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ABSTRACT: It is widely recognized that market failure prevents efficient risk sharing in natural disaster insurance, leading to several public-private partnership arrangements across the globe. We argue that risk selection, a situation where the public partner insures the majority of high risk agents, is potentially an important issue. To illustrate our concerns we build a simple model of reinsurance in a natural disaster insurance market. We show that risk selection is a likely equilibrium outcome and discuss the policy options available. The model is based on the French institutional setup and describes well the stylized facts. The policies implemented by the French government correspond to the ones we identify to alleviate risk selection. We also present two alternative public-private partnership setting that deal effectively with risk selection; hurricane insurance in Florida and catastrophe insurance in Spain.

JEL Codes: G22, L11, Q54

Keywords: Risk selection, natural disaster, property insurance, reinsurance

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[*] We wish to thank Marius Brülhart, Thomas Crossley, Dominique Demougin, the editor, Christian Gollier, John Leach, an anonymous referee and seminar participants at McMaster University for helpful comments. Remaining errors and omissions are ours.

1 Introduction

Market failure in natural disaster insurance is widely recognized. Gollier (2005) discusses aspects that lead to a breakdown of efficient risk sharing, such as asymmetric information, limited liability of insurance companies and the suboptimal possibility of time diversification of insurers. Recommended policy options in most cases include some sort of public sector intervention. Of particular interest are the ideas that '[t]he existence of extensive bankruptcy costs on financial markets implies that catastrophe risks cannot be insured without the government playing the role of reinsurer of last resort.' (Gollier, 2005, p. 11) and that '...the state may be in a better situation to organize time diversification.' (Gollier, 2005, p. 16). Both statements indicate an active role of the public sector in disaster insurance.

In practice this does indeed seem to be the case. Von Ungern-Sternberg (2004) discusses natural disaster insurance in five European countries (England, Spain, France, Switzerland and Germany). The scope of public intervention ranges from "laissez-faire" in England to state owned monopoly in Spain and parts of Switzerland, via the abolition of state monopolies in Germany and public reinsurance in France. In the USA, both the federal and state governments participate in the provision of natural disaster insurance. Examples are the federal National Flood Insurance Program (NFIP), the Citizens Property Insurance Corporation in Florida and the Florida Hurricane Catastrophe Fund (FHCF), and the California Earthquake Authority (CEA).

In this paper we argue that issues of risk selection should be a major concern in the design of private-public partnerships for catastrophe insurance, with significant financial consequences for the taxpayer. *By risk selection we mean a situation where private insurers can pass on mainly the high risks to the public part of the private-public partnership.*[1] Insurers obviously have every incentive to keep mainly the good risks for themselves, if the institutional framework is designed in such a way that they can thereby increase their expected profits. Risk selection can arise both in situations where the public sector provides direct insurance for risks the private insurers do not want to cover, and when the public sector provides reinsurance to the private insurers.

Currently, existing natural disaster insurance schemes are under financial distress in a number of countries (such as France or the U.S.). Furthermore, many countries do not

[1] Our definition is similar to the one used by the World Health Organization, applied to a context of public sector participation. "(A) process whereby an insurer tries to attract people with a lower-than-average expected risk ...and deter those with a higher-than-average expected risk in order to increase profits; the process can be explicit or covert" (`www.euro.who.int`). We do not use the term adverse selection, since this is generally associated with asymmetric information in the litterature. We think that asymmetric information is not fundamentally important for natural disaster insurance and abstract from this in our model.

have an adequate system of protection against the financial and economic consequences of natural disasters. The call for reforms of existing, or implementation of new, institutional frameworks for natural disaster insurance is evident.[2]

In order to demonstrate the potential for risk selection and its significant financial implications we build a simple model of a natural disaster insurance market with reinsurance. The model framework is based on the institutional setting of the French natural disaster insurance ("*assurance catastrophe naturelle*") as it was initially set up and captures its essential features: reinsurance cover provided by a publicly owned reinsurance company at a unique (and risk independent) premium rate across the whole country. We show that specialization of insurers into homogeneous portfolios is a likely equilibrium outcome. This implies a tendency towards risk selection and a financially unsustainable situation for the reinsurance company. We then explore the possible policy alternatives within the model to deal with risk selection, including premium increases and limiting the degree of reinsurance.

We next study whether our simple model may shed some light on the observed developments of the French system since its creation in 1982. Note that the public-private partnership is sometimes praised as a *successful* one (see e.g. Michel-Kerjan, 2001, or Gollier, 2005). As such, it is likely to be considered as a potential example to reform existing disaster insurance systems in other countries or as a guideline to create new systems. We find that the French system exhibits the main characteristics of the equilibrium outcome described in our model, and that the policy reactions of the authorities are very similar to the ones our model suggests might be used to reduce the degree of risk selection. We then provide an outlook for the future sustainability of the system. We conclude that risk selection is likely to continue to be an important issue within the French system. The system has already needed to be refinanced at a substantial cost to the taxpayer and it seems likely that the same might reoccur in the (not so distant) future.

Finally, we briefly discuss two public-private partnership settings that deal effectively with the issue of risk selection. In Florida (USA), risk selection in hurricane insurance is alleviated through the availability of post event assessments to the public insurer and reinsurer. These assessments allow spreading the losses among a large number of policy holders. In Spain, catastrophe insurance is effectively provided via a public monopoly.

Both Florida's and Spain's institutional settings are under attack from forces wanting a

[2] This was dramatically illustrated by the 2004 Tsunami-earthquake in Southeast Asia, or, for that matter, by 2005 hurricane "Katrina" in the United States. Kunreuther (2006) presents recommendations to reform natural disaster insurance for the U.S. It is noteworthy that the problems of risk selection we focus on here are entirely absent of his discussion of the relevant issues.

larger role for private insurance providers. To the extent such reforms are being considered, the extent to which they might give rise to problems of risk selection should be carefully considered.

The role of the public sector in the provision of natural disaster insurance has been recognized as early as the 1970's (e.g. Kunreuther, 1974). Jaffee and Russell (1997, p.205) argue that, despite the potential to increase private sector participation in natural disaster insurance, the 'government will continue to be an essential player in catastrophe insurance markets'. Lewis and Murdock (1996) discuss reinsurance of natural disasters, indicating that the public sector can exploit intertemporal diversification to complement the private insurance market. A point similar to the one outlined by Gollier (2005). Rather than contributing to this direction of research, we take the role of the public sector as given and analyze potential consequences in terms of risk selection.

