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The costs and benefits of reinsurance

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Abstract

Purchasing reinsurance reduces insurers' insolvency risk by stabilising loss experience, increasing capacity, limiting liability on specific risks and/or protecting against catastrophes. Consequently, purchasing reinsurance should reduce capital costs. However, transferring risk to reinsurers is expensive. The cost of reinsurance for an insurer can be much larger than the actuarial price of the risk transferred. In this article, we analyse empirically the costs and the benefits of reinsurance for a sample of U.S. property–liability insurers. The results show that the purchase of reinsurance significantly increases insurers' costs but significantly reduces the volatility of the loss ratio. With purchasing reinsurance, insurers accept to pay higher costs of insurance production to reduce their underwriting risk.

Keywords Reinsurance · Insolvency risk · Risk management · Financial intermediation · Cost function · Panel data

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Introduction

Insurers issue policies and collect premiums against the promise of paying claims when accidents occur. For many types of insurance, the gap between the time of the accident and the time of the settlement could reach several years. If an insurer is defaulting during that period, policyholders could lose part of their claims. Therefore, the ultimate interest of any policyholder is the continued financial viability of the insurance company. Policyholders cannot diversify their risk by using many insurers and they do not perfectly monitor the managers of insurance companies because it is costly and requires special expertise. Furthermore, the potential for large catastrophic losses and the cyclical nature of the insurance business exacerbate the incentive conflict between different stakeholders (Cummins et al. 1991; Harrington and Niehaus 2000; Weiss 2007). Managing the underwriting residual risks through reinsurance purchasing could limit large losses, alleviate the insurance cycle and reduce agency costs. Hence, reinsurance reduces insolvency risk and strengthens the financial viability of insurance firms (Bernard 2013). It also gives them access to liquidity creation activities (Desjardins et al. 2020).

Most reinsurance demand studies consider that insurers purchase reinsurance for the same reasons that motivate firms in other industries to purchase insurance or to actively manage their risks: limiting the expected costs of financial distress, stabilising sources of funding, decreasing expected taxes by exploiting the convex structure of the tax code and gaining comparative advantages in real services production (Mayers and Smith 1990; Jean-Baptiste and Santomero 2000; Cole and McCullough 2006; Powell and Sommer 2007; Adams et al. 2008). Maximisation of expected utility also motivates reinsurance demand (Aase 2004; Kaluszka and Okolewski 2008). Insurers may use other financial risk management activities such as derivatives and securitisation (Cummins and Weiss 2009; Cummins and Barrieu 2013; Barrieu and Loubergé 2013).

Corporate finance theory suggests that firms purchase insurance to help solve underinvestment problems. Underinvestment problems occur when stockholders have incentives to forgo an investment with positive net present value because all the benefits from the investment will accrue to debt holders. Mayers and Smith (1987) and Garven and MacMinn (1993) show that firms could guarantee incentive compatibility by including a covenant in the debt contract requiring insurance coverage.

The incentive conflict between stockholders and policyholders is specific to stock insurers. With the mutual ownership structure no such conflict exists because policyholders are themselves the owners. However, mutual insurers purchase reinsurance in the same manner as stock insurers. The mutual ownership structure reduces insurers' access to the capital market. Therefore, mutuals have traditionally relied on retained earnings as the primary, if not sole, source of capital. Retaining sufficient capital could prevent the need for frequent variations in premiums and dampen the effects of extraordinary periodic underwriting losses, but could also create a free cash flow problem. Wells et al. (1995) find that mutual insurers have a greater level of free cash flow than stock insurers. Thus, mutual insurers purchase reinsurance as an alternative source of capital and to reduce the free cash flow problem.

Transferring risk to reinsurers is expensive. In an examination of the catastrophe reinsurance market, Froot (2001) finds that insurers pay several times the actuarial price of the risk transferred. The high price of reinsurance relative to expected losses could be explained by the combination of many factors affecting the reinsurance market equilibrium. The shortage of capital in reinsurance and the resulting capacity shortfall drive up the price of reinsurance, especially following large losses. The agency problems that reinsurers face, due to shareholder–manager incentive conflict and the lack of transparency, increase the costs of reinsurance capital and consequently increase reinsurance prices. Furthermore, it seems that reinsurers' market power has intensified over time with the increase in capital and market shares of large reinsurers (Cummins and Weiss 2000).

In this article, we estimate the effect of reinsurance purchasing on the costs and underwriting risks of U.S. property–liability insurers (554 insurers between 1995 and 2003). Firstly, to estimate insurers' cost function we consider ceded premiums to professional reinsurers as an output quality variable. Hence, for a given level of output, an insurer purchasing more reinsurance is considered as producing higher quality insurance services. Since purchasing reinsurance is costly, this same insurer will operate with higher costs. We specify a cost function with four outputs (long- and short-tail personal, long- and short-tail commercial), one output quality variable (reinsurance as measured by ceded premiums), two intermediate output variables (risk management and financial intermediation, as defined by Cummins et al. 2009), six input prices (administrative labour, agent labour, risk labour, material, debt and equity) and yearly dummy variables. Reinsurance, risk management and financial intermediation are treated as endogenous variables. The results show that reinsurance positively and significantly affects insurers' costs in our sample.

Secondly, to estimate the effect of reinsurance purchasing on insurers' underwriting risks we consider the growth rate of ceded premiums to non-affiliates as a potential determinant of the growth rate of the volatility of the loss ratio. We control for the growth in underwriting risk exposure by including the growth rate of premiums written in each type of business and the growth rate of business concentration and geographic concentration. The results show that purchasing more reinsurance significantly decreases the volatility of loss ratio.

The remainder of the paper is organised as follows. In the next section, we define the costs and benefits of reinsurance. The subsequent section proposes the econometric model and estimation method, followed by a section presenting the data and variables. The penultimate section analyses the main results and the final section concludes.

Defining the costs and benefits of reinsurance

Reinsurance purchasing is essentially a capital structure decision. Insurers seek to keep an optimal level of underwriting risk relative to their capitalisation level. In the case of large losses, equity holders are only liable to pay losses until the assets of the company have been depleted. If there are remaining losses to be paid, equity holders have the option of declaring bankruptcy and defaulting the remaining losses.

