Does Reinsurance Need Reinsurers?

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Abstract

The reinsurance market is the secondary market for insurance risks. It has a very specific organization. Direct insurers do not trade risks with each other. They cede part of their primarily underwritten portfolios mainly to professional reinsurers with no direct business. This paper offers a model of equilibrium in reinsurance and capital markets where professional reinsurers arise naturally to monitor primary insurers. The interplay of financing and reinsurance decisions facing primary insurers is also explicitly modelled. The predictions are broadly in line with empirical evidence from the reinsurance market.

1 Introduction

The reinsurance market is the market in which direct insurance companies purchase covers for their primarily underwritten portfolios, or "cede" part of their risks according to reinsurance terminology. Reinsurance is an important feature of non life insurance business. Direct insurers have ceded business worth USD 103 billion in 1997. This corresponds to an average cession rate, or ceded premiums in terms of direct insurance premiums, of 14% (Swiss Re 1998)[1].

The reinsurance market has a very specific, "pyramidal", organization. The generic reinsurance deal involves two sorts of pure players, a primary or direct insurer and professional reinsurers. The primary insurer cedes all or part of the risks she underwrites on the primary market to the professional reinsurers whose purpose is to accept such secondary risks, but who do not carry out any direct business. This is not to deny that some risk transfer between direct insurers does also take place. But the bulk of reinsurance transactions comply with this pattern: According to Swiss Re (1998) estimations, the reinsurance business is dominated by specialized reinsurance companies. Professional reinsurers provide more than 80% of global reinsurance capacity, the top 4 providing around 30% of it.

The purpose of this paper is to develop a simple theory of reinsurance where this pyramidal organization arises endogenously.

[1] Global data on reinsurance are somewhat scarce, partly because of the over-the-counter nature of deals, and partly because it is difficult to disentangle actual risk transfers from internal reinsurance, aiming mainly at tax and regulatory arbitrage within insurance groups. These figures stem from the last study publicly released by Swiss Re, considered to be one of the most reliable sources within the industry.

1.1 Motivation

Economists have provided two theoretical frameworks to analyze reinsurance. The first one consists in viewing reinsurance through the lenses of optimal risk sharing among risk-averse agents. It has been pioneered by Borch (1962). Indeed, Borch used reinsurance terminology to write his seminal contribution to optimal risk sharing, and justified this choice as follows:

> "It is really suprising that economists have overlooked the fact that the [risk sharing] problem can be studied, almost under laboratory conditions, in the reinsurance market."

Surprisingly though, optimal risk sharing under complete information delivers very unsatisfactory predictions regarding the organization of reinsurance[2]. If optimal risk sharing among "risk averse" insurance companies was the primary driver for reinsurance, the pyramidal organization of the reinsurance market would be dramatically inefficient. Direct insurers would be better off pooling their primary risks, possibly after deductibles to account for moral hazard and adverse selection, and then take stakes in the pool in accordance with their appetites for risk. However, in practice:

(i) The extent of pooling is limited. Indeed, direct insurers cede 14% of their risks on average (no more than 3 or 4% for large groups). Thus it seems that direct insurers seek to cede as little risk as possible, and not to pool risks to the largest possible extent.

(ii) Direct insurers do not benefit directly from pooling. They use reinsurance mainly to reduce their exposure on their primary portfolio, but only

[2] This is of course not to deny that Borch contribution to economics of uncertainty was instrumental.

marginally to gain some exposure on other primary risks. Optimal mutualization takes place at the level of professional reinsurers only.

An empirical finding from Mayers and Smith (1990) confirms that diversification does not seem to be an important determinant of reinsurance demand. Within a sample of US insurance companies, they find that less diversified firms, either geographically or across business lines, demand less reinsurance. This does of course not support the view of reinsurance as a diversification device.

The second and more recent theoretical framework to study reinsurance borrows from corporate hedging theory. The starting point is to note, like Mayers and Smith (1990), that the decision of an insurer to purchase reinsurance resembles the decision of any industrial firm to purchase insurance. Thus, the reasons why firms hedge and why insurers demand reinsurance may well be close. In particular, this strand of literature has put forward that, because of their expertise in risk management, reinsurers provide real services to primary insurers and are able to mitigate agency problems within insurance companies. The evidence from Mayers and Smith (1990) that less diversified insurers demand less reinsurance is consistent with this: Highly focused insurers are more likely to develop in-house the required expertise for their business.

