Financial Markets and Financial Intermediaries: The Case of Catastrophe Insurance *

by

Prof. Dwight M. Jaffee
Haas School of Business
University of California
Berkeley CA 94920-1900
email: jaffee@haas.berkeley.edu

and

Prof. Thomas Russell
Leavey School of Business
Santa Clara University
Santa Clara, CA 95053
email: trussell@scu.edu

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 correlated at a point in time and discusses the role of capital markets in that framework. Traditional capital market instruments (debt, equity, and contingent loans) are shown to be imperfect in meeting 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.

Revised version as of January 15, 1999
Paper prepared for the NBER Insurance Conference, February 12 and 13, 1999.

* The authors would like to thank Howard Kunreuther for valuable comments on an earlier version of this paper.

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 generally find it optimal to join a syndicate with other farmers whose barns are also at risk.

When risk sharing is analyzed in an atemporal setting, questions of insurance financing do not arise. Premiums are assumed to be collected and losses paid simultaneously. 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".

In this intertemporal setting, problems of finance come to the fore. Insurance companies must pay claims in a timely manner, but they cannot always know in advance when these claims will be made. Insurance companies therefore share some important features with banks, which also must meet liquidity claims on demand.[1]

In the banking literature, the problems imposed by stochastic liquidity demands are the subject of an extensive literature starting with Diamond and Dybvig [1983] and now including Allen and Gale [1997], Allen and Santomero [1997], Diamond [1997], and others. A central

[1] Indeed large unexpected losses (such as those which follow a catastrophe) have much the same financial implications for insurance companies as bank runs have for banks.

question in this literature is why a financial intermediary such as a bank exists at all, given that financial markets allow the direct securitization of claims. The extension of these ideas to the insurance industry would seem likely to provide a number of insights into the current financial problems of this industry, but with the exception of Harrington, Mann, and Niehaus [1995] and Harrington [1997], the insurance literature has shown little interest in problems of how to finance claims which arise at an uncertain date.

In this paper, we examine insurance markets from an intertemporal viewpoint. It is clear that, just as with loans, insurance can be provided either through financial intermediaries (e.g. insurance and reinsurance companies) or by the direct use of financial markets. 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? [2] In particular will these instruments allow the revival of private markets for catastrophe insurance?

We turn now to an examination of insurance from an intertemporal perspective.

[2] 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.

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 ($0 \le t \le 1$) or in the interval ($1 < t \le 2$).[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 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.[5] The instantaneous utility function $U(C_i)$ is assumed to have the form

---

[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.

[5] For intertemporal decision problems with risky alternatives, it is frequently pointed out that the axioms of expected utility may overly constrain behavior: one parameter, the elasticity of the marginal utility of income, serves both as a measure of willingness to smooth intertemporally and as a measure of willingness to take risks.

A richer foundation for risky choice over time would provide separate parameters for each of these behavioral characteristics as in Epstein and Zin [1989], see also Dyer and Sarin [1982]. However, this approach will not be adopted here because the questions which we wish to examine in this paper go to the role of insurance markets in intertemporal choice when financial markets are fully operational. On these questions, it seems reasonable to

$U(\ ) = \log(\ )$ 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):

---

assume that the basic qualitative features of this discussion will not be affected one way or the other by the expected utility maximization assumption.

(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

Maximizing the expected utility function (1b) subject to the budget constraints (2a) and (2b) leads to the following solution:

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

since expected marginal utility must be equated across time periods. From this condition and recognizing the convexity of the derivative of the log function, it is easy to prove that the agent will optimally choose a level of initial consumption C_0 so that $C_0 < .5C_i^S + .5C_i^L \quad i = 1,2$. In other words, C_0 is less than the expected annual future consumption.[6] In contrast, the solution of this model in the case of certainty yields a flat path for consumption:

(4) $$C_0 = C_1 = C_2 \text{, with } C_1^S = C_2^S \text{ and } C_1^L = C_2^L .$$

Discussion

Compared to the case of certainty (4), the solution in (3) results in consumption values planned at date 0 for C_1 and C_2 that (a) are uncertain and (b) will generally not equal the value chosen for C_0. The difference between C_0 and expected future consumption is known in the

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

savings literature as precautionary savings; see Kimball [1990].[7] Precautionary saving transfers resources from current to future consumption, to guard against the uncertainty of future consumption.[8] This can be interpreted as a cost of self insurance, and we will now show this cost can be reduced if market insurance can be purchased at fair odds.

