

FINANCIAL INNOVATION IN THE MANAGEMENT OF CATASTROPHE RISK¹

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1. INTRODUCTION

Catastrophic events such as hurricane and earthquakes are the dominant source of risk for many property casualty insurers. Primary insurers usually limit the scale and geographic scope of their operations in order to focus on core competencies such as marketing, underwriting and loss control. But his often leaves them without sufficient geographic spread to diversify catastrophe risk.

The traditional hedge for the primary insurer is reinsurance. Specialist reinsurers achieve a spacial spread of risk and can therefore bear catastrophe risk that is undiversifiable to the primary. But the transaction costs associated with reinsurance, and therefore premiums, are high. High premiums, coupled with the fact that catastrophe losses exhibit little correlation with capital market indices, has attracted considerable activity in Wall Street in searching for new instruments that securitize catastrophe risk. Indeed many players are now talking of catastrophe risk being a new “asset class” and new instruments such as catastrophe options and catastrophe bonds are starting to appear.

The rationale for these new instruments is usually developed as follows. Recent catastrophe events such as Hurricane Andrew and the Northridge earthquake have imposed costs on the insurance industry of an order of magnitude not thought possible only a decade ago. More sophisticated modeling now presents potential losses to the industry of \$50 billion or more. Examples would be Andrew hitting Miami, a major quake on the New Madrid Fault and a repeat of the 1906 San Francisco earthquake. These events could wipe out 25% or more of the entire industry’s net worth which currently is in the order of \$200 billion. Two such events, or one such event combined with continued mass tort claims (e.g. successful plaintiff claims in tobacco litigation) could cripple the whole industry. However, losses of this size would hardly cause a ripple in capital markets. The U.S. capital market currently consists of securities representing some \$13 trillion of investor wealth and the loss scenarios cited above amount to less than one standard deviation of daily trading volume.

Presentations by merchant bankers, reinsurance brokers and others have echoed this potential for diversifying catastrophe risk within the capital market. The high transactions costs of reinsurance offers potential for hedging instruments to be offered to primary insurers that are both competitive with current reinsurance and which offer investors high rates of return. Moreover, since catastrophe risk is uncorrelated with market indices, the benchmark for such investments is just the risk free rate.

Pricing new instruments requires that the expected loss be estimated with some. Until recently, insurers and reinsurers had a comparative advantage in information on catastrophic events. But in the past decade a number of modeling firms have developed models that combine seismic and meteorological information with data on the construction, siting, and value of individual buildings. These models can be used to simulate the economic effects of many thousands of storms and earthquakes. Although such models are used by the insurance firms and reinsurers, mainly for loss estimation and re-balancing their exposure, the same models are now available to other companies and investors.

The arrival of the modelers and their models is eroding the comparative information advantage of insurers and reinsurers and opening the door to new players. Insurers will retain their comparative advantage over, say, merchant banks in related insurance services such as marketing, underwriting and loss settlement facilities. But the stage has been set for an unbundling of insurance products with insurers retaining marketing underwriting and settlement services and risk bearing by-passing the reinsurance industry and being provided more directly from the capital market.

But the combination of high transaction costs for reinsurance and the vast capacity of the capital market for diversification, is not sufficient to ensure the success of these new instruments. The costs associated with reinsurance do not necessarily reflect monopoly rent. Relationships between primary insurers and reinsurers involve moral hazard; the relationship relaxes the incentive for the insurer to underwrite carefully or to settle claims efficiently. Consequently, the reinsurer will monitor the primary. Moreover, long term relationships are often formed to counter such expropriation. The apparently high transaction costs of reinsurance may simply reflect the resolution of moral hazard. If new instruments such as catastrophe options and bonds are to compete successfully with reinsurance, they must be able resolve incentive conflicts between the primary insurer and the ultimate risk bearer. Indeed, if moral hazard is not resolved, using past insurance loss data to estimate the potential returns for purchasers of catastrophe bonds, etc, is spurious.

The purpose of this paper is to examine and categorize new catastrophe hedging instruments. These instruments will then be compared with traditional risk management strategies adopted by primary insurers in order to compare their relative efficiency at resolving incentive conflicts. Each instrument offers a different combination of credit risk, basis risk and moral hazard. For example, catastrophe reinsurance is subject to significant credit risk and moral hazard, but does not encounter significant basis risk. I will argue that the differential performance of the traditional and new instruments offers primary insurers with a richer portfolio of risk management strategies, though no strategy is dominant in its performance on all three criteria.

