ART versus reinsurance: the disciplining effect of information insensitivity

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Abstract

We provide a novel benefit of "Alternative Risk Transfer" (ART) products with parametric or index triggers. When a reinsurer has private information about his client's risk, outside reinsurers will price their reinsurance offer less aggressively. Outsiders are subject to adverse selection as only a high-risk insurer might find it optimal to change reinsurers. This creates a hold-up problem that allows the incumbent to extract an information rent. An information-insensitive ART product with a parametric or index trigger is not subject to adverse selection. It can therefore be used to compete against an informed reinsurer, thereby reducing the premium that a low-risk insurer has to pay for the indemnity contract. However, ART products exhibit an interesting fate in our model as they are useful, but not used in equilibrium because of basis-risk.

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1 Introduction

For a long time, indemnity-based reinsurance contracts have been the only way for insurers to cede some of their risk and find protection against possible bankruptcy following a large loss. In the past ten years, "Alternative Risk Transfer" (ART) products with parametric or index triggers have been developed, a prominent example are catastrophe (cat) bonds. Upon their introduction, ART products were expected to grow quickly and become a significant supplement to reinsurance. Empirically though, their growth has been low and stagnant, which seemed surprising given their apparent benefits.

A main advantage of parametric or index triggers, as discussed in the literature, is seen in its positive effect on moral hazard, where the optimal use of ART products trades off moral hazard and basis risk. We provide a novel argument in favour of parametric or index based ART products: information-insensitive parametric or index triggers help to overcome problems of asymmetric information when reinsurers are better informed about the risk of their own clients' insurance portfolios than about the risk of potential clients, i.e., other insurers. Asymmetric information between inside and outside reinsurers locks in insurers in their relation with their current reinsurer, who is therefore able to extract an information rent. This rent is limited by the competition from outside reinsurers. However, outside reinsurers must fear adverse selection and bid less aggressively than they would without asymmetric information. Information-insensitive ART products are not subject to the same adverse selection problem. They affect the competition between inside and outside reinsurers by placing an upper bound on the premium that an insurer is willing to pay for reinsurance. ART products help low-risk insurers to receive reinsurance at a lower premium without ever

being used in equilibrium. They are not used because of basis risk and the presence of an informed insider who can always offer a better deal: reinsurers will adjust the premiums so that it is never optimal for an insurer to choose the ART product over indemnity-based reinsurance.

The analysis is done in the simplest setting possible. There is one insurer who faces large cost of financial distress so that he wants to transfer risk to avoid the cost. The insurer can obtain indemnity-based reinsurance from his current reinsurer (incumbent or insider) or another reinsurer (outsider) or, alternatively, he can issue an ART product with a parametric trigger. The insurer and the insider know whether the insurer's expected loss is high or low, while the outsider does not have this information. Because of his information disadvantage an outsider fears that low-risk types will be retained by insiders and that only high-risk types will change the reinsurer. If he were certain to obtain only the high-risk types, he would set the premium equal to a high-risk type's expected loss. However, this would allow the insider to also increase the premium that he demands from a low-risk type up to the same level (or slightly below). Now it is profitable for the outsider to choose a premium below the insider's premium to sell to both types. Therefore, the insider and the outsider compete by choosing premium between the pooling premium and a high-risk type's expected loss in a mixed strategy equilibrium. Hence, the expected premium that a low-risk insurer has to pay exceeds the pooling premium. An ART product with a parametric trigger is independent of the insurer's expected loss and type. Therefore, it is not subject to adverse selection. Instead, there will be basis risk as the cash flows generated by the ART product will not be perfectly correlated with the insurer's loss, leaving him with a residual uninsured loss and the corresponding cost of financial distress. The insurer will issue the ART product if the reinsurance premium net of expected losses

exceeds the basis risk, which places an upper bound on the reinsurance premium that an insurer will accept. The insider and the outsider take this into account when making offers, which reduces the premiums aimed at attracting a low-risk type. Hence, parametric triggers can influence the reinsurance equilibrium and the hold-up problem without ever actually being issued. Our predictions are in line with the low and very slow growing demand for ART products and falling reinsurance premiums following the introduction of ART products in the mid to late 90's.

There exists a large literature that discusses potential benefits of ART products. One strand of the literature focuses on benefit of using index and parametric triggers to reduce moral hazard (Doherty, 1997) and how reinsurance can complement these ART products to reduce basis risk (Doherty and Richter, 2002, and Nell and Richter, 2002). Another strand argues that large catastrophic losses are costly to insure using traditional insurers or reinsurers because these intermediaries have high cost of raising and holding capital (see, e.g., Jaffee and Russell, 1997, Froot, 1997, 2001, and Niehaus, 2002).

Our main contribution is to provide a novel argument in favour of ART products with index or parametric triggers and to analyze their impact on competition in the market for traditional reinsurance. Froot (2001) argues that cat bonds reduce barriers to entry and that therefore the reinsurance market has become more contested, thereby decreasing premiums for traditional reinsurance. In our model the source of reinsurers' market power is asymmetric information between reinsurers that creates an adverse selection problem and therefore reduces competition. While we assume that an insider gains an information advantage over outsiders, we can alternatively assume that some reinsurers are more capable of evaluating an insurer's expected loss. Cat bonds with index or parametric triggers can reduce the cost of entry as they are

not subject to adverse selection. However, because of basis risk, the alternative does not restore perfect competition.

Basis risk is sometimes viewed a major obstacle to using index or indemnity-linked ART products. While ART products are not used in our model, the benefit of being able to use them would greatly diminish in the presence of large basis risk. However, Cummins, Lalonde, and Phillips (2000, 2002) show that, at least for hedging cat losses from Hurricanes in Florida, basis risk is unlikely to deter insurers from potentially using index-linked cat securities to hedge their exposure.

Our setting is closely related to the literature on relationship lending and informational lock-in in banking as developed as developed by Fischer (1990), Sharpe (1990), Rajan (1992), and von Thadden (2001). We apply this setting to the reinsurance market and extend the analysis by introducing an alternative that is information insensitive to the quality of insurers. The setting is closest to the one by Fischer (1990) and von Thadden (2001).

Informational lock-in in the insurance sector has been analyzed by Kunreuther and Pauly (1985), Cooper and Hayes (1987), and Nilssen (2000). Kunreuther and Pauly (1985) use a multi-period model with experience rating and myopic customer behavior and find informational lock-in for low-risk types. Nilssen (2000) shows that type-contingent contracts weaken, but do not always eliminate the informational lock-in. Cooper and Hayes (1987), in contrast, assume that the supplier of insurance can commitment to long-term contracts. Ge and Cox (2003) find empirical evidence for informational lock-in in insurance markets.

The paper is structured as follows. We introduce the model in the next section. The equilibrium without ART products is analyzed in Section 3, where we focus on the problem of informational lock-in between insurers and reinsurers. ART products are

introduced in Section 4, where we discuss the effect of the availability of ART products on reinsurance premiums. Extensions and empirical implications are discussed in Section 5. Section 6 concludes. Proof are relegated to the appendix and figures to the end of the paper.

