Can Security Markets Save the Private Catastrophe Insurance Market?

by

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Abstract: The purpose of this paper is to examine the role of capital markets in restoring the operation of a private market in catastrophe insurance . The paper develops a model of insurance markets in which risks are temporally dependent, and discusses the role of capital markets in that framework. Traditional capital market instruments (debt, equity, contingent loans) are shown to be ill suited to the needs of the catastrophe insurance industry. Newly designed instruments such as catastrophe bonds and catastrophe options, however, are shown to have many desirable features which could in principle permit the reestablishment of a private catastrophe insurance market.

1 Introduction Following the pioneering work of Arrow [1971], Borch [1962], Hirshleifer [1966], and Wilson [1968], the modern theory of insurance has largely concentrated on the problem of how a large number of risk averse agents can usefully exchange their risks at a single point in time; see Gollier [1991] for a comprehensive review. To take the simple case on which we will focus, a risk-averse farmer whose barn may burn down next year will certainly find it optimal to join a syndicate with other farmers whose barns are also at risk.

In fact, of course, individuals face risks, not just at a single point in time, but over their whole lifetime. Our risk averse farmer will face the risk that his barn will burn down, this year, next year, and indeed every year of his working life. And over a long enough horizon, the probability that the farmer's barn will burn down in a specific year translates into the near certainty that it will burn down in some year, the question becoming not "if" but "when". From this intertemporal viewpoint, we will see that an optimal insurance arrangement should smooth consumption across time (a la Fisher [1930]), in addition to its recognized role of smoothing consumption across states (a la Hirshleifer [1966]).

This intertemporal smoothing can be achieved either by the use of financial intermediaries (e.g. insurance and reinsurance companies) or by the direct use of financial markets. In this paper, we compare the efficacy of these two mechanisms in providing intertemporal smoothing of risk. We concentrate on the problem of how to smooth catastrophe risk, since intertemporal capital market issues have been identified as a source of recent problems with this line; see Jaffee and Russell [1997].

Motivated by the recent collapse of private catastrophe insurance markets in the U.S., we are particularly interested in two questions:

1) What are the advantages and disadvantages of alternative financial instruments for the smoothing and sharing of catastrophic risks.?

2) What will be the role of financial intermediaries, particularly reinsurance companies, if the financial markets for intertemporal catastrophe risk instruments continues to grow? [1] In particular will these instruments allow the revival of private markets for catastrophe insurance?

In this paper, we concentrate on problems of catastrophe insurance, but the intertemporal perspective we develop can be applied to many other insurance lines. To be sure, intertemporal consumption smoothing is traditionally associated with banks, not insurance companies. From the functional perspective, however, both insurance companies and banks provide liquidity on demand. The requirement that an insurance company promptly pay a policy claim is qualitatively the same as a bank's responsibility to redeem demand deposits.

[1] According to Lane [1998], $1 billion of risk transfer instruments have been issued in the last 2 years. This market is expected to grow to an annual size of $5 to $10 billion by the year 2000.

The opposite viewpoint, that banks act as insurance agencies, has formed the basis for an extensive recent literature in banking starting with Diamond and Dybvig [1983] and now including Allen and Gale [1997], Allen and Santomero [1997], Diamond [1997], and others. These authors have analyzed the financial intermediary/financial instrument nexus by assuming that a bank (intermediary) exists to satisfy demands for liquidity which arise at unpredictable points in time. The extension of these ideas to the insurance market provides a number of insights into the current difficulties in the market for catastrophe insurance. [2] We turn now to an examination of insurance from an intertemporal perspective.

2. Optimal Lifetime Consumption with Loan Markets but no Insurance Markets

In order to clarify the role of insurance markets, we begin with a simple example of an individual who faces a certain loss at an uncertain date. This individual has full access to loan markets, but for the moment has no access to insurance contracts. Let the individual (we think of him as a farmer) live for a period covering 3 dates, dates 0, 1, and 2. The individual must choose consumption at each date labeled C_i , $i = 0, 1\ 2$. The farmer has initial wealth of W, including a barn whose value at date 0 is B. [3] The farmer knows with certainty that this barn will burn down sometime, but does not know if this will occur in the interval $(0 \leq t \leq 1)$ or in the interval $(1<t\leq 2)$.[4] If it occurs in the interval (0-1), the farmer must rebuild the barn at date 1 at a cost B. If it occurs

[2] For example, catastrophe claims for an insurance company share features with a bank run for a banking firm.

