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HOW CAN INSURANCE COMPAGNIES COMPETE WITH MUTUAL INSURERS? THE ROLE OF COMMITMENT

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How Can Insurance Companies Compete With Mutual Insurers? The Role of Commitment.

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Abstract

The aim of this paper is to analyze the impact of the existence of mutual firms on the behavior of insurance companies and more precisely to study in which situations an insurance company can enter a market controlled by mutual arrangements. Our approach differs from the existing literature as we integrate the investment choices of the insurance company and the fact that, because it commits on a fix contract, it can become insolvent. In such a situation we are able to characterize the unique optimal choices of the monopolistic company and the conditions favoring its appearance.

Key words: Insurance market, Mutual firms, Commitment, Insolvency

JEL Classification No. : L1, D8, G22

1 Introduction

The growing literature on organizational forms in insurance mainly focuses on the coexistence of mutual firms with insurance companies but few papers analyze how those two kinds of firms compete. The papers dealing with such a competition mainly consider the case of mutual firm(s) competing with many insurance companies. In contrast we want to focus in this paper on situations where a single insurance company has to compete with mutual firms. This issue is relevant as it would correspond to the case of an insurance company that wants to enter a market exclusively controlled by mutual firms.

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It may for example fit with the situation of a stock firm that wishes to be set up in developing countries where rural communities often share risk with mutual arrangements (as communal access to land or work-sharing arrangements). Similarly, in developed countries, the issue would make sense after a deregulation making an insurance line reserved to mutual insurers (as health insurance in France) contestable. The main objective of this paper is to analyze the influence of the existence of mutual firms on insurance companies' choices when optimal behavior consists in decisions about both offered coverage and capital stock. We analyze more precisely the impact of the existence of mutual firms as individuals outside option on optimal choices of a monopolistic insurance company. We focus on the effects of parameters as the cost of capital, the distribution of income, the degree of risk aversion and the size of the population. In this way we are able to analyze how and when an insurance company may attract mutual firms policyholders and to determine which variable make or not an insurance company enter the market.

To do so, we build a model that captures the main features distinguishing mutual and stock insurers, namely : (i) a difference in the ownership structure : while insurance companies are owned by their shareholders, mutual firms belong to their policyholders, (ii) a difference in the objective of the organization : whereas insurance companies aim to maximize return on invested capital, mutual firms theoretically maximize its members satisfaction, and (iii) a difference in the definition of risk : stock firms have to precisely define at stake risks to contract on a fixed premia when mutual ones can define risk ex-post as they systematically adjust offered premia a posteriori. As this paper introduces in the discussion the investment choice of the insurance company this last difference will have an important role in our setting. Indeed, because an insurance company commits on a specific contract, it may become insolvent. Like most of the papers on this topic we then assume that agents are perfectly rational and thus take into account the probability of insolvency when making their choices. Therefore an individual may not ever wish an increase in coverage as it also increases the insolvency probability of the insurance company.

Under such considerations, we characterize in this paper the optimal choice of coverage and capital investment of a monopolistic company competing with a mutual firm, and show that it is unique. In doing so we are able to determine the conditions under which this equilibrium gives a positive profit, that is to state when an insurance firm can enter the market. Analyzing these conditions, this paper provides interesting comparative statics, either based on analytical results or simulations. This way we show that a decrease in the cost of capital highers the optimal capital stock, lowers optimal proposed coverage and thus highers the likelihood for a stock firm to be set up. We also prove in this paper that when a distribution of aggregate income dominates another one in the sense of first order stochastic dominance, the optimal offered coverage increases. Another result of interest is the fact that a higher individual degree of risk aversion increases optimal capital reserves, decreases optimal coverage and that those two forces result in an increase in the optimal profit. Simulations on the influence of the insured population size then allows to state that, when risks are independent, an increase in the number of policyholders highers the optimal offered coverage and lowers the possibility for a stock company to emerge. Lastly, we prove in this paper that the opportunity for an insurance firm to enter the market is higher when individual risk is high, as an increase in the variance of income increases optimal capital reserves and decreases optimal coverage.

We briefly discuss the relationship of the paper with the most closely related literature. This paper fits into the literature on organizational form in insurance that first tries to explain the coexistence of mutual firms with insurance companies. Focusing mainly on the difference in the ownership structure, Mayers & Smith (1988) argue that the two organizational forms coexist because each ownership structure has a comparative advantage in preventing for different types of agency problems (mutual firms prevent for conflict between shareholders and policyholders but have less incentive to control their managers). Alternatively, Smith & Stutzer (1990) and Doherty & Dionne (1993) take into account the additional feature that policyholders of mutual firms bear the aggregate risk (that is that mutual firms – contrary to stock companies – offer participating policies) to explain this coexistence arguing that stock and mutual firms insure different kind of individuals or different kind of risks [1].

Ours is not the first paper to includes the possibility of insolvency. Focusing on the solvability regulation, Rees, Gravelle & Wambach (1999) show that, in absence of mutual firms, it is optimal for

[1] Doherty & Dionne (1993) prove that, if covered risks are decomposable into diversifiable (idiosyncratic) and non-diversifiable parts, it is optimal, given participating nature of mutual firms policies, to combine insurance firms (non-participating) coverage with mutual risk sharing arrangements. On the same direction, Smith & Stutzer (1990) show, using a variant of adverse selection model of Rothshild & Stiglitz (1976), that because of their participating nature, mutual firms attract low risk individuals who want to signal their type.

the insurance companies to hold enough capital to avoid insolvency when total losses are bounded. However, if it is not always feasible to escape bankruptcy or if the market is not frictionless, this result does not hold. Laux & Muermann (2006) study optimal choices of mutual and stock insurers when there are frictions and more precisely when there exist conflicts between managers and owners. They first show that, without any competition between stock and mutual firms, it is optimal for policyholders to transfer wealth between solvency and insolvency states. Making capital choice endogenous, they show that capital stock and premia are both decreasing with governance problems and increasing with competition. Finally they prove that the incentive to increase the number of policyholders is higher for mutual firms. They however consider stock and mutual firms as independent entities that do not compete to attract policyholders. On the contrary when analyzing the impact of mutual firms on the insurance market, Fagart, Fombaron & Jeleva (2002) model competition between insurance companies and mutual firms but do not study optimal capital choice. They show that the expected utility of the consumers depends on the size of the organization they belong to and thus that the existence of mutual firms modifies optimal behavior of insurance companies, when it only consists of offered premia.

Our paper contributes to the literature on insurance forms by studying both competition between the two organizational forms and the investment choices of insurance companies.

The rest of the paper is structured in the following way. We present the model in Section 2 before characterizing the optimum and its implication on firms participation (in Section 3). Comparative statics either based on analytical results or simulations are provided in Section 4 and we conclude in Section 5.