This second approach seems more satisfactory than the optimal risk sharing view, but leaves important points unexplained. First, it does not offer a clear rationale for the role of specialized reinsurers and the pyramidal organization of the market. Second, it misses the dual nature of reinsurance. As emphasized by Garven and Lamm-Tennant (2003), reinsurance is both a risk management and financing decision. More precisely, a sufficiently high credit standing is a necessary input for insurance business, and capital and reinsurance are two (imperfect) substitutes which can be used to meet it[3]. This is documented by Garven and Lamm Tennant (2003), who find that reinsurance demand increases with financial leverage. Consistent with this dual nature of reinsurance is also the fact that in most prudential regulations (e.g. the US Risk Based Capital or European Solvency Margin), the minimum capital requirement is explicitly reduced by reinsurance purchase. More anecdotically, but interestingly, the so-called contracts of *bottomry*, which was the prevailing form of reinsurance in Italy in XIV^{th} century, consisted in an *ex ante* financing whose repayment was conditioned by the absence of loss. The risk management and financing sides of the operation were not disentangled.

This paper develops a simple theoretical model of equilibrium in the reinsurance market *(i)* which builds upon agency problems within insurance companies, *(ii)* where the pyramidal organization of the market with specialized reinsurers arise, and *(iii)* in which the relationship between capital structure and reinsurance decisions is explicitly modelled. The model is admittedly stylized but it is the first step, to my knowledge, towards a theory of reinsurance encompassing these three important features of the industry.

1.2 Main Intuition

The main intuition behind the model may be summarized as follows:

1. The representants of policyholders (large brokers, regulators) subject insurance companies to capital requirements.

[3]see Doherty and Tinic (1981) for a detailed analysis of this point.

2. Because of the expertise gap between risk managers and outside financiers, a moral hazard problem may prevent insurance companies from meeting such capital requirements with outside finance.

3. Some risk managers may mitigate this problem by becoming reinsurers and certifying risk management within primary insurance companies. Of course, they should be subject in turn to a moral hazard problem. But their certification may be credible if they take a sufficiently high stake in primary portfolios, namely if they write reinsurance treaties with primary insurers.

Reinsurance capacity plays thus the role of an informed financing. It is of course more costly than uninformed outside finance. As a result, direct insurers tap it only to the necessary extent: They seek to cede as little risk as possible.

The two important building blocks of the model are moral hazard within insurance companies and the reinsurers ability to mitigate it.

The reason why non life insurance companies are likely to suffer from a particularly important moral hazard problem is the well known inversion of the production cycle in insurance industry. The production costs of an insurance company (claims) are revealed only a long time after business has been underwritten and premiums cashed in, several years for long tailed business lines. Moreover, the final losses depend heavily upon insurers ability and efforts to mitigate losses during the run off period[4]. These efforts and ability are hardly verifiable by non experts outsiders, like shareholders

[4] The run off is the time interval between the claims and their settlements, which exceeds 5 years in many business lines.

without a seat on the board. Indeed, it is not difficult for a claim manager to underreserve-namely underestimate the final value of the claims-during several years. Thus, she can enter into a Ponzi scheme (finance losses on the run off of old underwriting years by underreserving for the recent ones) and conceal an inefficient losses management for quite a while.

This moral hazard problem being an important concern in non life insurance is epitomized by the following statement from Warren Buffet in the Berkshire Hathaway 2002 Shareholders Letter:

> "I can promise you that our top priority going forward is to avoid inadequate reserving. But I can't guarantee success. The natural tendency of most casualty-insurance managers is to underreserve, and they must have a particular mindset-which, it may surprise you, has nothing to do with actuarial expertise-if they are to overcome this devastating bias."

As is well acknowledged by practitioners, reinsurers have the ability to mitigate this problem because *(i)* they have more information about claims and more risk management skills than outside financiers; *(ii)* they are in general involved in a long run, repeated relationship with ceding companies who then behave so as to build a reputation. Doherty and Smetters (2002) find evidence that reinsurers play a role in loss mitigation, either by monitoring ceding companies or by designing efficient dynamic contracts (experience rating).