[3] We assume that the present value of the income generated by the barn is already included in the wealth W and that all of W will be used for consumption by the end of the horizon.

[4] Although we illustrate our discussion with the case where a barn of fixed value is sure to burn down exactly once over the individual's lifetime, we will comment on the more general case where the amount of the loss or the frequency of the loss over the lifetime is itself uncertain.

in the interval (1-2), the barn is to be rebuilt at date 2 at the cost B. The barn is equally likely to burn down in each interval.

Preferences

The farmer is assumed to satisfy the axioms of expected utility and, in addition, to have preferences which are time separable with discount rate δ, assumed for simplicity to equal the market interest rate r. The instantaneous utility function $U(C_i)$ is assumed to have the form $U(\,) = \log(\,)$ so that the individual's overall objective under certainty is to maximize:

(1a) $$V = \log(C_0) + \frac{\log(C_1)}{(1+d)} + \frac{\log(C_2)}{(1+d)^2}.$$

At date 0, the farmer must choose the current consumption level C_0, while recognizing that the specific date at which the barn will burn is uncertain. This means that, at date 0, the farmer will also contemplate plans for C_1 and C_2 that are conditional on the two possibilities for the date of the barn repair, date 1 or date 2. The consumption values conditional on the barn repair occurring at date 1 are labeled C_1^S *and* C_2^S for period 1 and 2 consumption respectively (S refers to "sooner"). The consumption values conditional on the barn repair occurring at date 2 are labeled C_1^L *and* C_2^L for period 1 and 2 consumption respectively (L refers to "later").

The criterion function (1a) can then be rewritten in terms of *expected* utility, based on whether the barn burns sooner (leading to C_1^S *and* C_2^S) or later (leading to C_1^L *and* C_2^L), each occurring with probability of 0.5 :

(1b) $$V = \log(C_0) + \frac{.5\log(C_1^S) + .5\log(C_1^L)}{1+d} + \frac{.5\log(C_2^S) + .5\log(C_2^L)}{(1+d)^2} \; .$$

Budget Constraint

At date 0, due to the uncertainty regarding the date of the barn repair, the present value of the wealth available for consumption is a random variable, taking on the value $W_0^S \, or W_0^L$, depending on whether the barn must be repaired sooner (at date 1) or later (at date 2):

(2a) $W_0^S = W - \frac{B}{1+r} = C_0 + \frac{C_1^S}{(1+r)} + \frac{C_2^S}{(1+r)^2}$, given the barn is to be repaired sooner (at date 1).

(2b) $W_0^L = W - \frac{B}{(1+r)^2} = C_0 + \frac{C_1^L}{(1+r)} + \frac{C_2^L}{(1+r)^2}$, given the barn is to be repaired later (at date 2).

For simplicity, the interest rate r is assumed constant across time periods.

Solution with Certainty

It is useful first to consider the solution to the problem of maximizing the utility function (1a) for a case in which the barn never burns down. In this case, the budget constraint simply requires that initial wealth W equal the present value of the consumption plan:

(2c) $$W = C_0 + \frac{C_1}{(1+r)} + \frac{C_2}{(1+r)^2}.$$

The problem is to maximize the utility function (1a) subject to the budget constraint (2c). This is, of course, just a textbook example of the consumption loan model.

The optimal solution has the feature that marginal utility is equalized across periods:

(3) $$\frac{1}{C_0} = \frac{1}{C_1} = \frac{1}{C_2}, \text{ which implies that } C_0 = C_1 = C_2.$$

Given that the utility function is time separable and the interest rate and discount rate are equal, the optimal plan is to consume equal amounts in each period.