II. FOUR PRINCIPLE STRATEGIES

To organize discussion, the generic strategies available to an insurer to manage catastrophe risk are classified as asset hedges, liability hedges, post-loss financing and leverage management.

Asset Hedge

An “asset hedge” can be defined as an asset which provides a hedge against the risk in some other asset. A portfolio comprising the basic asset and the hedging asset has little or no risk. The asset hedge can be represented in a portfolio F in which an amount \$ is invested in two assets. The first basic asset has a payoff of A_B for each dollar invested. The second asset, the hedging asset, has a per dollar payoff of A_H . The capital \$ is allocated over the two assets in the ratio {1:h} and the correlation coefficient ρ_{BH} is negative (in the limit approaching negative unity).

$$(1) \quad \text{ASSET HEDGE } F = \$(A_B + hA_H) \quad \text{where } 0 > \rho_{BH} \geq -1$$

If $\rho_{BH} = -1$, then some hedge ratio h^* can be chosen such that the portfolio is riskless; i.e. $\text{COV}\{\$(A_B + h^*A_H)\} = 0$. A reinsurance policy is a traditional form of asset hedge for the insurer. A newer instrument is the catastrophe option which is an option written on the value of an index of insurance company claims and yields a payoff when the index triggers a pre-set value (the striking price).

Liability Hedge

A hedge can be achieved on the opposite side of the balance sheet. Instead of the hedging asset, the portfolio includes a liability L_H as follows.

$$(2) \quad \text{LIABILITY HEDGE } F = \$(A_B - hL_H) \quad \text{where } 0 < \rho_{BH} \leq 1$$

If $B_H = 1$, then some hedge ratio h^* can be chosen such that the portfolio is riskless; i.e. $COV\{(A_B - h^*L_H)\} = 0$. Many of the newer risk management strategies are indeed liability hedges.

Post-loss Equity Re-Capitalization

The reasons for managing corporate risk include the avoidance of bankruptcy costs and the protection of the firm's continuing ability to pay for sudden losses and to finance investment opportunities. One way to address these concerns is to re-capitalize the firm after a loss. The gain is that the firm receives an injection of funds when it is most needed without an increase in leverage. Moreover, an insurer may be unable to pay for cat losses from current liquid assets, despite having substantial illiquid assets, especially the franchise value of future operations. Re-capitalization is a tool to release these illiquid assets and permits the firm to continue operating and preserve its franchise value. I will examine two strategies. The first is simple post-loss equity financing. A feature of this strategy is that the price at which new equity can be issued is reduced by the loss. A second strategy is for the insurer to purchase a put option on its own stock that can be exercised after a catastrophe of defined magnitude.

Leverage Management

Leverage management can be used to address *ex post* costs of financial distress, the agency costs that arise from leverage and prospective insolvency and the crowding out of new investments. Leverage management may simply involve reduction of the level of leverage. This reduces the agency cost between creditors and residual claimants and reduces the expected value of bankruptcy costs. Moreover, if a sudden loss arises, the firm will find itself in a stronger position to approach capital markets for new funding (either to reconstruct destroyed assets or to fund new investment projects). Alternatively, dividend policy may be used to enhance the ability of the firm to fund future projects from internal funds and reduce the probability that projects will be lost for lack of access to low cost capital.

In applying the above structure to the management of catastrophe loss, I will not discuss leverage management for insurers in any detail. This lack of attention does not reflect its lack of importance as a risk management strategy. Quite the reverse. The use of surplus management and reinsurance to reduce leverage and thereby reduce the probability of ruin, is the subject of an extensive actuarial literature. The newer innovations in insurer risk management have concentrated on new types of hedges, such as cat bonds and futures and this is where I will focus.

II. CATASTROPHE RISK: INSURANCE, REINSURANCE & FINANCIAL INNOVATION

(i). Reinsurance: Credit Risk, Basis Risk and Moral Hazard

Simple diversification will not always remove risk from a primary insurer's liability portfolio. For example, liability insurance is subject to significant correlation, since changes in liability rules can simultaneously affect all policies in an insurer's portfolio. Catastrophe insurance is subject to even more apparent correlation. Thus, the law of large numbers cannot be relied upon to remove relative risk. Reinsurance is the traditional hedging instrument available to primary insurers. However, its use does involve significant transaction cost which are now discussed.