1.3 Organization Of The Paper

Section 2 outlines the model and solves for the (unique) equilibrium. Section 3 derives and comments some predictions of the model. Section 4 concludes.

2 The Model

From a formal standpoint, the setup is a simple extension of Holmstrom and Tirole (1997) model of financial intermediation. Roughly, while Holmstrom and Tirole consider an economy where entrepreneurs cannot monitor each other[5], this assumption is relaxed here: Risk managers can monitor each other. The main building block of the model, capital constraints in direct insurance business, is outlined in next Subsection. Subsection 2.2 presents the general model and solves for the equilibria in the reinsurance and capital markets.

2.1 Capital Constrained Insurers

We consider an economy with a continuum of insurers with unit mass. Each insurer $i \in [0, 1]$ contemplates underwriting a primary insurance portfolio P_i.

Throughout the paper, what is referred to as an "insurer" is the close-knit team made of the top management and inside shareholders (e.g. members of the board) of an insurance company, who has control over the risk management and loss mitigation strategy. Insurance companies, like most financial

[5] "We assume that firms cannot monitor other firms, perhaps because they have insufficient capital to be credible monitors [...] or because they do not have the informational expertise."

institutions, are more likely to have such skilled top managers and inside shareholders than industrial firms: This is required to obtain a license in most countries.

The model is symmetric for notational simplicity. Each portolio P_i has the following characteristics. The gross outcome from underwriting it (initial capital plus premiums plus financial profits minus claims and administrative costs) is either nonnegative, with value R, or a large loss. The positive outcome occurs with probability p_B if the insurer enters into active loss mitigation, or p_S if she "shirks". However, loss mitigation entails a non verifiable cost, namely the loss of a private benefit B. As usual in the moral hazard literature, effort comes at a cost but enhances the outcome in the sense of first order stochastic dominance:

$$\Delta p = p_B - p_S > 0$$

This very simple stochastic structure enables to abstract from any security design consideration and focus on organizational issues, the aim of the paper. The results are robust to more realistic claims modellings provided this first-order stochastic dominance property holds.

As in Holmstrom and Tirole (1997), let us also make the extreme assumption that portfolios are perfectly positively correlated. This is meant to emphasize that reinsurance does not depend in any way on a mutualisation story in this model.

It is assumed that each insurer needs to commit an amount of capital I in order to be allowed to underwrite her portfolio. The situation I have in mind is that potential policyholders are dispersed and/or not financially sophisticated, but that they are represented imperfectly by an institution[6]. By setting a capital requirement, this institution ensures that the expected default of each insurer is below some threshold. Such an objective underlies the actuarial approaches of insurance regulation, based on ruin theory, as well as the Value at Risk approaches in banking.

The representant of policyholders may be either a large broker who does not offer any business to insurers whose credit rating is too low, or a prudential authority who does not let insurers operate if they fail to meet a statutory capital requirement.

The insurers has an initial net wealth $K < I$. She can tap competitive outside investors who have unlimited financing capacities. In this case, for simplicity, she makes them take-it-or-leave-it offers.

Besides insurance activity, there is an alternative investment opportunity available to all the agents of this economy yielding an expected return $\gamma > 0$.

All agents are protected by limited liability. They are risk neutral and do not discount future cash flows.

Following Holmstrom and Tirole (1997), it is assumed that

$$p_B R > (1 + \gamma) I > p_S R + B$$

Thus, an insurer cannot raise outside finance if she cannot credibly commit to enter into active loss mitigation.

The model is identical to Holmstrom and Tirole (1997) so far. If she finds the funding and underwrites her portolio, an insurer carries out loss mitigation only if her stake in the positive outcome, R_I, is sufficient. More

[6]see Dewatripont and Tirole (1994) for a detailed exposition of the *representation hypothesis* underlying prudential regulation.

precisely, the incentive compatibility constraint is

$$R_I \geq \frac{B}{\Delta p}$$

However, outside financiers must be willing to participate:

$$p_B (R - R_I) \geq (1 + \gamma)(I - K)$$

As a result, underwriting is feasible iff

$$K \geq \overline{K} \equiv I - \frac{p_B}{1+\gamma}\left(R - \frac{B}{\Delta p}\right)$$

"One lends only to the rich". Because active loss mitigation is not verifiable, insurers need to commit a sufficient amount of inside capital so as to underwrite credibly insurance business. Otherwise, the incentive compatible contracts do not leave a sufficient surplus to outside financiers. In other words, the capital requirement I induces an inside capital requirement $\overline{K}$ which increases with I, as well as with the extent of the moral hazard problem $\frac{B}{\Delta p}$, and the cost of outside capital γ.