It is in the area of health insurance that risk selection has been most extensively discussed. Newhouse (1996) presents a good early survey of the main issues in the health insurance market both from a theoretical and an empirical perspective. More recently, some empirical papers have attempted to assess whether risk selection is indeed present in health insurance or not. The evidence seems to be mixed: on the one hand, Polsky and Nicholson (2004, p. 21) 'find no evidence that HMO plans attract a disproportionate share of low-risk enrollees'. On the other hand, Nicholson *et al.* (2004) find risk selection for employer-sponsored plans. Shen and Ellis (2002), using simulation methods, find that risk selection can remain profitable for insurers even after the implementation of risk-adjustment formulas, while Lehmann and Zweifel (2003) document that risk selection partly explains the cost advantages of HMOs.

In the reminder of this paper we first present a simple model of risk selection in natural disaster insurance with a public reinsurer. In Section 3 we discuss the policy options available within the model. We then present with some detail the French natural disaster. Finally, we briefly discuss hurricane insurance in Florida and catastrophe insurance in Spain. Section 4 ends with some concluding remarks.

2 A Simple Model of Risk Selection

In this section we present a highly stylized model of a natural disaster insurance market with reinsurance. The framework is inspired by the French system of disaster insurance (*assurance catastrophe naturelle*), i.e. the assumptions are chosen so as to capture the es-

sential characteristics of the French system. We discuss in later sections how the framework could be extended to other institutional settings.

Consider a country with two regions of equal size $i \in [H; L]$. Each region has a stock of $\mathcal{H}$ houses. Without loss of generality, the value of a house is normalized to 1. We assume that a region is subdivided into a finite number of counties, each with housing stock $\mathcal{M}$. A county can be affected by damage, which destroys the hosing stock in that county completely, i.e. the damage value is $\mathcal{M}$. Damage occurrence for each county in region i is assumed to follow a binomial distribution with the probability of damage equal to p_i. We assume that damage occurrence is independent both among counties and among regions. Hence, for each region the expected damage is $\mathcal{H}p_i$. Regions differ only in the respective probability of an event occurring, with the H-region having a higher probability of damage than the L-region ($p_H > p_L$).

Housing insurance is compulsory, and its price is fixed at a rate θ independent of p_i. Insurance is provided by identical insurers in a competitive market. The equilibirium concept is that of symmetric, free-entry equilibrium. Whenever an insurer j decides to sell insurance in a particular region i, its market share will be given by $1/N_i$, where N_i is the number of insurers active in the region.[3]

There exists a single reinsurance company which offers proportional reinsurance contracts to the market in all regions. Reinsurance is voluntary, and each insurer can decide on the fraction of the portfolio that it wants to reinsure. We denote by $r_j \in [0, 1]$ the rate of retention for insurer j.[4] An insurer can reinsure only its entire portfolio and therefore can choose **only one** level of r_j, even when active in both regions.[5]

The premium income from the fraction $(1 - r_j)$ of the portfolio that is reinsured is divided as follows. The insurer keeps a percentage γ to cover administrative costs and passes on $(1 - \gamma)$ to the reinsurance company. For the remaining portfolio, the insurer keeps the full premium income. The reinsurer covers the fraction $(1 - r_j)$ of total claims payments. In terms of a particular house in region i, revenue for insurer j from signing a natural disaster insurance contract can be expressed by the following random variable:

$$Rev_j(i) = \begin{cases} \theta\gamma + r_j\theta(1-\gamma) & with\,prob. \quad (1-p_i) \\ \theta\gamma + r_j\left[\theta(1-\gamma) - 1\right] & \qquad\qquad\quad p_i \end{cases}$$

[3] We work with free-entry equilibria to make the model simple. If the number of firms is fixed, they would earn positive profits (see discussion below).

[4] Hence $(1 - r_j)$ is the fraction of the portfolio that is reinsured.

[5] A unique rate of reinsurance is standard in the industry.

The insurer is certain to obtain $\theta\gamma$ for each house it has under contract. Further, with probability $(1 - p_i)$ the house does not suffer a damage. The insurer then receives the remaining premium income for the fraction of retained risks (r_j). With probability p_i the house is destroyed (damage value equals 1) and "net revenue" to the insurer is the fraction of remaining premium income minus the fraction of damage that the insurance company bears.

For the direct insurers all costs other than claims payments are assumed to be fixed. We consider two types of fixed costs. A region specific fixed cost (f) and a country specific fixed cost (F). Regional costs represent, for example, branch activities. For simplicity we assume that regional fixed costs (f) are the same in both regions. The cost of claims settlement is assumed to be equal to zero.[6] F represents the fact that some costs, such as setting up a countrywide representation, must be incurred independently of the number of regions covered. The country specific fixed cost (F) plays a crucial role in this model. Without it, there would be no incentive for an insurer to serve both regions. In fact, in the absence of F and under a competitive insurance market characterized by free entry, each individual insurer will seek a homogeneous risk portfolio in order to choose an optimal rate of retention. Only through the introduction of country fixed costs might an insurer actually want to provide service in both regions.

Insurers are risk averse. Insurer j maximizes expected utility choosing the optimal rate of retention r_j

$$\max_{r_j} E\left[u\left(\pi_j\right)\right] = E\left[\pi_j\right] - \frac{\lambda}{2} Var\left[\pi_j\right], \tag{1}$$

where π_j is profit of insurer j, and λ is the parameter of risk aversion.[7]

Additionally to the rate of retention, each insurer can decide where to be active. We distinguish two types of insurers: A *specialist (insurer)* serves only one specific region, while a *generalist (insurer)* serves both regions. Expressions for expected profits and its variance are

[6] One could argue that administrative costs in the H-regions are higher since there will be, on average, more cases to evaluate and forms to fill out. We abstract from this.