Solution with Uncertainty

In the case of uncertainty, the farmer must maximize *expected* utility, since the date of the barn burning is not known as of date 0. This requires maximizing the utility function (1b) subject to the budget constraints (2a) and (2b). In the certainty case, we saw that marginal utility was equated across time periods (equation 3). Now, *expected* marginal utility is equated across time periods, giving the following necessary condition:

(4) $$\frac{1}{C_0} = [.5\frac{1}{C_1^S} + .5\frac{1}{C_1^L}] = [.5\frac{1}{C_2^S} + .5\frac{1}{C_2^L}] \ .$$

The result is summarized in the following proposition.

Proposition 1

At the optimum, the agent will choose a level of initial consumption C_0 and levels of future consumption $C_i^S, C_i^L, i = 1, 2,$ to satisfy the budget constraints and make:

$MU(C_0) = EMU(C_i) \quad c = 1,\ 2$

where MU is marginal utility and EMU is the expected marginal utility across the two states. This Proposition has the following corollary.

Corollary

At the optimum $C_0 < .5C_i^S + .5C_i^L \quad i = 1, 2$

The proof follows immediately from the convexity of the first derivative of the log function. We will refer to $\hat{C} = .5C_i^S + .5C_i^L,\ i = 1, 2$, as expected future consumption.[5]

[5] More generally, the relationship between current and expected future consumption will depend on the third derivative of utility: $C_0 \underset{>}{\leq} .5C_i^S + .5C_i^L \quad i = 1, 2$, as $U''' \underset{<}{\geq} 0$.

Discussion

Compared to the case with certainty, the solution here results in consumption values planned at date 0 for C_1 and C_2 that (a) are uncertain and (b) will not equal the value chosen for C_0. The difference between C_0 and expected future consumption is known in the savings literature as precautionary savings; see Kimball [1990].[6] Precautionary saving transfers resources from current to future consumption, to guard against the uncertainty of future consumption.[7] This can be interpreted as a cost of self insurance, given that insurance contracts are not yet available to the farmer. This demonstrates that there are certain insurance questions for which intertemporal issues are fundamental.

Equalizing expected marginal utility across time is the best our farmer can achieve if the only markets open are loan markets. We turn now to examine the role of insurance contracts.

3. Insurance with Intertemporally Independent Risks

Suppose now that we assume there are a large number of farmers and that the risk of barn burning is uncorrelated across farmers and across time. Then by the law of large numbers, for n large enough, the *individual probability* of loss of ½ in each period translates into a *collective frequency* of loss of ½ in each period. Assuming for simplicity that there are zero administrative costs, an insurance company can then offer a zero profit contract on which a farmer can pay an up front premium of $.5\frac{B}{(1+r)}+.5\frac{B}{(1+r)^2}$ and be certain to be reimbursed the cost of repairing the barn whenever the loss occurs.

[6] The role of uncertainty in generating this type of saving seems first to have been noted by Leland [1968] and Sandmo [1970]; see also, Moffet [1977], Dionne and Eeckhoudt [1984], and Eeckhoudt and Kimball [1991].

[7] As shown in the footnote (5), the actual amount of precautionary saving can be positive or negative, depending on the sign of the third derivative of the utility function.

The farmer's budget constraint can then be written:

$$W - \left[.5\frac{B}{(1+r)} + .5\frac{B}{(1+r)^2} \right] = C_0 + \frac{C_1}{(1+r)} + \frac{C_2}{(1+r)^2} \ .$$

This constraint is identical to the budget constraint (2c) used for the case of certainty, except that the insurance premium term is now subtracted. It follows that optimizing farmers will choose a flat path for consumption, $C_0 = C_1 = C_2$, the same pattern we saw in the case of certainty, except that the level of consumption is now lower reflecting the cost of the insurance premium.