2 The model

We consider a two-period model with three types of risk-neutral agents, a (representative) primary insurer, reinsurers, and investors. In each period the (primary) insurer can incur a catastrophic loss. The expected loss depends on the insurer's type, high risk or low risk. Without loss of generality, we assume that a catastrophic event occurs with probability θ and that, conditional on the catastrophic event, the insurer realizes a loss X with probability $p_i \in \{p_l, p_h\}$, where p_l denotes the loss probability of the low-risk type and p_h the loss probability of the high-risk type, with $p_l < p_h$. The proportion of low-risk types in the economy is q and the proportion of high-risk types is $1 - q$. If there is no catastrophic event, the insurer incurs no loss. Catastrophic events are independent over time and the risk-free interest rate is zero.

The loss X, if borne by the insurer, results in (indirect) bankruptcy cost B. This assumption captures the idea that a large loss is difficult to finance ex post, that this can distort incentives and that policyholders are then reluctant to do business with the insurer.

In each period the insurer can finance the potential loss ex ante by either buying a one-period reinsurance contract that indemnifies the loss X or by issuing a one-period ART product that pays X conditional on the realization of a parametric trigger or

an index, e.g., a cat bond.[1] Given a catastrophic event, the ART product pays the amount X with probability p_T. We assume that the probability does not depend on the insurer's type. This assumption implies that a parametric trigger is used or that the insurer's portfolio is a negligible part of the index. We make this assumption for ease of exposition. The ART product is described in more detail in Section 4.

If the insurer's loss is covered by the reinsurance contract or the ART product, no bankruptcy cost B occurs. Without loss of generality, we assume that the insurer always finds it worthwhile to buy protection given the equilibrium conditions of the available contracts. Relaxing this assumption does not change our results about the role of ART products; a brief discussion is provided in Section 5.3.

Two-period reinsurance contracts are not available. This reflects the observation that in practice multi-period reinsurance contracts are rare, probably also because long-term contracts in more general settings can result in incentive problems and complete contracts cannot be written.

All parameters, but the specific type of the insurer, are common knowledge. Initially, the insurer's type is unknown even to the insurer. The insurer and, if reinsurance is used in the first period, the reinsurer who provides this reinsurance (insider) learns the insurer's type after the first period. We focus on the effect that ART products have on the price of reinsurance contracts in the second period, when the insider has an information advantage over other reinsurers (outsiders) about the insurer's type. Therefore, we assume that the insurer uses a reinsurance contract in the first

[1] For example, the payoff might depend on a predetermined Richter scale value for an earthquake in a special geographic region. While indemnity triggers used to dominate the contract specifications in the beginning, now 96% of all ART products are based on parametric triggers or index thresholds, see Lane and Beckwith (2003) for details.

period and show in Section 5.1 that this is indeed optimal for the insurer. Moreover, we assume that full reinsurance is obtained from one reinsurer; the possibility to use multiple reinsurers and retention are discussed in Sections 5.2 and 5.3.

In the first period there is no asymmetric information and Bertrand competition between reinsurers. Reinsurers $j = 1,..,m$ quote the premiums K^j at which they are willing to indemnify the insurer's loss. The insurer randomly picks a contract from the group of reinsurers who demand the lowest premium. A loss is realized with probability θp_i, which is then indemnified by the reinsurer. The insurer and the incumbent reinsurer learn the insurer's type $i \in \{h,l\}$. In the second period the incumbent and outside reinsurers quote the premiums at which they are willing to indemnify the insurer's loss. For ease of exposition, we assume that there is one representative outsider who chooses the premium to be equal to the expected indemnity payment in equilibrium. K^j, with $j \in \{in,out\}$, is the premium demanded by the incumbent and the outsider respectively. The insurer chooses between a reinsurance contract and an ART product with a parametric trigger, which he can obtain at a fair premium. The insurer maximizes the total expected net payoff; if he is indifferent, he stays with the incumbent. Losses are again realized with probability θp_i and the contract makes the promised payment.

3 Reinsurance equilibrium

In this section we analyze the competition between asymmetrically informed reinsurers if only indemnity-based reinsurance contracts are available. The insider and the outsider simultaneously quote the premiums at which they are willing to offer full reinsurance. The insider has an information advantage over the outsider as he knows

whether the expected loss is $\theta p_l X$ or $\theta p_h X$ and can therefore offer different contracts to both types, $K^{in}(l)$ and $K^{in}(h)$. The outsider offers a type-independent premium K^{out}. We define $K_l \equiv \theta p_l X$,$K_{\ h} \equiv \theta p_h X$, and $K_{pool} \equiv (1 - q + qp_l)\theta X$ as the fair premiums for a low-risk and a high-risk type and the pooling premium, respectively. The outsider does not know the type and must fear that only a high-risk type changes the reinsurer. To show the problem of asymmetric information between reinsurers, we suppose that the outsider demands the pooling premium, i.e., $K^{out} = K_{pool}$. At this premium a reinsurer expects to break even if both types accept the contract. The insider can attract the low-risk type by demanding a premium $K^{in}(l) = K^{out}$ and leave the high-risk type to the outsider by demanding the fair premium, $K^{in}(h) = K_h$. (Recall that we assume that the insurer chooses the insider if he is indifferent. Alternatively, the insider has to choose $K^{in}(l)$ slightly below K^{out}.) The outsider foresees that only a high-risk type will accept the contract. To break even, he has to set $K^{out} = K_h$. Again, it is optimal for the incumbent to choose $K^{in}(l) = K^{out}$, which is now equal to K_h. But this cannot be an equilibrium either, because outsiders can now make a profit by offering reinsurance at a premium $K_{pool} < K^{\ out} < K_{\ h}$, which will be chosen by both types if $K^{in}(l) = K_h$. The following lemma directly follows from the discussion.

Lemma 1 *There exists no equilibrium in pure strategies.*

Instead, there exists a mixed equilibrium in which the insider and the outsider randomize. The insider sells to the low-risk type whenever $K^{in}(l) \leq K^{out}$. In this case the outsider is left with the high-risk type and makes a loss if $K^{out} < K_{\ h}$. If $K^{in}(l) > K^{\ out}$, both types choose the outsider's contract and the expected indemnity payment equals K_{pool}. Therefore, K_{pool} places a lower bound on K^{out} while $K^{out} = K_h$

constitutes an upper bound at which the outsider's profit from selling to a high risk type is zero.

Proposition 1 *The following mixed strategies constitute a Nash equilibrium:*
(i) The insurer chooses the contract with the lowest premium; if he is indifferent, he stays with the insider.
(ii) The insider chooses $K^{in}(h) = K_h$ *for a high-risk type and* $K^{in}(l) \in [K_{pool}, K_h]$ *with density*

$$\omega(K) = \frac{K_{pool} - K_l}{q(K - K_l)^2} \tag{1}$$

for a low-risk type.
(iii) The outsider chooses $K^{out} \in [K_{pool}, K_h]$ *where* $K^{out} = K_h$ *has a point mass of* $(1 - q)$ *and* $K^{out} \in [K_{pool}, \theta X)$ *has density*

$$\phi(K) = q\omega(K). \tag{2}$$

The insider's information advantage allows him to earn a rent, which equals the expected profit that he makes at $K^{in}(l) = K_{pool}$. In this case a low-risk type always stays with the insider and the rent is $K_{pool} - K_l$. Increasing $K^{in}(l)$ increases the expected profit from a low-risk insurer, but reduces the probability of selling reinsurance to a low-risk type because now the outsider's premium may be lower. The outsider's mixed strategy has the property that the insider is indifferent between any $K^{in}(l) \in [K_{pool}, K_h]$. The outsider's expected profit equals zero, which he can guarantee by choosing $K^{out} = K_h$. In this case he will never sell to a low-risk insurer. By reducing K^{out}, the outsider might also sell to a low-risk insurer, but at the same time he will make an expected loss if he does not succeed in underbidding the insider. The insider's mixed strategy has the property that the outsider is indifferent between any $K^{out} \in [K_{pool}, K_h]$.