[7] The assumption of risk averse insurers allows for interior optimal choices for the rate of retention. Jametti and von Ungern-Sternberg (2004) build a similar model with risk neutral insurers, leading to binary choices for r_j. Alternatively, Kunreuther and Michel-Kerjan (2008) argue that insurers need to consider both expected losses and variance of losses when setting insurance premiums.

$$E[\pi_j] = \frac{\mathcal{H}}{N_i}[\theta\gamma + r_j(\theta(1-\gamma) - p_i)] - f - F, \tag{2a}$$

$$Var[\pi_j] = r_j^2 \frac{\mathcal{H}}{N_i} p_i(1-p_i), \tag{2b}$$

for specialists; and

$$E[\pi_j] = \begin{cases} \frac{\mathcal{H}}{N_L}[\theta\gamma + r_j(\theta(1-\gamma) - p_L)] \\ +\frac{\mathcal{H}}{N_H}[\theta\gamma + r_j(\theta(1-\gamma) - p_H)] - 2f - F, \end{cases} \tag{3a}$$

$$Var[\pi_j] = r_j^2 \left[\frac{\mathcal{H}}{N_L} p_L(1-p_L) + \frac{\mathcal{H}}{N_H} p_H(1-p_H)\right], \tag{3b}$$

for generalists.

Given the two types of insurers, three equilibrium characterizations are possible: all insurers are specialists $\Longrightarrow$ a *Specialist equilibrium* (SE); all insurers are generalists $\Longrightarrow$ a *Generalist equilibrium* (GE); both specialists and generalists coexist $\Longrightarrow$ a *Hybrid equilibrium* (HE).

Insurers maximize expected utility, while free-entry determines the number of active insurers such that expected utility is zero. Since there is no asymmetric information in the model, the equilibrium concept used is Nash equilibrium. Even though this model setup appears to be as simple as possible, useful analytic expressions for the equilibrium conditions for hybrid equilibria are impossible to obtain. For this reason we restrict the rest of our analysis to Specialist and Generalist equilibria. For each equilibrium candidate we calculate the conditions such that deviation (D) is not profitable. Deviation strategies are defined by entering or retiring from a particular region choosing the optimal rate of retention.[8] Equilibrium conditions, as well as the expression for the equilibrium rate of retention and number of insurers, are given in Table 1 where we have used the following definition:

Definition 1 *Risk-adjusted unitary profit (ω_{ij}) for insurer j in region i is defined as*

$$\omega_{ij} = \left[\theta\gamma + r_j[\theta(1-\gamma) - p_i] - \frac{\lambda}{2}(r_j)^2 p_i(1-p_i)\right]. \tag{4}$$

[8] Retiring from the market is never a profitable deviation, since equilibria are characterized by zero expected utility.

Figure 1, below, illustrates the equilibrium conditions in the θ-p_H space for two possible equilibrium outcomes.[9] The shaded area to the left corresponds to generalist equilibria with interior rates of retention, while the area to the right represents specialist equilibria with full reinsurance in the high probability region. The line *GE cond* represents situations where the generalist equilibrium condition from Table 1 holds with equality; similarly the line *SE cond* represents situations where the specialist equilibrium condition holds; finally, the third line represent points where $r_H = 0$ (i.e specialists in the H-region choose full reinsurance). Note that in the remaining areas of the graph other equilibrium characterizations would apply (such as hybrid equilibria or specialist equilibria with an interior rate of retention also in the H-region).[10]

The graph illustrates that the area of GE exists mainly for small differences in damage probabilities across regions. On the other hand, the (particular) specialist equilibrium occurs for high differences in damage probabilities. More formally we have the following result:

Proposition 1 *Assume $r_j < 1$ at least for some insurers and damage probabilities are such that there exist premium rates (θ) where some insurers choose to become specialists.*

Then discrete changes in θ will eventually lead to more specialization by insurers.

The proof is illustrated in Figure 1.[11]

The proposition characterizes the fundamental trade-off in the model: for small probability differences, the incentive to distribute the country fixed cost between two regions prevails (generalist insurers), while for larger differences the incentive to optimally set the rate of retention dominates (specialist insurers). Moving north-east in the graph implies thus the following: either some (or all) insurers decide to become specialists, or the premium rate is sufficiently high such that $r_j = 1$ for all insurers.

We are now in the position to analyze the problem of risk selection within the model. Risk selection affects the situation of the reinsurance company. It may end up with a disproportionate share of risks from the high probability region in its portfolio.

Definition 2 *We define the degree of risk selection as the number of high risks divided by*

[9] Without loss of generality we define p_H and p_L in terms of a mean preserving spread $\overline{p} = \frac{p_H + p_L}{2}$, which implies that high values of p_H correspond to large differences in the damage probabilities between the regions. We assume θ to be at least actuarially fair.

[10] Indeed, our model satisfies the conditions of Proposition 8.D.3 of Mas-Colell, Whinston and Green (1995) implying existence of a pure strategy equilibrium.

[11] A formal prove is available upon request. Jametti and von Ungern-Sternberg (2004) obtain similar results.

the number of low risks that are reinsured.

$$\rho = \frac{(1-r_H)\,\frac{N_{SH}}{N_{SH}+N_G} + (1-r_G)\,\frac{N_G}{N_{SH}+N_G}}{(1-r_L)\,\frac{N_{SL}}{N_{SL}+N_G} + (1-r_G)\,\frac{N_G}{N_{SL}+N_G}} \geq 1 \tag{5}$$

where N_{SH} represents the number of specialists in the high probability region, etc.

The numerator consists of a weighted average of the rate of reinsurance in the H-region of specialists $(1-r_H)$ and generalists $(1-r_G)$, weighted by the percentage of insurers of each type in this region. The denominator is the equivalent expression for the L-region. A value of $\rho = 1$ implies that the reinsurer has a balanced portfolio (the same percentage of reinsurance in both regions. Values of $\rho > 1$ imply a certain degree of risk selection.[12] "Full risk selection", a situation where the reinsurer only reinsures risks from the H-region implies a value of $\rho = \infty$.

We are also interested in the expression for the expected profits of the reinsurer. For this we assume that the reinsurer does not incur costs other than the claims payments. Expected profits are then given by

$$\pi_R = \sum_i \sum_j \frac{N_{ij}}{N_{iS}+N_{iG}} \mathcal{H}\,(1-r_{ij})\,[\theta\,(1-\gamma) - p_i]\,. \tag{6}$$

For example, in the case of a generalist equilibrium this expression reduces to

$$\pi_R = \mathcal{H}\,(1-r_G)\,[(\theta\,(1-\gamma) - p_L) + (\theta\,(1-\gamma) - p_H)]\,.$$

Figure 2 takes up our example of generalist and specialist equilibrium areas and illustrates the outcome in terms of our measure of risk selection (ρ) and expected profits of the reinsurer (π_R), for premium rates that are at least actuarially fair.