The farmer's consumption when using the insurance contract represents a significant improvement over the solution when only loan markets are available. In particular, the farmer's consumption is now (a) certain and (b) equal across time periods. The pooling of risks afforded by the insurance contract increases utility for 2 reasons:

Risk pooling across individuals. Risk pooling across individuals allows the farmer to replace the stochastic budget constraint with its mean value, thus removing the utility lost due to stochastic consumption paths with high and low marginal utility. As usual, risk averse individuals prefer the utility of the average to the average utility. The value of the insurance increases with the degree of risk aversion , which depends on the *curvature of the total utility function*.

Intertemporal income smoothing. Insurance increases utility in the intertemporal dimension as well. With insurance, the farmer can now smooth income by setting $C_0 = C_1 = C_2$, so there is no need to engage in precautionary saving. The insurance company thus performs a 'banking' function as well as its insurance function.[8] The value of this service depends on the *curvature of the marginal utility function*.

[8] Recall that precautionary saving can be either positive or negative, as developed in footnote (5).

It seems likely that some form of insurance collective will emerge to take advantage of these utility gains. The following factors reinforce this conclusion.

Ascending term structure of interest rates. We have assumed that the term structure of interest rates is flat. In the banking literature following from the Diamond and Dybvig [1983] model, it is assumed that long-term interest rates are higher than short-term interest rates. The insurance collective in this case would be able to remove any utility loss created by individuals holding too much of the lower yielding short-term asset.

Imperfect loan markets. We have assumed that loan markets are perfect, so that in the absence of insurance markets, individuals can smooth income enough to equate marginal expected utilities. In fact, loan markets may be very imperfect. In this case, an insurance collective can still use its premiums as a source of capital, thus providing an alternative to a bank.

Behavioral issues of self-control. We have assumed that individuals allocate their wealth to smooth consumption optimally. The evidence that individuals in fact do this is at best mixed, see e.g. Cambell and Mankiw [1991]. If consumers do have self-control problems, see e.g. Thaler [1991], then an insurance company which collects annual premiums may serve as a 'piggy bank,' forcing consumers to do the saving which is necessary for income smoothing.

All of these advantages provided by an insurance arrangement assume independent risks. The situation is very different when risks are dependent. We turn now to this case, the natural setting for an analysis of catastrophe insurance.

4. Insurance with Time Dependence: The Case of Catastrophes

To focus discussion, we consider an extreme case in which when one farmer's barn is lost, all farmers' barns are lost (a catastrophe). In this case, no advantage is gained by forming a collective at a point in time. With N farmers, each with a barn of value B, an insurance company must now be prepared to meet total losses of NB at each point in time, which requires that it have access to the amount of capital NB even on the first day of business. More generally, any entity insuring against catastrophe risks faces two related issues:

1) How should it arrange for the financial resources to fulfill its obligations to pay claims? We call this the *liquidity problem.* A catastrophe insurance company with time dependent risks faces essentially the same problem as the individual farmer discussed above. Unlike the farmer, however, the insurance company has no initial wealth. If we assume that the annual probability of a catastrophe is p, then the actuarially fair annual insurance premium would be pB and the company's aggregate annual premium income would be pNB. This amount is less, of course, than the claims of NB that arise when the catastrophe actually occurs.

2) How should it share the risks with regard to the timing and the amount of catastrophe losses? We call this the *risk transfer* problem. The risk transfer problem can be solved separately (the company's own reserves, for example, might be used to pay claims, while it retains the risk) or it might be solved together with the liquidity problem (reinsurance for example, provides the resources to pay claims and removes the risk).

The fundamental question is then how the primary insurers resolve these problems. There are a number of possibilities.

Reinsurance

Reinsurance stands to primary insurance in much the same way primary insurance stands to the individual policyholder. If the reinsurance company is able to diversify the primary insurer's potential loss of NB, then a contract of reinsurance will enable insurance with temporally dependent risks to proceed as it did for independent risks. [9]

It is not coincidental that reinsurance became unavailable for catastrophe risks at the same time during the 1990s that the primary insurance companies became unwilling to offer catastrophe policies to consumers. After all, both reinsurers and primary insurers face the same basic issues of (a) who should bear the risk and (b) how to obtain liquid funds to pay claims. Traditionally, reinsurers have also diversified risks geographically, a service of value to locally-based primary insurers. But reinsurers no longer seem able to provide complete diversification, both because catastrophes now appear to be correlated across risks (earthquakes, floods, and hurricanes), and because estimates of the maximum probable loss from catastrophes have escalated (estimates now run as high as $100 billion). Furthermore, when reinsurance is available, the price generally exceeds the actuarial cost by a large margin; see Froot and O'Connell [1997] for the empirical evidence and a discussion.

