Captive insurance companies and the management of non-conventional corporate risks

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ABSTRACT

We examine under what conditions setting up a captive insurance company with reinsurance is an optimal solution for risk-averse firms when the insured firm, the insurer and the reinsurer do not know the probability distribution of some risks, and have conflicting estimates of this distribution.

Keywords : corporate insurance, reinsurance, uncertainty, ambiguity, non-conventional risks, captive insurance companies

JEL Classification N° : D 81, G22, Q2

1. Introduction

This paper investigates the corporate management of non-conventional risks such as (among others risks) environmental risks and disasters, medical malpractice, litigation-related risks, and terrorism risks (see e.g. Gollier (2007), p.11). Environmental and catastrophic risks have been studied by a number of authors. Zagalski [1991], Kronenberg [1995], Freeman and Kunreuther (1997), and Lesourd and Schilizzi (2003: chapter 7) have been concerned with the specific features of environmental risks. Catastrophic risks have been studied by Kleffner and Doherty (1996), Zeckhauser [1996], and, in the context of crop insurance, by Miranda and Glauber [1996] and Duncan and Myers (2000). Many of these studies show that insurance and reinsurance companies can refuse to insure non-conventional risks such as environmental risks.

Information about the probability distributions of such non-conventional risks is most often incomplete or unknown. This leads to behaviours that can be incompatible with standard expected utility theory, as was clearly demonstrated by Ellsberg [1961] in his seminal paper. In this paper, he defines ambiguity as uncertainty on the probability distributions. In this case, decision makers will consider a range of probability distributions and will usually give more weight to the more pessimistic ones. This is the standard interpretation of the so-called Ellsberg paradox.

Uncertainty regarding probability distributions also means that different agents will typically have different and even conflicting estimates of the risks involved. One may see this as a consequence of Ellsberg's ambiguity and will be of importance in the analysis that follows. In particular, different parties to an insurance contract for non-conventional risks, the insured

firm, the insurer and the reinsurer, can, if the risks are ambiguous, have diverging estimates of the risks involved. Cabantous (2007) has examined the effects on insurability when different parties have conflicting probability estimates. She concludes that insurers will set a higher premium for a risk with ambiguous probability than for a risk with non ambiguous probability. When the parties to an insurance policy disagree on the set of probability distributions, she adds that insurers will set a higher premium for an ambiguous risk with a conflicting probability than for an ambiguous risk with a consensual but imprecise probability.

Of the techniques available for the management of uninsurable corporate risks is the setting up of a *captive insurance company* (Porat and Powers 1995, 1999; Scordis, Barrese, and Yokohama, 2007). The particular case of environmental risks has been discussed by Lesourd and Schilizzi (2001). A captive insurance company (hereafter simply referred to as "a captive") is an insurance company entirely owned by a parent company, providing insurance services mainly, or exclusively, to its parent company. A captive provides direct access to reinsurance; however, in some cases a *reinsurance captive* can be established, which specializes in reinsuring its parent company. The potential advantages of a captive lie, first, in its direct access to reinsurance, saving transaction costs of intermediation and, secondly, in the fact that there no longer is the risk of moral hazard, since the parent company and the captive should in principle share the same information. For covering non-conventional risks, setting up a captive can be cheaper than contracting conventional insurance: the captive is able to charge lower premiums than conventional insurance contracts, for various reasons, some of which will be examined in this paper. Captives constitute a particular case, and a particular practical solution, of the more general self-insurance problem (Chiu, 2000; Gollier, 2003).

Our concern in this paper differs from most of the literature on insurance captives, which has mostly been concerned with their fiscal status (see e.g. Lai and Witt, 1995; Porat and Powers, 1995, 1999). Here we are interested in determining the conditions under which a captive will be preferred to conventional insurance when risks are ambiguous and the parties have different and possibly conflicting perceptions of the risks involved. Among the few studies that discuss non-fiscal issues concerning captives, one can mention Diallo and Kim [1989], who are interested in asymmetric information, Scordis and Porat (1998), who address captive manager-owner conflicts, and Scordis, Barrese, and Yokohama (2007), who study the value of captives for their parent company. Though these topics are somewhat related to ours, their approach, which is empirical and econometric, is different.