Quite naturally, in the case of a generalist equilibrium, there is no risk selection. However, it must be noted that an important part of the area is in situations where the reinsurance company is not financially viable. Indeed, the horizontal line indicates points where $(\theta\,(1-\gamma) - p_L) + (\theta\,(1-\gamma) - p_H) = 0$, i.e. below this line the reinsurer is not financially viable even in a case where it receives the entire housing portfolio. For the upper left part of the GE-area, π_R can be positive or negative. The intuition behind this result is straightforward. If the premium rate is sufficiently low so that the insurers can make little profit even on the low risks (in excess of the share of premiums they keep to cover their administrative costs) then they will purchase full reinsurance. However, the premium income for

[12] Values of $\rho < 1$ do not occur in equilibrium.

the reinsurer might then not be sufficiently high to cover its expected claims payments.

In the case of a specialist equilibrium, there is always a certain degree of risk selection ($\rho > 1$). Specialist insurers in the H-region will have a lower rate of retention (a higher rate of reinsurance) than their counterparts in the L-region. In the specific case displayed in Figure 2, the SE-area corresponds to a situation with "full risk selection", where specialists in the H-region fully reinsure and those in the L-region fully retain their risks. In such a situation, the expected profit of the reinsurer must be negative.

Proposition 2 *Assume $r_j < 1$ at least for some insurers and damage probabilities are such that there exist premium rates (θ) where some insurers choose to become specialists.*

Then discrete changes in (θ) will eventually lead to more risk selection (higher ρ) and losses for the reinsurer ($\pi_R \leq 0$)

The proof is illustrated in Figure 2.

Thus, a move north-east in the graph implies a higher degree of risk selection (as long as there is any reinsurance), and this situation eventually leads to a worsening of the financial situation of the reinsurance company.

In conclusion, risk selection is an important feature of our model unless the country specific fixed costs are very large. It is particularly important in situations where there are significant differences in the damage probabilities across regions.

3 Discussion

3.1 Policy options within the model

One could argue that risk-dependent premium rates are an easy and immediate solution to risk selection within the model. This might be a somewhat fast conclusion. On the one hand, it is generally recognized that it is difficult to exactly measure the risk exposure for natural disasters given their characteristics of low probability high impact. Kunreuther and Michel-Kerjan (2008) show that insurers require significant premium increases in situations of parameter uncertainty. On the other hand, the same authors argue convincingly, that high risk exposure can affect the credit rating of an insurers, thus increasing the cost of capital for the entire portfolio. This in turn implies that load factors, i.e. premiums above actuarially fair rates, increase with risk exposure.

Hence, risk-dependent premium rates do not automatically imply a generalist equilibrium outcome. It might be that premium rates, although differentiated across regions, are

such that insurers still have the incentive to specialize into one region. The problem of risk selection then remains. Furthermore, significantly higher charges in disaster prone areas might not be politically feasible.[13]

A uniform increase in the premium rate might not be an adequate solution for two reasons: first, it might actually worsen the problem of risk selection, as a higher premium rate increases the incentive of insurers to specialize into a homogeneous risk portfolio (see Proposition 2); second, increasing premium rates, in particular increasing premium rates above actuarially fair rates, comes at a cost to the final customer, who pays an ever higher price for the service.[14] In our model, due to the free-entry assumption, higher premium rates translate into a higher number of insurers in the market, which creates an inefficiency since regional and country fixed costs are multiplied.

Within the model, a more adequate policy mix would consist of two measures: increase the premium rate and make a substantial rate of reinsurance compulsory. The problem of risk selection is created by the possibility of insurers to serve only the low risk customers, buy little reinsurance and make profits on these low risk customers. The model shows that insurers have an incentive to do so. If these insurers are forced to reinsure a substantial part of their portfolio, the cost for them of accepting some high risk customers will fall, and this leads to a reduction in the degree of risk selection (ρ).

3.2 The case of France

3.2.1 The institutional framework

Natural disaster insurance was introduced in France in 1982 as a reaction to a severe flood a few months earlier. The term natural disaster ("*catastrophe naturelle*") is not defined in the law creating the system.[15] A commission, formed of representatives of the Ministries of Interior, Finance and Environment, has to decide whether a given occurrence is deemed

[13] More generally, redistribution towards people living in high damage areas seems acceptable to most societies worldwide. Otherwise it would be difficult to explain the significant public and private disaster relief spending. Frame (2001) shows that redistribution towards households in disaster prone areas might be beneficial also to households in safe areas. In this spirit, it would be interesting to build a more general model that endogenizes the choice of the institutional framework including, for example, equity aspects to argue in favour of a uniform premium rate. We leave these considerations for future research.

[14] Jametti and von Ungern-Sternberg (2004) provide an analysis of the cost of service provision in their model. They calculate "social" cost as the sum of the reinsurer's losses and premium payment (free entry implies zero profits for insurers). They find that increasing the premium rate in a situation of risk selection is significantly more costly relative to a situation of full reinsurance.

[15] The description below is drawn from von Ungern-Sternberg (2004). Additional information was obtained from a letter by the CEO of the public reinsurer to a private insurer dated in October 1996 (CCR, 1996). The letter is written in French, any translations in this paper have been done by the authors, which are not certified translators. Copies of this letter can be obtained from the authors upon request.

a natural disaster and hence makes claimants eligible for reimbursement. The conditions of insurance (in particular premium rates and excesses) are fixed by decree and uniform across the country.[16] Insurance is compulsory, presumably to reduce problems of adverse selection among property owners. Similarly, all insurance companies offering (other types of) property insurance in a specific area are obliged to include protection against natural disasters. Premium rates are defined as a percentage of other property insurance premiums (in particular fire), while excesses (for non-commercial buildings) are fixed per contract and per event.[17]

An important institutional feature of the system is the existence of a publicly owned reinsurance company, the *Caisse Centrale de Réassurance* (CCR). Reinsurance is not compulsory, and insurers are free to contract with other, private, reinsurance companies. Reinsurance with the state reinsurance company is, however, potentially attractive, both because the reinsurance premiums charged are low and because it can offer unlimited cover (it is covered by a state guarantee). Insurance companies that decide to reinsure with the public reinsurer are offered two types of contracts; proportional contracts (for a given percentage of premium income the reinsurance company covers a given percentage of claims) and stop-loss contracts (the reinsurance company covers all claims that exceed a given multiple of annual premium income).