2 The Model

2.1 General Assumptions and Notations

We consider n identical risk averse individuals with increasing and concave utility function $u(.)$ that satisfies the Inada conditions. Each agent receives random revenue $\widetilde{x}_i$, $i = 1, ..., n$. We assume then that aggregate revenue in the economy called $\widetilde{\omega} \equiv \sum_{i=1}^{n} \widetilde{x}_i$ is distributed according to some cumulative distribution function $F(.)$ with density $f(.)$.

2.2 The Insurance Process

As agents are risk averse, they want to be insured against risks of changes in revenue and we consider that they face two kinds of organizations to do so.

- Either, they can be insured by a mutual firm that optimally provides equal sharing of resources.[2] Thus, policyholders of a mutual firm with n members get $u\left(\frac{\omega}{n}\right)$ whatever the state of the world.

- Or, they can choose to share risk by subscribing a policy in a monopolistic insurance company that proposes to provide a fixed income y to each of its policyholders. This firm is owned by shareholders that invest in the insurance market a capital stock K at the beginning of the period (i.e. before the realization of the $\widetilde{x}_i$s is known) and gets the profit of the company Π at the end (that is after having indemnified the policyholders). They however face a discount factor δ that represents the opportunity cost of capital[3]. Thus, if this company insures the entire population, it goes bankrupt when $\omega < n.y - K$ and its probability of insolvency is equal to $F(n.y - K)$. In such cases we state that it equally shares its whole resources (premia plus capital) among its policyholders and thus that each policyholder of a company that insures the n agents gets $u\left(\frac{\omega + K}{n}\right)$ (which is less than $u(y)$ when $\omega < n.y - K$). As we assume that policyholders fully anticipate this probability of insolvency, the expected utility of an individual insured with all the others in the monopolistic insurance company is :

$$U(y, K) \equiv [1 - F(n.y - K)].u(y) + \int_{-\infty}^{n.y-K} u\left(\frac{\omega + K}{n}\right) f(\omega)\, d\omega$$

Remark 1 *The expected utility of an individual insured in a monopolistic stock firm is increasing in both the offered coverage and the company capital stock.*

[2] See Borch (1962) or Eeckhoudt & Gollier (1995)

[3] If capital has no opportunity cost or if there is no discount factor, the company has an incentive to accumulate an infinite amount of capital and thereby avoid bankruptcy.

2.3 The Incentive Constraint and the Profit of the Insurance Company

As it competes on the same risk with a mutual firm, the monopolistic firm has to provide its policyholders with at least as much utility as the mutual firm. As all agents are homogenous, the entity providing them the highest expected utility will insure the entire population. Thus, to attract policyholders, the insurance company has to propose a contract satisfying the following incentive constraint:

$$[1-F(n.y-K)].u(y)+\int_{-\infty}^{n.y-K} u\left(\frac{\omega+K}{n}\right) f\left(\omega\right) d\omega \geq E\left(u\left(\frac{\omega}{n}\right)\right)$$

Remark 2 *If it does not hold any stock of capital, the insurance company is unable to sell any policy as agents will then be better off being insured in the mutual firm whatever the coverage proposed by the company.*

If $K=0$, the incentive constraint can never be satisfied with a finite coverage (as then, in case of solvency $y<\frac{\omega}{n}$) and the only way it holds is by setting $y=+\infty$ in which case the behavior of the company exactly amounts to the one of a mutual firm. So, without capital, an insurance company can not actually exist as its optimal choice is then to act just like a mutual firm. This moreover implies that the existence of a mutual firm by itself forces the company to hold capital as, in the absence of mutual firms, an insurance firm can still make positive profits even if it does not hold capital.

So, in order to attract policyholders, an insurance company has to invest in capital stock before the realization of the risk variable. Its expected profit can then be written as:

$$\Pi(y,K)=\delta.\int_{n.y-K}^{+\infty} \left(\omega+K-n.y\right) f\left(\omega\right) d\omega - K$$

As this expected profit is decreasing in both y and K, the only incentive for the company to increase y and K is to attract policyholders. The fact that the insolvency probability influence policyholders' behavior leads us to study the stock of capital as a choice variable of the insurance company.

3 Optimal Behavior of a Monopolistic Insurance Company Facing a Mutual Firm

The program of the monopolistic insurance company consists in the maximization of $\Pi(y, K)$ under the constraint that individuals subscribe its policy, that can be rewritten as:

$$C(y,K) \equiv \int_{-\infty}^{n.y-K} \left[u\left(\frac{\omega+K}{n}\right) - u\left(\frac{\omega}{n}\right)\right] f(\omega)\, d\omega + \int_{n.y-K}^{+\infty} \left[u(y) - u\left(\frac{\omega}{n}\right)\right] f(\omega)\, d\omega \geqslant 0$$

As this constraint is increasing in both y and K (see Remark 1) when profit is decreasing with those two variables, it is satisfied with equality.

The problem thus become

$$\max_{y,K} \quad \left\{ \delta. \int_{n.y-K}^{+\infty} (\omega + K - n.y)\, f(\omega)\, d\omega - K \right\} \tag{3.1}$$
$$\text{s.t.} \quad \begin{cases} C(y,K) \equiv \displaystyle\int_{-\infty}^{n.y-K} \left[u\left(\frac{\omega+K}{n}\right) - u\left(\frac{\omega}{n}\right)\right] f(\omega)\, d\omega \\ \qquad + \displaystyle\int_{n.y-K}^{+\infty} \left[u(y) - u\left(\frac{\omega}{n}\right)\right] f(\omega)\, d\omega = 0 \end{cases}$$

Proposition 1 *Suppose that either the support of $\widetilde{\omega}$ is unbounded or the upper bound of the support $\overline{\omega}$ satisfies*

$$\frac{1-\delta}{\delta} < \frac{\displaystyle\int_{-\infty}^{\overline{\omega}} \left(u'\left(\frac{\omega}{n}\right) - u'\left(\frac{\overline{\omega}}{n}\right)\right) f(\omega) d\omega}{u'\left(\dfrac{\overline{\omega}}{n}\right)} \tag{3.2}$$

Then there exists a unique optimal solution for program (3.1) that yields to a positive profit, fully characterized by the two following equations:

- $\Phi(y,K) \equiv \displaystyle\int_{-\infty}^{n.y-K} \left[\frac{u'\left(\frac{\omega+K}{n}\right) - u'(y)}{u'(y)} \right] f(\omega)\, d\omega - \frac{1-\delta}{\delta} = 0$
- $C(y,K) \equiv \displaystyle\int_{-\infty}^{n.y-K} \left[u\left(\frac{\omega+K}{n}\right) - u\left(\frac{\omega}{n}\right)\right] f(\omega)\, d\omega + \int_{n.y-K}^{+\infty} \left[u(y) - u\left(\frac{\omega}{n}\right)\right] f(\omega)\, d\omega = 0$

Proof*: See Appendix*

Proposition 1 states that, if aggregate wealth can be infinite, an insurance company can always enter a market controlled by mutual firms. However, when aggregate wealth is bounded, an insurance company may not be able to make a positive profit by entering the market and competing with the mutual firm.