Phillips et al. (1998) find that policyholders consider the value of the insolvency option when deciding how much they are willing to pay for the insurance contract. To achieve their solvency target, insurers could increase their capitalisation by raising new capital or reduce the risk by transferring a part of it to reinsurers. Thus, reinsurance plays the role of a substitute for capital (Hoerger et al. 1990; Garven and Lamm-Tennant 2003; Lee and Lee 2012).

With reinsurance contracts, an insurer transfers premiums collected from customers to a reinsurer. In turn, the reinsurer accepts to bear a part of the risk assumed by the insurer. With proportional reinsurance, premiums and claims are shared between the insurer and the reinsurer in the proportion stipulated in the contractual agreement. In addition, the reinsurer pays a 'ceding commission' to the insurer to compensate it for the costs of underwriting the ceded business. However, the commission is also determined by the nature and composition of the insured business and by the underwriting results. In non-proportional reinsurance, the reinsurer assumes only the losses that exceed a certain amount, called the retention or priority. In calculating the price of the risk transferred, the reinsurer takes into account the loss experience during the previous years and the expected future losses according to the type of risks involved.

An insurer will accept to pay loading fees over the actuarial price of the risk transferred. The loading fees should correspond to the cost of the marginal capital needed to support the risk. Since the cost and the quantity of the capital needed to support the risk could be different for the insurer and the reinsurer, the transaction could take place without arbitrage. The reinsurance contract is generally negotiated and signed before the beginning of its effectiveness. At that time, the agreement is accepted by both sides and considered as a fair contract. Moreover, loading fees could include the price of the insurer's benefits from the reinsurer's product development skills and risk management expertise. The reinsurer plays an important role in assessing and underwriting risks, and in assisting insurers' efforts to handle claims efficiently (Baur et al. 2004).

An insurer is able to diversify underwriting risk when losses of individual policyholders are statistically independent. In insurance markets where risks are statistically independent, such as automobile collision insurance, the expected losses from a large pool of risks are highly predictable and the loss per claim is moderate. Hence, an insurer will provide coverage for a large number of policyholders without having to hold large amounts of costly equity capital relative to the quantity of insurance being underwritten (Doherty and Dionne 1993).

The problem is that statistical independence is violated when a megacatastrophe occurs. A single event can cause losses to many policyholders simultaneously. However, the risk of a catastrophe in the U.S., for instance, is independent from the risk of a catastrophe in other countries. This provides an economic motivation for a global reinsurance market. The U.S. insurance industry diversifies losses across the world to provide coverage and pay losses in areas such as Florida and California, which have high exposure to catastrophic risks and large concentrations of property values. Thus, with global diversification, the amount of capital needed by international reinsurers to support catastrophic risks is lower than the amount of capital needed by local insurers.

Insurance markets are subject to cycles, experiencing alternating phases of hard and soft markets (Cummins and Outreville 1987; Cummins et al. 1991; Harrington and Niehaus 2000; Weiss 2007). In a hard market, the supply of coverage is restricted and prices rise; in a soft market, coverage supply is plentiful and prices decline. Hard markets are usually triggered by capital depletions resulting from large event losses that cause insurers to reevaluate their pricing practices and reassess their exposure management. Following a large loss, it is difficult for insurers to raise capital at a relatively low cost. Thus, insurers have the choice between reducing coverage supply, increasing insolvency risk and purchasing more reinsurance. Reinsurance allows insurers to maintain client relationships without increasing insolvency risk. However, underwriting cycles characterise both insurers and reinsurers because both share the large unexpected losses (Weiss and Chung 2004; Meier and Outreville 2006). In soft markets, insurers take advantage of low reinsurance prices and high coverage supply to increase their underwriting capacity. In hard markets, when insurers have the largest need for reinsurance, reinsurers' capacities are also reduced and reinsurance prices rise. Actually, this could aggravate insurers' crises in hard markets (Berger et al. 1992).

In spite of its susceptibility to cycles and crises, the reinsurance market is a global market, and capital markets respond quickly to new capital needs of reinsurers. Following catastrophic losses in 2004–2005, the reinsurance industry raised about USD 30 billion in new capital in a multitude of ways: new equity capital for startup companies (USD 9.5 billion), seasoned equity issues (USD 12.5 billion), sidecars (USD 5 billion) and CAT bonds (USD 5 billion) (Cummins 2007). Because of this superior capacity to raise new capital quickly, the reinsurance market responded efficiently to large unexpected losses and reinsurance prices began to soften in late 2006 and early 2007 (Benfield 2007). Hence, reinsurance alleviates the underwriting cycle and increases the speed of primary insurers in exiting hard market periods.

Even if reinsurance prices exceed the actuarial price of the risk transferred, the reinsurance purchased could remain profitable if the benefits are higher than the costs. Reinsurance reduces insurers' insolvency risk by stabilising loss experience, increasing capacity, limiting liability on specific risks and/or protecting against catastrophes. In addition, the purchase of reinsurance reduces incentive conflict between different stakeholders and consequently reduces agency costs.[1]

[1] On the marginal cost and benefit considerations regarding optimal insurance–reinsurance decisions see the theoretical contribution of Lo (2016). This article formalises the value created by reinsurance with respect to the underwriting capacity of an insurer. It also considers reinsurers' default possibility and its influence on optimal insurance–reinsurance policies. Other theoretical contributions include Zhuang et al. (2016, 2017), Cheung and Lo (2017) and Lo (2017).

Econometric models and estimation methods

Cost analysis

Most of the existing studies account for the risk pooling and financial intermediation functions in estimating the cost function of insurers (Cummins and Weiss 2013). Cummins et al. (2009) also account for asset–liability management activities. They consider financial intermediation and asset–liability risk management as intermediate activities performed by the insurer. In this paper, we use the amount of reinsurance purchased as an output attribute variable associated with the level of output produced by an insurer.[2]

We assume that insurance services are produced using a vector of inputs and two intermediate outputs: asset–liability risk management and financial intermediation. For a given level of insurance services, the amount of inputs used by an insurer would be affected by the level of ceded insurance (reinsurance). Presumably, reinsurance is costly and an insurer purchasing more reinsurance will have higher costs for a given level of insurance services. In this framework, reinsurance plays the role of an output attribute or quality variable defining more accurately the output of an insurer. Therefore, we suppose that an insurer produces insurance services according to the following production function:

$$Y\left(Q,\ Re;R,\ F,\ X^I,\ X^R,\ X^F,\ T\right) = 0, \tag{1}$$

where Q is the quantity of insurance services produced; Re is the quantity of reinsurance purchased; R and F are the intermediate outputs (asset–liability risk management and financial intermediation activities); X^I, X^R and X^F are, respectively, the quantities of inputs used to produce insurance services, asset–liability risk management and financial intermediation; and T represents time (for simplicity, we omit the time and firm subscripts).