These problems are exacerbated by issues of moral hazard and adverse selection, as pointed out by Doherty [1997] and Froot [1997]. Primary insurers may also now feel there is a significant risk of default by reinsurers, since the cost of a mega-disaster could exceed all available reinsurance capital. Thus, even though some traditional reinsurance remains available

[9] As an historical aside we note that diversification of temporally dependent risks was the reason for the growth of the reinsurance industry. In the 19th century, a small, local, urban fire insurance company faced the risk that a fire would burn a whole neighborhood. For the insurance company this was a "catastrophe," since it would lead to many claims at once. By diversifying geographically, a reinsurer would allow the primary insurer to set its premiums close to the expected value of claims.

for catastrophes, the total capacity is not large enough to allow primary insurers to hedge their catastrophe risk adequately.

This has set in motion a search for alternative arrangements involving direct access to financial markets. Financial markets have the advantages that they (a) specialize in dealing with intertemporal issues and (b) have available capital which vastly exceeds that of the insurance industry. As we will now show, however, traditional financial market instruments will not satisfy the special needs of the insurance industry, and therefore new financial instruments have had to be designed..

Traditional Capital Market Instruments and Catastrophe Risk

The traditional capital market instruments we consider include equity, debt, and forward commitments. The insurance firm can use these traditional instruments to address its liquidity problem, but not its risk transfer problem (capital market instruments that transfer risk are discussed in the next section). To discuss this in more detail, we maintain the 3 date, 2 period, model used in the previous section, but now apply it from the standpoint of the insurance firm, either a primary insurer or a reinsurer. We also now assume that the aggregate amount of claims is stochastic, since the number of individual claims will depend on the exact location and severity of the catastrophe.

The insurance firm can, as one possibility, issue debt or equity at date 0. We describe these as *ex ante instruments*, since the firm does not know as of date 0 whether the catastrophe claims will occur at date 1 or at date 2. A second possibility is for the insurance firm to issue debt or equity after the catastrophe has occurred. We call these *ex post instruments*. A third possibility is to initiate *forward commitments* at date 0, which the insurance firm will take down when the catastrophe claims actually occur. In all cases, the main question is this: assuming the insurance firms are themselves diversified across risks, will access to these capital market instruments be enough to revive a private market for catastrophe insurance?

There are a number reasons why traditional debt and equity instruments are not adequate by themselves to revive the private catastrophe insurance markets. First, the *ex ante instruments* turn out to be an imperfect means for meeting the liquidity needs of catastrophe insurance firms. Second, due to factors of moral hazard and adverse selection, the *ex post instruments* create investor concern that an implicit risk transfer is occurring. The investors respond either by withdrawing their capital or by setting a very high supply price. Third, the *forward commitments* raise issues of performance risk, which could limit their usefulness. We now look at the various instruments in order to develop these conclusions.

<u>Ex Ante Debt and Equity Issues</u>

At date 0, the insurance firm could issue debt or equity, keeping the proceeds in liquid securities until needed to pay the catastrophe claims (at either date 1 or date 2). For a variety of reasons, however, the instruments are an inefficient means for providing the liquidity.

The high cost of liquidity. Liquidity obtained by issuing ex ante securities creates an unnecessary "inventory cost", measured by the rate spread between the company's cost of capital and the lower rate it earns on its liquid assets. A rate spread occurs because the cost of capital reflects the average riskiness of the firm (including the default risk of any debt), even though the cash proceeds are actually invested in liquid assets. An ascending yield curve further raises the rate spread. Furthermore, the inventory cost will be greater the *less* likely is the catastrophe, since the expected waiting time will be longer.