When an insurance company can enter the market, Proposition 1 moreover characterizes its optimal behavior, that consists of investing capital stock K^* and proposing a coverage y^* that satisfies the first order condition $\Phi(y, K) = 0$ and the constraint $C(y, K) = 0$. One can also show that this optimal behavior is unique as the first order condition expresses an increasing relationship between the offered premium and the stock of capital whereas the constraint defines a decreasing mapping between those two variables. The direction of those two relationships characterizing the equilibrium may be intuitively explained. The fact that the profit maximization gives rise to an increasing relationship between the coverage and the stock of capital may be explained by the effect of those two variables on the insolvency probability. As an increase in coverage increases this probability, the company has to also rise the stock of capital to restore a reasonable insolvency probability. Concerning competition with the mutual insurer, an increase in y increases the attractiveness of the company. Thus, everything else being equal, the company can decrease its capital stock without losing any policyholders. Figure 1 illustrates the first order condition and the contraint in the plan (K, y).

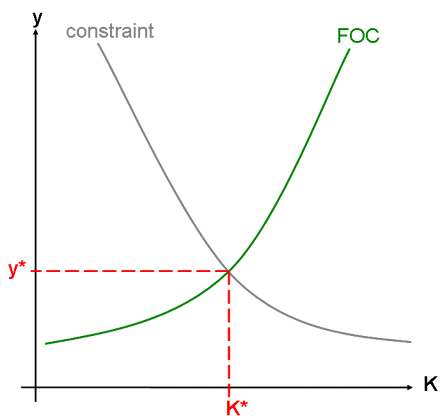


Figure 1: The Optimal Behavior of the Insurance Company

4 Comparative Statics

In this section, we analyze the effect of different variables on the firm's optimal choices and profit. By studying how parameters of the model affect the monopolistic firm's profit, we are able to characterize conditions under which formal insurance companies are likely to emerge.

4.1 Analytical results

We first derive 3 analytical results, relating the insurance company's choices and profit to the cost of capital, distribution of aggregate income and degree of risk aversion.

Proposition 2 *:*

(i) A decrease in the cost of capital (i.e. an increase in the discount factor δ) increases the optimal capital stock (K^*) and decreases optimal proposed coverage (y^*)

(ii) Let $F_1(.)$ and $F_2(.)$ be two distributions of aggregate income. Then, if $F_1(.)$ stochastically dominates $F_2(.)$, optimal offered coverage (y^*) is higher under $F_2(.)$ than under $F_1(.)$

(iii) The profit of a monopolistic insurance company that compete with a mutual firm is always increasing with the insured's degree of risk aversion. Moreover, when $\delta < 1$ and individuals are risk neutral, an insurance firm can not enter a market in which a mutual insurer performs.

Proof*: See Appendix.*

In providing comparative statics on δ, Proposition 2 first states the effect of changes in the cost of capital on the optimal choice of the insurance company: as it increases the return on invested capital (by decreasing the cost of capital), an increase in δ increases optimal capital (K^*) and then allows the company to lower y^* without increasing its insolvency probability. This is illustrated in Figure 2.

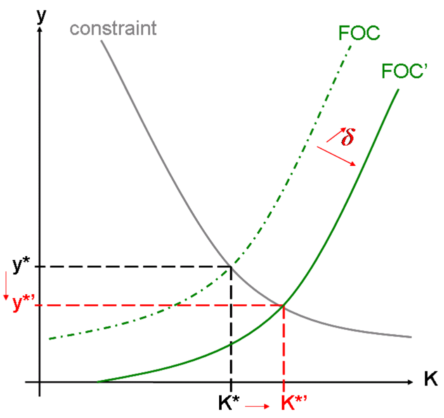


Figure 2: The Effect of Changes in δ

The second part of Proposition 2 shows that if a distribution of aggregate income dominates (in the sense of first order stochastic dominance) another one, the optimal offered coverage increases. The effect of such a change on optimal capital stock is however ambiguous as it results from two effects:

- as it lowers the probability of low aggregate revenue and thus of bankruptcy, this change leads to a decrease in optimal invested capital
- but because of the increase in offered premia, the insurance company has to raise K^* not to increase its insolvency probability.

One can see from the proof that these effects come from the fact that the change in the distribution we study here shifts the first order condition to the North-West and the constraint to the North-Est resulting, as shown in figure 3, in an increase in y^* and an ambiguous effect on K^*.

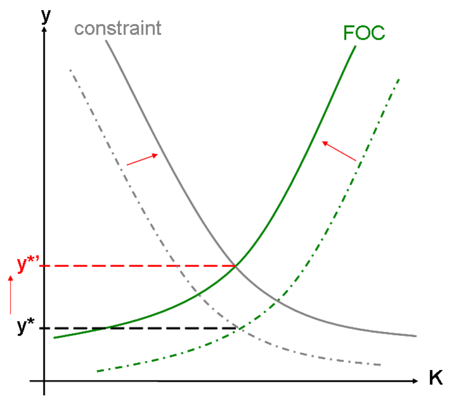


Figure 3: The Effect of Changes in the Distribution of Risks

As it impacts individual insurance decision, risk aversion also has an important part in the determination of the equilibrium and optimal profit. If the effect of the degree of risk aversion on choice variables is hard to grasp in the general case (see next section), Proposition 2 states that, as it increases expected profit, an increase in the degree of risk aversion increases the opportunity for an insurance firm to emerge. Thus, an insurance company seems to be more likely to be set up when individuals are highly risk averse. This important result can be intuitively explained by the fact that an increase in individual degree of risk aversion increases the attractiveness of the insurance company that, contrary to a mutual firm, bears aggregate risk when it is solvent.

4.2 Simulations

If the effects of the variables mentioned in the previous subsection can be analytically analyzed, the effect of other variables requires the use of simulations. For exemple, the effect of the size of the population (n) is complex because it affects the distribution of aggregate income $\left(\sum_{i=1}^{n} \widetilde{x}_i\right)$ and we need to specify completely the relationship between the distribution of individual and aggregate income to analyze changes in n. In order to study the impact of individual risk aversion on the choice variables (Proposition 2 only states the effect of risk aversion on optimal profit) we also need to specify an utility function and a cumulative distribution function. For all these complex comparative statics, we use simulations with specific utility function and distribution, that also allows for the study of the impact of changes in risk aversion on the choices of insurance company.

4.2.1 The Retained Specification

We focus on individuals facing independent and normally distributed risks. So, we assume that $\widetilde{x}_i$ follows a $N(m, \sigma^2)$ distribution and thus, according to the Central Limit Theorem, that $\widetilde{\omega}$ is also distributed according to a normal distribution: $N(n.m, n.\sigma^2)$. Except in the study of changes in the variance of individual income, we analyze the case of agents' revenues with zero mean ($m = 0$) and a variance equal to one ($\sigma = 1$).

We suppose that agents have a CARA (Constant Absolute Risk Aversion) utility function: $u(c) = -\frac{1}{\rho}.\exp(-\rho.c)$ where ρ represents the coefficient of risk aversion. When necessary, we specify a coefficient of risk aversion, ρ, equal to 0.9 [4].