3. Insurance with Uncorrelated Risks

We next consider the utility gains that are available to our farmer when insurance contracts are available along with loan markets. We assume there is a large number of farmers N 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.

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 in the case of certainty, except that the fixed cost of the insurance premium is subtracted from the initial wealth W. It follows that optimizing farmers will choose the flat path for consumption which satisfies their budget constraints.

---

[7] 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].

[8] As shown in the footnote (6), 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 consumption when using the insurance contract represents an 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:

(1) 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.

(2) 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.[9] The value of this service depends on the curvature of the marginal utility function.

It seems likely that some form of insurance collective would 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

[9] Recall that precautionary saving can be either positive or negative, as developed in footnote (6).

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. Campbell 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.

Financing Issues with Uncorrelated Risk

When risks are uncorrelated there are no difficulties in financing claims. The law of large numbers guarantees that the level of claims in any period is known in advance. In this model, exactly half the barns burn down in each period, so even if each farmer pays a premium in each period equal to the expected per capita loss in that period, the insurance collective has sufficient funds in each period to meet all claims. More generally, as long as the claims are predictable in this sense, an insurance collective has no need of external funds, and can easily be organized as a mutual.

For a small farmer, an insurance arrangement is the natural vehicle for risk transfer. For completeness, however, and to motivate our further discussion, we note that there is an alternative financial arrangement for risk transfer. The farmer could turn the farm into a publicly traded corporation, using the equity markets to transfer risk. The farmer would expect to raise exactly $W - \left[.5\frac{B}{(1+r)} + .5\frac{B}{(1+r)^2} \right]$ in an initial public offering; that is, the farm value of W minus the expected loss of the barn to fire (with no risk premium because the loss of a barn is uncorrelated with general market risk). This assumes that diversified investors would price this IPO at the risk free (zero beta) interest rate. Since at this level the farmer is indifferent between using a financial institution (the insurance firm) or using the equity markets to optimize utility, the desirability of insurance is a second order matter (the transaction costs of insurance versus the transaction costs of an IPO).

The situation is very different when risks are correlated. We turn now to this case, the natural setting for an analysis of catastrophe insurance.

4. Insurance with Correlated Risks: 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 This requires that it have access to the amount of capital NB even on the first day of business, and this requirement rules out the possibility of arranging insurance through a self financing mutual. As we will now show, however, it does not rule out the possibility of reducing the risk by the use of general financial markets.

Financing Issues with Correlated Risks

As we discussed in the case of uncorrelated risks, a farmer could reduce risk by selling claims to the returns from the farm on an equity market. How would such an stock offering be priced with correlated risks? Remarkably, by standard finance theory, a farmer facing correlated farm losses would expect to raise exactly the same amount from an IPO as in the uncorrelated case: $W - \left[.5\frac{B}{(1+r)} + .5\frac{B}{(1+r)^2} \right]$.

The fact that all of the barns burn down together is irrelevant to the financial market, since it is not the correlation across the returns of farms which determines the price of equity, but rather the correlation between the returns on the farms and the return on the global capital market. If our set of farmers is small relative to the global capital markets, then the returns on all of the farms (and therefore in particular the return of any one of them) is a zero beta asset and the market will value this asset at the same price whether the risk of fire is correlated across farms or not.

Indeed, if, for some reason, the farmers wished to form a joint stock company to manage their risk, this corporation could also raise zero beta capita and could therefore arrange a premium schedule in exactly the same manner as an insurance collective which carried uncorrelated risks. Obviously, it would not be possible in this case of correlated risks to set up a self-financing mutual.

