility function with a point of satiation (the global maximum), as shown in Fig. 7.3d. Formally, such a function can, e.g., be described by the function $u(x_1, x_2) = x_1 - (x_1)^2 + x_2 - (x_2)^2$, whose indifference curves are shown in Fig. 17.2.

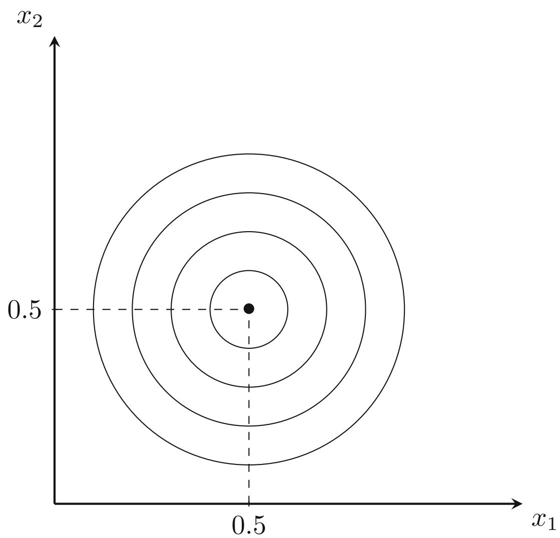
The unconstrained maximum of this function is at $x_1 = x_2 = 0.5$. If the set of admissible solutions is restricted to lie on the function $ax_1 + bx_2 = c$ (i.e., a linear constraint is introduced, which must lie "below" the global maximum), the global maximum is no longer attainable. Instead, the relative maximum now lies on the straight line drawn in Fig. 17.3.

Analogous considerations hold if the choice set is not constrained by a linear restriction, but by a general restriction of the form $g(x_1, \ldots, x_2) = c$. This is illustrated in Fig. 17.4.

17.4.1 Sufficient Conditions

We assume in the following that we want to solve an optimization problem with n variables $x_1, \ldots, x_n$. In order to determine the constrained optimum, we need to develop a method that ensures that we only search for solutions within the admissible subset defined by the constraint. Such a method is the *Lagrange method*.

Fig. 17.2 Global maximum



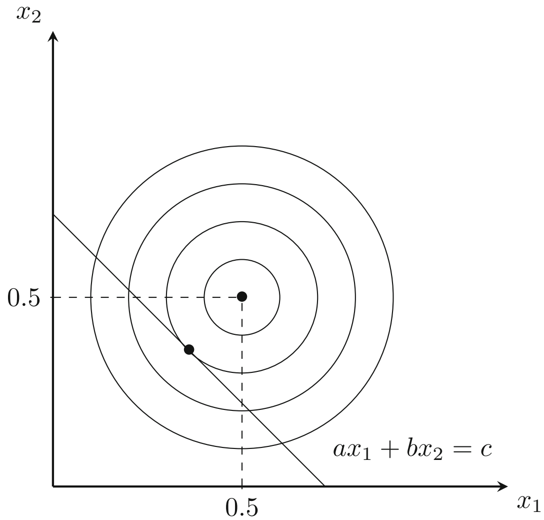


Fig. 17.3 Constrained maximum with linear constraint

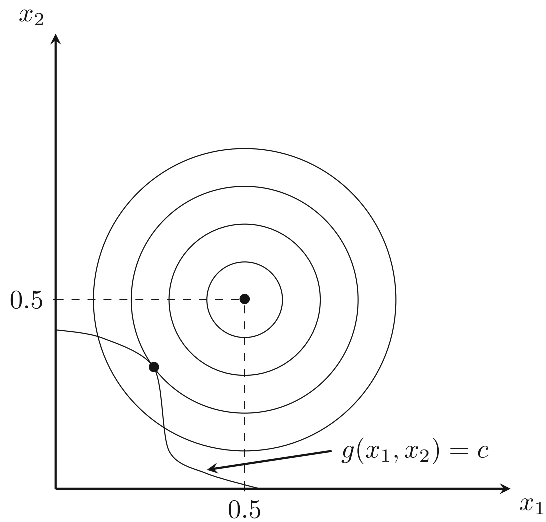


Fig. 17.4 Constrained maximum with nonlinear constraint

We assume here that the structure of the objective function and the constraint is such that there exists a unique maximum that can be determined using first-order conditions. To determine the optimum, we then proceed as follows:

1. One first rewrites the constraint such that $g(x_1, \ldots, x_n) = c$ reads $\hat{g}(x_1, \ldots, x_n, c) = g(x_1, \ldots, x_n) - c = 0$.