For this purpose, a model derived from the maxmin expected utility (MMEU) models of Gilboa and Schmeidler (1989) and Kelsey (1994) is developed. A necessary consequence of

our model is that the insurance premium can be too high for a conventional insurance contract to find a market. This is in line with, and adds to, what authors like Einhorn and Hogarth (1985, 1986), Gollier (2005, 2007) and Cabantous (2007) find, that if probabilities are ambiguous, the insurer will ask for a higher premium, or even refuse altogether to provide insurance coverage. We study this problem with the aim of deriving the conditions under which a captive is a better solution than conventional insurance for addressing corporate risks characterized by ambiguity, as discussed above. Our model leads to as yet unpublished conditions for setting up a captive with reinsurance.

The rest of our paper is organised as follows. The second section develops our model for insuring ambiguous risks, and the third presents and discusses the conditions under which a captive is economically attractive. A fourth section concludes.

2. Insuring risks under ambiguous distributions: the model

Under conditions of ambiguity in Ellsberg's (1961) sense, experiments have shown that the insured firm, the insurer, and the reinsurer can all have different estimates of the unknown probability distribution (Cabantous, 2007). This is in line with the ambiguity hypothesis of Einhorn and Hogarth [1985, 1986]. These authors assume that an agent implicitly calculates a 'judged probability' function which can be either larger or smaller than what they term an 'anchor probability'. They describe an 'anchor probability' as a first estimate of the unknown probability. When losses are at stake and when the agent is ambiguity averse, this estimate is larger or more pessimistic[1], meaning higher cumulative probabilities of losses, so that a more pessimistic distribution dominates, in the sense of first-order stochastic dominance, a less pessimistic one.

Gilboa and Schmeidler [1989] and Kelsey [1994] developed a discrete maxmin expected utility (MMEU) model in which an economic agent takes into account a pessimistic estimate of some poorly known probability distribution. Ozdenoren, Casadessus and Klibanoff (2000) suitably generalized their approach to continuous probability distributions. Bose, Ozderenen and Pape (2006) show, in the context of auctions, that ambiguity, and situations such as the one described by Ellsberg (1961), can be equivalently described by Gilboa and Schmeidler's MMEU approach. Gilboa and Schmeidler (1989) and Kelsey (1994) developed a discrete maxmin expected utility (MMEU) model in which an economic agent takes into account a pessimistic estimate of some poorly known probability distribution. Ozdenoren, Casadessus and Klibanoff [2000] suitably generalized their approach to continuous probability

distributions. Bose, Ozderenen and Pape [2004] L_n show, in the context of auctions, that ambiguity, and situations such as the one described by Ellsberg [1961], are compatible with Kelsey's MMEU approach. Applying this MMEU approach in the case of insurance, we describe the case where, under a discrete distribution of losses, the insured, the insurer, and the reinsurer, have different perceptions of the distribution of losses. This is related to Einhorn and Hogarth's (1985, 1986) model. Moreover, their conclusions, rather than those of the standard subjective expected utility (SEU) model, have been vindicated by experiment (Di Mauro and Maffioletti, 2001). Therefore, our MMEU approach seems appropriate.

Let us now develop our model. Let L_0, L_1, L_2, … , L_i, … L_n be the possible losses, with $L_0=0 < L_1 < L_2 < \ldots < L_i < L_{i+1} < \ldots < L_{n-1} < L_n = \overline{L}$ with discrete probability distributions P_d $\{p_0, p_1, p_2, \ldots, p_i, \ldots p_n\}$ ($\sum_{i=1}^{n} p_i = p_0$). Let probability distribution $\underline{P}_d$ $\{\underline{p}_0, \underline{p}_1, \underline{p}_2, \ldots, \underline{p}_i, \ldots \underline{p}_n\}$ be a distribution that is possible according to the agent's information, but is less pessimistic than P_d, with $p_1 \geq \underline{p}_1$, $p_2 \geq \underline{p}_2 \ldots$, $p_i \geq \underline{p}_i$, … $p_n \geq \underline{p}_n$, and at least one j ($0 < j \leq n$) such that $p_j > \underline{p}_j$. P_d dominates distribution $\underline{P}$ in the sense of first-order stochastic dominance and is the most pessimistic distribution within the set of distributions that the firm assumes possible and compatible with the information available. Let U be the insured firm's utility function, which we assume to be a strictly increasing, twice differentiable and strictly concave function. We also assume that an insurer is able to offer an insurance policy providing for an insurance premium π with a deductible D, calculated on the basis of the insured firm's distribution P_d. Our results have been derived using the following assumptions:

Assumption 1: The utility function is strictly increasing and concave, continuous and twice differentiable.

Assumption 2: The subjective set of distributions according to which the insured party is assumed to use for its decisions is a set of distributions for the possible losses $L_0=0 < L_1 < L_2 < \ldots < L_i < L_{i+1} < \ldots < L_{n-1} < L_n = \overline{L}$ defined as the set of distributions S_d $\{s_0, s_1, s_2, \ldots, s_i, \ldots s_n\}$ such that, if $P_d = \{p_0, p_1, p_2, \ldots, p_i, \ldots p_n\}$ ($\sum_{i=1}^{n} p_i = p_0$), and $\underline{P}_d = \{\underline{p}_0, \underline{p}_1, \underline{p}_2, \ldots, \underline{p}_i, \ldots \underline{p}_n\}$ one has:

[1] Gollier (2007) points out that "pessimism is another word for ambiguity aversion".

$p_1 \geq s_1 \geq \underline{p}_1$, $p_2 \geq s_2 \geq \underline{p}_2 \ldots$, $p_i \geq s_i \geq \underline{p}_i$, … $p_n \geq s_n \geq \underline{p}_n$, with at least one i ($0 < i \leq n$) such that $s_j > \underline{p}_j$.

Assumption 3: The decision criterion is MEU on the basis of the limiting distribution $P_d = \{p_0, p_1, p_2, \ldots, p_i, \ldots p_n\}$ (the most pessimistic distribution).

The firm's minmax expected utility under this policy is, under its P_d distribution :

$$\text{MMEU} = \sum_{i=0}^{n} p_i U[R - L_i + \sup(L_i - D, 0) - \pi] \tag{1}$$

In this equation, $\pi = E[\sup(L_i - D, 0)](1+a) = E[L_i - D](1+a)$, is the insurance premium, with an insurance load factor a >0, and $W(D, a, P_d) = R - L_i + \sup(L_i - D, 0) - \pi$.

Let $P^+ = \sum_{j=h+1}^{n} p_j$., the first-order condition for maximization of MMEU is :

$$\frac{\partial \text{MMEU}}{\partial D} = P^+(1+a)\sum_{i=0_{ii}}^{h} p_i U'(R - L_i - \pi) + [P^+(1+a) - 1] \quad U'(R - D - \pi) = 0 \tag{2}$$

In this equation, h is a state of nature such that, for all i < h, L < D; for i = h, L $\leq$ D, and for j > h, L > D. For any given a > 0, the second-order condition ensures a unique solution in D since :

$$\frac{\partial^2 \text{MMEU}}{\partial D^2} = \sum_{i=0}^{n} p_i \left(\frac{\partial W}{\partial D}\right)^2 U''(W_i) < 0 \tag{3}$$

Since $U''(W_i)$ always strictly negative, this is always negative, so that there always exists one, and only one optimal solution D that obeys the first-order condition (2). Let $E(L_i - D)$ be the mean of $L_i - D$; we also have :

$$\frac{\partial^2 \text{MMEU}}{\partial D \partial a} = -P^+(1+a)E(L_i - D)\sum_{i=1}^{n} p_i U''(W_i) + P^+(1+a)\sum_{i=0}^{n} p_i U'(W_i) > 0 \tag{4}$$

This quantity is always strictly positive, whence, defining the optimum insurance coverage, L_n - D though equation (2) as an implicit function C(a) of the load factor a (the demand for coverage), one can see that $\frac{\partial C}{\partial a} < 0$, so that this demand function is strictly decreasing.