This suggests that equity capital markets solve the problem of financing catastrophe insurance as easily as they solve the problem of financing any other type of risk. In fact. however, equity capital markets appear to have difficulty financing catastrophe risks and we turn now to an examination of the reasons why equity financing is so difficult.

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.

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.

Actions that eliminate the risk transfer problem necessarily eliminate the liquidity problem. This is illustrated when a primary insurance company cedes some of its exposure to a reinsurance firm. Conversely, actions that deal with the liquidity problem do not necessarily solve the risk transfer problem. For example, a company may accumulate liquid assets to meet future expected claims, while continuing to hold the risk itself.

We now consider a variety of possibilities for how the primary insurers can resolve the liquidity and risk transfer problems. We begin with reinsurance, and then turn in the following sections to traditional and new capital market instruments.

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 correlated risks to proceed as it did for independent risks.[10]

[10] As an historical aside, we note that diversification of correlated 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.

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 has at time exceeded 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; see Harrington, Mann, and Niehaus [1995] . Thus, even though some traditional reinsurance remains available 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 capital available 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.

5. 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 to transfer risk outside the firm (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. Following Harrington, Mann, and Niehaus [1995], 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, giving rise to *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?

Ex Ante Debt and Equity Issues

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). Harrington, Mann, and Niehaus [1995] discuss a number of problems with using traditional ex ante debt and equity instruments for financing casualty insurance companies:

1) The insurance firm must raise sufficient capital to cover most, if not all, of its possible policy claims, because policyholders and other stakeholders are likely to be highly averse to the risk of insolvency.
2) Corporate debt financing still leaves the insurance firm subject to the potentially high dead-weight costs of bankruptcy .
3) Equity capital is costly for several reasons, including the double taxation of investment income, the agency costs of monitoring managerial behavior, and the transaction costs of issuing equity .

We expand on this list, with the following points:

4) Ex ante debt and equity are an expensive way for an insurance firm to raise liquidity, because the firm earns only the risk-free (zero-beta) interest rate on its liquid investments while awaiting its claims, but the cost of these funds is likely to reflect the firm's higher (positive beta) cost of capital. In other words, there is no apparent way for the insurance firm to separate its demand for liquidity from its demand for general business capital using traditional debt and equity instruments. Furthermore, the impact of the high liquidity costs is greater the less likely is the catastrophe, since the expected waiting time will be longer.
5) The insurance firm must issue an amount of ex ante debt or equity equal to its maximum possible loss, even though this may be substantially 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 have to exceed the average waiting time until the catastrophe, again raising costs, especially if the yield curve is ascending.

6) 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.

7) 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. Harrington, Mann, and Niehaus [1995] discuss two key problems with using ex post debt and equity instruments for financing casualty insurance firms:

1) There is a potential time inconsistency problem, in that the insurer may renege on its earlier promise to issue ex post equity, in view of its high cost. This reflects the more general problem that new capital providers are always reluctant to finance past losses, and that 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]

2) New equity investors may worry about asymmetric information following large catastrophic events. For example, the investors may worry that the actual loss is larger than the amount publicly known, or that the insurance company is better informed of changes in the risk of future catastrophes.

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.

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

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

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.

The Reluctance of Shareholders to Bear The Risk of Catastrophic Loss

A common feature of all these capital market instrument solutions is that the shareholders of insurance firms continue to bear the risk of loss.[12] It has become increasingly clear, however, that the owners of insurance companies simply have no desire to bear the risk of catastrophe loss, and this has led to a search for financial instruments which remove the risk of this loss from the insurance companies' books. Since catastrophe risk is a zero beta asset, the reluctance of the equity holders in insurance firms to hold this asset is a puzzle. Moreover, understanding this puzzle is crucial if the market is to design financial instruments which make the holding of catastrophe risk palatable.