Note that because outside investors have no bargaining power, their participation constraint is binding so that

$$p_B R_I - (1 + \gamma) K = p_B R - (1 + \gamma) I > 0$$

In words, if insurance can be financed, it is more profitable for insurers than the outside opportunity, because they extract all the surplus in excess of γI.

Note also that, with a more general distribution of claims, the optimal form of outside finance under our first order stochastic dominance assumption would be subordinated debt (see Innes 1990). However, it would remain that insurers should commit a sufficient initial amount of capital in order for deals to take place.

2.2 Reinsurers

Let us focus on the situation of particular interest where parameters satisfy:

$$0 < K < \overline{K} \equiv I - \frac{p_B}{1+\gamma}\left(R - \frac{B}{\Delta p}\right)$$

In this case, none of the insurers is able to underwrite the primary portfolio available to her because of capital constraints.

However, insurance remains possible in such circumstances. Indeed, departing from Holmstrom and Tirole (1997), it is assumed that insurers can monitor the loss mitigation carried out by their fellow insurers, because they own the required skills in risk management. Let us term "reinsurer" an insurer who monitors a fellow insurer.

Monitoring is imperfect. More precisely, if the management of claims deriving from a primary portfolio $i \in [0, 1]$, is monitored by some reinsurers:

1. The best reinsurers can do when monitoring is reducing the primary insurer's i private benefit from shirking from B to $b_I < B$.

2. Monitoring the portfolio entails a non verifiable collective cost, c_R, shared fairly among reinsurers[7].

Reinsurance reduces only partially the moral hazard problem in loss mitigation (B reduces to b_I), and there is of course no reason why outside investors, who cannot verify primary insurers efforts, could have any ability to verify the monitoring effort exerted by reinsurers.

One plausible reason why primary insurers are only imperfectly monitored by reinsurers is that part of the information relevant to manage claims is

[7] This cost being independent of the number of reinsurers is for simplicity only, a more general specification does not provide more insights.

by nature "soft". The primary insurer, for instance because she owns the distribution network, has access to this information. The reinsurers have only access to the "hard" part of the information, essentially all that is in the books and files of the primary insurer, but miss the soft part. This soft part is for instance the primary insurer's guess about the psychology of the claimholders and thus whether they are willing to reach a quick compromise or bargain toughly. Such a guess is built during an ongoing close interaction with them, but is difficult to quantify or describe precisely in an administrative file[8].

Let us now derive the equilibrium (if any). Let us first take for granted that insurers specialize: Either they underwrite their primary portfolio and commit all their capital K to it, or they give up this primary business and use all their capital to provide reinsurance capacity to primary insurers. Let λ denote the proportion of insurers acting as reinsurers at the equilibrium (if any). Thus, the remaining $1-\lambda$ insurers underwrite the primary portfolio available to them. Let also

$$\alpha = \frac{\lambda}{1-\lambda}$$

the ratio of reinsurers for one primary insurer. This ratio, which will turn out to fully characterize the equilibrium, may be interpreted as the "cession rate" in the reinsurance market.

There are two moral hazard problems now for a given primary portfolio. The primary insurer and her reinsurers must behave. Thus, both the primary insurer and reinsurers must have a sufficient stake in the positive outcome. Let R_I and R_R denote their respective stakes. The residual surplus can be

[8] see Berger, Miller, Petersen, Rajan and Stein (2002) for a related discussion of the soft and hard information relevant for loans decisions in retail banking.