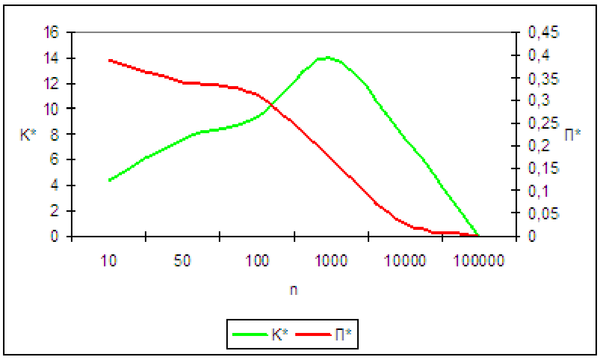
As we want to study the effects of changes in different variables on the optimal behavior of the insurance company, we focus on cases where it has a high incentive to be set up, that is on situations where the cost of capital is low. We thus specify here $\delta = 0.99$.

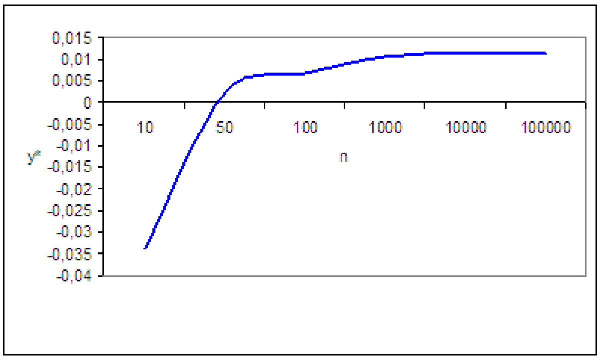
Lastly, we have to give a specific value to n when the size of the population is not the studied variable. In those cases we specify $n = 100$.

4.2.2 The Effect of Changes in the Size of the Population

As we already pointed out, the analyzis of the effect of changes in the size of the population (n) is complex because it also implies changes in the distribution of aggregate income. To study the implications of such variations on the optimal behavior of the insurance company we thus need to resort to simulations (c.f. Figure 4).

[4] As recommended in most of recent papers (see for exemple Chetty (2006) or Bombardini & Trebbi (2005)) we use here a coefficient of risk aversion around one





$(\delta = 0.99, u(c) = -\frac{1}{0.9}.\exp(-0.9.c), \widetilde{\omega} \sim N(0, n))$

Figure 4: The Effect of Changes in n

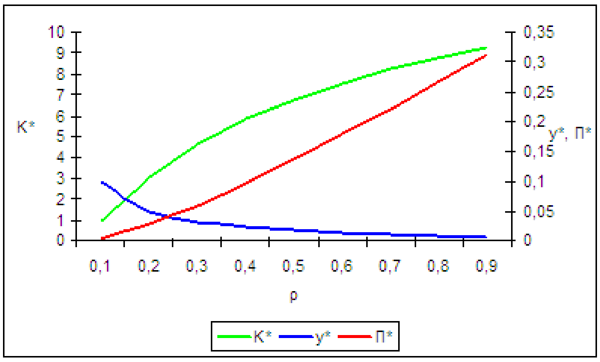
According to those simulations it appears that: *when risks are independent, an increase in the number of policyholders increases the optimal coverage offered by the insurance company and decreases its optimal profit.*

The positive effect of an increase in the number of policyholders on the offered coverage and its negative effect on optimal profit are intuitive as, by increasing risk pooling, an increase in n improves the performances of the mutual firm. The effect on the optimal stock of capital is then ambiguous as it is driven by two conflicting forces. First, as the sum of due coverage increases with n and y, the firm has to raise capital not to increase its insolvency probability. However, because it increases risk pooling, the increase in n lowers the risk of bankruptcy and the need for capital. It seems from our simulations that this last effect dominates for high values of n. Anyway, as an increase in n decreases optimal profit, it seems that it is all the more difficult for an insurance company to be set up as risk is initially shared among a lot of individuals.

4.2.3 The Effect of Changes in Risk Aversion

Proposition 2 states the effect of changes in risk aversion on profit in the general case, but is silent on its effect on the insurance company's choice. We simulate the effect of changes in the degree of risk aversion ρ on optimal capital and coverage.

Figure 5 outlines the outcomes of those simulations.



$(\delta = 0.99, \widetilde{\omega} \sim N(0,n), n = 100, u(c) = -\frac{1}{\rho}.\exp(-\rho.c))$

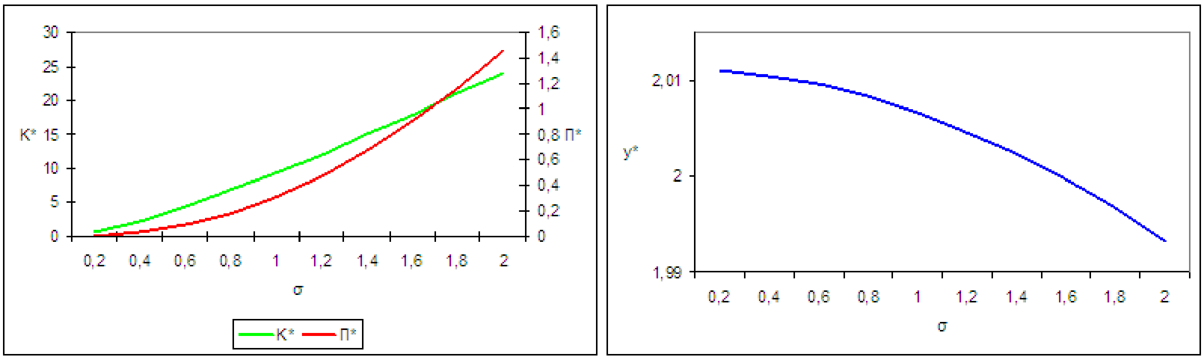
Figure 5: The Effect of Changes in ρ

Based on those results we learn that: *an increase in individual risk aversion increases optimal capital reserves and decreases optimal coverage*.

As already pointed out, because of the increase of their risk aversion, individuals are less demanding, and the company can propose a lower coverage. However, the result of such an increase is also to make policyholders even more reluctant to insolvency of the insurance firm that thus has to increase its capital stock. Still, as the decrease in y also has a negative effect on K, the first effect dominates. As stated in Proposition 2, the total influence on optimal profit is then positive. Those simulations confirm that the higher risk aversion, the larger the opportunity for a insurance firm to enter the market.

4.2.4 The Effect of Changes in the Variance of Individual Income

The last interesting analysis allowed by the specification of a particular cumulative distribution function concerns the effect of changes in the variance of individual income, σ.