Credit Risk

Catastrophe hedging instruments face design choices that trade off various inefficiencies against each other. Reinsurance can be used to illustrate these trade offs. First, there is credit risk; the risk that the reinsurer will be unable to pay its obligation to the ceding firm. The recent \$17 billion Andrew losses and the \$12 billion Northridge losses revealed some chinks in the insurance industry's armor and estimates of a repeat of the 1906 San Francisco earthquake have forecast widespread insolvencies amongst primary firms.

Such insolvencies would be transmitted to reinsurers. Indeed, the defaults could be disproportionately large in the reinsurance industry.

A common way in which a ceding firm can off-load risk to a reinsurer is with a “stop loss” (i.e., the contract contains a deductible with the reinsurer paying only the excess above the deductible). Payoffs from such plans only occur when losses penetrate the right tail of the loss distribution. For such payoffs, the coefficient of variation is very high and consequently large catastrophes would probably cause widespread insolvencies. Initial estimations of potential industry payouts for large catastrophes (Cummins and Doherty 1996) support this conclusion with the number of insolvencies rising disproportionately with the size of the catastrophic loss.

Basis Risk

While credit risk is present with reinsurance, basis risk is resolved. Reinsurance payoffs are geared to losses sustained by the primary insurer. Contracts usually cover the primary firm’s portfolio losses on designated lines of business (treaty reinsurance), or specific primary policies (facultative reinsurance). Moreover, policies share risk between primary insurer and reinsurer according to linear or non-linear formulae. Thus, while the primary firm will retain some risk, there is no mismatch between the asset on which the reinsurance payoff is defined and the asset to be hedged; there is no basis risk.

It is possible to imagine a “reinsurance” contract with basis risk. If an insurer purchased a reinsurance contract with a payoff structured on industry losses, rather than on the primary firm’s own losses, there would be basis risk. The extent of basis risk would then depend on the correlation between industry and firm losses; the lower the correlation, the higher the basis risk. The discussion of basis risk is important since it forms an important design element in structuring new hedges and it can be used to mitigate another inefficiency, moral hazard.

Moral Hazard

Moral hazard is the flip side of basis risk. Moral hazard arises with all insurance policies. With reinsurance contracts, moral hazard can take two generic forms; *ex ante* or *ex post* moral hazard. *Ex ante* moral hazard arises when, due to reinsurance protection, the primary insurer fails to take actions to reduce future losses or takes actions that increase losses. This occurs because the reinsurer cannot monitor the primary continuously and condition the reinsurance contract on the primary’s behavior. Thus, the primary firm may be lax in its underwriting procedures, pay inadequate attention to spread of risk and fail to provide adequate risk audits for potential new policies. Naturally, the reinsurer will anticipate this behavior and some level of monitoring will take place. But monitoring is costly and the combination of the costs of monitoring and the excess losses suffered due to inadequate underwriting provides a measure of the costs of moral hazard. These costs are substantial.² These direct costs take the form of commissions and premium loading. In addition, many reinsurance relationships are implicitly long term and implicitly experience rated, to compensate for costly monitoring. These temporal relationships constrain the parties and contribute to the costs of moral hazard. It may be noticed that moral hazard arises from the quality of the hedge; i.e., from the absence of basis risk. Consequently, the structuring of a catastrophe hedge, provides the opportunity for trading off these two features.

²Industry sources frequently put the transaction cost of reinsurance at 20% of premiums or higher. Evidence of catastrophe reinsurance contracts presented by Froot and O’Connell suggests that over the past decade, the ratio of price minus expected losses to expected losses, has been in the order of sixty to seventy percent and can be much higher on high level coverages.

Ex post moral hazard arises when the loss settlement practices of the insurer are relaxed due to the presence of reinsurance. This is a particular problem for catastrophic losses. The loss settlement capacity of any insurer (and of the industry) is geared to its normal loss frequency. When an event such as hurricane Andrew arises, primary firms simply do not have the capacity to inspect and negotiate claims settlements thoroughly. Thus, it becomes more difficult to prevent the “build up” of claims (policyholders including uninsured damage in the claim or exaggerating the size of the loss) or outright fraud on the part of policyholders. However, the incentive for the primary insurer to control its claims will be relaxed if it has reinsurance protection. The primary may be able to avoid the abnormal transaction costs of settling claims, and even buy some goodwill with its policyholders by making generous settlements with policyholders and passing the costs of excess settlements to its reinsurer. Also, insurers are often pressured by regulators to be prompt and generous in settling losses in a highly publicized catastrophe. When protected by reinsurance, the primary insurer can achieve regulatory goodwill and pass the cost to the reinsurers.