distributed to outside investors, this drives the quantity of outside finance which can be raised. Any shortfall has to be filled by the primary insurer's capital and K_R, the "reinsurance capacity", namely the capital committed by reinsurers. The following equations characterize the equilibrium (if any):

$$\begin{aligned} R_I &\geq \frac{b_I}{\Delta p} && (II) \\ R_R &\geq \frac{c_R}{\Delta p} && (RI) \\ p_B\left(R - R_I - R_R\right) &\geq (1+\gamma)\left(I - K - K_R\right) && (OP) \\ K_R &= \alpha K && (ER1) \\ p_B R_I &= \frac{1}{\alpha}\left(p_B R_R - c_R\right) \geq (1+\gamma) K && (ER2) \end{aligned}$$

(II) states that the contract has to be incentive compatible for the primary insurer of any portfolio. Her stake must be sufficiently high so that she is better off managing claims efficiently provided she is monitored by reinsurers.

(RI) states that the contract has to be incentive compatible for her reinsurers. Their stake must be sufficiently high so that they effectively monitor her.

(OP) is the outside investors participation constraint when outside finance is required, namely when

$$K_R + K < I$$

In this case, (OP) is obviously binding since outside investors have no bargaining power.

$(ER1)$ is the first equilibrium condition in the reinsurance market. It states that the demand for reinsurance capacity equates the supply.

$(ER2)$ is the second equilibrium condition in the reinsurance market. Any insurer must be indifferent between her primary insurance business and reinsurance. More precisely, reinsurance capacity and insurance capital must yield the same expected return. This return has to be higher than the one of the alternative investment opportunity. It is left to the reader to check that this latter condition actually holds as soon as (OP) is binding.

The reason why any primary insurer, if she underwrites her primary portfolio, specializes in primary insurance, namely invests her entire inside capital into primary insurance business, is now clearer. Indeed, acting simultaneously as a reinsurer of other portfolios and hence investing some of her funds in them cannot make her better off. At the equilibrium, the return she would get on these funds would strictly equate the cost of additional reinsurance capacity she would have to use to replace her informed capital[9].

A crucial remark is that, because reinsurance is as profitable as primary insurance, reinsurance capacity is a more expensive financing than outside capital. As a result, primary insurers appeal as little as possible to reinsurance. They demand the minimal reinsurance capacity required for reinsurers to behave, so that (RI) is binding.

To sum up R_R is determined by (RI), hence R_I by the equality in $(ER2)$. K_R is determined by $(ER1)$. If

$$K_R + K \geq I$$

no outside financing is required. I rule this case out by focusing on the

[9]Interpreting the model literally, a primary insurer would be neither worse nor better off providing some reinsurance capacity and purchasing the same amount of reinsurance instead of specializing, but such equilibria are very unrealistic. Indeed, introducing arbitrarily small fixed costs of entering insurance and reinsurance suffices to rule this out.

interesting situations where reinsurance and outside capital coexist, namely where

$$K_R + K < I \longleftrightarrow \alpha < \frac{I}{K} - 1$$

In this case, replacing R_I, R_R and K_R in (OP) and rearranging yields that α must satisfy at the equilibrium

$$\alpha^2 + \left(1 + \frac{p_B R - p_B \frac{c_R}{\Delta p} - (1+\gamma) I}{(1+\gamma) K}\right)\alpha - \frac{p_S}{(1+\gamma) K} \frac{c_R}{\Delta p} = 0 \qquad (CR)$$

By virtue of $(ER2)$, (II) becomes

$$\alpha \leq \frac{p_S}{p_B} \frac{c_R}{b_I}$$

and the positive root of (CR) meets this condition if the parameters satisfy:

$$K \geq \frac{I - \frac{p_B}{1+\gamma}\left(R - \frac{b_I + c_R}{\Delta p}\right)}{1 + \frac{p_S}{p_B}\frac{c_R}{b_I}}$$

Let us summarize these results in the following step.

Lemma 1

Assume

$$K \geq \overline{\overline{K}} \equiv \frac{I - \frac{p_B}{1+\gamma}\left(R - \frac{b_I + c_R}{\Delta p}\right)}{1 + \frac{p_S}{p_B}\frac{c_R}{b_I}}$$

Let

$$\begin{cases} \rho_I = 1 + \frac{p_B R - p_B \frac{c_R}{\Delta p} - (1+\gamma) I}{(1+\gamma) K} \\ \rho_R = \frac{p_S}{(1+\gamma) K} \frac{c_R}{\Delta p} \end{cases}$$

If the positive root, α, of

$$\Pi(X) = X^2 + \rho_I X - \rho_R$$

is smaller than $\frac{I}{K} - 1$, then there is an unique equilibrium where primary insurers tap both reinsurers and outside investors. This equilibrium is fully characterized by α, the cession rate in the reinsurance market.