$(\delta = 0.99, u(c) = -\frac{1}{0.9}.\exp(-0.9.c), n = 100, \widetilde{\omega} \sim N(2, n.\sigma))$

Figure 6: The Effect of Changes in σ

Those simulations give rise to the next finding: *an increase in risk (that is in the variance of each individual income distribution) increases optimal capital reserves, decreases optimal coverage and increases optimal profit.*

These effects can be intuitively explained by the fact that for higher σ, the insurance company becomes more attractive with respect to the mutual firm. As it automatically raises the variance of aggregate income ($\widetilde{\omega}$) when income are independent, an increase in the variance of individual income favors the insurance company that enables policyholders to avoid aggregate risk when it is solvent. The firm can then lower offered coverage without losing policyholders. However, the effect this decrease in y has on the capital stock, seems to be offset by the need for capital induced by the increase in aggregate risk. Still, maybe because of this effect of y^* on K^*, optimal profit appears to be positively affected by this increase in risk. So, the likelihood for a company to be set up and to compete with a mutual firm is higher when risks are high.

5 Conclusion

In studying both the competition between organizational forms in insurance and the investment choice of stock firms, this paper highlights the interaction between insurance contracts and capital stock, through the probability of insolvency. Given this interdependence, we specify the optimal choice of coverage and capital investment of a monopolistic company competing with a mutual firm, and show that it is unique. This paper moreover establishes that the possibility for a stock firm to be set up in insurance lines controlled by mutual firms (or mutual arrangements) is higher as the size of the insured population and the capital cost are low, and as risk and individual risk aversion are high.

This model explains how and why some risks are exclusively insured through mutual or stock firms but, as it considers homogeneous agents, does not explain another feature of insurance market: the coexistence of the two organizational forms. As agents are here homogeneous, the insurance company just needs to give the same utility as the mutual firm to insure the entire population. A possible way to model the coexistence of stock and mutual insurers in our framework would be to introduce heterogeneity. Insurance companies may then attract some kinds of individuals while mutual companies will insure the others. Because agents remaining in the mutual firm are not indifferent to the emergence of an insurance company, such an extension may allow a welfare analysis that would lead to policy advices concerning the regulation of insurance markets.

It also seems interesting to take into account the dynamic implications of the possibility of insolvency. In future work it would indeed be worthwile to analyze the long term effects of bankruptcy of insurance companies on their policyholders' utility. It might be that this expected utility is no longer strictly increasing with the coverage offered by the company. The long-run effect of a bankruptcy might then make the negative influence of an increase in coverage on insolvency probability exceed the positive one it has on monetary gains in case of solvency. Moreover, the introduction of a dynamic framework might also change the optimal agreement offered by the mutual firm since, as shown by Génicot & Ray (2003), it is not always optimal for mutual insurance arrangement to provide equal sharing.

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Appendix

Proof of Proposition 1

- First Order Conditions

The program of the insurance company being:

$$\max_{y,K} \quad \Pi(y,K) \equiv \delta. \int_{n.y-K}^{+\infty} (\omega + K - n.y)\, f(\omega)\, d\omega - K \tag{5.1}$$

$$\text{s.t.} \quad C(y,K) \equiv \int_{-\infty}^{n.y-K} \left[u\left(\frac{\omega+K}{n}\right) - u\left(\frac{\omega}{n}\right)\right] f(\omega)\, d\omega + \int_{n.y-K}^{+\infty} \left[u(y) - u\left(\frac{\omega}{n}\right)\right] f(\omega)\, d\omega = 0$$

its first order condition can be written as:

$$\begin{aligned}
& -\frac{\partial\Pi(y,K)/\partial K}{\partial C(y,K)/\partial K} = -\frac{\partial\Pi(y,K)/\partial y}{\partial C(y,K)/\partial y} \\
\Leftrightarrow\ & \frac{1-\delta[1-F(n.y-K)]}{\frac{1}{n}\int_{-\infty}^{n.y-K} u'\left(\frac{\omega+K}{n}\right) f(\omega)\, d\omega} = \frac{n.\delta}{u'(y)} \\
\Leftrightarrow\ & \frac{1-\delta[1-F(n.y-K)]}{\delta F(n.y-K)} = \frac{E\left(u'\left(\frac{\omega+K}{n}\right) | \frac{\omega+K}{n} \leq y\right)}{u'(y)} \\
\Leftrightarrow\ & \Phi(y,K) \equiv \int_{-\infty}^{n.y-K} \left[\frac{u'\left(\frac{\omega+K}{n}\right) - u'(y)}{u'(y)}\right] f(\omega)\, d\omega - \frac{1-\delta}{\delta} = 0
\end{aligned}$$

- Second Order Conditions

It can then be proved that this first order condition along with the constraint correspond to necessary and sufficient conditions that describe a maximum.

To do so let us study the following larger problem:

$$\max_{y,K,z(.)} \quad \int_{-\infty}^{+\infty} \omega f(\omega) d\omega - n \int_{-\infty}^{+\infty} z(\omega) f(\omega) d\omega - \frac{1-\delta}{\delta} K \tag{5.2}$$

$$\text{s.t.} \quad \begin{cases} \int_{-\infty}^{+\infty} u(z(\omega)) f(\omega) d\omega \geq \int_{-\infty}^{+\infty} u\left(\frac{\omega}{n}\right) f(\omega) d\omega \\ \min\left(\frac{\omega+K}{n}, y\right) \geq z(\omega)\ \forall \omega \end{cases}$$

The objective function of (5.2) $\left(V(K,y,z(.)) = \int_{-\infty}^{+\infty} \omega f(\omega) d\omega - n \int_{-\infty}^{+\infty} z(\omega) f(\omega) d\omega - \frac{1-\delta}{\delta} K\right)$

is linear in K, y and $z(.)$. Thus if the constraints define a convex set, then problem (5.2) is regular and its first order conditions are both necessary and sufficient for a maximum.

To verify whether it is true let us consider two triplets $K_1, y_1, z_1(.)$ et $K_2, y_2, z_2(.)$ that satisfy the constraints:

$$\begin{cases} \int_{-\infty}^{+\infty} u(z_1(\omega))f(\omega)d\omega \geq \int_{-\infty}^{+\infty} u\left(\frac{\omega}{n}\right) f(\omega)d\omega \\ \min\left(\frac{\omega+K_1}{n}, y_1\right) \geq z_1(\omega)\ \forall\omega \end{cases}$$

$$\begin{cases} \int_{-\infty}^{+\infty} u(z_2(\omega))f(\omega)d\omega \geq \int_{-\infty}^{+\infty} u\left(\frac{\omega}{n}\right) f(\omega)d\omega \\ \min\left(\frac{\omega+K_2}{n}, y_2\right) \geq z_2(\omega)\ \forall\omega \end{cases}$$

Then:

1. $\forall\alpha \in [0,1]$
   $\alpha \int_{-\infty}^{+\infty} u(z_1(\omega))f(\omega)d\omega + (1-\alpha)\int_{-\infty}^{+\infty} u(z_2(\omega))f(\omega)d\omega \geq \int_{-\infty}^{+\infty} u\left(\frac{\omega}{n}\right) f(\omega)d\omega,$
   $\alpha \int_{-\infty}^{+\infty} u(z_1(\omega))f(\omega)d\omega + (1-\alpha)\int_{-\infty}^{+\infty} u(z_2(\omega))f(\omega)d\omega \leq \int_{-\infty}^{+\infty} u(\alpha z_1(\omega) + (1-\alpha)z_2(\omega))f(\omega)d\omega$
   and thus: $\int_{-\infty}^{+\infty} u(\alpha z_1(\omega) + (1-\alpha)z_2(\omega))f(\omega)d\omega \geq \int_{-\infty}^{+\infty} u\left(\frac{\omega}{n}\right) f(\omega)d\omega$