Of course, there are constraints on this type of behavior. For moderate losses, the primary firm may well consider its reputation in the reinsurance market before engaging in such opportunistic behavior. Primary insurers will seek future reinsurance protection and a history of moral hazard will hardly stand them in good stead. For severe catastrophes, normal constraints on insurer moral hazard will be dulled. When insurers are facing financial stress, their reputation in returning to reinsurance markets in the future, is unlikely to be so constraining.

Insurance moral hazard is an example of a principal agent problem and there is a standard solution that relates compensation to output. In the insurance case, the solution is well known; *the optimal reinsurance premium R is a non decreasing function of the revealed loss L .*³ The optimal design of the reinsurance contract is one with retrospective premiums and long term contracts. Casual observation of the reinsurance market suggests that it follows the model. While I am not aware of formal tests, long term relationships are normal in this market and it is common practice for poor claims experience against the reinsurer to be recovered in future premiums. This practice has been formalized over recent years with the introduction of finite reinsurance. By defining a fixed period, and limiting indemnity in relation to accumulated premiums, the reinsurance contract begins to look more like a debt instrument. But whether formally, or informally, setting reinsurance premiums to actual loss experience increases the degree of risk retained by the primary insurer; this additional retention being part of the cost of addressing the moral hazard.

Reinsurers also can address moral hazard by increasing the resources devoted to monitoring the behavior of the ceding firms and conditioning the reinsurance coverage on this behavior. If reinsurers can monitor at low cost, then it will be more efficient to do so than to impose risk on the primary through *ex post* rating. In practice, one would expect the costs of moral hazard would be incurred partly in monitoring cost, partly in imposing risk on the primary through *ex post* rating and, to the extent that these did not completely eliminate expropriatory behavior, partly through increased claims.

(ii). Alternative Risk Management Strategies For the Primary Insurer

(ii)a. Asset Hedges:

Catastrophe Options

³ See Kreps chapter 16 and Lambert for a presentation of this problem (not in a reinsurance setting) and for the necessary assumptions.

New catastrophe instruments are often explained in terms of the need to provide direct access to capital markets to supplement the limited capacity of reinsurance markets. Noting that catastrophe risk is not highly correlated with capital market returns, the required rate of return to attract capital is the risk free rate. Current rates on line for reinsurance are sufficiently high to be able to beat the risk free rate. But this explanation is incomplete. If attractive investment opportunities are available to investors from shorting catastrophe risk, why is there not an influx of capital into reinsurance firms? It seems that high rates on line support the high transaction costs associated with reinsurance rather than excess returns to reinsurance shareholders. Thus, if new instruments are to compete successfully with reinsurance and to be attractive to investors, they must be designed to lower transaction costs. Moreover, since the dominant transaction costs is that due to moral hazard (excess losses, the additional costs of monitoring, and locking parties into long term relationships), then successful securitization of catastrophe risk, requires more effective ways of dealing with moral hazard. As we shall see, one of the main defining features of cat options, and some other new instruments, is their introduction of basis risk as a method of addressing moral hazard. Also important is the ability of new instruments to address credit risk.

Catastrophe options are traded on the Chicago Board of Trade. The basic structure of these contracts is similar to other options and, except for the difference in basis risk, resembles stop loss reinsurance. The CBOT contracts are defined on various industry (mostly quarterly) indices of property liability losses. The indices are defined by region within the U.S. There is a national index, regional indices (Western, Midwestern, Southeastern, Northeastern and Eastern) and state indices (California, Florida and Texas). When index losses exceed the striking price, the contract pays the difference between the index value and the striking price. The basic instrument can be used to derive many trading strategies (spreads, strips, etc.) in much the same fashion as stock options.⁴

The size of the basis risk will vary. First, the insurer's own losses will contribute to the index, but for many insurers this will be modest. Second, to the extent that the primary has a portfolio similar to that of the other insurers comprising the index, the basis risk will be small. Indeed one would expect the hedging demand for CBOT options to be strongest for insurers with representative portfolios.