The initial conditions of insurance were the following: The premium rate was set at 5.5% of the basic housing insurance contract, and excesses for a residential structure were FF 800 (€124). The basic CCR conditions were: for proportional contracts insurers could choose any rate of reinsurance between 40% and 90%. Stop-loss contracts were only offered to insurers that also participated in the proportional contract. Conditions for the stop-loss contracts were negotiated on a case by case basis. Furthermore, the CCR offered the private insurers a commission for administrative expenses of 24% of the reinsured premium income.

3.2.2 The main changes to the system since its creation

There have been four major changes to the system since its creation in 1982.

[16] The uniform premium rate and insurance conditions are a fundamental cornerstone of the system, presumably as a result of equity concerns. It should be noted that so far no-one has advocated changing this feature.

[17] One could argue that it is impossible to treat the natural disaster insurance "market" independently from other housing insurance, since these contracts are sold together. We would argue that this is not the case. It is easily conceivable that losses in the natural disaster segment drive an insurer out of a particular region, even if premium income from this segment is relatively small. Imagine a region where the basic housing insurance is delivered in a competitive market with no returns to scale. Clearly, an insurer would opt not to provide insurance in a situation where the disaster insurance incurrs losses, even if the fraction of premium income from this segment is small.

In 1983, i.e. just one year after its creation, the premium rates for buildings were increased by more than 50% (from 5.5% to 9%). At the same time the excesses were also revised upwards (from FF800 to FF1500).

In 1990 the French overseas districts (Départements Outre Mer, DOM, e.g. Guadeloupe, Martinique) were included in the natural disaster insurance scheme. Insurers had to provide disaster insurance if they wanted to operate in the DOM. The private insurers accepted this introduction only under the condition that these territories could be reinsured separately from the mainland portfolio. The legislator and the CCR accepted this condition.

In 1996, after its reserves had dwindled to less than €300 million (2 billion FF), the CCR substantially revised its reinsurance conditions. The range for the proportional reinsurance rate was reduced to a rate between 40% (minimum unchanged) and 60% (maximum reduced by 30 percentage points). The minimum retention rate for the insurers in the proportional reinsurance cover was thus increased from 10% to 40%. For insurers with a high share of industrial risks, the maximum rate was further limited to 40%, i.e. their compulsory retention rate was fixed at 60%. The possibilities to obtain stop-loss cover were also reduced. The minimum loss for the insurer before the stop-loss could come into play was increased to equal 100% of the insurers **total** (gross) premium income. For small insurers or insurers with a bad risk portfolio (mainly industrial risks or risks in the DOM), the minimum excess was even higher. Finally, the commission to cover administrative costs varied, according to the historic claims/premium ratio of the insurers, between 18% and 24%.

In spite of these changes the CCR was virtually bankrupt by the end of the year 1999. The resulting bail-out by the government was accompanied by a major financial reorganisation. The premium rate was increased by one third (from 9% to 12%) and the excesses were multiplied by a factor of (approximately) 2.[18] The commission for administrative costs was entirely abolished.[19]

The rate of proportional reinsurance was fixed at 50%, i.e. the maximal and minimal rates are now equal. If the insurance companies wish to continue obtaining separate cover for their risks situated in the DOM, they can do so only at the cost of accepting a substantial excess (1600% of annual premium income) on those risks.

[18] The factor is less than 2 for damage due to flooding, and more than 6 for damage due to subsidence.

[19] The 24% commission in France should be compared with the commission of just 5% paid by the "Consorcio" in Spain.

3.2.3 Does the model apply to the case of France?

We would argue that risk selection is a fundamental flaw that lead to the virtual collapse of the system by the year 2000. Our conjecture is supported by the fact that most of the changes outlined above coincide with the policy recommendations emanating from our model to reduce risk selection. Ideally, one would like to analyse these issues on the basis of individual firm data, in particular to obtain an empirical measure of ρ. Unfortunately, no firm-level data is available, and we have to limit ourselves to the interpretation of system-wide information.

Before turning to the specific aspects of the development of the disaster insurance system it is important to appreciate that the institutional setup, which combines proportional and stop-loss contracts, implies the CCR will bear most of the cost when a large-scale disaster occurs. If the reinsurer is unable to accumulate sufficient reserves to face "spikes" in damage payments, this will trigger the state guarantee. Hence, the tax payer might end up paying the bill of a large disaster, or a series of large disasters.

Let us now turn to the overall financial performance of the system. Table 2 presents information of the first 20 years of existence of the natural disaster insurance. The first column of data presents the industry claims-premium (C/P) ratio. Over the period 1982-2001 the average C/P ratio was 58%, with important yearly variation due to the infrequent occurrence of natural disasters. This is in line with other segments of the insurance industry. However, the crucial difference is that within the French system, where natural disaster contracts are compulsory and an add-on to basic housing insurance contracts, acquisition and administrative costs should be very low.

The second column gives an estimate of the overall profitability (including capital income) of the system. The methodology used for this computation is detailed in Appendix A1. Accumulated system-wide profits over the first 20 years are estimated at roughly 7.2 billion €. Column three shows the rate of reinsurance of the private insurers. One can observe the important drop in the rate of reinsurance from above 80% at the beginning of the system to 40% (the lowest the CCR would allow, while still offering stop-loss contracts) by the end of the 1990's. Note that the final increase in the rate of reinsurance was the introduction of the unique rate of 50% by the reinsurer.[20] Finally, columns four and five indicate information on the financial evolution of the CCR, presenting the ceded premium income and the evolution of reserves of the public reinsurer.

[20] The reason why the rate of reinsurance is not exactly equal to 50% is due to the fact that the figures include insurance/reinsurance of minor items such as vehicles, which are not subject to the 50%-rule.