Under the assumption that insurance firms are cost minimisers and that Q, Re, R and F are predetermined, the restricted cost function associated with the technology described by (1) is:

$$CR = CR\left(Q,\ Re,\ R,\ F,\ P^I,\ P^R,\ P^F,\ T\right), \tag{2}$$

where CR are total costs, and P^I, P^R and P^F are, respectively, the prices of inputs X^I, X^R and X^F. The restricted cost function defined by (2) gives the minimum cost of producing the level of insurance services (Q) given the level of reinsurance (Re), asset–liability risk management (R) and financial intermediation (F) undertaken by the insurer, the different input prices (P^I, P^R and P^F) and time (T), which is included to take technical change into account.

Since the exact functional form of the restricted cost function defined by (2) is unknown, we use the well-known translog approximation, which is given by:

[2] See Dionne et al. (1998) for a discussion on the utilisation of output attributes in the context of transportation firms.

$$\ln CR_{it} = \alpha_i + \sum_v \beta_v^Q \ln Q_{vit} + \beta^{Re} \ln Re_{it} + \beta_i^R \ln R_{it} + \beta_i^F \ln F_{it} + \sum_s \beta_s^I \ln P_{sit}^I + \sum_j \beta_j^R \ln P_{jit}^R + \sum_k \beta_k^F \ln P_{kit}^F + \textit{second-order terms} + \sum_t \beta^t D_t + u_{it}, \quad (3)$$

where subscripts i and t represent, respectively, firms and time, and D_t are time dummy variables (the sample first year being the omitted category). The intercept (α_i) and the coefficients associated with the asset–liability risk management and financial intermediation variables (β_i^R and β_i^F) are firm specific. For the estimation, we treat these three parameters as random variables that follow a normal distribution with means α, β^R and β^F and variance–covariance Ω. Finally, u_{it} are i.i.d. random disturbances. Linear homogeneity of degree one in input prices is imposed prior to estimation by dividing total costs and all input prices but one by this last price. Finally, all continuous variables on the right-hand side of (3) are divided by their sample means (the point of approximation).

The reinsurance (*Re*), asset–liability risk management (*R*) and financial intermediation (*F*) variables are likely to be endogenous. Endogeneity is taken into account by first instrumenting these three variables. The set of instruments used includes the log of the insurance output and input prices, time dummy variables and other dummy variables measuring the insurer's characteristics: ownership structure, group membership, distribution system and head office state. Output and input prices are determined, respectively, on the insurance and labour markets and therefore are properly considered exogenous. Also, ownership structure, group membership, distribution system and head office state are, most of the time, once and for all decisions unaffected by the current situation of the firm (in fact, in our sample, these characteristics are constant over time for almost all firms). It is therefore very unlikely that unobserved variables affecting reinsurance, risk management and financial intermediation would also affect these variables. The predicted values of each endogenous variable are obtained from OLS regressions on the set of instruments and are substituted for the actual values in Eq. (3). Equation (3) is then estimated by restricted/residual maximum likelihood (REML), as implemented in the *Xtmixed* procedure of *Stata*. The proper test statistics of the different estimated parameters of the model are obtained from bootstrapped standard errors with 500 replications.

Benefits analysis

Even though insurers can reduce underwriting risk by diversification, significant residual risk remains, and insurers' claims payments are highly stochastic. Reinsurance is used to reduce insolvency risk by limiting large losses and alleviating the underwriting cycle. Here, we measure the benefits of reinsurance through its effect on the volatility of the loss ratio (the ratio of the present value of incurred losses-to-earned premiums). Thus, to assess the consequences of insurers' decisions to purchase more or less reinsurance on underwriting risk we estimate the following equation:

$$\Delta\sigma(lr)_{it} = \alpha + \beta_{\mathrm{Re}}\Delta\mathrm{Re}_{it} + \beta_X\Delta X_{it} + \beta_Z Z_{it} + \beta_t D_t + e_{it}, \tag{4}$$

where $\Delta\sigma(lr)_{it}$ is the growth rate of the volatility of loss ratio during the current year, ΔRe_{it} is the growth rate of the reinsurance purchased during the current year, ΔX_{it} is a vector of variables measuring the growth rate of insurers' exposure to underwriting risks, Z_{it} is a vector of insurers' specific control variables and D_t are time dummy variables.

To measure the growth rate in insurers' exposure to underwriting risks, we use the growth rate of premiums written in each type of business, the growth rate of business concentration, the growth rate of geographic concentration, and the growth rate of insurer size. Concentration is measured using Herfindahl indices based on net premiums written. As control variables, we use insurers' specific characteristics: ownership structure, group membership and distribution system.[3]

Data and variables

Data

The primary data for our analysis are taken from the regulatory annual statements filed by U.S. property–liability insurers with the National Association of Insurance Commissioners (NAIC). We include data for all property–liability insurance firms reporting to the NAIC for the period 1995 through 2003. However, we eliminate reporting firms showing negative surplus, assets, losses or expenses. Such firms are not viable operating entities but are retained in the database by the NAIC for regulatory purposes, such as the resolution of insolvencies. Because insurers formulate investment and risk management strategies at the overall corporate level, our analysis focuses on groups of insurers under common ownership and unaffiliated single insurance firms. Data for insurance groups are obtained by aggregating the data for affiliated insurance firms which are members of the group. Our analysis focuses on multiple line insurance firms reporting strictly positive outputs in each of the four lines of insurance business: long-tail personal, short-tail personal, long-tail commercial and short-tail commercial, where the length of the tail refers to the length of the claims payout period for the line of business. Also, insurers reporting non-strictly positive input prices, asset–liability risk or reinsurance are dropped.