The equity aversion puzzle is just one aspect of the original Mayers/Smith problem of why widely held corporations buy insurance in the first place, see Mayers and Smith [1982] and

[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.

[1990]; see also Doherty and Smith [1993]. An equity holder in an insurance firm, be it a primary insurer or a reinsurer, is in the same position as a diversified equity holder in any corporation. That is, if these shareholders are concerned about the risk of catastrophic loss, say because a reinsurance firm has a large exposure to California earthquake loss, they can diversify this risk by holding the market portfolio. As Mayers and Smith note, however, equity diversification does not seem to provide a full solution to the problem of risk transfer within a corporation. Particularly when risks are large enough to threaten bankruptcy, it may be value enhancing for equity holders in a publicly traded firm to have the firm purchase insurance. Mayers and Smith give a number of reasons for this, but for our purposes three reasons are particularly apposite:

1) The purchase of insurance will avoid bankruptcy and thereby avoid the consequent conflict of interest and other costs associated with bankruptcy, see Myers [1977].
2) There may be tax advantages to the purchase of insurance.
3) Agency costs may cause the firm's managers whose human capital is not diversified to purchase insurance even when the value of equity is reduced.

Mayers and Smith develop these arguments within the context of a non-insurance firm's decision to purchase insurance, but it is clear that the risk of catastrophe loss raises exactly the same questions about the role of equity in an insurance company itself, as has been noted by Harrington, Mann, and Niehaus [1995]. Since a catastrophe can threaten the financial solvency of even a large insurance or reinsurance firm, the equity holders in such a firm have good reason to avoid bankruptcy costs by moving catastrophe risk elsewhere.

In the above papers, the limitations of equity finance are discussed under the assumption that the owners of the firm are well diversified. If, as seems to be the case, equity holders are often not well diversified, additional and quite different explanations can be given for the reluctance of equity holders to carry certain risks. Efficient market theory notwithstanding, it seems that many investors take non-diversified positions in a company because they believe that the stock will yield superior risk adjusted returns. This belief may be based on superior information, superior ability to process information, or it may simply be an error.

Whatever the basis for investors' belief that they can pick stocks, it must be clear to them that there are some events which could prove them wrong. Some of these events are outside the control of the management of the firm, and for that reason we call these risks external risks. Catastrophes such as earthquakes and hurricanes, movements in exchange rates, and movements in interest rates for example, all affect corporate earnings in a way that has nothing to do with the risks of running a business in the normal way. On the other side, there are also normal business risks, which we call internal risks.

We argue that whereas undiversified investors are willing to hold internal risks, they want no part of external risks since they do not believe they have any skills in pricing them. To take an example, an investor in Intel may know a great deal about the computer chip industry and the competitive position of Intel, but this investor may know nothing about Intel's exposure to earthquake risk and is therefore not prepared to bear that risk at promised equity rates of return. This shareholder will look for ways to remove external risk and we argue that this is precisely what the new instruments are trying to achieve. These non-diversification issues appear to be especially relevant to the question of how to design new instruments to facilitate the holding of catastrophe risk.

6. <u>New Capital Market Instruments and Catastrophe Risk</u>

The new capital market instruments include Catastrophe (or Act of God) bonds and insurance options and derivatives traded on the Chicago Board of Trade. These instruments have the key feature that they allow an insurance company, whether a primary insurer or reinsurer, to transfer its risk directly to capital market investors. We also discuss the traditional Lloyds of London insurance facility in this category, because its key feature was a put option issued by the so-called "names", which allowed unexpectedly large claims to be paid directly by the names. We begin by looking at catastrophe bonds.

Catastrophe Bonds

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 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].