We now discuss the behaviour of both the insurer and the reinsurer if the distribution is not well known. It is reasonable to assume that both the reinsurer and the insurer, not knowing the actual distribution, will assume a more pessimistic probability distribution of the losses L_i ($i > 0$) than the insured firm. Why in practice an insurance company will have less information than the insured firm about the loss distribution P and will therefore resort to a more pessimistic distribution in order to price its premium, is open to discussion. Several general reasons have recently been stated by several authors. Gollier (2007) invokes a number of reasons, among which the most important are adverse selection (some agents are more risky than the average population, but the reasons for this cannot be observed fully), so that insurers will increase their premium rates for all their clients, ex ante moral hazard (the insured will not disclose some pertinent information, such as its efforts to decrease the insured risks), and ex post moral hazard (the risk of fraudulent claims). Cabantous (2007) discusses the general problem of ambiguity aversion, which she defines as "uncertainty about the probability", especially in the case of risks with " a lack of large, reliable historical data base"; even if there is a consensual but imprecise probability, ambiguity will induce insurers to set higher premiums, and, in the case in which there are conflicting estimates of probability ranges, higher premiums than in the consensual case.

It seems reasonable to assume that the insured firm will not disclose part of the information available to it to any external party. Such disclosure can be costly or technically difficult, and it could reveal secret details of the firm's technology. Proprietary information and private information give the firm a competitive edge, and in many cases is "unarticulated, and hardly even articulable" (Hayek, 1988) meaning that it cannot even be clearly stated. Even if the insured firm will disclose such information, it is reasonable to assume that the insurer will not without high costs have the ability to gather such highly technical information; in addition, such information might not appear sufficiently trustworthy.

In the case of a reinsurer, things can be quite different. Reinsurers usually have larger capital reserves, and overall operate at a much larger scale than ordinary insurers; thus they can afford technical and engineering expertise and acquire better information on risk distributions. They also have better statistics on the probabilities of large losses than ordinary insurers. Finally, the establishment of a captive which can directly negotiate with a reinsurance company can be more effective in protecting private technical information held by the firm.

Let us specify more precisely these assumptions. It seems reasonable to assume that the insurer, in its assessment of the distribution P, due to the above information problems under possibly conflicting estimates of the distributions, will increase its premium above the optimal

premium calculated on the basis of the insured firm's estimate of the distribution. However, in the limiting case of consensual but still ambiguous estimates, the insurer could accept the already pessimistic distribution P_d. As far as the reinsurer is concerned, one can reasonably assume that it is concerned only with the higher losses. Let us assume for simplification that the reinsurer is covering only large losses, for instance, losses above the loss L_m with $m < n$ The reinsurance market especially addresses the fact that insurers are constrained by their size not to insure major risks, but in many cases they can achieve a lower price by reinsuring, so that insurers can also be driven by market forces to reinsure the risk of the higher losses. Thus, under our hypotheses, the reinsurer will cover only the risk of the higher loss L_j ($L_j > L_m > 0$ for some $m < n$) in terms of non-proportional reinsurance. Although this is a simplifying assumption, we also assume that the load factor a is the same for the insurer and the reinsurer, as argued by Blazenko (1986). Thus, the insurer will cover only the risk of the lower losses L_i, $0 < i \leq m$, for which it has less information than the insured firm, but as much information as the reinsurer. As far as the largest risks are concerned, the reinsurer can be assumed to possibly know better the probability distributions than the insurer, but less than the insured since he is obliged to rely on the insurer's appreciation of the insured's particular situation.