Our calculations indicate that despite the system-wide financial viability, the surplus of the system was not used to keep the public part of the public-private partnership afloat. The premium income of the CCR remained fairly stable over time and, more importantly, the reinsurer was never able to accumulate any significant reserves. To the contrary: the reserves of the CCR were drained from over 500 million € in 1992 to practically zero in 1999. At this point the French government stepped in, refinancing the CCR with approximately 450 million €. In spite of the substantial premium hike in 1999 the CCR's reserves were still only at 427 million € by the end of 2001, i.e. less than the government injection of funds. To summarize, the entire surplus of the system landed in the pockets of the private insurers.

Our model highlights that risk selection contributed significantly to this situation. A first point to note is the rapid rise in the retention rate, mentioned above. Two symptoms would contribute to explaining this development. First, the substantial rise in premium rates in 1984 made a higher retention rate much more attractive. Second, this same rise in premium rates and the accompanying reduction in retention rates made it more expensive to keep high risks on a portfolio of essentially low risks. Specialising on low risk customers, and retaining all risks, or specialising on high risk customers and reinsuring became much more profitable strategies than offering across-the-board service (Proposition 1). Note that this is exactly the result of our model, i.e. higher premium rates imply lower rates of reinsurance and lead to more risk selection (Proposition 2). As mentioned before, we do not have firm level data to establish whether this is in fact what happened.

All the changes of policies implemented in the insurance system are easily understandable if one accepts risk selection to be a problem in the system. They all aim at increasing the amount of low risks in the portfolio of the reinsurer. They are, indeed, in line with our policy discussion: increase the premium rate and increase the rate of reinsurance.

Quite obviously, our model abstracts from various points of reality. It is conceivably possible to build a much more complex model that might explain the outcome in France without relying on risk selection. In the spirit of Occam's razor, we favour our simple and straightforward explanation.

As a final point of illustration of the problems of risk selection we quote the communication of the CCR to the private insurers from 1996, when outlining the situation in the DOM: "The logic of the system requires that there should, at the reinsurance level, be some degree of coinsurance between the insurers heavily engaged in the DOM and those that have no contracts in that region. However, the major events like the floodings due to

the three hurricanes in 1995 have allowed us to establish, that the CCR has had to cover 98% of the costs, i.e for these events 650 million Francs, as compared to 24 million Francs income in the form of reinsurance premiums. It has thus become necessary to reestablish an equilibrium that is more acceptable to the market as a whole, by raising the excess of the non-proportional reinsurance cover to be born by the insurers" (CCR, 1996).

3.2.4 An outlook

When trying to assess the efficiency of the system as it now stands, a first point to emphasise is that it is getting more and more costly for the houseowner. As shown, the overall system was economically viable with the premium rates set in 1984. Nevertheless, rates were increased by one third in the year 2000. The houseowners now have to pay considerably more for a lower coverage (higher excesses).

Second, while the CCR's premium income more than doubled from 303 million € in 1999 to 680 million € in 2004 (CCR, 2005) its reserves, after increasing to almost 600 million € in 2002, are currently only slightly over 400 million €. This is nowhere near the amount necessary to cover the reinsurance cost of a major natural disaster.

Finally, it is unclear at what stage a private insurer might decide that it is more profitable to concentrate on the good risks, and stop buying reinsurance cover from the CCR altogether. There is always the possibility to turn to private competitive reinsurance companies. They may be unwilling to offer unlimited reinsurance cover, but it is likely that for a good portfolio they can offer considerably lower costs of reinsurance.

It is by no means certain that the "carrot" of unlimited reinsurance cover will in the long run be sufficient to limit the extent of risk selection and allow the CCR to reinsure a sufficiently large fraction of the low risks. The lawmaker intended these low risks to subsidise the system. Their (compulsory) premium payments may however just end up increasing the profits of the insurance companies.

3.3 Risk selection in other institutional settings

Our model illustrates the importance of carefully taking into account issues of risk selection when supplying natural disaster insurance via public-private partnerships. We based our theoretical framework on the institutional setting prevailing in France. It is therefore difficult to apply our model directly to other institutional settings. Nevertheless, public-private partnerships do exist in natural disaster insurance in several other countries and they also are prone to problems of risk selection. We would thus argue that our model helps

to better understand the structure of these other institutional settings. In the remainder of this section we illustrate two examples that we think deal successfully with the issue of risk selection in different ways. The examples are hurricane insurance in Florida and catastrophe insurance in Spain.

3.3.1 Florida

A comparable situation of a public-private partnership with a potential issue of risk selection is hurricane insurance in Florida (USA).[21] Besides private sector companies, the two public institutions directly involved in the sector are the Citizens Property Insurance Corporation (Citizens) a not-for-profit corporation acting as a "insurer of last resort" and the Florida Hurricane Catastrophe Fund (Cat Fund) providing reinsurance. The public sector involvement is a reaction to the unwillingness of private insurance providers to continue offering hurricane insurance in some areas, notably after hurricane Andrew in 1992.

Participation in the Cat Fund is compulsory for each insurer wishing to provide housing insurance in the State of Florida. In the basic contract, insurers select a rate of reinsurance of 45%, 75% and 90% above an individually calculated deductible.[22] The deductible roughly depends on the insurer's market share with a system wide deductible of $4.5 billion in 2008. Guaranteed coverage of the reinsurer depends on: current premium income, accumulated reserves and a assigned borrowing capacity of the Cat Fund, amounting to roughly $15 billion in 2008. Additionally, insurers can buy, at the same premium rates, additional coverage up to $12 billion, if they wish to do so. There is no formal government guarantee for the Fund. Finally, premium rates vary across regions, based on an actuarial evaluation by an independent consultant. The specificity of the Cat Fund is that it can levy post event assessments on all property insurance contracts and use these fundds to repay any debts it may have contracted to cover its reinsurance obligations.

Citizens was created in 2002 from the merger of two existing public insurance providers: the Florida Residential Property and Casualty Joint Underwriting Association (JUA) and the Florida Windstorm Underwriting Association (FWUA).[23] Per mandate Citizens offers property insurance to individuals in good standing who do not have access to insurance in the private market. Nevertheless, Citizens is supposed to charge premiums that allow it to cover costs. Further, similar to the Cat Fund in case of a major event the provider is

[21] The section is drawn, in part, on von Ungern-Sternberg (2009).