The insider's *ex ante* expected information rent is $q\left(K_{pool}-K_l\right)=q(1-q)\left(K_h-K_l\right)$. It has a maximum at $q=0.5$; increasing q has a positive effect since it increases the probability of a low-risk type, but also a negative effect as it reduces the pooling premium. The rent also depends on the difference between the expected losses of a high-risk type and a low-risk type, K_h-K_l. This difference can be interpreted as a measure of the degree of adverse selection in the economy. The higher the degree of adverse selection, the more valuable is the inside information and the higher is the rent that the insider can extract.

We now take a closer look at a low-risk insurer's cost of buying reinsurance in the described equilibrium. The insurer buys reinsurance either from the insider or from the outsider at the premium $\min\{K^{in}(l),K^{out}\}$. Since $E[\min\{K^{in}(l),K^{out}\}]>K_{pool}$, the expected premium exceeds the pooling premium. Therefore, a low risk-type with an inside reinsurer has higher cost of buying reinsurance than he would in a pooling equilibrium. The reason is that with asymmetric information about the insurer's type, an uninformed outsider's bid is less aggressive because of the adverse selection problem. With symmetric information, the outsider would bid K_{pool}. The potential profit from insuring a low-risk insurer, $K_{pool}-K_l$, compensates for the potential loss from selling to a high-risk insurer, K_h-K_{pool}. This cross subsidization of types is required for a reinsurer to expect to break even in a pooling equilibrium. With asymmetric information, cross subsidization is still important, but now the outsider also has to be compensated for situations in which only a high-risk type accepts an offer $K^{out}<K_h$. To obtain this additional profit from a low-risk type, the insider must not bid too aggressively. The expected cross subsidization, i.e., the profit that

the outsider expects to make from a low-risk type, is

$$\begin{aligned} E\left[\Pi^{out}|l\right] &= \int_{K_{pool}}^{K_h} (1-\Omega(K))(K-K_l)\phi(K)dK \\ &= \frac{(1-q)^2}{q}(K_h-K_l)\left[\frac{q}{1-q}+\ln(1-q)\right], \end{aligned} \tag{3}$$

and derived in the appendix. In addition, the insider's expected rent from a low-risk type is $E\left[\Pi^{in}|l\right] = (K_{pool} - K_l)$. We can therefore quantify the expected cost of the adverse selection problem for a low-risk type:

$$\begin{aligned} E[\min\{K^{in}(l), K^{out}\}] - K_l &= E\left[\Pi^{in}|l\right] + E\left[\Pi^{out}|l\right] \\ &= (K_{pool}-K_l)\left[2+\frac{1-q}{q}\ln(1-q)\right]. \end{aligned}$$

The expected cost to a low-risk type consists of the expected rent that the insider extracts and the expected cross subsidization in the outsider's offer. Therefore, a low-risk type will finance the insider's expected profit and the outsider's expected loss from insuring a high-risk type at a premium below K_h.

4 ART product

Catastrophe (cat) bonds have emerged as a capital market based alternative to reinsurance about ten years ago. From the perspective of our paper a main difference to an indemnity-based reinsurance contract is that the payment is not conditional on the actual loss of the insurer, but on the realization of a parametric trigger or an index. Cat bonds are structured similar to regular bonds with an additional forgiveness provision. If an insurer issues cat bond, the investors pay the principal amount X to a "special purpose vehicle", which acts as a clearing institution. If the trigger is set off, the insurer gets the principal X and the investors loose their investment, otherwise

they get back the full amount X. In addition, investors receive a fixed premium that compensates them for the potential loss of the principal amount. The premium equals $\theta p_T X$, which is the expected loss for investors and the cat bond's expected payoff to the insurer who issued it.

An important feature of the cat bond is the trigger's correlation with the insurer's loss. The higher the correlation, the lower is the basis risk and therefore the expected bankruptcy cost. We define p_T^i as the probability that the trigger is set off and that an insurer of type $i \in \{l,h\}$ incurs a loss, with $p_T^i \in (p_T p_i, \min\{p_i,p_T\})$. That is, the higher p_T^i, the higher the correlation between the trigger and the insurer's loss. The lowest value, $p_T p_i$, corresponds to the case of zero correlation, and the highest value, $\min\{p_i,p_T\}$ to the case of maximum correlation. With a cat bond the insurer pays the fair premium for the insurance component, but unless the cat bond's payoff and the insurer's loss are perfectly correlated, i.e., $p_i = p_T^i$, the insurer of type i has to bear basis risk $B_i^{risk} \equiv (p_i - p_T^i)\,\theta B$. (For ease of exposition, we assume that $B^{risk} > 0$.)

A low-risk insurer trades off the difference between the premium and his expected loss for an indemnity based reinsurance contract, $K - K_l$, and the basis risk, B_l^{risk}, which he incurs when he uses an ART product. He chooses the reinsurance contract if $K - K_l \leq B_l^{risk}$. Hence, the availability of the ART product places an upper bound on the reinsurance premium that a low-risk type will accept. It is the highest K for which the inequality is binding. That is,

$$K_{ART}^{max} \equiv K_l + B_l^{risk}. \tag{4}$$

Put differently, if $\min\{K^{in}(l),K^{out}\} > K_{ART}^{max}$, the insurer chooses the ART product instead of the reinsurance contract.

A high-risk insurer will never choose an ART product over reinsurance, because the maximum premium he has to pay is the fair premium, K_h. Therefore, with

reinsurance, a low-risk insurer can avoid basis risk and might benefit from a premium below his expected loss.

The insider makes zero profit if the low-risk insurer does not buy insurance from him. Hence, the insider will never demand a premium that exceeds K_{ART}^{max}. The constraint binds if the maximum premium in the equilibrium in Proposition 1, K_h, exceeds K_{ART}^{max}. Rearranging $K_h > K_{ART}^{max} = K_l + (p_l - p_T^l)\theta B$ yields

$$B < B_{crit_1} \equiv \frac{K_h - K_l}{(p_l - p_T^l)\,\theta}. \tag{5}$$

Condition (5) holds ceteris paribus for low bankruptcy cost, B, a "high correlation" between the insurer's and the ART product's payoff, p_T^l, and for a high degree of adverse selection, $K_h - K_l$.

For very low K_{ART}^{max} the insider may not even be able to demand the pooling premium, K_{pool}. Formally, this is the case if

$$B < B_{crit_2} \equiv \frac{K_{pool} - K_l}{(p_l - p_T^l)\,\theta}. \tag{6}$$

If this condition is satisfied, the following proposition holds.