All this results in the following hypotheses :

$$\underline{p}_i < p_{id} \leq p_{ir} = p_{iR} \qquad (0 < i \leq m) \tag{5}$$

And :

$$\underline{p}_i < p_{id} \leq p_{iR} \leq p_{ir} \qquad (m < i \leq n) \tag{6}$$

We assume that an insurer is able to offer an insurance policy with an insurance premium π_d and a deductible D. The question now is whether this insurance coverage is marketable or not, that is, acceptable or not for the insured firm. This insurance premium, with $a > 0$ being the load factor, is assumed to be exogenous. This premium is calculated under the distribution of losses assumed by the insurer (with reinsurance of the risk of the higher losses L_j). If the insurer reinsures the risk of the higher losses, L_j, this leads to a reinsurance premium calculated according to the reinsurer's estimate of the distribution pertinent for the higher risk (P_R), More precisely :

$$\pi_r = E_r(L_i - D)(1+a) + E_R(L_j - D)(1+a) \quad (0 < i \leq m < j \leq n) \tag{7}$$

Let us define the differences between the probability distributions p as assumed by the insurer (p_{ir} for $1 < i \leq m$), and by the reinsurer ($p_{jR}$for $m < j \leq n$), and their respective counterparts in the insured firm's estimates as :

$$q_{ir} = p_{ir} - p_{id} \quad (0 < i \leq m) \tag{8}$$

And :

$$q_{jR} = p_{jR} - p_{jd} \quad (m < j \leq n) \tag{9}$$

Clearly, according to our hypotheses, $q_{ir} \geq 0$ $(0 < i \leq m)$, and $q_{jR} \geq 0$ $(m < j \leq n)$. It is evident that, if we consider the MEU function of the insured firm taking into account the premium priced according to (7), $\frac{\partial MEU}{\partial q_{ir}} < 0$ $(0 < i \leq m)$; $\frac{\partial MEU}{\partial q_{jR}} < 0$ $(m < j \leq n)$, and $\frac{\partial (L_n - D)}{\partial q_{ir}} < 0$ $(0 < i \leq m)$; $\frac{\partial (L_n - D)}{\partial q_{jR}} < 0$ $(m < j \leq n)$, so that MEU and the deductible S are strictly decreasing with the q_{ir} $(0 < i \leq m)$, and the q_{jR} $(m < j \leq n)$.

3. Conditions underlying the attractiveness of a captive

Equation (2) gives as an implicit function the demand for insurance, which is a strictly decreasing function of a. However, if one assumes that both the insurer and the reinsurer are risk-neutral, the supply curve will be a vertical line a = constant. This also means the load factor a, interpreted as the price of insurance coverage, is exogenous. It reflects the costs of coverage with a suitable mark-up for profit; it is unique if the market is perfectly competitive. Thus, as shown on Figure 1, for each value of a (for example a_1) the equilibrium demand for insurance is the intercept of the demand line and of a vertical line with a = constant, provided such an intercept exists for a positive and meaningful value of coverage (i.e. to the left of a_0). If the insurer, as is assumed here, covers the risks for the smaller loss L_1, the deductible D (besides being nonnegative) has to be smaller than L_m.

Thus, given our assumptions, a necessary but not sufficient condition for feasibility of insurance coverage is:

$$0 \leq D < L_n \tag{9}$$

Proposition 2 leads us to discuss several possibilities that can occur in terms of the optimal insurance decision for the insured firm.

Firstly, in the limiting case where $p_{1r} = p_{1d}$ and $p_{2rr} = p_{2d}$, and if $0 \leq D < L_1$, insurance with reinsurance, or establishing a captive with reinsurance, is indifferent.

Secondly, still under $p_{1r} = p_{1d}$, if $p_{2d} < p_{2rr}$, and if $0 \leq D < L_1$, establishing a captive with reinsurance is the optimal solution. This means that cooperation between the captive and the reinsurer will provide some additional information about the distribution of the *larger* loss, resulting in the economically more attractive solution of a captive with reinsurance. This is empirically observed as discussed in Lesourd and Schilizzi [2003: chapter 7] and others.

Thirdly, if $p_{1d} < p_{1r}$, and if $p_{2d} = p_{2rr}$, and if $0 \leq D < L_1$, establishing a captive with reinsurance is again the optimal solution. This means that the captive has some additional information about the distribution of the *smaller* loss, but that direct access to reinsurance provides no additional information about its distribution; this again leads to the economically more attractive solution of a captive with reinsurance.