[22] Note that by 2007 only one insurer remained with the option of 75% reinsurance. 32 (15.8%) selected the 45% and 169 (83.7%) the 90% option.

[23] The FWUA was created in 1970 already, while the JUA originated only months after Hurricane Andrew.

allowed to charge *ex post* assessments to recoup incurred losses. Currently Citizens holds a market share of roughly 30% (Citizens, 2008).[24]

The above description shows some similarities with our model: the existence of a publicly administered reinsurance company offering a choice of proportional reinsurance contracts. Further, the private sector can pass high risk customers to Citizens, which in turn reinsures mainly with the Cat Fund.[25] Risk selection could be an important concern under these circumstances.

In the spirit of our model, the possibility to charge risk adjusted premium rates by the public players should substantially alleviate the issue of risk selection, even if it does not entirely eliminate it. In fact, it is doubtful that regional premium rates are truly actuarially fair.

The simple fact that reinsurance with the Cat Fund is compulsory for all insurance providers strongly indicates that its reinsurance premiums are likely to have a redibstibutive element from low to high risk properties. Similarly, Citizens premium rate are unlikely to be actuarially fair because of the (contradicting) mandate of offering affordable, yet cost effective, insurance.[26] (In 2006 Citizens applied for premium increases based on an actuarial valuation but the Florida legislator imposed a premium freeze until 2010.)

We would argue that the possibilty of charging post event assessments goes a long way in solving the issue of risk selection. These taxes imply that both Citizens and the Cat Fund do not need to accumulate important reserve *ex ante* to face a major hurricane (or a series of hurricanes), but rather can distribute the cost of a major disaster upon a large number of (captive) policy holders.[27] Note that a private reinsurer does not have this possibility (and would therfore need to charge much higher premiums to accumulate significant reserves).

Since the Cat Fund can assess all insurance providers, which are also its clients, *ex post* with a proportional tax to recoup its losses,[28] it can effectively distribute the surcharge over a large number of policy holders. The increased cost per policy holder is thus quite low. The abilty to charge these assessments allow the Cat Fund to keep its reinsurance premiums and cost of capital low despite the large risk exposure. Both of these factors contribute significantly to reducing the cost of reinsurance for the Florida policy holder.

[24] Thus, Citizens is the largest property insurance provider in the State. Some discussion has arisen as to whether this qualifies still as an "insurer of last resort".

[25] Over 40% of the Cat Fund's portfolio is from Citizens (von Ungern-Sternberg, 2009).

[26] Jaffee and Russell (1997, p. 12) note that the JUA, a predecessor of Citizens charged premium rates based on 'an artful mix of actuarial science and politics'.

[27] Indeed, the assessment base both for Citizen and the Cat Fund go beyond housing insurance policies and include other insurance lines, e.g. car insurance.

[28] In order to recover the losses from the 2004 and 2005 hurricane seasons, the Cat Fund implemented a 1% emergency assessment in 2007 for the next eight years.

Similarly, Citizens' assessments allow the public insurer to offer fairly low premium rates to high risk property owners. This has both advantages and disadvantages to the private sector. On the positive side, Citizens as insurer of last resort, reduces the risk exposure of private insurers. This lowers the average cost of capital, thus allowing private insurers to compete more effectively for lower risks. On the negative side, however, Citizens clearly acts in an uneven palying field, raising competitive policy concerns. In fact, the possibility to assess private insurers implies that Citizens can pass part of its cost on to its "competitors".

Despite the competition policy concerns, which are non-negligible given the size Citizens has acquired since its inception, we would argue that the current framework of hurricane insurance addresses the issue of risk selection quite ingeniously, offering hurricane insurance at an affordable price to Floridians. There have been recent calls for reform aiming at reducing the role of the public sector. These reforms should consider the issue of risk selection very carefully.

3.3.2 Spain

Another solution to the issue of risk selection is presented in the case of natural disaster insurance in Spain. The publicly owned "Consorcio de Compensacion de Seguros" is a pure monopoly. Arguably, the issue of risk selection had an important impact in shaping the current institutional seting in Spain.

Catastrophe insurance[29] in Spain is compulsory. It has to be contracted with the conclusion of most, privately provided, insurance policies, such as fire, car insurance etc. Private insurers act solely as financial intermediaries and remit all premiums to the Consorcio. Claims are settled by the Consorcio itself. Premium rates are uniform across the country. Hence in Spain just as in France, there are major redistributive effects between the low risk and the high risk areas.[30]

It is only because of its monopoly status, that risk selection has never been an issue for the Consorcio. Its benefits to the property owners come from the fact that it runs an extremely efficient organization. Total administrative costs (including a 5% commission to the insurance companies) represent only 10% of premium income. By comparison, the US Federal National Flood Insurance Program (NFIP) has administrative expenses of the order of 40% of premium income, (including a 35% commission to the insurance companies). A further indication of the effectivenes of the program is the average claims - premium ratio

[29] In the case of Spain this includes extraordinary events such as terrorism.

[30] Von Ungern-Sternberg (2004) indicates that 65% of damages are concentrated in 5 (out of 50) Provinces.

for the period 1971 to 1999 which was of the order of 98%.[31]

Despite offering comprehensive catastrophe insurance at very low cost, the role of the Consorcio was under heavy attack from the European Union via its third non-life insurance directive. This directive aimed at eliminating monopolies in the insurance sector. Spain realized that the absolute monopoly of the Consorcio was essential to avoid issues of risk selection. It avoided the abolition of the Consorcio's monopoly status redefining the Consorcio's premium rates as "indirect taxes". So far the European Union has accepted this "rephrasing" (see von Ungern-Sternberg, 2004).

4 Conclusions

Most natural disaster insurance schemes include various degrees of public sector participation. We argue that in all such situations careful thought should be given to the issue of risk selection, which we define as a situation where private insurers "pass on" the high risks to the public part of the partnership, while keeping the low risks for themselves.