Our final samples include 2966 observations (554 firms). Even though the restriction of strictly positive outputs in all four lines reduces the sample size, most of the firms eliminated are small, specialised firms. In fact, our sample accounts for about 84% of total industry premium volume in 2003.

[3] The Hausman test shows that the growth rate of reinsurance and the growth rate of size are endogenous. Thus, we first instrument these two variables using the same set of instruments as in the first stage of cost function estimation.

Cost analysis

Most previous studies estimating insurer cost functions consider only the net business assumed, excluding reinsurance quantity from the outputs and reinsurance costs from the total costs. In this paper, since we include reinsurance as an output attribute, we adjust the definition of total costs and the definition of quantities of outputs to reflect those of the total business written and not only outputs and costs associated with the net business assumed.

Total costs

The total costs of the net business assumed are generally computed as the sum of total expenses (net of loss adjustment expenses, which are part of the incurred loss outputs) and the cost of capital. To measure total costs related to the total business written we should add the costs of underwriting the ceded premiums to reinsurers. Because direct insurers issue insurance policies and assume all the attached administrative costs, they receive compensation in the form of commissions from reinsurers when they cede the premiums collected. Thus, the total costs (*Costs*) of business underwritten are the sum of total expenses, commissions received from reinsurers and the cost of capital.

The cost of capital is the sum of the cost of equity capital and the cost of debt capital.[4] The equity capital (*Equity*) is defined as the sum of policyholders' surplus and the redundant statutory liabilities (excess of statutory over statement reserves plus provision for reinsurance). The debt capital (*Debt*), i.e. liabilities, is defined as the sum of losses and loss adjustment expense reserves, unearned premium reserves and borrowed money.

Output quantities and output prices

The conventional measures of the quantities of outputs for insurers are incurred losses in the four principal property–liability insurance business lines: *Long-tail personal, Short-tail personal, Long-tail commercial* and *Short-tail commercial*. The output quantity for a given year is usually defined as the present value of incurred losses arising only from the exposure related to the business written during that year. Losses paid during that year that arise from exposures related to the business written during previous years are not included in that year's output quantity. To compute the present value of incurred losses we use the chain ladder parameters and the interest rates term structure obtained for the estimation of liabilities' effective duration.[5]

[4] The cost of equity capital is the average quantity of equity capital held by the insurer during the year multiplied by *Equity price*. The cost of debt capital is the average quantity of debt capital held by the insurer during the year multiplied by *Debt price*. Equity price and debt price are defined in the main text.

[5] The chain ladder method is a widely accepted actuarial technique for measuring loss payout patterns. See Taylor (2000).

To be consistent with our approach of accounting for reinsurance, we measure the output associated with the total business written by the insurer rather than the output of the net business assumed only. Thus, incurred losses associated with the premiums ceded to non-affiliated insurers are included in the total output produced by direct insurers.

Output prices are calculated as the difference between premiums earned and the output quantity expressed as a ratio to the output quantity: $\textit{Output price}_{\mathrm{ikt}} = [\textit{Premium}_{\mathrm{ikt}} - Q_{\mathrm{ikt}}]/Q_{\mathrm{ikt}}$, where *Premium* is premium earned, Q is the output quantity and subscripts i, k and t refer to insurer i, output k and year t, respectively. Thus, for each insurer we obtain four different prices: *Price of long-tail personal, Price of short-tail personal, Price of long-tail commercial* and *Price of short-tail commercial*.

Reinsurance

The quantity of reinsurance purchased is an attribute of the output produced by direct insurers. All else being equal, insurers purchasing more reinsurance are assumed to have lower insolvency risk. Reinsurance reduces the insolvency risk of direct insurers by stabilising their loss experience, limiting their liabilities and protecting against catastrophes. The most common measure of the quantity of reinsurance purchased is *Premiums ceded to non-affiliates*. However, since larger insurers produce more outputs, they can purchase a larger quantity of reinsurance compared to small insurers without ceding a higher proportion of the premiums written. Reinsurance demand studies show that larger insurers cede a lower proportion of premiums written compared to smaller insurers (Mayers and Smith 1990; Cole and McCullough 2006). In our analysis, we also use the share of written premiums that is ceded to non-affiliate insurers (*Share ceded to non-affiliates*) as an alternative measure of reinsurance.

Intermediate outputs

The first intermediate function we consider is financial intermediation. The insurer receives the premium payments from policyholders at the beginning of the period. When a claim occurs, the insurer pays the claim amount at some time in the future. The period between the date of claim occurrence and the date of claim payment depends on the type of insurance policy. Financial intermediation activities involve investing the amount of premiums received until the claim is paid. We measure the quantity of financial intermediation activities by the value of total assets under management, which is equal to invested assets (*Invested Assets*). This measure of intermediate output has been used in several insurance efficiency studies (Cummins and Weiss 2000) and is equivalent to measures used in banks' efficiency studies under the intermediation approach (Berger and Humphrey 1997).

The second intermediate function is risk management (Cummins et al. 2009). During the 1995–2003 period, U.S. property–liability insurers invested, on average, 62% in bonds, 14% in common stocks, 2% in preferred stocks and 20% in cash and short-term investments. Thus, the two main risks that affect the value of assets of property–liability insurers are interest rate risk and credit risk. In this study we focus on interest rate risk.