2. One then attaches this constraint to the function to be optimized, adding a so-called Lagrange parameter λ. This establishes the Lagrange function:

$$\begin{aligned}\mathcal{L}(x_1, \ldots, x_n, \lambda) &= f(x_1, \ldots, x_n) - \lambda(\hat{g}(x_1, \ldots, x_n, c)) \\ &= f(x_1, \ldots, x_n) - \lambda(g(x_1, \ldots, x_n) - c).\end{aligned}$$

3. Once the Lagrange function is set up, one determines its first-order conditions by determining the partial derivatives with respect to $x_1, \ldots, x_n$, and λ and setting them equal to zero:

$$\frac{\partial \mathcal{L}(x_1, \ldots, x_n)}{\partial x_i} = \frac{\partial f(x_1, \ldots, x_n)}{\partial x_i} - \lambda \cdot \frac{\partial g(x_1, \ldots, x_n)}{\partial x_i} = 0, \quad i = 1, \ldots, n,$$

$$\frac{\partial \mathcal{L}(x_1, \ldots, x_n)}{\partial \lambda} = g(x_1, \ldots, x_n) - c = 0.$$

   This gives a system of $n+1$ equations with $n+1$ endogenous variables. One can see the role of the Lagrange parameter in the last derivative: it ensures that the solution is compatible with the constraint $g(x_1, \ldots, x_n) - c = 0$.
4. The system of $n+1$ equations has to be solved with respect to the endogenous variables $x_1, \ldots, x_n, \lambda$, and we call this solution $x_1^*, \ldots, x_n^*, \lambda^*$. The general solution to this problem only allows us to derive the following property about the structure of the optimum:

$$\frac{\frac{\partial f(x_1, \ldots, x_n)}{\partial x_i}}{\frac{\partial f(x_1, \ldots, x_n)}{\partial x_j}} = \frac{\frac{\partial g(x_1, \ldots, x_n)}{\partial x_i}}{\frac{\partial g(x_1, \ldots, x_n)}{\partial x_j}} \quad \forall i, j = 1, \ldots, n, i \neq j.$$

   This condition states that in an optimum, the ratio of the partial derivatives of the objective function must equal the ratio of the partial derivatives of the restriction. Graphically speaking, this means that we have a point of tangency between the objective function and the constraint. However, if the objective function and the constraint are specified, a solution can in principle be explicitly determined.

   It may be unclear why this procedure maximizes the objective function $f(x_1, \ldots, x_n)$ under the constraint $g(x_1, \ldots, x_n) - c$. We can see this by substituting the solution $x_1^*, \ldots, x_n^*, \lambda^*$ into these functions,

$$\mathcal{L}(x_1^*, \ldots, x_n^*, \lambda^*) = f(x_1^*, \ldots, x_n^*) - \lambda^* \cdot (g(x_1^*, \ldots, x_n^*) - c).$$

   Since the solution was constructed such that $g(x_1^*, \ldots, x_n^*) - c = 0$, it follows that

$$\mathcal{L}(x_1^*, \ldots, x_n^*, \lambda^*) = f(x_1^*, \ldots, x_n^*).$$

   Hence, we have determined the maximum of the objective function.