Proposition 2 *Assume that an ART product as described above is available. For $B \leq B_{crit_2}$, the following pure strategies constitutes a Nash equilibrium:*
(i) A high-risk insurer always chooses the reinsurance contract with the lowest premium. A low-risk insurer chooses the contract with the lowest premium if the premium does not exceed K_{ART}^{max}, otherwise he chooses the ART product; if he is indifferent, he stays with the insider.
(ii) The insider chooses $K^{in}(h) = K_h$ and $K^{in}(h) = K_{ART}^{max}$.
(iii) The outsider chooses $K^{out} = K_h$.

The insurer always stays with the insider, the ART product is never chosen

If (6) holds, the ART product constrains the insider to choose a premium for a low-risk type below the pooling premium. The outsider will never offer a premium below the pooling premium because his contract is chosen either by both insurers or only by the high-risk insurer, yielding an expected loss. The premium that the insider offers to a low-risk type is sufficiently low so that it is never optimal for the insider to choose the ART product.

If (6) is violated, but (5) holds, we again obtain a mixed strategy equilibrium with K_{ART}^{max} as a new upper bound. The following proposition states the new equilibrium.

Proposition 3 *Assume that an ART product as described above is available. For* $B_{crit_2} < B \leq B_{crit_1}$, *the following mixed strategies constitutes a Nash equilibrium:*
(i) The insurer behaves as in Proposition 2.
(ii) The insider chooses $K^{in}(h) = K_h$ *and* $K^{in}(l) \in [K_{pool}, K_{ART}^{max}]$ *where* $K^{in}(l) = K_{pool}$ *is chosen with probability*

$$\frac{1-q}{q}\left[\frac{B_{crit_1}}{B} - 1\right]$$

and $K^{in}(l) \in (K_{pool}, K_{ART}^{max}]$ *with density* $\omega^{ART}(K) = \omega(K)$.
(iii) The outsider chooses $K^{out} \in \{[K_{pool}, K_{ART}^{max}], K_h\}$ *where* $K^{out} = K_h$ *is chosen with probability*

$$(1-q)\frac{B_{crit_1}}{B}$$

and $K^{out} \in [K_{pool}, K_{ART}^{max}]$ *with density* $\phi^{ART}(K) = \phi(K)$.

The ART product is never chosen in equilibrium.

For $B = B_{crit_1}$, we obtain $K_{ART}^{max} = K_h$, and the equilibrium strategies are equivalent to those in Proposition 1. As B and therefore K_{ART}^{max} decrease, the insider no longer chooses $K^{in}(l) \in (K_{ART}^{max}, K_h]$ because a low-risk insurer would then choose the

ART product; the probability mass over this region is shifted to $K^{in}(l) = K_{pool}$. As a consequence, the outsider will also no longer offer contracts in this region because these contracts will only be accepted by a high-risk type; the probability mass is shifted to $K^{out} = K_h$. For $B = B_{crit_2}$, we obtain $K_{ART}^{max} = K_{pool}$ and a pure strategy equilibrium with $K^{in}(l) = K_{pool}$ and $K^{out} = K_h$. This equilibrium coincides with the one in Proposition 2 for $B = B_{crit_2}$.

The reinsurers' equilibrium strategies depend on the basis risk of the ART product for the low-risk type. The the higher the bankruptcy cost, the higher the basis risk when using the ART product and the higher the value from a perfect hedge through an indemnity reinsurance contract.

Proposition 4 *The availability of an ART product reduces the hold-up and adverse selection problem inherent in the reinsurance relationship. For $B_{crit_2} < B$, the source of the benefit to a low-risk insurer is a reduction in the insider's rent. For $B_{crit_2} \leq B < B_{crit_1}$, the source of the benefit is that the ART product reduces the expected cross subsidization.*

For $B_{crit_2} \leq B < B_{crit_1}$, the insider can still guarantee himself an expected profit of $K_{pool} - K_l$ since a reinsurance contract with a pooling premium is preferred to the ART product by a low-risk type. However, the expected premium that the insider demands from a low-risk type is lower and the insider therefore has to pay a lower expected premium. It may come as a surprise that the insider is nevertheless able to capture the same rent as without the ART product. To understand the rationale it is important to observe that a higher premium does not result in a higher profit because the likelihood that the outsider underbids the offer increases as well and the insider's expected profit does not change. The benefit of a lower premium for a low-risk insurer

stems from a higher expected premium for a high-risk insurer. The outsider puts less probability mass on premiums with which he tries to attract a low-risk insurer if the insider reduces the premium. This reduces the probability that a high-risk insurer benefits from premiums below his expected loss. That is, the expected amount of cross-subsidization is smaller than in the pure reinsurance case. For a low-risk type, the difference between the expected cross subsidization in the pure reinsurance case and in the case with the ART product is

$$\Delta = \frac{(1-q)^2}{q}\left(K_h - K_l\right)\left[\frac{K_h - K_l}{B_l^{risk}} - \ln\left[\frac{K_h - K_l}{B_l^{risk}}\right] - 1\right] > 0 \tag{7}$$

for $B_{crit_2} < B < B_{crit_1}$ and derived in the appendix. The difference is decreasing in the ART product's basis risk, B_l^{risk}, and reaches zero for $B = B_{crit_1}$. The intuition is that with higher basis risk the upper boundary of the equilibrium strategies is raised, increasing the probability masses on $[K_{pool}, K_{ART}^{max}]$. Δ is increasing in the degree of adverse selection, $K_h - K_l$, as its effect on cross subsidization increases in the probability that a high-risk type receives a premium below his expected loss, which is higher without the ART product.

If $B \leq B_{crit_2}$, the cross subsidization is zero. The insider's information rent is now determined by the basis risk of the ART product for the low-risk type, B_l^{risk}.

Figure 1 shows the dependence of the insider's rent and the degree of cross subsidization on the bankruptcy cost, B.

5 Discussion

5.1 First period

In the first period, all reinsurers have the same information and will therefore place identical bids. Since all reinsurers can become insiders when winning the bid in the first period, Bertrand competition will drive down the first-period premium which then internalizes the insider's second-period rent. Bertrand competition implies perfect competition, no financing constraints for the reinsurers, and full internalization of insider profits. The first-period premium is then

$$K_{t=0} = \begin{cases} K_{pool} - q(K_{pool} - K_l) & B > B_{crit_2} \\ K_{pool} - qB_l^{risk} & B < B_{crit_2}. \end{cases} \tag{8}$$

The level of expected cross subsidization plays no role because this is a redistribution between types and in the first period insurers do not know their types either. The expected value of cross subsidization is zero.

These costs have to be compared to the costs of the alternative of issuing an ART product in the first period and then issuing either an ART product in the second period or buying reinsurance at the pooling premium.

Lemma 2 *Given the premiums in (8), it is never optimal to issue an ART product in the first period; the availability of an ART product reduces the discount in the premium in the first period if* $B < B_{crit_2}$.

The first part of the lemma follows directly from the observation that insurers receive a fair premium in the first period that takes into account the rent that is extracted in the second period. In contrast, the ART product involves basis risk. The

second part follows directly from the observation that the insider's second-period rent is reduced when an ART product is available and $B<B_{crit_2}$.