An excessive amount of liquidity. Since, at date 0, the insurance company does not know the exact size of its future loss, the debt or equity issue must equal the maximum possible loss, which may be substantial larger (and commensurately more costly) than the *expected loss*. For the insurance firm, this is analogous to the individual's precautionary saving discussed earlier, raising similar issues of inefficiency. Similarly, since the insurance company does not know the exact date of the future loss, the maturity of a debt issue would exceed the average waiting time until the catastrophe, again raising costs.

Underinvestment problem with ex ante debt. Ex ante debt may create an "underinvestment problem" comparable to the issue in corporate finance; see Myers [1977]. That is, debt holders may worry that, even when the company's expected future profits remain positive after a catastrophe, shareholders might opt to default on the existing debt and to form a new company.

Takeover risk with ex ante equity. Under current U.S. accounting rules for casualty insurance firms, it is not possible to earmark assets to pay only claims on expected future events. As a result, an insurance firm holding liquid assets to pay future claims may become a takeover target, since the acquirer could allow the insurance contracts to mature, and then use the liquid assets for its own purposes; see Jaffee and Russell [1997] for further discussion.

Ex Post Debt and Equity Issues

Given the problems with standard ex ante capital market instruments, a natural strategy would be to wait till the catastrophe occurs, then issue debt or equity on an ex post basis. The debt or equity would then be repaid or redeemed from future net premium income. Ex post instruments eliminate all of the problems just listed for ex ante instruments. However, ex post instruments raise problems of their own.

Moral hazard and adverse selection problems. Following a catastrophe, investors might worry that the insurance firm's financial position is actually worse than they think, thus raising the cost of issuing ex post instruments. [10] Specifically, investors might worry that the actual loss is larger than the amount publicly known, or that the risk of a future catastrophe has risen and that the insurance company is better informed of this change.

Requirement to commit new funds to new business. Lenders may require that the bond proceeds be used to finance the insurance firm's ongoing business, not to pay for past losses. An insurance company that has just suffered a catastrophe loss will find it hard to claim creditably that the proceeds of a new bond issue are not being used to pay off the recent loss. [11]

Forward Commitments

Given these problems with standard ex post capital market instruments, the insurance firm could instead negotiate a commitment at date 0, allowing it to issue debt or equity in the amount necessary to cover the shortfall of liquidity created when the catastrophe actually occurs. The debt or equity will be then be repaid or redeemed from future net premium income. Such a commitment has the potential to combine the better features of ex ante and ex post borrowing. Indeed, the literature on bank loan commitments emphasizes that commitments can deal with a wide range of ex ante and ex post problems that result from principal-agent and asymmetric information; see Snyder (1998), Martin and Santomero (1997), and Berkovitch and Greenbaum (1991) for recent papers and references to this large literature.

[10] Doherty (1997) specifically discusses the costs of post-loss secondary equity issues.

[11] Banks with large loan losses are commonly reorganized into "good" and "bad" banks for this reason. Lloyds of London was also reorganized to separate its new business from disputes regarding past losses.

Forward commitments, in particular, allow non-linear pricing, combining a fixed fee (thought of as the cost of *not* using the commitment) with a cost of funds below the market rate (subsidized by the fixed fee). The lower cost of capital can remove various principal-agent problems that might otherwise arise with ex post borrowing, and since the commitment is taken down after the catastrophe has occurred, the problems of an ex ante bond issue are also avoided.

In fact, so-called "contingent credit facilities" have been created in recent years for such insurance entities as the State Farm Group, the Nationwide Group, and the Hawaii Hurricane Relief Fund; see Best's [1998]. A market in ex ante equity commitments is also beginning to form. These instruments have the drawback, of course, that the commitment writer could fail to perform on the commitment. Actual experience with such instruments will be required before insurance firms will have sufficient confidence in their performance to use them as the basis for taking on substantial new catastrophe risks.