The major benefit of defining the option on the index, is that it controls moral hazard. The primary insurer that is able to practice *ex ante* or *ex post* mitigation, will receive much of the benefit of that activity in the form of reduced claims. However, this benefit will not be offset by a reduction in the payoff to the option, except to the limited extent that the primary's reduced losses affects the index. The idea can be illustrated by a simple example. Suppose that an insurer has a portfolio that represents 5% of the market covered by the index and correspondingly wishes to buy a call option that pays 0.05 times the payoff on the amount by which industry losses exceed the exercise price. If the index is the sum of industry losses, then spending of " a_i " on mitigation by insurer " i " will reduce the insurer's losses and the index by L_i . Since the primary is hedging only five percent of changes in the index, the primary's payoff on its call position will be reduced only at the rate 0.05 times L_i .⁵ In contrast, spending on mitigation reduces the primary's own claims obligations to its policyholders at the full rate L_i . Thus, mitigation yields a large marginal net benefit to the primary (0.95 times L_i).

⁴Other hedging strategies can be derived. One that offers some continuity with traditional reinsurance strategies is to buy a spread. This involves holding a call option with one striking price and selling another call with a higher striking price. The effect is to obtain a layer of hedge protection between a range of index losses. Apart from the fact that the loss is defined on the index, this arrangement is similar to layered reinsurance arrangements.

⁵The same concepts can be described in the appropriate terminology. CBOT options are denominated in payment of \$200 for every \$100 million change in the index. Each \$100 million in the index is referred to as a "point" Thus, the primary wishing to hedge for a 5% of the amount by which the index exceeded a chosen striking price, would purchase 25,000 units. Thus, if the strike price was 400 and the index was 450, the payoff on this position would be (450-400) times (200) times 25,000 = \$250 million. Notice that \$250 million is exactly 5% of the amount by which industry losses (\$45 billion) exceed the strike price (\$40 billion).

Catastrophe options face similar credit risk to reinsurance. Many financial instruments use “mark to market” to address credit risk. When the instrument is written on an underlying asset whose price evolves as a smooth process, “mark to market” offers considerable credit protection. This device prevents the build up of large liabilities. However, the temporal path of catastrophe insurance liabilities is anything but smooth. With storms, the lead time is, at most a few days. With earthquakes, the liability can change from zero to billions of dollars in one second. “Mark to market” is of little use. Sellers of catastrophe bonds are required to maintain a margin account. However, this device offers only limited protection unless the account is maintained at a level equal to (or close to) the maximum possible loss. Thus, catastrophe options impose some credit risk. The CBOT options offer a second line of defense. The CBOT maintains a security fund. However, the scale of this fund is fairly insignificant compared with the multi billion dollar liabilities that are plausible with these instruments. This is not to say that the credit risk is severe, only that it is potentially severe. The degree of credit risk depends on the spread of liability amongst investors who take short positions in these instruments. The point is that the structural design of this, and other asset hedges, introduces credit risk. As we shall see below, the structural design of the liability hedges avoids this problem.

(ii)b Liability hedges

Catastrophe Bonds

Debt forgiveness instruments go by several names; insurance linked bonds, Act of God bonds, catastrophe bonds and (anciently) bottomry. The idea is very old, dating to the medieval origins of insurance in Italy. A primitive arrangement was for merchants to fund ventures by borrowing to pay for the ship and/or cargo. However, in the event of the loss of ship or cargo, the debt would be forgiven; lenders were “insuring” the vessel and its cargo. The idea has recently re-appeared. Recently, bond issues have been announced by insurers, that have forgiveness provisions in the event of catastrophic losses; the consideration being a higher interest rate. The generic design can allow for interest and/or principal forgiveness which can be total, partial or scaled to the size of the loss. Moreover, the forgiveness can be triggered either by catastrophic losses to the issuing firm, or to catastrophic losses measured on some composite index of insurer losses.

The analysis of moral hazard is similar to that for asset hedges and depends on whether there is basis risk or not. If the cat bond is forgiven on the basis of the primary’s own catastrophic losses. The moral hazard is similar to that under reinsurance. Controlling losses simply increases the amount of debt that must be repaid. Now if the cat bond is forgiven on the basis of some industry index of catastrophe losses, the moral hazard is similar to that for the catastrophe option. The primary spending on mitigation will only reduce the debt forgiveness to the extent of its share of the index. Thus, the primary contracting for forgiveness at the rate of 5% of the index (i.e., \$5 of debt is forgiven for every \$100 increase in industry losses) will reap a net benefit from mitigation equal to 95% of the reduction in its direct claims.