To illustrate our concerns we build a simple model of a natural disaster insurance market. Caracteristics of the model are: a unique and risk-independent premium rate and the existence of a reinsurer offering proportional contracts. We show that in this framework risk selection is a likely equilibrium outcome, in particular if there exist significant regional differences in damage probabilities. Policies to remedy this situation focus on achieving a better balanced portfolio for the (public) reinsurer. The assumptions of the model are chosen so as to capture the essential features of the French natural disaster insurance system. We note that the evolution of the system over the last 20 years strongly indicate that problems of risk selection are indeed a major source of financial instability. In case of a major event, the taxpayer will end up having to pay for most of the costs.

Using hurricane insurance in Florida and catastrophe insurance in Spain, we further illustrate that well devised public-private partnerships can solve (or reduce) problems of risk selection. Of course, the private insurance sector's profits are lower under these institutional set-ups. It is noteworthy that both examples are under pressure to implement reforms that give the private part of the partnership a larger role. When discussing these reforms, one should carefully consider the impact any modification of the system has on the issue of risk selection.

[31] Two factors are responsible for this surprisingly high C/P ratio. First, as already mentioned, it has very low administrative costs. Second it has managed to earn high interest incomes on its reserves during the periods of high inflation.

A Calculation of system surplus

In this appendix we briefly describe our financial performance evaluation of the natural disaster insurance system in France.[32] Data were obtained from the official CCR publications and the IMF International Financial Statistics Yearbook (2004).

We first calculate the per year gross result of disaster insurance as the difference between premium income and claims payments. From this we subtract administrative costs, estimated at 10% of premium income to obtain gross profits of the system. Finally, profits enter the accumulated system surplus with financial returns estimated at the government bond rate of interest.

The claims-premium ratio, the rate of reinsurance and the CCR's reserves are obtained directly from the official publication of the public reinsurer (CCR, various years).

[32] The detailed table of calculations is available from the authors upon request.

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Table 1
Equilibrium conditions

Equilibrium	Rate of retention	Number of insurers	Eqm. condition
SE	$r_j = \frac{\theta(1-\gamma)-p_i}{\lambda p_i(1-p_i)}$	$N_i = \frac{\mathcal{H}\omega_i}{f+F}$	$f\left[\frac{\mathcal{H}\omega_{LD}}{\mathcal{H}\omega_L+f+F} + \frac{\omega_{HD}}{\omega_H} - 2\right] + F\left[\frac{\mathcal{H}\omega_{LD}}{\mathcal{H}\omega_L+f+F} + \frac{\omega_{HD}}{\omega_H} - 1\right] < 0$
GE	$r_G^* = \frac{\theta(1-\gamma)-p_L+\theta(1-\gamma)-p_H}{\lambda[p_L(1-p_L)+p_H(1-p_H)]}$	$N_G = \frac{\mathcal{H}\omega_G}{2f+F}$	$\frac{\omega_L}{\omega_G}(2f+F) - f - F < 0$

Note: The displayed expression for the number of insurers corresponds to an interior solution for the rate of retention. The deviation strategy (D) in the SE is to become a generalist, while in the GE it is to reduce service to the L-region.

Table 2
Financial performance of the system

Year	C / P Ratio (%)	Acc. system surplus (million €)	Rate of reinsurance (%)	CCR premium inc. (million €)	CCR Reserves (million €)
'82/'83	163	-214	83	243	*n.a.*
'84	5	93	75	297	*n.a.*
'85	3	496	75	335	*n.a.*
'86	12	918	73	341	223
'87	36	1,281	52	274	338
'88	52	1,618	41	232	424
'89	46	2,012	51	234	416
'90	99	2,135	43	238	466
'91	42	2,638	40	235	483
'92	77	2,958	38	234	525
'93	116	3,050	41	263	499
'94	48	3,547	41	297	406
'95	91	3,800	45	320	349
'96	83	4,140	39	348	300
'97	53	4,691	40	304	310
'98	50	5,261	40	303	230
'99	88	5,526	40	303	155
'00	33	6,316	48	447	261
'01	32	7,231	47	469	427
'02	*n.a*	*n.a*	*n.a*	515	591
'03	*n.a*	*n.a*	*n.a*	628	340
'04	*n.a*	*n.a*	*n.a*	680	418

Sources: von Ungern-Sternberg (2004) and CCR (2003, 2005). Due to the different years covered by the various sources, not all information is available over the full period.

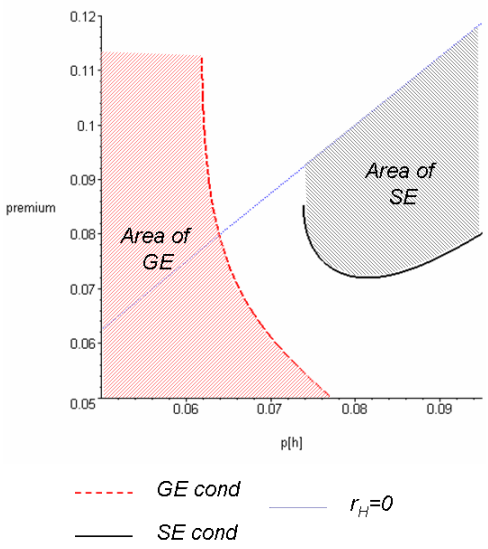

Figure 1: Equilibrium areas for generalist and specialist equilibria.

Parameter values: $\mathcal{H}$=100,000, γ=0.2, f=100, F=200, λ=1.

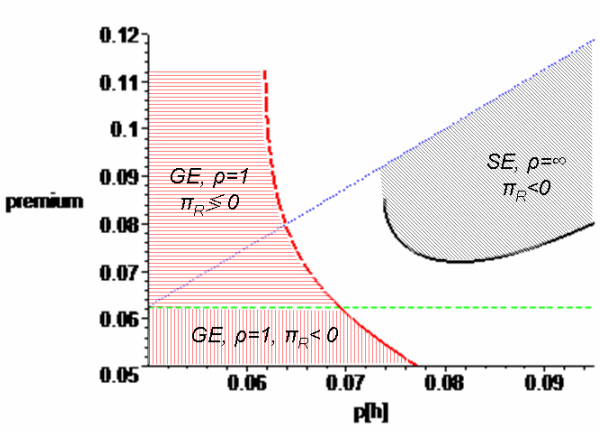

Figure 2: degree of risk selection and profits of reinsurer.

Parameter values as in Figure 1.

2007

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