17.4.2 Necessary Conditions

We know from optimization problems without constraints, $\max_x f(x)$, that first-order conditions $f'(x) = 0$ are merely sufficient, not necessary for a maximum or minimum of a function. In addition, the objective function must be strictly concave (maximum) or convex (minimum). This can be checked under certain conditions using the second derivatives of the objective function, and we get $f''(x) \leq 0$ for a maximum and $f''(x) \geq 0$ for a minimum. For optimization problems with multiple endogenous variables and with constraints, this test has to be generalized. Whether there is a maximum or a minimum is determined by the signs of the principal minors of the so-called *bordered Hessian matrix.*

The bordered Hessian matrix is a particular arrangement of the second derivatives of the Lagrangian function. In order to have a lean notation, we will use the following abbreviations. The first derivatives of the functions $\mathcal{L}$, f and g with respect to $x_i, i = 1, \ldots, n$ and λ are denoted by $\mathcal{L}_{x_i}, \mathcal{L}_{\lambda}$, f_{x_i}, f_{λ}, and g_{x_i}, g_{λ}, respectively. Analogously, the second derivatives are denoted as $x_j, j = 1, \ldots n$ $\mathcal{L}_{x_i x_j}$, $\mathcal{L}_{\lambda x_j}$, $f_{x_i x_j}$, $f_{\lambda x_j}$, and $g_{x_i x_j}$, $g_{\lambda x_j}$, λ $\mathcal{L}_{x_i \lambda}$, $\mathcal{L}_{\lambda\lambda}$, $f_{x_i \lambda}$, $f_{\lambda\lambda}$, $g_{x_i \lambda}$, $g_{\lambda\lambda}$. With this notation, the first-order conditions can also be written as follows:

$$\mathcal{L}_{x_i} = f_{x_i} - \lambda \cdot g_{x_i} = 0, \quad i = 1, \ldots, n,$$
$$\mathcal{L}_{\lambda} = g - c = 0.$$

This system of equations yields $(n+1) \cdot (n+1)$ second-order conditions, which are systematically denoted as the bordered Hessian matrix:

$$H(x_1, \ldots, x_n, \lambda) = \begin{pmatrix} \mathcal{L}_{\lambda\lambda} & \mathcal{L}_{\lambda x_1} & \ldots & \mathcal{L}_{\lambda x_n} \\ \mathcal{L}_{x_1\lambda} & \mathcal{L}_{x_1 x_1} & \ldots & \mathcal{L}_{x_1 x_n} \\ \ldots & \ldots & \ldots & \ldots \\ \mathcal{L}_{x_n\lambda} & \mathcal{L}_{x_n x_1} & \ldots & \mathcal{L}_{x_n x_n} \end{pmatrix} = \begin{pmatrix} 0 & g_{x_1} & \ldots & g_{x_n} \\ g_{x_1} & f_{x_1 x_1} - \lambda g_{x_1 x_1} & \ldots & f_{x_n x_1} - \lambda g_{x_n x_1} \\ \ldots & \ldots & \ldots & \ldots \\ g_{x_n} & f_{x_n x_1} - \lambda g_{x_1 x_1} & \ldots & f_{x_n x_n} - \lambda g_{x_n x_n} \end{pmatrix}.$$

The bordered Hessian matrix is square and mirror symmetric with respect to its main axis, $\mathcal{L}_{x_1 x_j} = \mathcal{L}_{x_j x_1}$, $\mathcal{L}_{x_i \lambda} = \mathcal{L}_{\lambda x_i}$. It can be split into submatrices

$$H_1 = \mathcal{L}_{\lambda\lambda}, H_2 = \begin{pmatrix} \mathcal{L}_{\lambda\lambda} & \mathcal{L}_{\lambda x_1} \\ \mathcal{L}_{x_1\lambda} & \mathcal{L}_{x_1 x_1} \end{pmatrix}, \ldots,$$

where the last submatrix H_{n+1} is identical to matrix H. For each of these submatrices one can then calculate its determinants that are called *principal minors*, $D_1, D_2, \ldots D_{n+1}$. The optimization problem characterizes a *maximum* if these determinants alternate in their signs in the following way: $D_1 \geq 0, D_2 \leq 0, D_3 \geq 0, \ldots$. It characterizes a *minimum* if these signs are all negative, $D_1 \leq 0, D_2 \leq 0, D_3 \leq 0, \ldots$.