The analysis of the first period seems to suggest that ART products are irrelevant since insurers are compensated for the future extraction of information rents by lower premiums in the first period. However, this is not true. First, the benefit of using ART products in the second period remains: low-risk insurers benefit from the availability of ART products in the second period; no matter how large the discount was in the first period. Second, reinsurers must be willing to pay for expected future rents. In a more general setting, they may be reluctant to do so because of potential intertemporal incentive and hold-up problems–such as, e.g., the threat to invent ART products.

5.2 Multiple insiders

We now consider the case where the insurer can obtain reinsurance from multiple reinsurers in first period. In the absence of monitoring costs and with symmetric information by insiders, Bertrand competition will drive down the premiums demanded by the insiders from a low-risk type in the second period to the fair premium, K_l. The ART product will then have no impact on the premiums as competition between insiders eliminates the lock-in from asymmetric information. However, this argument critically hinges on the assumption that both insiders will have the same information. If they may end up with asymmetric information, the situation is equivalent to the one with an informed insider and an uninformed outsider. Rajan (1991, 1992) argues that in the presence of even small monitoring cost and unequal access to a firm's information, insiders are again able to extract information rents, reestablishing the impact that the ART product exerts on the reinsurers' strategies.

5.3 Retention

We have assumed that it is always optimal for the insurer to buy reinsurance. This assumption is particularly relevant for a low-risk type in the second period. If the premium exceed the sum of the expected loss and bankruptcy cost, i.e., $K > K_l + \theta p_l B$, it is not optimal for the insurer to buy reinsurance.[2] Therefore, the possibility not to buy reinsurance also places an upper bound on the possible price if $K_l + \theta p_l B < K_h$. The new equilibrium is equivalent to the equilibrium described in Proposition 3 for $K_{pool} \leq K_l + \theta p_l B$ and the equilibrium described in Proposition 2 for $K_{pool} > K_l + \theta p_l B$, where $K_{ART}^{max} = K_l + B_l^{risk}$ is replaced by $K_l + \theta p_l B$. The constraint imposed by the ART product is always stricter than "no insurance" since the basis risk, $B_l^{risk} = (p_l - p_T^l)\theta B$, is strictly lower than the expected bankruptcy cost, $\theta p_l B$, whenever $p_T^l > 0$.

If Rothschild-Siglitz type "price-quantity policies" are possible, outsiders may offer two types of contracts, one with full insurance and a premium K_h for a high-risk type (h-contract) and one with partial insurance and a fair premium for a low-risk type (l-contract), where the retention is chosen so that a high-risk type will not choose this contract. Without loss of generality, we assume that the retention is implemented through a probability $q > 0$ with which, conditional on a loss, the insurer is not reimbursed for this loss, while he receives X with probability $1 - q$. Incentive compatibility implies that the cost saving for a high-risk type net of the increase in expected bankruptcy cost must not be positive, when choosing the l-contract instead of the h-contract, i.e., $(1 - q)(K_h - K_l) - q\theta p_h B \leq 0$. The lowest

[2] We note that we implicitly assume that holding capital as an alternative way of protection is too costly due to regulatory and agency cost as well as accounting and tax rules that penalize the accumulation of equity capital. For details, see Jaffee and Russell (1997).

q that satisfies this condition is $q = (K_h - K_l)/(\theta p_h B + K_h - K_l)$. Again, this contract places an upper bound on the maximum price that a low-risk insurer is willing to pay for full reinsurance coverage. The argument is analogous to the case of no reinsurance, which is akin to $q = 1$ and where the maximum premium that a low-risk type is willing to pay for full insurance is $K_l + q\theta p_l B$. The ART product is useful even with Rothschild-Siglitz type "price-quantity policies" if the basis risk is lower than the expected bankruptcy cost with the incentive-compatible retention, i.e., if $B_l^{risk} = (p_l - p_T^l)\theta B < q\theta p_l B$. Rearranging terms yields $1 - p_T^l/p_l < q$.

5.4 Monitoring cost

So far, we have assumed that the insider obtains the information about the insurer's type at no cost. If monitoring is costly, the resulting equilibrium and the impact of the ART product depends also on the level of the monitoring cost. Let c denote the fixed monitoring cost per insurer. For $B > B_{crit_2}$, the insider's expected net profit is $E[\Pi^{in}] = q(K_{pool} - K_l) - c$. Monitoring will take place and inside information will be obtained if $c < q\ (K_{pool} - K_l)$. The equilibrium strategies and the boundaries of the mixed equilibrium remain unchanged because the outsider never monitors and the insider finances the monitoring cost through his expected profit. If the monitoring cost exceeds the expected insider profit, nobody monitors and no inside information is revealed. The game in the second period is the same as in the first period with all reinsurers demanding the pooling premium. For $B > B_{crit_2}$, the insurer will always buy reinsurance in both periods since the expected cost of issuing an ART product are higher than the cost of reinsurance.

If $B < B_{crit_2}$, the insider's expected net profit is reduced to $E[\Pi^{in}] = qB_l^{risk} - c$. As long as the expected profit exceeds the monitoring cost, i.e., $c < qB_l^{risk}$, the game

is the same as in the case without monitoring cost. The only difference is that the insider's profit is reduced by the monitoring cost. If the monitoring cost exceeds the expected insider profit, no monitoring takes place and reinsurers will demand the pooling premium in the first period. In the second period a low-risk types will issue the ART product and a high-risk types will be reinsured at their fair premium of K_h.

5.5 Transaction cost and risk premium

We have assumed zero transaction costs on the side of the reinsurance or the ART product. For the reinsurance, these costs could arise from overhead cost, cost of capital, other opportunity cost or minimum return requirements on the reinsurance portfolio. Such costs lead to a higher required break-even premium for all types, and raise the boundaries of the mixed strategy equilibrium. Let us denote the additional cost by c_{RI}. The break even premium is then $(K_i + c_{RI})$ for an insurer of type i. The randomization range in the pure reinsurance setting is ceteris paribus given by $[K_{pool} + c_{RI}, K_h + c_{RI}]$ in the pure reinsurance case. The equilibrium densities are changed to

$$\hat{\omega}(K) = \frac{K_{pool} - K_l}{q\left(K - K_l + c_{RI}\right)^2}$$

and

$$\hat{\phi}(K) = q\hat{\omega}(K).$$

The insider's profit and the cross subsidization remain unchanged compared to the case without opportunity costs, as the higher premiums just cover the additional cost.

Analogously, transaction cost or a risk premium demanded by the investors raise the costs of issuing an ART product. Let us denote the additional cost per unit of the ART product by c_{ART}. The maximum premium that a low-risk type will pay in

the presence of an ART product is now

$$K_{ART}^{max} = K_l + B_l^{risk} + c_{ART}$$

Assume

$$\hat{B}_{crit_2} \equiv \frac{K_{pool} - K_l + c_{RI} - c_{ART}}{(p_l - p_T^l)\theta} < B < \frac{K_h - K_l + c_{RI} - c_{ART}}{(p_l - p_T^l)\theta} \equiv \hat{B}_{crit_1}.$$

While the insider's profit remains unchanged for the case of $B'_{crit_2} < B < B'_{crit_1}$ because the costs are accounted for by the higher premiums, the cross subsidization now depends on the relative size of the costs of the different instruments. Compared to the case without additional costs, the cross subsidization increases for $c_{ART} > c_{RI}$ and vice versa.