2. Similarly, $\forall\alpha \in [0,1]$, we have
   $\alpha \min\left(\frac{\omega+K_1}{n}, y_1\right) + (1-\alpha)\min\left(\frac{\omega+K_2}{n}, y_2\right) \geq \alpha z_1(\omega) + (1-\alpha)z_2(\omega)$
   Then, the two variables function $\min(a,b)$ being concave from $\mathbb{R}^2$ into $\mathbb{R}$, it follows that:
   $\alpha \min\left(\frac{\omega+K_1}{n}, y_1\right) + (1-\alpha)\min\left(\frac{\omega+K_2}{n}, y_2\right) \leq \min\left(\frac{\omega+\alpha K_1 + (1-\alpha)K_2}{n}, \alpha y_1 + (1-\alpha)y_2\right)$
   Which leads to: $\min\left(\frac{\omega+\alpha K_1 + (1-\alpha)K_2}{n}, \alpha y_1 + (1-\alpha)y_2\right) \geq \alpha z_1(\omega) + (1-\alpha)z_2(\omega)$

Thus, the constraints of program (5.2) define a convex set and, as already pointed out, its first order conditions are both necessary and sufficient for a maximum.

Now, to prove that the equations $\Phi(y,K) = 0$ and $C(y,K) = 0$ define the optimum choice of the insurance company we have to prove that they satisfy the first order conditions of the program (5.2). Indeed, if those equations define the maximum of program (5.2) that is larger than (5.1) in imposing $\min\left(\frac{\omega+K}{n}, y\right) \geq z(\omega)\ \forall\omega$ instead of $\min\left(\frac{\omega+K}{n}, y\right) \equiv z(\omega)\ \forall\omega$, they also define the maximum of (5.1).

Calling λ and $\mu(\omega)f(\omega)$ the multipliers associated with the constraints, the first order conditions of (5.2) can be written as:

$$\forall\omega, \qquad -nf(\omega) + \lambda u'(z(\omega)f(\omega) = \mu(\omega)f(\omega) \tag{5.3}$$

$$\int_{ny-K}^{+\infty} \mu(\omega)f(\omega)d\omega = 0 \tag{5.4}$$

$$-\frac{1-\delta}{\delta} + \frac{1}{n}\int_{-\infty}^{ny-K} \mu(\omega)f(\omega)d\omega = 0 \tag{5.5}$$

the complementarity conditions being:

$$\begin{aligned}
\lambda &\geq 0 \\
\mu(\omega)f(\omega) &\geq 0 \\
\lambda \int_{-\infty}^{+\infty} \left(z(\omega) - u\left(\frac{\omega}{n}\right)\right) f(\omega)d\omega &= 0 \\
\mu(\omega)f(\omega)\left(\min\left(\frac{\omega+K}{n}, y\right) - z(\omega)\right) &= 0
\end{aligned}$$

(5.3) together with $\mu(\omega) \geq 0$ then leads to $\omega \geq ny - K \Longrightarrow \mu(\omega)f(\omega) = 0$ which gives, using (5.4): $\omega \geq ny - K \Longrightarrow z(\omega) = cte = z$

We then have:

$$\begin{aligned}
\lambda u'(z) &= n \\
\frac{1}{n}\int_{-\infty}^{ny-K} [-n + \lambda u'(z(\omega))]f(\omega)d\omega &= \frac{1-\delta}{\delta} \\
\mu(\omega)f(\omega)\left(\frac{\omega+K}{n} - z(\omega)\right) &= 0 \text{ for } \omega \leq ny - K \\
z(\omega) &= z \text{ for } \omega \geq ny - K \\
\lambda(\int_{-\infty}^{+\infty} \left(u(z(\omega)) - u\left(\frac{\omega}{n}\right)\right) f(\omega)d\omega &= 0
\end{aligned}$$

And one then can see that $\lambda, z(\omega), y, K$ verifying:

$$\begin{aligned}
\lambda u'(y) &= n \\
\frac{1}{n}\int_{-\infty}^{ny-K}\left[-n+\lambda u'\left(\frac{\omega+K}{n}\right)\right]f(\omega)d\omega &= \frac{1-\delta}{\delta} \\
z(\omega) &= \min\left(\frac{\omega+K}{n}, y\right) \\
\int_{-\infty}^{+\infty}\left(u(z(\omega)) - u\left(\frac{\omega}{n}\right)\right)f(\omega)d\omega &= 0
\end{aligned}$$

(that are the solutions of (5.1)) are solutions of previous equations (that is of (5.2)) with $y = z$.

Thus, the solutions of the program of the insurance company being the maximum of a larger program containing the one of the firm, it is also the maximum our this first program.

- The Existence of An Optimum

Once the optimum characterized we need to focus on the conditions under which an optimum giving a positive expected profit exists. As the company can always make null profit by mimicking a mutual firm in setting $K = 0$ and $y = +\infty$, this will be the case when there exists an optimum different from $K = 0$ and $y = +\infty$.

Rewriting the first order condition as: $\int_{-\infty}^{ny-K}\left(u'\left(\frac{\omega+K}{n}\right) - u'(y)\right)f(\omega)d\omega = \frac{1-\delta}{\delta}u'(y)$ we can see that the left hand side is increasing in y and decreasing in K, when the right hand side is decreasing in y and independent on K. Thus, a necessary condition for a solution not to exist is that for $K = 0$ and $y = +\infty$ the right hand side to be strictly lower than the left hand side, that is $\int_{-\infty}^{+\infty}\left(u'\left(\frac{\omega}{n}\right) - u'(+\infty)\right)f(\omega)d\omega < \frac{1-\delta}{\delta}u'(+\infty)$.
So,

- if $\widetilde{\omega}$ is not bounded, as the utility function satisfies the Inada condition, $u'(+\infty) = 0$ and an optimum that gives positive profit always exists
- if $\widetilde{\omega}$ is upward bounded, that is if $\mathbb{A} \equiv \{A \in \mathbb{R} \text{ s.t. } P(\omega \geqslant A) = 0\} \neq \varnothing$, with $\overline{\omega} \equiv inf\,(\mathbb{A})$, the company can not credibly propose $y > \left(\frac{\overline{\omega}}{n}\right)$ when $K = 0$, and an equilibrium exists only

$$\text{if } \frac{1-\delta}{\delta} < \frac{\int_{-\infty}^{\overline{\omega}} \left(u'\left(\frac{\omega}{n}\right) - u'\left(\frac{\overline{\omega}}{n}\right)\right) f(\omega)d\omega}{u'\left(\frac{\overline{\omega}}{n}\right)}$$

- Uniqueness of The Optimum

Rewriting the first order condition of the firm's program as:

$$\frac{E\left(u'\left(\frac{\widetilde{\omega}+K}{n}\right) | \frac{\widetilde{\omega}+K}{n} \leq y\right)}{u'(y)} = \frac{1-\delta.[1-F(n.y-K)]}{\delta.F(n.y-K)}$$

one can then show that when it holds, this condition corresponds to a unique mapping between the offered premia (y) and the capital stock (K). Indeed, keeping K constant, the left hand side is increasing in y from 1 to $+\infty$, when the right hand side is decreasing from $+\infty$ to 1. So, for each value of stock of capital the first order condition of studied programm gives a unique optimal premium.