Reducing an insurer's financial risk could create value by reducing the market discount in insurance premiums for insolvency risk, among other things. As a result, managing the impact of interest rate movements on both assets and liabilities is crucial for insurers (Staking and Babbel 1995; Santomero and Babbel 1997). We use the dollar duration of the surplus (*Asset–liability risk*) as a proxy for the quantity of output associated with risk management activities.[6] The dollar duration of the surplus is defined as: $SD_S = A\ D_A - PV(L)\ D_L$, where D_S is the duration of surplus, D_A is the duration of assets, D_L is the effective duration of liabilities, A is the market value of invested assets and $PV(L)$ is the present value of liabilities. The surplus of the firm is immunised ($D_S = 0$) when the effect of the interest rate changes on assets is equal to the effect of interest rate changes on liabilities. We do not assume that nil duration of surplus is optimal for insurers. The dollar duration of the surplus is a measure of the quantity of risk that is left after the insurer conducts risk management activities. Rather, we assume that increased insurer risk management activities imply a smaller dollar surplus duration, which contributes to increasing the insurer's added value for policyholders.[7]

Variable inputs

Insurers use three primary inputs: labour, materials and business services, and capital. In order to better measure the effects of risk management activities, we utilise three labour inputs: administrative labour services, agent labour services and risk management labour services. Prior insurance efficiency papers have lumped administrative and risk management labour together into a single category. Separating administrative and risk management labour allows us to measure variations in the intensity of risk management across insurers. The other inputs, which are standard in insurance analyses, are materials and business services, debt capital and equity capital. Administrative labour and materials/business services are shared by insurance, risk management and financial intermediation activities and, therefore, prices are the same for these activities. Agent labour services are only used for insurance activities. Risk management labour services are used only for the risk management activities. Debt capital and equity capital are inputs needed for financial management and also to support the insurance activities through their impact on insolvency risk.

The price of administrative labour services (*Administrative labour*) is the average weekly wage in the U.S. state where the head office of the insurer is located for *SIC* code 6331-Fire, Marine, and Casualty Insurers. The price of agent labour services (*Agent labour*) is a weighted average of the average weekly wages in each U.S. state where the insurer operates for *SIC* code 6411-Insurance agents and brokers. In that case, the weight is the share of premiums written in each state by the insurance firm.

[6] Surplus is the term used for the book-value of equity capital in the insurance industry.

[7] See Cummins et al. (2009) for details on the computation of the dollar duration of the surplus.

The price of risk management input (*Risk labour*) is the average weekly wage in each U.S. state where the head office of the insurer is located for the North American Industry Classification System (*NAICS*) code 52392-Portfolio management. The price of materials/business services (*Business labour*) is the average weekly wage in the U.S. state where the head office is located for *SIC* code 7300-Business services. The *SIC* and *NAICS* average weekly wages used to compute prices are obtained from the U.S. Bureau of Labor Statistics.

The price associated with debt capital (*Debt price*) is defined as the required return by policyholders. This required return is a function of the credit quality of the insurer and the expected waiting time between the occurrence of the accident and the payment of the claim. We compute *Debt price* for each insurer as the annualised interest rate equivalent to the rate on the term structure corresponding to the firm's credit quality and with maturity equal to the effective duration of the insurer's liabilities. This produces a different price for each insurer, which varies by credit quality and effective duration of liability.[8]

The price associated with equity capital (*Equity price*) is defined as the required return by equity holders. We use the Fama–French three-factor model to estimate the required returns for listed insurers on financial markets.[9] We assume that listed and unlisted insurers that have the same credit quality also have the same required return on equity. In other words, we categorise insurers by debt quality and take an average within each debt rating of the Fama–French cost of capital for the listed insurers.

Control variables

Yearly dummy variables (*Year96–Year03*) are used to take time into account. Also, another set of dummy variables is used to account for insurer characteristics. The *Stock ownership* dummy is equal to 1 for stock insurers and 0 otherwise. The *Group* dummy is equal to 1 if the insurer is an insurance group and 0 otherwise. The *Distribution* dummy is equal to 1 if the insurer uses independent agents and 0 otherwise and the *State*(s) dummy equals 1 if the head office of the insurer is in state s. The omitted state is New York.

Benefits analysis

To assess the benefits of reinsurance purchasing we estimate Eq. (4). The dependent variable in Eq. (4) is the *Growth rate of the volatility of the loss ratio*. The loss ratio is defined as the ratio of the present value of incurred losses to premiums earned during the same year. It is measured as: $\Delta\sigma(lr)_{it} = (\sigma(lr)_{it} - \sigma(lr)_{i,t-1})/\sigma(lr)_{i,t-1}$, where $\sigma(lr)_{it}$ is the volatility of the loss ratio including current year t and $\sigma(lr)_{i,t-1}$ is the

[8] The credit quality term structures are obtained from Bloomberg, and insurer credit quality is obtained from Best's Key Rating Guide (A.M. Best Co.).

[9] We split listed insurers into three groups based on their A.M. Best rating. For each year, we estimate the cost of equity capital for each group. The prices of the three Fama–French risk factors were obtained from Kenneth French's website.

volatility of the loss ratio excluding current year t. In other words: $\sigma(lr)^2_{it} = \frac{1}{n}\sum_{j=t-n}^{t}\left(lr_j - \overline{lr}\right)^2$ and $\sigma(lr)^2_{i,t-1} = \frac{1}{n}\sum_{j=t-n}^{t-1}\left(lr_j - \overline{lr}\right)^2$, where n is the number of historical observations used to calculate the volatility of the loss ratio. We use the historical data reported by insurers in Schedule P: Part 1 of the NAIC database that go up to the nine previous years. Hence, $\Delta\sigma(lr)_{it}$ is the relative change in the volatility of the loss ratio due only to the underwriting result of the current year.

Our main independent variable used to explain the change in the volatility of loss ratio is the *Growth rate in the amount of reinsurance purchased*, measured as $\Delta Re_{it} = \left(Re_{it} - Re_{i,t-1}\right)/Re_{i,t-1}$, where Re_{it} is defined as the premiums ceded to non-affiliates. As with the cost function estimation, we also use the share of premiums ceded to non-affiliates as an alternative measure of reinsurance as a robustness check.

To control for changes in insurers' exposure to underwriting risk, we use the growth rate of total premiums written in each type of business (short- and long-tail, personal and commercial). In addition, we control for the change in the level of diversification of underwriting activities. For that purpose, we use the *Growth rate in line concentration* and the *Growth rate in geographic concentration*. Line concentration is computed as the Herfindahl index of the percentage of premiums in each line of business written by the insurer, and geographic concentration is computed as the Herfindahl index of the percentage of premiums written in each state by the insurer. A higher Herfindahl index implies that the insurer is concentrated in fewer lines of business or in fewer states. Since large insurers are likely to be more diversified, we also use the *Growth rate in size*. We measure insurers' size as the natural logarithm of total assets.