For $B < \hat{B}_{crit_2}$, we will again have an equilibrium in pure strategies with the insider offering reinsurance to the high-risk types at $K_h + c_{RI}$ and to low risk types at $K = \max\{K_l + B_l^{risk} + c_{ART}, K_l + c_{RI}\}$. If the opportunity cost of reinsurance exceeds the basis risk and the opportunity cost of the ART product, i.e., $c_{RI} > c_{ART} + B_l^{risk}$, it is optimal for a low-risk type to choose the ART product. Therefore, differential transaction costs may be a reason for using the ART product.

5.6 Empirical implications

In this section we discuss some empirical implications of our model. Most importantly, in our model the benefit of ART products arises from their availability, not from their use. Therefore, our predictions are in line with the observation that cat bonds are rarely used. Cat bonds account for only one percent of the entire catastrophe reinsurance volume and the market share has been stagnant since their first introduction in

the mid 90's, as shown in Figure 2.[3] Figure 3 shows that the number of issues stayed relatively constant at around eight issues per year with a peak in 1999. Guy Carpenter (2004) reports that of the 33 issues with non-indemnity triggers, only 6 have been issued by insurers and three by corporations, the remaining 24 have been issued by reinsurers. Trading of Property Claim Services (PCS) options on the CBOT decreased to virtually zero by the end of 1999 and was discontinued. Similarly, the trade of catastrophe-linked options on the Bermuda Commodities Exchange was suspended in 1999 due to lack of activity.

The second implication of the model is that reinsurance premiums ceteris paribus decline with the introduction of ART products. Empirical and anecdotal evidence that ART products decrease reinsurance premiums is found by Froot (2001). Figure 4 shows the ratio of premiums to expected losses. This ratio declined from 1994 to 1999 and increases again since 2001. Naturally, premiums are not only influenced by expected losses and we do not suggest that the development is entirely driven by the introduction of ART products. Nevertheless, the overall development of premiums is in line with the model's predictions for the mid to late 90's.

We would expect to observe the premiums to decrease more in countries with highly developed capital markets where bankruptcy cost are lower and in regions where very specific perils exist, which allow for a higher correlation between the individual insurer's losses and the parametric trigger or the index. Unfortunately, no detailed country-based data is available.

As discussed in Section 5.5, ART products might be issued if they also have a

[3]Data are from Guy Carpenter (2004) and Swiss Re (2002). The first cat bonds were issued in 1995, but were mostly indemnity based so that they closely resembled classical reinsurance contracts. Data on issuances and volumes is consistently recorded since 1997.

comparative cost advantage over reinsurance and the basis risk is low. Therefore we also expect to see a higher demand for ART products in countries with highly developed capital markets and regions with very specific perils and highly correlated triggers and indices. Figure 5 shows a higher percentage share of cat bonds in the US and Japan for 1997. Both regions do not only have well developed capital markets, but Californian and Japanese Earthquakes as well as East-Coast hurricanes and Japanese typhoons are well specified and regionally concentrated perils.

6 Conclusion

We have shown how the existence of information-insensitive ART products can reduce the asymmetric information and lock-in problem in a reinsurance relationship and discipline the rent extraction from insider information. The availability of information-insensitive ART products reduces the maximum demandable reinsurance premium for sufficiently small basis risk. As consequence, the reinsurers place less probability mass on their mixed equilibrium strategies which decreases the degree of cross subsidization from the low risk types to the high risk types. If the costs of issuing ART products are even lower than the pooling premium, cross subsidization is zero and the insider's information rent is reduced. The disciplining effect of the ART product is just exerted through its presence - in the basic model it will never be actually issued. These main results are robust to a number of extensions. The empirical implications of the model are in line with the very low and stagnant market share of ART products and a decrease in the ratio of reinsurance premiums to expected losses following the introduction of ART products in the mid 90's. Since the results of the model are mainly driven by the difference in information sensitivity of the individual

instruments, they may also be relevant in other financing situations in which information sensitivity impacts premiums and prices such as, for example, in the credit securitization literature.

7 Appendix

Proof of Proposition 1. The proof is closely related to von Thadden (2001) and the equilibrium concept uses the results from auction theory for asymmetrically informed bidders by Engelbrecht-Wiggans, Milgrom, and Weber (1983). First, we show that the interval $K \in [K_{pool}, K_h]$ is the optimal support for the randomization strategies. For any bid below the pooling premium, the outsider's participation constraint is violated, so his minimum premium will be K_{pool}. Therefore, it also cannot be optimal for the insider to offer a lower premium to the low risk type because raising the premium to the pooling premium increases profits. The upper bound K_h follows from the zero-profit constraint for offering a contract to a high-risk type.[4]

Second, we derive the optimal strategies. Let $\Phi(K)$ denote the cumulative density function (CDF) of the mixed equilibrium strategy by the outsider and $\Omega(K)$ denote the insider's CDF. Given the offer K^{out}, the outsider's expected net payoff is $\Pi^{out}(K^{out}) = (1 - \Omega(K^{out}))(K^{out} - K_{pool}) + \Omega(K^{out})(1 - q)(K^{out} - K_h)$, where $(1 - \Omega(K^{out}))$ is the probability that $K^{out} < K^{in}(l)$. The expected profit in this case is the premium minus the expected average loss. If $K^{out} \geq K^{in}(l)$, a low risk type stays with the insider and the outsider will only sell the reinsurance contract if the insurer has high-risk, which occurs with probability $(1 - q)$ and results in an

[4] With Bertrand-competition between outside insurers, the upper bound converges to θX. (See von Thadden (2001) or Engelbrecht-Wiggans, Milgrom, and Weber (1983).)

expected loss of $K^{out} - K_h$. In equilibrium, the outsider makes an expected profits of zero. Moreover, in the mixed strategy equilibrium the outsider must be indifferent between different premiums K^{out}. Hence, $\Pi^{out}(K^{out}) = 0$ for all $K^{out} \in [K_{pool}, K_h]$. From $(1-\Omega(K^{out}))(K^{out}-K_{pool}) = -\Omega(K^{out})(1-q)(K^{out}-K_h)$ and $K_{pool} = qK_l+(1-q)K_h$ the insider's CDF is $\Omega(K) = [K - K_{pool}] / [q(K - K_l)]$ for $K \in [K_{pool}, K_h]$.