This analysis shows that cat bonds can be designed to achieve different balances between basis risk and moral hazard. Given freedom to select indices, the primary may be able to identify some industry portfolio with similar exposure to its own. If it can, the basis risk from writing the cat bond on this index will be small, and the moral hazard problem will be largely mitigated. If the primary’s portfolio is not represented well by a convenient industry loss index, then the hedging properties of an index based cat bond will be poor, even though moral hazard is addressed. In such circumstances, a cat bond based on the primary’s own losses may be preferable with other controls (e.g. monitoring or coinsurance) used to address the moral hazard.

Cat bonds avoid the credit risk to the issuer, that is found with reinsurance or catastrophe options. Bondholders provide the hedge to the insurer by forgiving existing debt. Thus, the value of the hedge is independent of the bondholders’ assets and the issuing primary insurer has no risk of non-delivery on the hedge. In essence, the cat bond is similar to a reinsurance contract in which the reinsurer opens a margin account equal to

the maximum expected loss. Moreover, the primary insurer has access to the margin account. This avoids possible default to the primary.⁶

A variation on the theme of debt forgiveness is the conversion of the debt into another asset, notably equity. This idea is to embody a conversion option in the debt, but the option is exercised by the issuer, not the bondholder. This can be called “reverse convertible debt” (RCD). A pure form for RCD permits the issuer to convert at a fixed ratio of shares for bonds. When the share price falls, the option will be “in the money”. This instrument provides a partial hedge against a fall in share price and it does not matter whether the cause was a catastrophic loss or a fall in the value of the primary’s asset portfolio. Doherty (1995) has shown that this instrument can be potentially useful for non insurance firms since it can be used to resolve incentive conflicts between stakeholders and it avoids the transaction costs of bankruptcy. Indeed the resolution of these problems can be so effective that RCD has greater value than regular debt (i.e., the conversion option can have negative value). A more limited version of RCD for primary insurers could embody an event trigger; the conversion option can be exercised in the event of a defined catastrophe which could be based on firm losses or an index.

The value created for the primary on conversion is the difference between the outstanding debt and the value of the equity used to redeem that obligation. Investors holding such bonds could well find them attractive despite their short position in the embedded option, since the conversion option carries more favorable incentives than the implicit default put in non-convertible debt. RCD may also be attractive to policyholders. I will note below the analogy between debt and the primary’s policy liabilities. Drawing on this analogy, scaling the payout of policyholder claims to the size of a catastrophe, is equivalent to a mutual insurance in which scaling is achieved by policyholder dividends. There are strong theoretical and practical reasons why mutualization of catastrophe risk is an efficient form of risk sharing and there is a pressing case for considering contract design as part of a risk management program.

Policy Conditions and Mutualization.

Perhaps the most direct way in which the insurer can hedge its catastrophe risk is to require that the policyholder bear some of this risk. To explore this further, it is useful to take a small detour into the economics of insurance. With catastrophe risk, the law of large numbers is violated since losses are highly correlated. Thus, the insurer cannot rely simply on many policies to diversify its risk away. Moreover, if risk is costly to the insurer (why otherwise would we be discussing hedging strategies?), then the insurer would be forced to charge a risk premium and the optimal amount of insurance would be less than full coverage. It is important to understand that “optimal” reflects the interests of insurer and insured. The risk premium reflects the cost of risk bearing and this is a real social cost. The insured is better off having less insurance (and avoiding part of the risk premium) than being fully insured and facing the full risk premium. In short, the insured is trading off expected wealth against risk.

Now this reasoning can be refined in several ways following the seminal work of Karl Borch (1962). Where risk cannot be fully diversified, the optimal insurance arrangement from all policyholders’ perspectives, is one in which all are full insured for idiosyncratic (read diversifiable) risk, but in which each shares in the social loss. This is tantamount to a mutual insurance arrangement; each policyholder is insured for catastrophe risk, but the proportion of insurance depends on the size of the catastrophe. In practice, this can be accomplished by a mutual which pays everyone’s claim, but which reduces its dividend to all policyholders (or assesses them) by an amount related to total losses.⁷

⁶ The risk to the bondholder is of interest. Had the primary issued a non forgiveness bond, it would have been subject to default risk. However, one of the most likely causes for default on such an issue would be that the primary insurer suffered catastrophic losses. What the cat bond does, is to turn the default risk (i.e. the implicit default put) into an explicit embedded option.