We control for insurer-specific characteristics by including the *Stock ownership* dummy, *Group* dummy and *Distribution* dummy, as defined previously. Finally, we include yearly dummy variables (*Year96–Year03*) to take into account the effect of time.

Summary statistics

Summary statistics for all variables used in the cost function and reinsurance benefits estimation are presented in Table 1. Insurers ceded on average about USD 124 million/year of premiums to non-affiliated reinsurers, representing about 21% of total premiums written and assumed from non-affiliates during the period 1995–2003. The insurers in the sample produced more personal insurance than commercial insurance, and they produced more long-tail insurance than short-tail insurance. The average amount invested in financial assets is USD 1926 million, the average return required by policyholders is 6%, and the average required return by equity holders is 17%.

Table 1 also indicates that the average volatility of the loss ratio is 9%. The insurance firms are more likely to be organised as insurance groups and more likely to use independent agents to sell their policies. The number of stock insurers in the sample is almost equal to the number of mutuals. During the 1995–2003 period,

Table 1 Summary statistics: 1995–2003

Variable	Mean	Standard deviation
Premiums ceded to non-affiliates	124.15	448.54
Total premiums ceded	624.42	2485.29
Share ceded to non-affiliates	0.21	0.18
Premiums ceded to total premiums	0.32	0.20
Invested assets	1926.00	6758.46
Asset–liability risk	18,116.37	73,846.93
Long-tail personal outputs	221.30	1090.78
Short-tail personal outputs	99.62	501.45
Long-tail commercial outputs	225.94	731.54
Short-tail commercial outputs	60.40	191.40
Price of long-tail personal	0.41	0.66
Price of short-tail personal	0.53	0.96
Price of long-tail commercial	1.30	7.66
Price of short-tail commercial	0.89	2.59
Administrative labour	945.33	170.26
Agent labour	800.99	150.46
Risk labour	2050.42	1091.83
Material/business labour	609.43	194.60
Debt price	0.06	0.02
Equity price	0.17	0.06
Equity	984.52	3930.24
Debt	1310.10	4131.37
Total costs	499.25	1637.21
Volatility of loss ratio	0.0926	0.0844
Size	19.40	2.11
Long-tail personal premiums	323.38	1541.18
Short-tail personal premiums	158.18	751.04
Long-tail commercial premiums	351.08	1158.61
Short-tail commercial premiums	117.93	377.89
Line concentration	0.31	0.15
Geographic concentration	0.49	0.38
Group dummy	0.68	0.47
Stock ownership dummy	0.51	0.50
Distribution dummy	0.67	0.47
Number of observations	2966	
Number of firms	554	

Quantities of intermediate outputs, outputs and reinsurance are in USD million (real 1995 dollars). Equity, debt, total costs and premiums are in USD millions (current dollars)

Table 2 Results from first-stage regressions for cost function estimation

Variable	Asset–liability risk		Invested assets		Ceded premiums to non-affiliates	
	Estimate	*t*-ratio	Estimate	*t*-ratio	Estimate	*t*-ratio
Intercept	− 3.4016	− 17.23	− 2.7299	− 15.71	− 2.7429	− 15.90
Price of long-tail personal	0.0506	2.78	0.0322	2.01	-0.0185	− 1.17
Price of short-tail personal	0.1052	4.94	0.1079	5.76	0.0748	4.02
Price of long-tail commercial	0.0281	1.74	0.0143	1.01	0.0188	1.34
Price of short-tail commercial	0.0883	3.93	0.0713	3.60	0.0535	2.72
Price of administrative labour	0.6180	0.74	0.4953	0.68	0.4791	0.66
Price of agent labour	0.5672	1.33	0.9392	2.49	− 0.6901	− 1.85
Price of risk labour	− 0.3141	− 1.22	− 0.0942	− 0.41	0.3772	1.67
Price of material/business labour	0.7130	1.40	0.9458	2.11	1.4515	3.26
Debt price	1.5549	3.95	2.1048	6.07	1.0641	3.09
Equity price	− 0.6351	− 3.09	− 0.5657	− 3.12	0.1125	0.63
Distribution dummy	− 0.9103	− 12.40	− 0.8152	− 12.61	− 0.3184	− 4.96
Stock ownership dummy	− 0.0379	− 0.52	0.0987	1.54	0.3479	5.47
Group dummy	2.6431	35.83	2.3554	36.26	1.9487	30.22
Number of observations	2966		2966		2966	
Number of insurers	554		554		554	
Adjusted R^2	0.4868		0.5054		0.3820	

insurers increased, on average, the volume of premiums written in each type of business and the average volatility of the loss ratio also increased; at the same time, they increased, on average, their reinsurance purchases, their business diversification and their geographical diversification.

Empirical results

Cost analysis

Table 2 presents the estimation results for the first stage regressions of the endogenous variables.[10] The adjusted R^2 for *Asset–liability risk* (0.48), *Invested assets* (0.50) and *Premiums ceded to non-affiliates* (0.38) are relatively high. Several coefficients associated with the instruments are statistically significant. Some interesting results show up from these regressions. For instance, insurer groups have significantly higher *Asset–liability risk*, *Invested assets* and *Premiums ceded to non-affiliates* than unaffiliated single insurers. This is consistent with insurance groups being larger and more sophisticated than unaffiliated single insurers. Insurers that use

[10] The Hausman general test shows that reinsurance, asset–liability risk and financial intermediation variables are endogenous in the cost function specification described by Eq. (3).