Given the outsider's mixed strategy $\Phi(K)$, the insider's expected net payoff is $\Pi^{in}(K^{in}(l)) = q[(1-\Phi(K^{in}(l)))(K^{in}(l)-K_l)]$ for $K^{in}(l) \in [K_{pool}, K_h)$ and $\Pi^{in}(K^{in}(l) = K_h) = q[\Pr(K^{out} = \theta X)(K_h - K_l)]$ for $K^{in}(l) = K_h$. At $K^{in}(l) = K_{pool}$ the low-risk type will always stay with the insider who makes an expected profit of $\Pi^{in}(K_{pool}) = K_{pool} - K_l$. In a mixed strategy equilibrium the insider must be indifferent between different $K^{in}(l)$ given the outsider's strategy. Therefore, it must be the case that $\Pi^{in}(K^{in}(l)) = \Pi^{in}(K_{pool})$ for all $K^{in} \in [K_{pool}, K_h]$. From this we can derive the the outsider's equilibrium strategy, which is $\Phi(K) = [K - K_{pool}] / [K - K_l] = q\Omega(K)$ for $K \in [K_{pool}, K_h)$ and $\Phi(K) = 1$ for $K = K_h$. The densities of the players' strategies can now be derived by differentiating the CDFs with respect to K, which yields (1) and (2). □

Equation (3). Assume that the insurer is a low-risk type; given the premium K, the outsider's expected profit is $\Pi^{out}(K) = (1 - \Omega(K))(K - K_l) = [(1-q)/q](K_h - K)$. Taking the expectation over the choice of K yields $E[\Pi^{out}|l] = \int_{K_{pool}}^{K_h}(1 - \Omega(K))(K - K_l)\phi(K)dK = [(1-q)/q]\int_{K_{pool}}^{K_h}(K_h - K)\phi(K)dK = [(1-q)/q](K_{pool} - K_l)\int_{K_{pool}}^{K_h}(K_h - K)\frac{1}{(K-K_l)^2}dK$.

Integration by part yields

$$E\left[\Pi^{out}|l\right] = \frac{1-q}{q}(K_{pool} - K_l)\left[\left[-\frac{K_h - K}{K - K_l}\right]_{K_{pool}}^{K_h} - \int_{K_{pool}}^{K_h}\frac{1}{K - K_l}dK\right]$$

Using $K_{pool} = qK_l + (1-q)K_h$, we obtain equation (3).

Proof of Proposition 3. We show that the mixed strategies in Proposition 3 constitute a Nash equilibrium. First, consider the insider's strategy, taking the outsider's and insurer's strategies as given. $K^{in}(h) = K_h$ is optimal since $K^{in}(h) < K_h$ results in an expected loss and $K^{in}(h) > K_h$ yields the same expected payoff as $K^{in}(h) = K_h$.$K^{in}(l) > K_{ART}^{max}$ is never optimal since a low risk-type will then buy the ART product; $K^{in}(l) < K_{pool}$ is also never optimal since the rent can be increased by increasing $K^{in}(l)$. Hence, $K^{in}(l) \in (K_{pool}, K_{ART}^{max})$. Given the outsider's strategy $\Phi(K) = [K - K_{pool}] / [K - K_l]$ for $K \in (K_{pool}, K_{ART}^{max})$,the insider's expected profit is $\Pi^{in}(K^{in}(l)) = q[(1-\Phi(K^{in}(l)))(K^{in}(l) - K_l)] = q(K_{pool} - K_l)$ and therefore independent of the own offer for any $K^{in}(l) \in (K_{pool}, K_{ART}^{max})$. The insider's mixed strategy in the proposition is therefore a best response. We now consider the outsider's strategy. It is never optimal for the outsider to choose $K \neq K^{out} \in \{(K_{pool}, K_{ART}^{max}), K_h\}$; for $K < K_{pool}$ both types accept the contract and their expected loss exceeds the premium; for $K_{ART}^{max} < K^{out} < K_h$ only the high-risk type accepts the contract at a premium below his expected loss. For $K^{out} = K_h$, $\Pi^{out}(K^{out}) = 0$, and for $K^{out} \in (K_{pool}, K_{ART}^{max})$, $\Pi^{out}(K^{out}) = (1-\Omega(K^{out}))(K^{out} - K_{pool}) + \Omega(K^{out})(1-q)(K^{out} - K_h) = 0$ given the mixed strategy $\Omega(K) = [K - K_{pool}] / [q(K - K_l)]$ derived in Proposition 1. Therefore, the outsider's mixed strategy is weakly optimal. □

Equation (7). $\Delta = E[\Pi^{out}|l] - E[\Pi^{out}|l, ART]$ where $E[\Pi^{out}|l]$ is given by equation (3). $E[\Pi^{out}|l, ART]$ is the expected cross subsidization when the ART product is available. It is derived in the same way as equation (3), with the only difference that K_h is replaced by K_{ART}^{max} in the integral. We obtain

$$E\left[\Pi^{out}|l, ART\right] = \frac{(1-q)^2}{q}(K_h - K_l)\left[\frac{1}{1-q} - \frac{K_h - K_l}{B_l^{risk}} - \ln\frac{B_l^{risk}}{(1-q)(K_h - K_l)}\right],$$

using $K_{pool} = qK_h + (1-q)K_l$ and $K_{ART}^{max} = K_l + B_l^{risk}$. Taking differences yields

$$\Delta = \frac{(1-q)^2}{q}(K_h - K_l)\left[\frac{K_h - K_l}{B_l^{risk}} - \ln\left[\frac{K_h - K_l}{B_l^{risk}}\right] - 1\right],$$

which is positive since $B_{crit_2} < B < B_{crit_1}$ implies $(K_h - K_l)/B_l^{risk} > 1$.

References

Cooper, R., and B. Hayes, 1987, Multi-period insurance contracts, *International Journal of Industrial Organization* 15, 211-231

Cummins, D., and D. Lalonde, and R. Phillips, 2000, The basis risk of catastrophic-loss index securities, Working Paper

Cummins, D., and D. Lalonde, and R. Phillips, 2002, Managing risk using index-linked catastrophic loss securities, Working Paper

Doherty, N., 1997, Financial innovation in the management of catastrophe risk, *Journal of Applied Corporate Finance* 10, 84-95.

Doherty, N., and A. Richter, 2002, Moral hazard, basis risk, and gap insurance, *Journal of Risk and Insurance* 69, 9-24

Engelbrecht-Wiggans, R., and P. Milgrom, and R. Weber, 1983, Competitive bidding and proprietary information, *Journal of Mathematical Economics* 11, 161-169

Fischer, K., 1990, Hausbankbeziehungen als Instrument der Bindung zwischen Banken und Unternehmen, Thesis

Froot, K., 2001, The market for catastrophe risk: A clinical examination, *Journal of Financial Economics* 60, 529-571

Froot, K., 1997, The limited financing of catastrophe risks: An overview, NBER Working Paper No. 6025

Ge, Y., and L. Cox, 2003, Temporal profitability and pricing of long-term care insurance, Southern Illinois University Working Paper

Guy Carpenter, 2004, The catastrophe bond market at year-end 2003, Marsh & McLennan Publications

Jaffee, D., and T. Russell, 1997, Catastrophe insurance, capital markets and uninsurable risks, *Journal of Risk and Insurance* 64, 205-230

Kunreuther, H., and M. Pauly, 1985, Market equilibrium with private knowledge: An insurance example, *Journal of Public Economics* 26, 269-288

Lane, M., and R. Beckwith, 2003, 2003 Review of trends in insurance securitization, Lane Financial Trade Notes

Nell, M., and A. Richter, 2002, Improving risk allocation through cat bonds, Working Paper

Niehaus, G., 2002, The allocation of catastrophe risk, *Journal of Banking and Finance* 26, 585-596