Moreover,

- As:
$\frac{\partial\Phi(y,K)}{\partial K} = \frac{1}{n.u'(y)} \int_{-\infty}^{n.y-K} u''\left(\frac{\omega+K}{n}\right) f(\omega)\, d\omega < 0$, and
$\frac{\partial\Phi(y,K)}{\partial y} = -\frac{u''(y)}{u'(y)^2} \int_{-\infty}^{n.y-K} u'\left(\frac{\omega+K}{n}\right) f(\omega)\, d\omega > 0$,
the first order condition of our problem gives rise to an increasing relationship between y and K $\left(\frac{\partial y}{\partial K} \equiv -\frac{\partial\Phi(y,K)/\partial K}{\partial\Phi(y,K)/\partial y} > 0\right)$.

- Likewise, as
$\frac{\partial C(y,K)}{\partial K} = \frac{1}{n}.\int_{-\infty}^{n.y-K} u'\left(\frac{\omega+K}{n}\right) f(\omega)\, d\omega > 0$
$\frac{\partial C(y,K)}{\partial y} = [1-F(n.y-K)].u'(y) > 0$
the constraint corresponds to an decreasing relationship between y and K $\left(\frac{\partial y}{\partial K} \equiv -\frac{\partial C(y,K)/\partial K}{\partial C(y,K)/\partial y} < 0\right)$.

So, the optimal behavior of a monopolistic insurance company that competes with a mutual firm, characterized by the two equations $\Phi(y,K) = 0$ and $C(y,K) = 0$, is unique (when it exists).

Proof of Proposition 2

(i) Effect of Changes in δ

As the optimal choice of the company is fully characterized by the two equations $\Phi(y,K)=0$ and $C(y,K)=0$, and as $C(y,K)$ is independent on δ, the effect of the capital cost (δ) on the equilibrium has to verify:

$$\begin{cases} \dfrac{\partial C(y,K)}{\partial y}.\dfrac{\partial y}{\partial \delta}+\dfrac{\partial C(y,K)}{\partial K}.\dfrac{\partial K}{\partial \delta}=0 \\ \dfrac{\partial \Phi(y,K,\delta)}{\partial y}.\dfrac{\partial y}{\partial \delta}+\dfrac{\partial \Phi(y,K,\delta)}{\partial K}.\dfrac{\partial K}{\partial \delta}+\dfrac{\partial \Phi(y,K,\delta)}{\partial \delta}=0 \end{cases}$$

That is:

$$\frac{\partial y}{\partial \delta} = \frac{\dfrac{\partial C(y,K)}{\partial K}.\dfrac{\partial \Phi(y,K,\delta)}{\partial \delta}}{\dfrac{\partial C(y,K)}{\partial y}.\dfrac{\partial \Phi(y,K,\delta)}{\partial K}-\dfrac{\partial C(y,K)}{\partial K}.\dfrac{\partial \Phi(y,K,\delta)}{\partial y}}$$

and,

$$\frac{\partial K}{\partial \delta} = \frac{-\dfrac{\partial C(y,K)}{\partial y}.\dfrac{\partial \Phi(y,K,\delta)}{\partial \delta}}{\dfrac{\partial C(y,K)}{\partial y}.\dfrac{\partial \Phi(y,K,\delta)}{\partial K}-\dfrac{\partial C(y,K)}{\partial K}.\dfrac{\partial \Phi(y,K,\delta)}{\partial y}}$$

Now as, $\dfrac{\partial C(y,K)}{\partial y}>0$, $\dfrac{\partial C(y,K)}{\partial K}>0$, $\dfrac{\partial \Phi(y,K,\delta)}{\partial y}>0$, $\dfrac{\partial \Phi(y,K)}{\partial K}<0$ and $\dfrac{\partial \Phi(y,K,\delta)}{\partial \delta}=\dfrac{1}{\delta^2}>0$ one ends up with $\dfrac{\partial y}{\partial \delta}<0$ and $\dfrac{\partial K}{\partial \delta}>0$.

(ii) Effect of Changes in The Distribution of $\widetilde{\omega}$

If $F_2(\widetilde{\omega})$ first-order stochastically dominates $F_1(\widetilde{\omega})$ $\Big(F_1(\widetilde{\omega})\geq F_2(\widetilde{\omega})\,\forall\widetilde{\omega}\in]-\infty,+\infty[\Big)$ then:

- The first order condition: $\Phi(y,K)=0$ can be written as:

$$\int_{-\infty}^{n.y-K} u'\left(\frac{\omega+K}{n}\right) f(\omega)\,d\omega-\frac{1-\delta\,[1-F(n.y-K)]}{\delta}u'(y)=0$$

  that is, after integrating by parts: $\Phi_p(y,K,F)\equiv-\int_{-\infty}^{ny-K} u''\left(\frac{\omega+K}{n}\right) F(\omega)\,d\omega-\frac{1-\delta}{\delta}u'(y)=0$

Thus,

$$\Phi_p(y,K,F_1) - \Phi_p(y,K,F_2) = \int_{-\infty}^{ny-K} \underbrace{\left[F_2(\omega) - F_1(\omega)\right]}_{<0 \text{ by assumption}} \underbrace{u''\left(\frac{\omega+K}{n}\right)}_{<0} d\omega \geq 0 \quad (5.6)$$

- Similarly, integrating by parts the incentive constraint $C(y,K)=0$, one gets:

$$\begin{aligned} C_p(y,K,F) &\equiv u(y) - \lim_{a\to+\infty} u(a) + \int_{-\infty}^{n.y-K} \left[u'\left(\frac{\omega}{n}\right) - u'\left(\frac{\omega+K}{n}\right)\right] F(\omega)\, d\omega \\ &+ \int_{ny-K}^{+\infty} u'\left(\frac{\omega}{n}\right) F(\omega)\, d\omega = 0 \end{aligned}$$

And,

$$\begin{aligned} C_p(y,K,F_1) - C_p(y,K,F_2) &= \int_{-\infty}^{n.y-K} \left[u'\left(\frac{\omega}{n}\right) - u'\left(\frac{\omega+K}{n}\right)\right] \left[F_1(\omega) - F_2(\omega)\right] d\omega \\ &+ \int_{ny-K}^{+\infty} u'\left(\frac{\omega}{n}\right) \left[F_1(\omega) - F_2(\omega)\right] d\omega \geq 0 \quad (5.7) \end{aligned}$$

Using (5.6) and (5.7) one can then prove by contradiction that changing the distribution from $F_1(.)$ to $F_2(.)$ leads to a increase in the optimal offered coverage.