Table 3 Cost function estimates (Eq. 3)

	Model 1		Model 2		Model 3	
	Estimate	*t*-ratio	Estimate	*t*-ratio	Estimate	*t*-ratio
Intercept	13.3993	212.00	13.5267	182.61	13.7071	116.20
Financial intermediation	−0.5793	−4.95	−0.7538	−4.81	−0.5207	−2.60
Asset–liability risk	0.7790	7.19	0.8673	6.72	0.8549	4.16
Reinsurance			0.1696	2.75	0.3482	2.64
Long-tail personal	0.2338	15.04	0.2157	13.61	0.1920	9.95
Short-tail personal	0.0837	5.52	0.0905	5.92	0.1024	5.76
Long-tail commercial	0.2586	23.32	0.2600	22.75	0.2626	18.56
Short-tail commercial	0.1207	8.94	0.1309	9.47	0.1315	7.40
Agent labour	0.4643	2.99	0.8499	4.96	1.3033	5.13
Risk labour	0.1466	2.99	0.1208	2.30	0.1052	1.56
Business labour	0.0641	0.70	−0.0565	−0.57	−0.0207	−0.16
Debt price	0.0945	1.24	0.1499	1.92	0.0937	1.11
Equity price	0.3870	10.54	0.3285	8.22	0.3970	8.43
Year96	−0.1055	−8.62	−0.0947	−7.56	−0.0967	−7.70
Year97	−0.0331	−2.45	−0.0214	−1.55	−0.0320	−2.36
Year98	−0.0951	−4.73	−0.0688	−3.21	−0.0870	−4.22
Year99	0.0018	0.08	−0.0016	−0.07	−0.0033	−0.15
Year00	−0.0431	−1.83	−0.0398	−1.69	−0.0449	−1.91
Year01	−0.0618	−1.24	−0.0355	−0.71	−0.0419	−0.84
Year02	0.0418	0.56	0.0286	0.39	0.0435	0.59
Year03	0.2495	2.64	0.1983	2.11	0.2411	2.57
Number of observations	2966		2966		2966	
Number of insurers	554		554		554	
−2 Log likelihood	−189		−183.6		−183.8	

Model 1: Specified without reinsurance

Model 2: Specified with reinsurance defined as premiums ceded to non-affiliates

Model 3: Specified with reinsurance defined as share of premiums ceded to non-affiliates

independent agents have lower *Asset–liability risk*, lower *Invested assets* and less *Premiums ceded to non-affiliates* than direct writer insurers. Thus, insurers that use independent agents are more active in asset–liability management but less active in the reinsurance market than insurers using direct marketing or exclusive agents.

Table 2 also shows that stock insurers purchase significantly more reinsurance than mutual insurers. In the prior literature, empirical results on the effect of organisational form on reinsurance demand are mixed. Mayers and Smith (1990) find that mutual insurers utilise more reinsurance than stock insurers. On the other hand, Garven and Lamm-Tennant (2003) find no significant difference, whereas Cole and McCullough (2006) find that stock insurers purchase more reinsurance than mutuals. These differences may be due to the measure of reinsurance purchasing used or the time period examined. Our empirical results show that stock insurers purchase more reinsurance from non-affiliated insurers than mutual insurers. This finding is expected given the importance of stockholder–policyholder incentive conflicts among stock insurers and the greater involvement of stock insurers in complex lines of business.[11]

Table 3 presents the results of the estimation of the cost function, as specified in Eq. (3), with random intercept and random coefficients associated with the risk management and financial intermediation variables. Model 1 is specified with *Invested assets* and *Asset–liability risk* but without a reinsurance variable, Model 2 includes a reinsurance variable defined as the quantity of *Premiums ceded to non-affiliates*, and Model 3 is specified with a reinsurance variable defined as *Share ceded to non-affiliates*. The inclusion of reinsurance purchasing as a quality variable enhances the cost function specification and allows it to account for the level of underwriting risk being covered by professional reinsurers.

The results for Model 1 show that the coefficient for *Invested assets* is negative and significant at the 1% level. A negative coefficient means that the financial intermediation activities decrease the insurance activity costs. The coefficient for *Asset–liability risk* is positive and also significant at the 1% level. Thus, insurers with higher surplus durations or lower risk management have higher insolvency risk and higher insurance costs, primarily due to higher costs of debt and equity capital. The results for financial intermediation and risk management are in line with those found by Cummins et al. (2009).

The results of Model 2 show that the coefficient associated with *Premiums ceded to non-affiliates* is positive and significant at the 1% level. A positive coefficient means that insurers ceding more premiums to non-affiliated insurers have higher insurance costs. This result confirms that reinsurance is costly, as it increases the cost of producing insurance services. The results for Model 2 show that the coefficient associated with *Asset–liability risk* is positive and statistically significant at the 1% level, and the coefficient for *Invested assets* is negative and statistically significant at the 1% level.

The results obtained for Model 3 show that the coefficient associated with the *Share ceded to non-affiliates* is positive and significant at the 1% level. Thus, even after controlling for the quantity of premiums written and assumed, ceding premiums to non-affiliated insurers increases the total costs incurred by direct insurers. The results for *Invested assets* and *Asset–liability risk* remain significant, with the same signs as in Models 1 and 2.

Benefits analysis

Table 4 presents the estimation results for the first stage regressions of the endogenous variables in the volatility of the loss ratio specification described by Eq. (4).

[11] Head office state dummy variables control for the effect of state insurance regulations. Regulation could limit managerial discretion in investment and risk management decisions. Many of these dummy variables are statistically significant.

Table 4 Results from first-stage regressions for volatility of loss ratio estimation

Variable	Growth rate of size (log of total assets)		Growth rate of premiums ceded	
	Estimate	*t*-ratio	Estimate	*t*-ratio
Intercept	0.01406	2.45	6.24959	1.65
Price of long-tail personal	0.00057	2.16	0.29511	1.70
Price of short-tail personal	−0.00010	−0.56	−0.05795	−0.48
Price of long-tail commercial	0.00002	0.89	0.00097	0.07
Price of short-tail commercial	0.00013	1.95	0.00283	0.06
Price of administrative labour	−0.00001	−2.43	0.00056	0.20
Price of agent labour	−0.00001	−2.42	−0.00376	−2.13
Price of risk labour	0.00000	3.49	0.00018	0.57
Price of material/business labour	0.00000	0.94	0.00205	0.94
Debt price	0.06513	1.11	−54.01708	−1.39
Equity price	−0.02328	−3.84	−4.25408	−1.06
Distribution dummy	−0.00065	−1.66	−0.41769	−1.61
Stock ownership dummy	0.00113	2.85	0.47825	1.83
Group dummy	−0.00137	−3.40	0.09660	0.36
Number of observations	2966		2966	
Number of insurers	554		554	
Adjusted R^2	0.0432		0.0157	

The results from the Hausman tests show that endogeneity of the growth rate of insurers' size and the growth rate of reinsurance is not rejected.