Proof. See above. ■

ρ_I and ρ_R are closely related to the respective surpluses created by primary insurance and reinsurance activities:

$p_B R - c_R - p_S \frac{c_R}{\Delta p} - (1+\gamma) I$ is the expected payoff from a monitored portfolio net of reinsurers share compared to $(1+\gamma) I$.

$p_S \frac{c_R}{\Delta p} = p_B \frac{c_R}{\Delta p} - c_R$ is the share of reinsurers in the cash flows generated by a primary portfolio.

To ensure that such equilibria exist for some values of the parameters, the two following points remain to be checked.

First, the condition $K \geq \overline{\overline{K}}$ needs to be consistent with $K < \overline{K}$. Remember that this is required for primary insurance being impossible without reinsurance. It is easy to see that this is the case if

$$b_I + c_R - B \leq (1+\gamma) \frac{p_S}{p_B} \left(1 - \frac{p_S}{p_B}\right) \overline{K} \times \frac{c_R}{b_I}$$

This inequality holds obviously if the left-hand side is negative ($b_I + c_R < B$). In this case, it means that the global cost of efficient losses mitigation is smaller when the portfolio is reinsured. This may correspond to the situation where the real services provided by reinsurers are important.

But interestingly, there is room for reinsurance even when $b_I + c_R > B$, namely when the joint action of the primary insurer and her reinsurers is socially less efficient than loss mitigation by the primary insurer only. This may occur when the cost of their coordination and communication overcomes the value added by reinsurers services. In this case, reinsurance may still be useful if the private benefit b_I is sufficiently small all else equal, namely if monitoring by reinsurers is sufficiently efficient.

Second, it must be checked that α is smaller than $\frac{I}{K} - 1$ for some values of the parameters. Note that α decreases with ρ_I, increases with ρ_R, and hence decreases with c_R, tending to 0 as $c_R \to 0$. Thus, α is sufficiently small, in particular smaller than $\frac{I}{K} - 1$, if c_R is sufficiently small. Otherwise, the minimal stake of reinsurers in the surplus gets so large that the capacity they have to supply for reinsurance not being overly profitable is sufficient to meet the statutory requirement I.

On the whole, Lemma 1 may be precised as follows.

Proposition 2

If

1. $K \geq \overline{\overline{K}} \equiv \frac{I - \frac{p_B}{1+\gamma}\left(R - \frac{b_I + c_R}{\Delta p}\right)}{1 + \frac{p_S}{p_B}\frac{c_R}{b_I}}$
2. *If reinsurance is sufficiently efficient and cheap: All else equal,* b_I *and* c_R *are sufficiently small.*

Then primary insurers use both reinsurance and outside finance. The equilibrium on both markets is fully characterized by the cession rate α*, the positive root of*

$$\Pi(X) = X^2 + \rho_I X - \rho_R$$

Namely,

$$\alpha = \frac{1}{2}\left(\sqrt{\rho_I^2 + 4\rho_R} - \rho_I\right)$$

Proof. See above. ■

The reader may wonder why reinsurers raising outside funds has been ruled out so far. This is because it is actually immaterial. All that matters to ease the financial constraint is a sufficient amount of informed financings (primary insurers and reinsurers capital) being committed to a primary portfolio. Once this amount is sufficient, whether outside finance transits through reinsurers balance sheet or not before ending in primary portfolios is irrelevant[10]. This irrelevancy property, which simplifies the analysis, depends crucially upon perfect correlation. Relaxing this assumption would add another benefit from reinsurance to the one emphasized here. Indeed, diversification within reinsurance companies would mitigate their moral hazard problem, because reinsurance treaties could cross pledge each other[11]. In this case it would be optimal to have reinsurers intermediating outside finance.

Next Section studies the comparative statics of this equilibrium.