A common feature of all these capital market instrument solutions is that the primary insurer continues to bear the risk of loss. [12] This has led to the search for a financial instrument which not only solves the liquidity problem, but also the risk transfer problem. Catastrophe bonds and related instrument offer an innovative solution to this problem. We turn now to examine the key features of this instrument.

Catastrophe Bonds, Protected Liquidity, and Risk Transfers

The various catastrophe bonds issued so far differ in their details with respect to forgiveness of interest and principal. Some of these features reflect the need to sell these bonds to different sectors of the financial market, and other features are designed to influence the

[12] Of course, some shifting of the risk of loss would occur as a consequence of moral hazard and adverse selection, although this is not what the contracts are designed to achieve.

bond's rating, see Lane [1998]. Abstracting from these details, a stylized catastrophe bond would have the following features. Upon its issue at date 0, the proceeds are placed in secure short-term assets to be liquidated at the time of the catastrophe. Interest is paid on the bond until a catastrophe occurs, at which time interest payments cease and the principal is forgiven. In other words, a catastrophe bond is a junk bond, but one in which the "default" is triggered by a specific and anticipated event; see Briys [1996].

The catastrophe bond instrument has a number of desirable features:

1) *It solves the liquidity problem.* The insurance company now has sufficient liquid capital with which to meet claims whenever they occur.

2) *It solves the takeover problem.* The catastrophe bond requires that the liquid reserves it creates be used only to pay catastrophe claims, so the firm can hold large liquid reserves without fear of takeover.

3) *It solves the problem of taxation***.** If an insurance company were to set aside premium income in a reserve fund, the income would be fully taxable. Insurance companies are currently lobbying to allow this reserve to be tax-free (as it is in various state catastrophe funds such as the California Earthquake Authority). Taxation is not an issue with catastrophe bonds, however, since the interest paid on the bonds is an allowable business expense and it exceeds the income earned on the collateral fund of liquid assets.

4) *In solves the problem of transferring risk***.** A catastrophe bond transfers the risk of catastrophe loss to the bond investor. Since the bond is part of the investor's diversified portfolio of investment assets, it should be priced with little or no risk premium. The catastrophe bond is attractive because it permits *diversification across all financial assets*, not just across other insurance risks. With catastrophe bond pricing based on expected claims, insurance

premiums can be set at expected value, and the consumer obtains the same insurance and liquidity benefits on a catastrophe risk that are now received on standard casualty risks such as auto and fire.

The fact that the catastrophe bond solves so many problems in one package suggests that as investors gain familiarity with its features, it could support the revival of a private catastrophe insurance industry. Whether the bonds are issued by primary insurers or reinsurers depends on who has the lower costs of accessing the capital market. This is not a fundamental issue for the catastrophe insurance industry as a whole, although it is important to the investment bankers who organize the issuance of these bonds..

Catastrophe Option Instruments

Despite the many advantages catastrophe bonds have, one major drawback is that they create a high cost of liquidity and require an excessive amount of liquidity on average, for exactly the same reasons we discussed earlier with regard to ex ante issues of standard debt and equity. These problems can be eliminated, however, by using catastrophe options, which are analogous to the forward commitments discussed earlier. There are two functioning versions of catastrophe options.

The CBOT Option Contracts [13]

The Chicago Board of Trade has been trading option contracts where the payoff is triggered by the amount of industry losses related to a specific catastrophic event. Although the contracts have been designed for hedging catastrophe risks, they have not been used in large amounts by the insurance industry. A significant reason for the lackluster trading is related to

[13] See Jaffee and Russell [1997] for a more complete description of these contracts.

the need for guarantees to ensure performance by the option writer. With standard common stock options, most of the performance risk is removed by mark to market margin requirements. Mark to market margins, however, are not effective for catastrophe options, since price changes occur as a jump process following an event, rather than as the smooth diffusion process normally associated with stock options. As a result, the CBOT has designed the contracts themselves in a way to limit the loss that could be associated with a contract. On the other side, this necessarily limits the use of the contracts to hedge catastrophe risk.