Fourthly, if $p_{1d} < p_{1r}$, and if $p_{2d} < p_{2rr}$, and if $0 \leq D < L_1$, establishing a captive with reinsurance is a third case where it is an optimal solution. This means that the captive has some additional information about the distribution of the smaller loss, and its direct access to reinsurance also provides additional information about the distribution of the larger loss.

It can also happen that the necessary condition for insurance ($0 \leq D < L_1$) is not met, but that demand for reinsurance is still positive ($L_1 \leq D < L_2$). In this case, insurance coverage would be too expensive at current market price and under the insurer's estimate of the risk. Then, neither the external insurance company, nor an insurance captive can provide any insurance coverage. A 'reinsurance captive' can, in this case, be useful to reinsure against the higher risk.

Table 1 hereafter summarises all these conditions.

4. Conclusion

This paper addresses the problem of insuring non-conventional risks such as environmental risks, product risks, medical malpractice, litigation-related risks and terrorism. Conventional risks, such as, for instance, risks related to road accidents, theft and fire, can be characterised by well known probability distributions which can be assumed to be available precisely and at low cost. On the contrary, non-conventional risks are characterised by the fact that their probability distribution is not well known. In this case, the insured firm, the insurer and the reinsurer all differ in their estimates of the probability distribution, which leads to different prices on the insurance or reinsurance markets. This is a situation first described in terms of ambiguity by Ellsberg in 1961 and later by Einhorn and Hogarth [1985, 1986]. We address this problem by developing a maxmin expected utility model as in Gilboa and Schmeidler [1989], and as in Kelsey (1994), which, as shown by Bose, Ozdenoren and Pape [2004], is equivalent to a description in terms of ambiguity.

More precisely, we assume on reasonable grounds that (1) reinsurance companies specialise in higher risks for which they have a competitive advantage leading to a lower estimate of the probability of these higher risks, that (2) insurers can be less informed than the insured firm about the lower risks and that (3) there can be a gain for an insured firm from direct access to reinsurance. Under these assumptions, we are led to specify conditions under which the operation of a captive with reinsurance of higher risks is optimal for the firm. This will occur whenever the insured firm, and the captive it establishes, has more information about the lower risks than a standard insurance company, and whenever direct access to reinsurance through a captive is profitable. Within a simplified framework, we provide as yet unpublished conditions on the perceived probabilities of both the lower and the higher risks. If the demand for insurance coverage is positive, under the above conditions, the operation of a captive with reinsurance is optimal.

In the future, it might be interesting to extend our approach to more general distributions, and to introduce costly information as well as moral hazard into our model. Following Di Mauro and Maffioletti [2001] and other earlier work such as Hogarth and Kunreuther [1985], Camerer [1987], and Camerer and Kunreuther [1989], an experimental investigation of the predictions of our model might allow us to probe deeper into this increasingly important issue.

Conditions	$P_{jd} = p_{jR}$	$P_{jd} < p_{jR}$
$0 \leq D < L_m$		
$P_{id} = p_{ir}$	Captive with reinsurance, or insurance with reinsurance indifferent	Captive with reinsurance optimal, insurance with reinsurance suboptimal
$P_{id} < p_{ir}$	Captive with reinsurance optimal, insurance with reinsurance suboptimal	Captive with reinsurance optimal, insurance with reinsurance suboptimal
$L_m \leq D < L_n$		
$P_{id} = p_{ir}$	Reinsurance captive, or insurance with reinsurance indifferent	Reinsurance captive optimal, insurance with reinsurance suboptimal
$P_{id} < p_{ir}$	Reinsurance captive optimal, insurance with reinsurance suboptimal	Reinsurance captive optimal, insurance with reinsurance suboptimal
$L_n \leq D$		
$P_{id} = p_{ir}$	No insurance and reinsurance feasible	No insurance and reinsurance feasible
$P_{id} < p_{ir}$	No insurance and reinsurance feasible	No insurance and reinsurance feasible

Table 1

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