3 Comparative Statics

This Section determines and discusses the variations of the equilibrium cession rate α with respect to the parameters of the model. This aims at checking whether the predictions seem broadly consistent with stylized facts from the reinsurance market. Inconsistency would of course support that the story for

[10] This point is similar to the "certification versus intermediation" point made in Holmstrom and Tirole (1997).

[11] see Tirole (1996) for an exposition of this broad idea, closely related to the rationale for intermediation pioneered by Diamond (1984).

reinsurance emphasized here is not important in practice.

Proposition 3

α increases with respect to I, c_R and γ, and decreases with respect to K.

Proof. See the Appendix. ■

In order to gain some intuition and interpret those results, it is worth describing the effect of an increase in α in more details. If the cession rate increases, primary insurers are more reinsured in the sense that the reinsurance capacity K_R provided to each portfolio increases. It reduces reinsurance profitability. Because primary insurance and reinsurance profitabilities cannot differ at the equilibrium, the stake of primary insurers in the positive outcome is reduced. This makes more cash flows pledgeable to outside financiers, who at the same time have less capital to commit because K_R has increased. As a result, an increase in the cession rate reduces the profitability of insurance and reinsurance capital while making outside finance more profitable: Eventually, it transfers value from insiders to outsiders.

The results in Proposition 2 may now be commented as follows.

The reason why α increases with respect to I is clear. If the exogenous capital requirement increases, it means that more outside finance will be required. This increases the stake of outsiders in the cash flows, or reduces the stake of primary insurers and reinsurers. Because the stake of reinsurers is incompressible, primary insurers have to reduce their stake. It makes reinsurance more profitable than primary insurance, hence more insurers give up their primary portfolio to exert reinsurance. As a result, this model delivers the well known trade off between solvency and capacity of the primary insurance market faced by the regulator. Toughening capital requirements makes firms more solvent but reduces the number of primary portfolios underwritten ($1-\lambda=\frac{1}{1+\alpha}$).

If c_R increases, the share of reinsurers in the cash flows has to increase, as a result they have to supply more capacity, hence α increases. The interpretation is that when the monitoring of primary insurers by reinsurers is more difficult, primary insurers cede more. It has been pointed out in the Introduction that the reason why risk managers are difficult to monitor in non life business is because a long time elapses between claims occurence and settlement. c_R should thus be all the larger because the primary business is a long tailed one. Indeed, the true production costs of insurance are more difficult to guess in this case. As a result, the prediction of the model is that primary insurers with long tailed business should cede more, consistent with the findings of Garven and Lamm-Tennant (2003).

α decreases with K because as K increases, less outside finance is required and primary insurers, who provide a higher proportion of the funds, must have an increasing stake in the cash flows. A low K means that the insurance company is financially constrained. In practice, this is more likely to be the case for closely held firms, reluctant to dilution. The prediction that the cession rate is higher for closely held firms is consistent with the findings from Mayers and Smith (1990).

Finally, α increases with respect to γ because if outside investors require a higher return, then value must be transferred from insiders to outsiders. I have stressed that an increase in the cession rate was a mechanism to achieve this transfer in this model. This is broadly consistent with the soft reinsurance market observed during the $90s$. Capital markets were bullish, so that outside finance was cheap, and cession rates were low over the period (see e.g. The Worldwide Reinsurance Review 1999).

4 Concluding Remarks

This paper offers a model of equilibrium in reinsurance and capital markets where reinsurers arise endogenously. The pyramidal structure of the reinsurance market and the interaction between reinsurance and financing decisions are both addressed. The model, admittedly very stylized, is only a first step towards a theory of reinsurance, but the consistency of some of its predictions with empirical evidence is encouraging.