Lloyds of London as a Put Option

The risk hedging facility provided by Lloyds of London, at least prior to its recent reorganization, is best interpreted as a catastrophe put option. That is, a Lloyds syndicate obtains the financial resources to pay large claims by putting its losses to its Names, these Names being liable up to the level of their total wealth. In many ways, Lloyds represented the epitome of a catastrophe hedging mechanism: the financial resources to pay claims were kept in productive use by the Names until they were required, while performance was guaranteed by reputation and by the unlimited liability of the Names; see Cutler and Zeckhauser [1997] for further discussion.

Unfortunately, after centuries of success, the Lloyds system broke down, and has now been replaced with one of limited liability. One conjecture is that the Lloyds system broke down due to a principal-agent problem between the Names and the Syndicate organizers who allocated specific risks to specific Names. However, more study is needed to determine whether the problems at Lloyds reflect fundamental difficulties with a put arrangement or more special problems associated with adverse selection among syndicates.

5. <u>Catastrophe Bonds and Reinsurance Companies</u>

We next consider the issue whether catastrophe bonds and reinsurance companies will act as complements or substitutes in a revived catastrophe insurance market. There is a *prima facie* case of substitution, since primary insurance companies can (and already have) issued their own catastrophe bonds, thus reducing or eliminating their demand for reinsurance services. Reinsurance companies, however, have also issued catastrophe bonds, using the proceeds to finance their traditional reinsurance business. This suggests that catastrophe bonds are complementary to the reinsurance business, and that the reinsurers can remain as intermediaries, linking the primary insurers with the financial markets.

The need for reinsurance companies to serve this intermediary function depends on issues of basis risk in the use of catastrophe bonds. In principle, the trigger that releases the resources of a catastrophe bond to pay claims can be defined by (i) the losses suffered by a specific primary insurer, or by more aggregated variables such as (ii) an event itself (such as a California earthquake of magnitude 7.0 or higher), or (iii) the size of the industry losses attributed to an event. Investors will particularly disfavor catastrophe bonds with company-level loss triggers, since issues of moral hazard and adverse selection suggest that access to the catastrophe bonds may cause the insurance companies to adopt lower underwriting and/or claim settlement standards. At the same time, a primary insurance company will prefer a catastrophe bond with a company-level loss trigger, since more aggregated triggers create a basis risk between the company's insurance risk and the bond's payoff.

In this setting, a reinsurance company may provide intermediary services by issuing catastrophe bonds with aggregate triggers (thus satisfying financial market investors), while selling reinsurance contracts to primary insurers based on company-level risks. The reinsurance company should bear little risk on net, as long as it synchronizes its reinsurance contract risk with the triggers on its catastrophe bonds. It is noteworthy that this type of intermediation is quite similar to that initially carried out by the Federal National Mortgage Association (FNMA), when it acquired individual mortgages and funded them through mortgage backed bonds.[14]

6. Conclusion

We have shown that in order to manage temporally dependent risks such as those created by catastrophes, insurance companies require access to general capital markets. Annual premiums are simply not sufficient to meet a heavy loss in the early part of a company's life.

The recent failure of the private catastrophe insurance industry in the U.S. can be explained by a failure of traditional capital market instruments to provide sufficient capital at an acceptable price. In this paper, we have examined the role of new capital market instruments designed specially to meet the needs of the catastrophe insurance industry. We have shown that catastrophe bonds and, more particularly, catastrophe options not only solve the problem of diversifying intertemporally dependent risks, they also solve the liquidity problem by arranging protected tax free liquidity on demand. These instruments thus offer hope that a private insurance company which financed itself in this way could offer catastrophe insurance at close to fair odds.

However, we do not expect the revitalization process to be instantaneous. The recent crisis in this industry has led to the creation of many state-run catastrophe schemes in the US. Many large insurers have committed themselves to these schemes, and this will slow down the speed of innovation. For those insurers not now committed to state schemes, however, the profit potential in catastrophe insurance hedged with these new instruments may be just what is needed to bring this industry back to life

[14] In more recent times, FNMA has sold its mortgages directly to investors through mortgage passthrough

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securities. The same transformation could occur eventually in the catastrophe bond market as well.

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