Catastrophe bonds directly solve the liquidity problem by providing the firm with a pool of liquid assets that can be accessed whenever the catastrophe occurs. Catastrophe bonds have some particular advantages over traditional debt and equity instruments:

1) Because the liquid assets are restricted for use only to meet catastrophe claims, catastrophe bonds eliminate the takeover problem of ex ante debt and equity instruments. For the same reason, catastrophe bonds minimize the agency problems that may otherwise arise for firms that are holding large pools of unused liquid assets.
2) Catastrophe bonds receive desirable tax treatment since the interest paid on the bonds is an allowable business expense that would generally exceed the interest income earned on the collateralized fund of liquid assets.
3) Since catastrophe bonds guarantee that funds are available to pay claims, they eliminate the insolvency and bankruptcy costs that are associated with other forms of debt instruments.

Catastrophe bonds also solve the problem of risk transfer, because they move the risk of catastrophe loss to the bond investor. For a catastrophe bond to be priced with little or no risk premium, it must be held in a diversified portfolio of investment assets.[13] 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

[13] Unlike the equity holders in insurance firms, this suggests that the investors in catastrophe bonds would be highly diversified institutional investors such as pension funds.

catastrophe insurance industry as a whole, although it is important to the investment bankers who organize the issuance of these bonds.

The CBOT Option Contracts [14]

Despite the many advantages catastrophe bonds have, one major drawback is that they retain 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 the financial market equivalent of the forward commitments discussed earlier.

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. It seems that a significant reason for the lackluster trading is related to 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.[15]

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

[15] Harrington, Mann, and Niehaus [1995] are more optimistic than we are concerning the ability of mark to market margin and the capital resources of the exchange itself to provide meaningful performance guarantees on catastrophe options. Harrington [1997] notes that basis risk may limit the usefulness of these instruments for hedging purposes.

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.

7. Catastrophe Bonds and Reinsurance Companies

We finally 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 can be 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 critically 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, by (ii) an event itself (such as a California earthquake of magnitude 7.0 or higher), or by (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 and contains the moral hazard and adverse selection that might otherwise occur.[16] It is noteworthy that this type of intermediation is quite similar to that

[16] Harrington [1997] also raises the possibility that reinsurers could issue wrap-around products that would eliminate the basis risk that otherwise arises when primary insurers use catastrophe bonds or CBOT options for risk transfer.

initially carried out by the Federal National Mortgage Association (FNMA), when it acquired individual mortgages and funded them through mortgage backed bonds.[17]

8. Conclusion

We have shown that in order to manage correlated 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

[17] In more recent times, FNMA has sold its mortgages directly to investors through mortgage passthrough securities. The same transformation could occur eventually in the catastrophe bond market as well.

References

Allen, Franklin and Douglas Gale [1997], "Financial Markets, Intermediaries and Intertemporal Smoothing," Journal of Political Economy, 105 (3), 523-546.

Allen, Franklin and Anthony Santomero [1997], The Theory of Financial Intermediation," Journal of Banking and Finance, 21, 1461-1486.

Berkovitch, Elazar and Stuart Greenbaum, "The Loan Commitment as an Optimal Financing Contract,"" Journal of Financial and Quantitative Analysis, Vol 26, No 183-95.

Best's Review [1998], "Investing in Risk Gets Real," April 1998, 35-39.

Briys, Eric [1996], "From Genoa to Kobe: Natural Hazards, Insurance Risks and the Pricing of Insurance-Linked Bonds," unpublished paper, November 1996.

Campbell J.Y. and Mankiw G. [1991] "The Response of Income to Consumption", European Economic Review, Vol. 35 715-721.

Cutler, David and Richard Zeckhauser [1997], "Reinsurance for Catastrophes and Cataclysms", NBER Working Paper 5913.

Diamond, D.W. and P.H. Dybvig, [1983] "Bank Runs, Deposit Insurance, and Liquidity" Journal of Political Economy, Vol. 91, 401-419.

Diamond, D.W. [1997], "Liquidity, Banks, and Markets," Journal of Political Economy, Vol., 105, No. 5, 928-955.

Dionne, G. and L. Eeckhoudt [1984] "Insurance and Saving: Some Further Results" Insurance: Mathematics and Economics, Vol. 3 101-110.