⁷To argue that mutualization of this sort is “optimal” is often misunderstood. Policyholders would certainly be better off if they could fully insure at no risk premium. But this is not an option in a competitive market since

The second way in which this reasoning can be refined is to address moral hazard between the policyholder and the primary insurer. This is closely related to the moral hazard occurring at the interface between the primary insurer and the reinsurer. For example, the *ex post* moral hazard that can arise between the primary insurer and reinsurer, stems from the lack of appropriate actions by the primary to prevent policyholders from “building up” claims or filing fraudulent claims. In short, the moral hazard that arises between primary and reinsurer is largely a “pass through” of the moral hazard between the policyholder and the primary. Policyholder moral hazard can be addressed by requiring that the policyholder share the loss, normally through the use of a deductible or policy limit (see Shavell 1979 and Stiglitz 1983). This idea has been extended by Smith and Stultzer (1994) who have shown that sharing risk through dividends also helps control moral hazard.

(ii)c. Post-loss equity financing

Post-loss Equity Issues

Another approach to insurer risk management is post-loss financing. This may or may not, involve a hedging arrangement. When an insurer sustains abnormally large losses, its internal capital is depleted and its ability to fund new investment projects is compromised. The most prominent “project” is for the firm to continue to operate into the future and to reap future profits. Refer to the present value of future earnings as the “franchise value” and consider a firm that suffers very large losses but still has a significant franchise value. The firm can still have a positive equity value, but the franchise component of that value is illiquid. If losses exhaust available funds, the insurer may be unable to continue to operate and lose the value of its franchise. The problem is that the franchise value is not liquid, and cannot be used to pay for current losses. Post-loss equity financing provides a method for releasing the franchise value or, more generally, for releasing illiquid assets.

Absent transaction costs, post-loss financing should always enable a firm to pay its losses as long as the value of the franchise and post-loss surplus is positive.⁸ However, the issue of new equity can lead to severe dilution, ceding much control to new shareholders and leaving existing shareholders with little value after a severe loss. Nevertheless, post-loss re-capitalization can be a rational strategy for a firm with high franchise value.

Post-loss equity capitalization also can be useful following less traumatic losses. A more modest liquidity crisis can arise without severe financial distress. With large losses and an asset portfolio predominantly illiquid, the insurer will be forced to a “fire sale” or to other forms of control such as delaying claims payments to policyholders. The former results in a direct asset loss, the latter may compromise reputation and future profitability. If the *ex ante* advantages of holding a relatively illiquid

investors would require that the insurer cover any cost of bearing undiversified risk. Thus the real choice for policyholders is (a) to have a policy with a large risk loading which would induce policyholders to accept a large deductible or coinsurance or (b) to accept a policy which covers idiosyncratic risk but which requires the policyholder to contribute in proportion to total losses. The argument here is that option (b) is better for policyholders than option (a). Notice that this argument is identical to the reasoning of the capital asset pricing model. In that model it is shown that the optimal investment strategy is for risk averse investors to hold a diversified portfolio (i.e., the market portfolio) such that each shares in the total market risk but each diversifies away idiosyncratic risk.

⁸See Doherty 1997 for proof.

portfolio are substantial, then post-loss equity financing provides a method of avoiding the potential liquidity crunch.⁹

Catastrophe equity puts (CE Puts)

The discussion of post-loss financing sets the stage for CE puts. One version of this type of instrument, known as a CatEPut, was designed by Aon, have recently been used by Centre Re in a pair of transactions with insurers. The cateput is a post-loss equity financing arrangement, but with price of the equity issue fixed before the loss. This is a put option contract which gives the option to the insurer to sell a given number of shares to the counter-party (e.g., a reinsurer) after a defined loss and at a fixed price. The second innovation, is that there is a another trigger; the insurer's losses must lie between pre-determined upper and lower bounds (this can be called the *exercise window*) before the capitalization option can be exercised.

It is easily deduced that exercise will only be chosen if the post-loss share price is below the striking price. This possibility for gain to the insurer on exercise makes this instrument a hedge. Strictly, the hedge is not against losses per se, but against a fall in the insurer's share price. The value created for the insurer stems partly from the fact that post-loss capitalization secures the franchise value and partly from the efficiency gains associated with reductions in corporate risk.