17.5 Elasticities

The measurement and comparison of changes are very important in economics and market research. The so-called *elasticities* are a bread-and-butter concept with which everyone should be familiar. This subchapter will introduce the problems to which elasticities provide an answer and introduce the concept formally.

Assume one wants to know how demand $x(p)$ reacts to price changes. To be more specific, I will analyze the demand for bread and will assume that the demand function is linear, $x(p) = 100 - p$. Additionally, the price is in Swiss Francs and the quantity is in kilos.

An obvious candidate for the measurement of the effect of price changes is the partial derivative of the demand function:

$$\frac{dx}{dp} = x'(p) = -1.$$

This finding has a very straightforward interpretation: an increase in the price of bread by one Swiss Franc reduces the demand by one kilo.

This is a perfectly reasonable and informative statement and one could leave it at that. However, it has one disadvantage that limits its usefulness in practice: the instrument depends on the units in which one measures the dependent, as well as the independent, variable. Why is this a problem? Assume that one measures bread in grams instead of kilos. In this case, the demand function would be $x(p) = 100{,}000 - 1000 \cdot p$ and the partial derivative becomes

$$\frac{dx}{dp} = x'(p) = -1000.$$

This is, again, a perfectly reasonable number: an increase in the price of bread by one Swiss Franc reduces the demand by 1000 grams. However, without knowing the units of measurement, one cannot compare the two numbers and, at first glance, one could conclude that they are referring to completely different markets.

The same thing happens if one measures the price in Rappen instead of Franks. The demand function becomes $x(p) = 100 - 0.01 \cdot p$, and the first derivative is

$$\frac{dx}{dp} = x'(p) = -0.01;$$

an increase in the price of bread by 1 Rappen reduces the demand for bread by 0.01 kilos (or 10 grams).

This dependence on the units of measurement also limits the usefulness of the instrument, because it makes it difficult to compare changes between countries that use different currencies. However, it is a potentially interesting question to ask if Swiss customers react more or less strongly to price changes than, for example, the French customers. Nevertheless, even within a country, it may be interesting to understand if the demand for bread reacts more or less strongly to price changes than does the demand for smartphones and it is very hard to make the units of measurement for these two products commensurable.

This is why economists use a measure that is independent of the units of measurement. The basic idea is to focus on relative instead of absolute changes. The absolute change in demand is given by dx and the relative change can be constructed by dividing the absolute change by some reference level x^r:

$$\text{relative change in demand} = \frac{\text{absolute change in demand}}{\text{reference level of demand}} = \frac{dx}{x^r} = \frac{x - x^r}{x^r}.$$

The same can be done for price changes. Let dp be the price change and p^r the reference price; one gets

$$\text{relative change in price} = \frac{\text{absolute change in price}}{\text{reference level of price}} = \frac{dp}{p^r} = \frac{p - p^r}{p^r}.$$

The relative changes are independent of the units of measurement, because they cancel out: if the numerator is measured in, for example, kilos or Swiss Francs, the denominator is measured in kilos or Swiss Francs, as well. Relative changes can be transformed into percentage changes, by multiplying them by 100.

Now that the units of measurement have been eliminated, one can come back to the initial question of how to measure changes in demand that are caused by changes in prices. An *elasticity* relates the relative change of one variable (demand) to the relative change in another variable (price):

$$\text{price elasticity of demand} = \frac{\text{relative change in demand}}{\text{relative change in price}}$$

or, more formally:

$$\epsilon_p^x = \frac{dx/x}{dp/p} = \frac{dx}{dp} \cdot \frac{p}{x}.$$

This elasticity is called the *price elasticity of demand* and it measures the percentage change in demand that is caused by a 1% change in the price.

If one allows for infinitesimal changes in prices, one can use partial derivatives to characterize elasticities:

$$\epsilon_p^x = \frac{dx/x}{dp/p} = \frac{dx}{dp} \cdot \frac{p}{x} = \frac{\partial x}{\partial p} \cdot \frac{p}{x}.$$

The elasticity one gets for infinitesimal changes is also called *point elasticity*.