Doherty, Neil [1997], "Innovations in Managing Catastrophe Risk," The Journal of Risk and Insurance, Vol 64, No. 4, 713-718.,

Doherty, Neil and Clifford Smith, [1993], "Corporate Insurance Strategy: The Case of British Petroleum," Journal of Applied Corporate Finance, Vol. 6, No. 3, pp. 4-15 .

Dyer and Rakesh Sarin, [1982], "Relative Risk Aversion", Management Science, 28 875- 886.

Eeckhoudt, L and M. Kimball [1991l "Background Risk, Prudence, and the Demand for Insurance" in G. Dionne ed. Contributions to Insurance Economics, 239-255, Kluwer Boston

Epstein, Larry and Stanley Zin, 1989 Substitution, Risk Aversion, and the Temporal Behavior of Consumption Growth and Asset Returns 1: A Theoretical Framework, Econometrica, 57 pp 937-969.

Froot, Kenneth [1997], "The Limited Financing of Catastrophe Risk: An Overview," NBER Working Paper no. 6025, May 1997; forthcoming in K. Froot, ed., The Financing of Catastrophe Risk, University of Chicago Press.

Froot, Kenneth and Paul O'Connell [1997], “"The Pricing of US Catastrophe Reinsurance," with P. O'Connell, NBER Working Paper no. 6043, May 1997; forthcoming in K. Froot, ed., The Financing of Catastrophe Risk, University of Chicago Press, 1998.

Harrington, Scott, Steven Mann, and Greg Niehaus [1995], “Insure Capital Structure Decisions and the Viability of Insurance Derivatives, The Journal of Risk and Insurance, Vol. 62, No. 3, 483-508.

Harrington, Scott [1997], “Insurance Derivatives, Tax Policy, and the Future of the Insurance Industry, The Journal of Risk and Insurance, Vol. 64, No. 4, 719-725.

J. Hirshleifer, [1966] "Investment Decisions Under Uncertainty: Applications of the State Preference Approach," Quarterly Journal of Economics, 80, 252-277.

Kimball, Miles, [1990], “Precautionary Saving in the Small and in the Large, Econometrica, 58, 53-73.

Lane, M.N. [1998] " Price, Risk, and Ratings for Insurance-Linked Notes" Presentation Draft. Sedgwick Lane Financial

Leland, H.E. [1968] "Saving and Uncertainty: The Precautionary Demand for Saving", Quarterly Journal of Economics, Vol. 82 465-473.

Martin, J. Spencer and Anthony Santomero [1997], “Investment Opportunities and Corporate Demand for Lines of Credit”, Journal of Banking and Finance, 21, 1331-1350.

Mayers, David and Clifford Smith [1982], “On the Corporate Demand for Insurance”, Journal of Business, 55: 281-296.

Mayers, David and Clifford Smith [1990], “On the Corporate Demand for Insurance: Evidence form the Reinsurance Market, Journal of Business, 63: 19-40.

Moffet, D. [1977] "Optimal Deductible and Consumption Theory" The Journal of Risk and Insurance, Vol 44, 669-683.

Myers, Stewart [1977] " The Determinants of Corporate Borrowing", Journal of Financial Economics", Vol. 5 147-175.

Myers, Stewart and N. Majluf [1984], “Corporate Financing and Investment Decisions When Firms Have Information that Investors Do Not, *Journal of Financial Economics*, 13: 187-221.

Sandmo, A., [1970] "The Effect of Uncertainty on Saving Decisions", Review of Economic Studies, Vol.37 353-360

Smith, Clifford and Rene Stulz [1985], "The Determinants of Firm's Hedging Policies, Journal of Financial and Quantitative Analysis, 20: 291-406.

Snyder, Christopher [1998], "Loan Commitments and the Debt Overhang Problem", Journal of Financial and Quantitative Analysis, Vol 33, No 1, 87-116.

Thaler, R [1991], Quasi Rational Economics, Russell Sage Foundation New York