Table 5 presents the results of the estimation of reinsurance benefits, as specified in Eq. (4). Model 1 is specified with a reinsurance variable defined as the *Growth rate of premiums ceded to non-affiliates*, and Model 2 is specified with a reinsurance variable defined as the *Growth rate of share of premiums ceded to non-affiliates*.

The results for Model 1 show that the coefficient associated with *Growth rate of premiums ceded to non-affiliates* is negative and statistically significant at the 1% level. Thus, ceding more premiums to non-affiliated insurers significantly decreases the volatility of the loss ratio. This result confirms that reinsurance purchasing stabilises loss experience. The results obtained with Model 1 also show that writing more premiums or increasing the diversification of underwriting activities does not significantly affect the volatility of the loss ratio. However, group insurers and mutual insurers have significantly higher growth rates of loss ratio volatility.

The results obtained for Model 2 show that the coefficient associated with the *Growth rate of share of premiums ceded to non-affiliates* is negative and statistically significant at the 5% level. Hence, ceding a larger share of written premiums to non-affiliated insurers significantly reduces the volatility of the loss ratio. The results for the other variables are qualitatively the same as those obtained with Model 1, except for the coefficient associated with the growth rate of size, which becomes statistically significant. Increasing insurer size significantly reduces the growth rate of the volatility of the loss ratio.

Table 5 Volatility of loss ratio estimates (Eq. 4)

	Model 1		Model 2	
	Estimate	*t*-ratio	Estimate	*t*-ratio
Intercept	0.027180	2.10	0.033900	2.59
Growth rate of reinsurance	−0.013020	−2.62	−0.030140	−1.96
Growth rate of size	−1.989150	−1.23	−3.145200	−2.04
Growth rate of long-tail personal premiums	0.000006	0.35	0.000006	0.34
Growth rate of short-tail personal premiums	−0.000074	−0.83	−0.000066	−0.73
Growth rate of long-tail commercial premiums	0.001500	1.59	0.001470	1.56
Growth rate of short-tail commercial premiums	−0.000050	−0.60	−0.000051	−0.62
Growth rate of business concentration	−0.009420	−0.46	−0.011200	−0.55
Growth rate of geographic concentration	−0.011140	−1.01	−0.011510	−1.04
Group dummy	0.017260	2.80	0.014470	2.34
Stock ownership dummy	−0.016380	−2.73	−0.015820	−2.55
Distribution dummy	−0.000082	−0.01	0.001200	0.20
Year96	0.063030	5.91	0.060610	5.64
Year97	−0.011880	−1.11	−0.012460	−1.16
Year98	0.008500	0.77	0.005680	0.51
Year99	0.016990	1.26	0.005790	0.48
Year00	0.018480	1.47	0.015950	1.28
Year01	0.025860	2.34	0.024090	2.19
Year02	0.009520	0.86	0.008820	0.79
Year03	0.027500	2.44	0.028080	2.48
Number of observations	2966		2966	
Number of insurers	554		554	
Adjusted R^2	0.0309		0.0299	

Model 1: Specified with reinsurance defined as premiums ceded to non-affiliates

Model 2: Specified with reinsurance defined as share of premiums ceded to non-affiliates

Conclusion

Even though insurers can reduce underwriting risk significantly by diversification and risk management, significant residual risk remains and insurers' claim payments are highly stochastic. One of the most important tools for managing insurance claim risk is reinsurance. Reinsurance reduces insurers' insolvency risk by stabilising loss experience, increasing capacity, limiting liability on specific risks and/or protecting against catastrophes. In addition, reinsurance reduces the incentive conflict between the different stakeholders and, consequently, reduces agency costs. However, transferring risk to reinsurers is expensive. Reinsurance prices can be several times the actuarial price of the risk transferred (Froot 2001).

This article estimates the effects of reinsurance on insurers' costs and insurers' underwriting risk by analysing a sample of U.S. property–liability insurers over the 1995–2003 period. To estimate the effect of reinsurance on insurers' costs, we consider reinsurance as an output attribute of the insurance services produced, and we estimate a parametric cost function. To estimate the effect of reinsurance on insurers' underwriting risk, we consider the growth rate of reinsurance purchasing as a determinant of the growth rate of the volatility of the loss ratio, controlling for the growth of insurers' exposure to underwriting risk.

The empirical results clearly indicate that reinsurance significantly increases the costs of producing insurance services and significantly reduces the volatility of the loss ratio. These results are robust to the use of alternative reinsurance measures: the quantity of premiums ceded to non-affiliates and the share of total premiums that are ceded to non-affiliates. Thus, insurers purchasing reinsurance accept to pay higher costs for the production of insurance services to reduce their underwriting risk.

Our period of analysis covers the years 1995–2003 in the U.S. Climate risk was not an important issue for insurers during that period. Anderson and Gardiner (2008) assert that insurance availability and affordability are the major problems associated with climate risk. Born and Klimaszewski-Blettner (2013) show that some insurers tend to reduce their activities when they are subject to severe regulations or when they receive unanticipated large claims. This behaviour is less frequent for large insurers that are better diversified. Insurers and reinsurers alone cannot effectively reduce the social cost of climate risk. More coordination with governments is necessary to counter climatic events. Another potential failure of the traditional role of reinsurance is the missing link between sustainability and disaster resilience. Insurers and reinsurers must unify green and disaster resilience efforts more actively in sectors such as construction, agriculture and land use.

Mills (2009) analyses different mechanisms to improve the capacity of the insurance industry to cover insurable losses: new coverage products, a better understanding of climate change and the financing of activities intended to reduce climate risk. The government should act as a reinsurer of last resort to reduce bankruptcies associated with climate risk (see also Kunreuther 2018).

All these considerations were not taken into account in our analysis because we mostly concentrated on the private role of the reinsurance industry. Our basic framework, which introduces risk management (affordability) and financial intermediation (availability) in the study of reinsurance costs and benefits, should be reinforced by the presence of climate risk. An extension of our empirical analysis with new data certainly deserves to be included in the research agenda in the near future. The recent article by Drexler and Rosen (2020) is a good example of such research.

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