The main limitation is the minimalist modelling of the interaction between the insurance company and the policyholders or their representants, who can only impose a capital requirement. An explicit modelling of this block is an interesting route for future research. However, this limitation has also an upside. Indeed, it means that the point made here is fairly general and that "insurers" could be reinterpreted as "bankers", contemplating lending money but subject to a moral hazard problem. But then, why is it that the "rebankers" arising in the model seem absent from the real world? Note first that they are not totally absent. Some institutions such as MBIA for municipal bonds or Freddie Mac and Fannie Mae for housing loans strongly resemble reinsurers in the credit market. They specialize in bearing the tails of credit risks, and this credit enhancement is a device to commit to monitor the originator. Note also that, interestingly, reinsurers are fairly active in credit markets, either by assuming a lot of credit reinsurance[12] or

[12] Credit insurance is indeed heavily reinsured.

more recently by being big players in the credit derivatives market. It remains, however, that such patterns are not as important in credit markets as they are in insurance markets. This is probably because they respond to a phenomenon, moral hazard due to the slow revelation of production costs, which is a first order issue in property casualty insurance but not in banking. Because they transform durations, distressed retail banks face typically refinancing problems before being insolvent, and liquidity management is thus their main concern.

A final remark is that this model suggests a reason why financial innovations such as catastrophe bonds do not seem to be a substitute to the traditional reinsurance market. These instruments simply do not play the same role as "reinsurance by reinsurers" because they target investors who have no ability to monitor the issuing company. Consistent with this is the fact that such instruments do not provide a hedge against the portfolio of the issuer, but against a much broader risk such as the losses for the whole insurance industry in a given area, over which the issuer has little control. Catastrophe bonds may save the monitoring cost but they replace it by a basis risk.

5 Appendix

Let us remind the definitions of α, ρ_I, ρ_R :

$$
\begin{aligned}
\alpha &= \frac{1}{2}\left(\sqrt{\rho_I^2 + 4\rho_R} - \rho_I\right) \\
\rho_I &= 1 + \frac{p_B R - p_B \frac{c_R}{\Delta p} - (1+\gamma) I}{(1+\gamma) K} \\
\rho_R &= \frac{p_S}{(1+\gamma) K} \frac{c_R}{\Delta p}
\end{aligned}
$$

Hence

$$\frac{\partial \alpha}{\partial \rho_I} = -\frac{\alpha}{2\alpha + \rho_I} < 0$$

$$\frac{\partial \alpha}{\partial \rho_R} = \frac{1}{2\alpha + \rho_I} > 0$$

- α increases w.r.t. I because ρ_I decreases w.r.t. I.
- α increases w.r.t. c_R because ρ_I and ρ_R decrease and increase respectively w.r.t. c_R.
-
$$\frac{\partial \alpha}{\partial \gamma} = \frac{\partial \alpha}{\partial \rho_I}\frac{\partial \rho_I}{\partial \gamma} + \frac{\partial \alpha}{\partial \rho_R}\frac{\partial \rho_R}{\partial \gamma}$$

  And

$$
\begin{aligned}
\frac{\partial \rho_I}{\partial \gamma} &= -\frac{I - K}{(1+\gamma) K} - \frac{\rho_I}{1+\gamma} \\
\frac{\partial \rho_R}{\partial \gamma} &= -\frac{\rho_R}{1+\gamma}
\end{aligned}
$$

  So that

$$\frac{\partial \alpha}{\partial \gamma} = \frac{1}{(2\alpha + \rho_I)(1+\gamma)}\left(\alpha\left(\rho_I + \frac{I}{K} - 1\right) - \rho_R\right)$$

Now remember that by definition

$$\rho_I \alpha - \rho_R = -\alpha^2$$

Hence

$$\frac{\partial \alpha}{\partial \gamma} = \frac{\alpha}{(2\alpha + \rho_I)(1+\gamma)} \times \left(\frac{I}{K} - 1 - \alpha \right) > 0$$

because c_R is supposed to be sufficiently small so that the term between brackets is nonnegative.

•

$$\frac{\partial \alpha}{\partial K} = \frac{\partial \alpha}{\partial \rho_I} \frac{\partial \rho_I}{\partial K} + \frac{\partial \alpha}{\partial \rho_R} \frac{\partial \rho_R}{\partial K}$$

And

$$\begin{aligned} \frac{\partial \rho_I}{\partial K} &= \frac{1-\rho_I}{K} \\ \frac{\partial \rho_R}{\partial K} &= -\frac{\rho_R}{K} \end{aligned}$$

So that

$$\frac{\partial \alpha}{\partial K} = \frac{1}{(2\alpha + \rho_I) K} (\alpha (\rho_I - 1) - \rho_R) = \frac{-\alpha^2 - \alpha}{(2\alpha + \rho_I) K} < 0$$

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