This determines one important elasticity, but the concept can also be used to determine changes in demand that are caused by changes in other explanatory variables, as well: for example, income levels or prices of other goods. Definitions

14.1–14.3 cover the most commonly used elasticities of demand. The following notation is used: the demand for good i is a function of the price of good i, p_i, as well as of the prices of other goods j, p_j, as well as income b.

▶ **Definition 17.1 Price Elasticity of Demand** The price elasticity of demand measures the percentage change in the demand for good i that is caused by a 1% change in the price of good i:

$$\epsilon_{p_i}^{x_i} = \frac{dx_i/x_i}{dp_i/p_i} = \frac{dx_i}{dp_i} \cdot \frac{p_i}{x_i} = \frac{\partial x_i}{\partial p_i} \cdot \frac{p_i}{x_i}.$$

▶ **Definition 17.2 Cross-Price Elasticity of Demand** The cross-price elasticity of demand measures the percentage change in the demand for good i that is caused by a 1% change in the price of good j:

$$\epsilon_{p_j}^{x_i} = \frac{dx_i/x_i}{dp_j/p_j} = \frac{dx_i}{dp_j} \cdot \frac{p_j}{x_i} = \frac{\partial x_i}{\partial p_j} \cdot \frac{p_j}{x_i}.$$

▶ **Definition 17.3 Income Elasticity of Demand** The income elasticity of demand measures the percentage change in the demand for good i that is caused by a 1% change in income:

$$\epsilon_{b}^{x_i} = \frac{dx_i/x_i}{db/b} = \frac{dx_i}{db} \cdot \frac{b}{x_i} = \frac{\partial x_i}{\partial b} \cdot \frac{b}{x_i}.$$

The same type of question can also be asked for changes in supply. I will focus on the most commonly used elasticities in the following definitions. Assume that supply y_i is a function of the price of the good p_i and of wages w and interest rates r.

▶ **Definition 17.4 Price Elasticity of Supply** The price elasticity of supply measures the percentage change in the supply of good i that is caused by a 1% change in its price:

$$\epsilon_{p_i}^{y_i} = \frac{dy_i/y_i}{dp_i/p_i} = \frac{dy_i}{dp_i} \cdot \frac{p_i}{y_i} = \frac{\partial y_i}{\partial p_i} \cdot \frac{p_i}{y_i}.$$

▶ **Definition 17.5 Wage Elasticity of Supply** The wage elasticity of supply measures the percentage change in the supply of good i that is caused by a 1% change in the wage level:

$$\epsilon_{w}^{y_i} = \frac{dy_i/y_i}{dw/w} = \frac{dy_i}{dw} \cdot \frac{w}{y_i} = \frac{\partial y_i}{\partial w} \cdot \frac{w}{y_i}.$$

Definition 17.6 Interest Elasticity of Supply The interest elasticity of supply measures the percentage change in the supply of good i that is caused by a 1% change in the interest rate:

$$\epsilon_r^{y_i} = \frac{dy_i/y_i}{dr/r} = \frac{dy_i}{dr} \cdot \frac{r}{y_i} = \frac{\partial y_i}{\partial r} \cdot \frac{r}{y_i}.$$

Elasticities can be positive or negative. Economists usually use the convention to talk about elasticities in absolute values (i.e., the modulus of the function), unless this is misleading. This convention allows them to use the following qualitative categories (expressed in absolute terms):

Definition 17.7 Elastic Reaction A variable reacts elastically to a change in some other variable, if the elasticity is larger than 1.

Definition 17.8 Inelastic Reaction A variable reacts inelastically to a change in some other variable, if the elasticity is smaller than 1.

Definition 17.9 Isoelastic Reaction A variable reacts isoelastically to a change in some other variable, if the elasticity is equal to 1.

Note that these properties are local measures. A function can be elastic at one point and inelastic at some other point.

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