Indeed, if $y_1^* > y_2^*$ and F_2 first-order stochastically dominates F_1 then, according to the first order condition, we necessarily have $SP(y_1^*, K_2^*, F_1) = SP(y_2^*, K_2^*, F_2) = 0$ which means, from (5.6) and as $\dfrac{\partial \Phi_p(y,K,F)}{\partial y} > 0$ and $\dfrac{\partial \Phi_p(y,K,F)}{\partial K} > 0$, that the company will optimally choose $K_1^* < K_2^*$.

However, under the same assumption, according to the incentive constraint, we also necessarily have that $C_p(y_1^*, K_2^*, F_1) = C_p(y_2^*, K_2^*, F_2) = 0$. Now, with (5.7) and as $\dfrac{\partial C_p(y,K,F)}{\partial y} > 0$ and $\dfrac{\partial C_p(y,K,F)}{\partial K} > 0$ this would mean that $K_1^* > K_2^*$ which enters in contradiction with the previous result.

Thus, if F_2 first-order stochastically dominates F_1, then the company will necessarily choose $y_1^* < y_2^*$.

(iii) Effect of Changes in individuals degree of risk aversion

In the program of the insurance company:

$$\begin{array}{ll} \max\limits_{y,K} & \left\{ \delta. \int_{n.y-K}^{+\infty} (\omega + K - n.y)\, f(\omega)\, d\omega - K \right\} \\ \text{s.t.} & C(y,K,u(.)) \equiv \int_{-\infty}^{n.y-K} \left[u\left(\frac{\omega+K}{n}\right) - u\left(\frac{\omega}{n}\right) \right] f(\omega)\, d\omega + \int_{n.y-K}^{+\infty} \left[u(y) - u\left(\frac{\omega}{n}\right) \right] f(\omega)\, d\omega \geq 0 \end{array}$$

the objective function being independent of insureds utility function, the effect of risk aversion on optimal profit only goes through the constraint.

Let us take a strictly increasing and concave function g and set $w = g \circ v$. We then have that w is a Von Neumann Morgenstern utility function of a more risk averse individual than v.

We now can prove that because $C(y, K, w(.)) \geq C(y, K, v(.))$, that is because it enlarge the set of possible choices, an increase in individual risk aversion increase optimal profit.

Indeed as g is increasing and concave:

$$\begin{aligned} w\left(\frac{\omega+K}{n}\right) - w\left(\frac{\omega}{n}\right) &= g\left(v\left(\frac{\omega+K}{n}\right)\right) - g\left(v\left(\frac{\omega}{n}\right)\right) \\ &\geq g'\left(v\left(\frac{\omega+K}{n}\right)\right).\left(v\left(\frac{\omega+K}{n}\right) - v\left(\frac{\omega}{n}\right)\right) \\ &\geq g'(v(y)).\left(v\left(\frac{\omega+K}{n}\right) - v\left(\frac{\omega}{n}\right)\right) \qquad \forall \omega < n.y - K \\ \Rightarrow \int_{-\infty}^{n.y-K} \left[w\left(\frac{\omega+K}{n}\right) - w\left(\frac{\omega}{n}\right)\right] f(\omega) d\omega &\geq \int_{-\infty}^{n.y-K} \left[v\left(\frac{\omega+K}{n}\right) - v\left(\frac{\omega}{n}\right)\right] f(\omega) d\omega \\ &\text{and} \\ w(y) - w\left(\frac{\omega}{n}\right) &= g(v(y)) - g\left(v\left(\frac{\omega}{n}\right)\right) \\ &\geq g'(u(y)).\left(v(y) - v\left(\frac{\omega}{n}\right)\right) \\ \Rightarrow \int_{n.y-K}^{+\infty} \left[w(y) - w\left(\frac{\omega}{n}\right)\right] &\geq \int_{n.y-K}^{+\infty} \left[v(y) - v\left(\frac{\omega}{n}\right)\right] \end{aligned}$$

which together leads to $C(y, K, w(.)) \geq C(y, K, v(.))$.

It follows that if (y, K) is acceptable for a given individual, it is also acceptable for a more risk averse one. Thus, the profit of an insurance company increases with individuals risk aversion.

The second part of the proposition is obvious. Indeed, if individuals are risk neutral, the constraint becomes

$$\int_{-\infty}^{n.y-K}\left[\frac{\omega+K}{n}-\frac{\omega}{n}\right]f\left(\omega\right)d\omega+\int_{n.y-K}^{+\infty}\left[y-\frac{\omega}{n}\right]f\left(\omega\right)d\omega\geq 0$$

As the constraint is binding, it then leads to $\int_{n.y-K}^{+\infty}(\omega-n.y)f(\omega)d\omega=K.F(n.y-K)$ and the profit becomes $\Pi=-(1-\delta).K$

The optimal choice is thus to set $K=0$, and $y=+\infty$, which exactly amount to the behavior of a mutual firm.

References

Bombardini, M. Trebbi, F. (2005), 'Risk aversion and expected utility theory: A field experiment with large and small stakes', *working paper* .

Borch, K. (1962), 'Equilibrium in a reinsurance market', *Econometrica* **30**, 424–44.

Chetty, R. (2006), 'A bound on risk aversion using labor supply elasticities', *forthcoming American Economic Review* .

Doherty, N. Dionne, D. (1993), 'Insurance with undiversifiable risk: Contract structure and organizational form of insurance firms', *Journal of Risk and Uncertainty* (6), 187–203.

Eeckhoudt, L. Gollier, C. (1995), *Risk-Evaluation, Management and Sharing*, London: Harvester Wheatsheaf.

Fagart, M., Fombaron, N. Jeleva, M. (2002), 'Risk mutualization and competition', *The Geneva Papers on Risk and Insurance Theory* (27), 115–141.

Génicot, G. Ray, D. (2003), 'Group formation in risk-sharing arrangements', *Review of Economic Studies* (70), 87–113.

Laux, C. Muermann, A. (2006), 'Mutual versus stock insurers: Fair premium, and solvency', *working paper* .

Mayers, D. Smith, C. (1988), 'Ownership structure across lines of property-casualty insurance', *Journal of Law and Economics* (21), 351–78.

Rees, R., Gravelle, H. Wambach, A. (1999), 'Regulation of insurance markets', *The Geneva Papers on Risk and Insurance Theory* (24), 55–68.

Rothshild, M. Stiglitz, J. (1976), 'Equilibrium in competitive insurance markets: An essay on the economics of imperfect information', *Quarterly Journal of Economics* (90), 629–50.

Smith, B. Stutzer, M. (1990), ‘Adverse selection, aggregate uncertainty, and the role for mutual insurance contracts’, *The Journal of Business* **63**(4).