Nilssen, T., 2000, Consumer lock-in with asymmetric information, *International Journal of Industrial Organization* 18, 641-666

Rajan, R., 1991, Conflict of interest and the separation of commercial and investment banking, Mimeo, University of Chicago

Rajan, R., 1992, Insiders and Outsiders: The choice between informed and arm's-length debt, *Journal of Finance* 47, 1367-1400

Sharpe, S., 1990, Asymmetric information, bank lending, and implicit contracts: A stylized model of customer relationships, *Journal of Finance* 45, 1069-1087

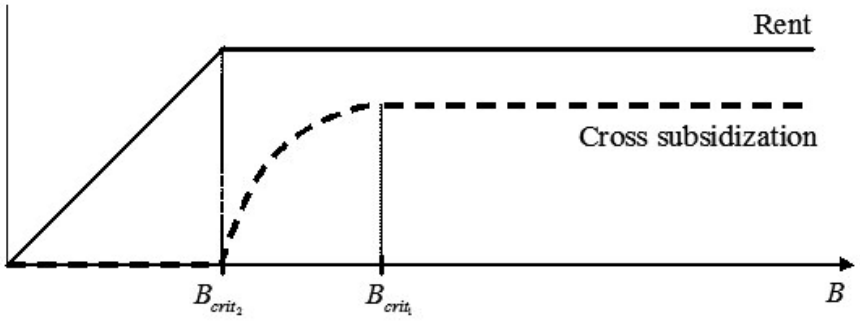
Swiss Re, 1997, Sigma 7/97, Swiss Re Publikations

Swiss Re, 2002, Focus Report: Cat reinsurance - meeting the sustainable level?, Swiss Re Publications

von Thadden, E., 2001, Asymmetric information, bank lending, and implicit contracts: the winner's curse, Working Paper

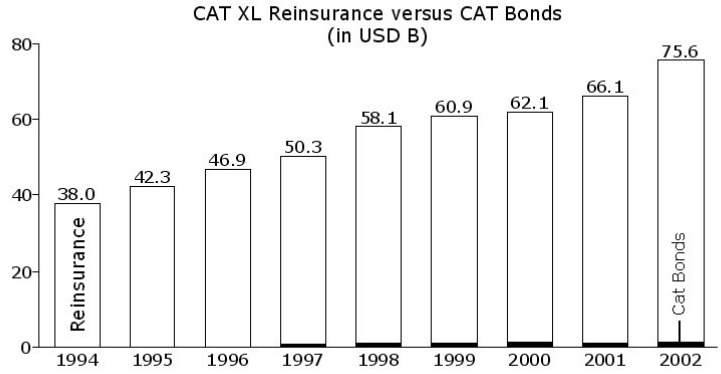
Figures

Figure 1: Insider's rent and cross subsidization



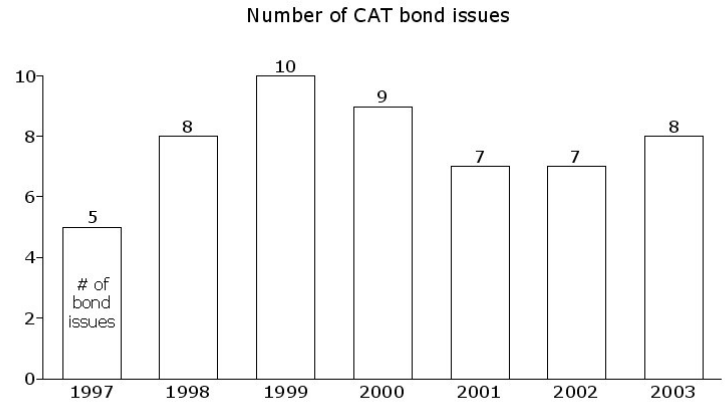
Notes: Since the basis risk of the ART product depends on B and p_T^l and p_l, the figure shows the dependence of the insider's rent and the cross subsidization on the basis risk of the ART product for given p_l^T and p_l.

Figure 2: Reinsurance Cat XL covers versus Cat bonds



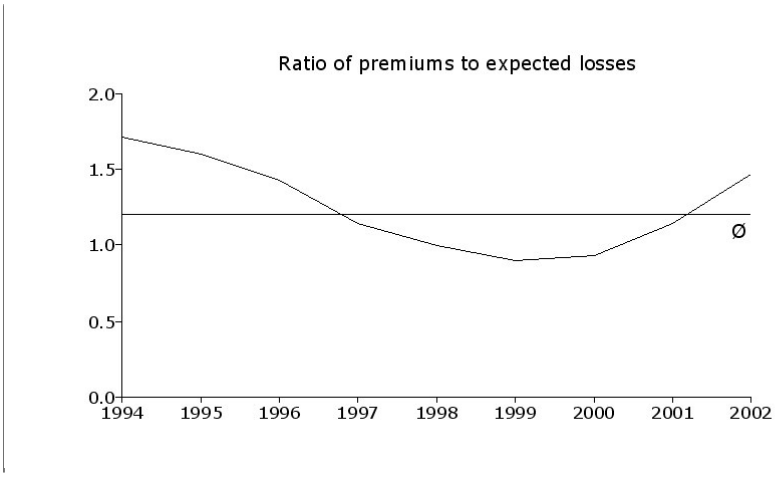
Notes: Reinsurance Cat XL covers for 14 main markets (CAMARES study by Swiss Re) and global volume of cat bonds in USD B. Cat bond volume has remained at approximately 1% of the catastrophe reinsurance volume since introduction in 1995.
Source: Guy Carpenter (2004) and Swiss Re (2002)

Figure 3: Number of Cat bond issues since 1997



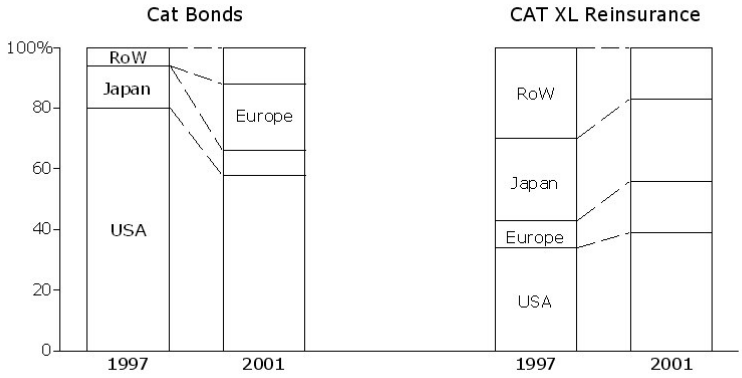
Notes: Number of Cat bond issues per year from 1997 to 2002.
Source: Guy Carpenter (2004)

Figure 4: Ratio of catastrophe insurance premiums to expected losses



Notes: Ratio of catastrophe reinsurance premiums to expected losses for 1994 to 2002.
Source: Swiss Re (2002)

Figure 5: Geographical distribution of reinsurance Cat XL covers and cat bonds



Notes: Geographical distribution of reinsurance Cat XL covers and catastrophe bonds in percentage of total for 1997 and 2001.

Source: Guy Carpenter (2004), Swiss Re (2002), and Swiss Re (1997)