The market value of the post-loss equity sold to the counter-party will be less than its purchase price under the put option if the option is in the money. Consequently, the put option will command a initial price which, following normal option technology, will depend upon the parameters of the underlying equity distribution (which depend on insurer leverage, loss distribution, investment distribution, etc) the exercise price, the current equity price, maturity and the risk free rate. Since the option is written on the underlying stock, its pricing would appear to be fairly conventional. However, there is the unusual twist introduced by the second trigger. The option can only be exercised if the catastrophe losses to the insurer lies between a lower and upper bound; which can be called the *exercise window*. The exercise window is important, particularly the upper boundary. One would expect a close negative relationship between the insurer's cat losses and its post-loss share price. For small losses, there is little need for re-capitalization and there is little likelihood that the share price would fall below a pre-arranged striking price. Thus, the lower trigger is not very interesting and the potential exercise could be controlled simply by choice of a sufficiently low exercise price. However, if cat losses are very high, the share price will fall sufficiently that the share value will fall well below the exercise price and the insurers payoff from exercise will be substantial. The upper loss boundary therefore becomes a method of limiting the risk to the counter-party and this will be reflected in a lower price for the option.

Figure 1 and 2 illustrate CE puts and the effects of the exercise window. The put option will assume positive value when either of two triggers kick in; either the loss is of sufficient size or the share price falls below the exercise price. Considering also that losses translate into lower share prices, the loss boundaries can be represented on the horizontal axis and are shown as B_L for the lower boundary and B^U as the upper boundary. In Figure 1, the lower boundary, B_L is set sufficiently low that it does not bind and is somewhat redundant since it is above the exercise price x . In Figure 2, the lower bound on losses is set sufficiently high that it kicks in only after share prices will have fallen to below the exercise price. Thus, when the exercise price is triggered, the option is

⁹This analysis assumes that insurer equity value falls following a catastrophe loss. This assumption can be set against some recent evidence. Insurer stock prices showed a *positive* response to the 17th October 1989 Loma Prieta earthquake (Shelor, Anderson and Cross 1992; and Aiuppa, Carney and Krueger, 1993). This has been interpreted as capturing the potential for price increases in a regulated market. However, Hurricane Andrew, a much larger loss for the industry, seems to have induced significant negative price effects (Lamb 1995). Insofar as positive price responses do occur, then post-loss equity re-capitalization can occur with relatively little stock dilution.

not available because of the loss trigger. Only when the loss trigger is activated, does the option become payable. The crucial issue in Figure 2 is the discontinuity of the payout, with a big jump when the lower loss bound is activated. This can have dysfunctional incentives as discussed below.

The moral hazard issues surrounding CE Puts are parallel to those for other instruments already discussed. Insofar as contracts offer the insurer indemnification for its own losses, there is a moral hazard cost. When contract payouts are indexed to industry losses, the moral hazard problem is mitigated. With CE Puts, the payout is not indexed and the insurer's behavior in underwriting and settling losses has direct implications for the realized value of losses and therefore for stock price. The purchase of the put relaxes incentives for loss control and, unless the counter-party is able to monitor, losses are likely to increase. However, there is an interesting twist. Consider the lower boundary B_D illustrated in Figures 1 and 2. The first problem is that, if the lower loss bound is high relative to the exercise price, the loss boundary may activate when the put option is already "in the money" as shown in Figure 2. This gives the insurer a discrete incentive to relax control of loss payout for a given catastrophic event, in order to activate the trigger. The threshold dollar of loss payouts that hits B_D can bring an enormous payoff if, as shown in Figure 2, the option can then be exercised well below its exercise price. The payoff is OM in Figure 2. On the upper side the incentive is reversed. If losses on the insurer are just above the upper trigger, B^U then a small reduction in loss payouts will bring a sudden payoff on the option of ON . These boundaries resemble a concept known as a "knock out" option in which a normal option is annihilated if a specified stock price is penetrated before maturity.

While the indemnification feature of the CE Put carries adverse incentives, the "knock out" characteristics of the loss boundaries are downright perverse. The incentive problem arises from limiting the hedge to one of catastrophe risk, but paying according to stock price. Two alternative designs are, first, to design a non specific hedge; i.e. that covers any fall in share price regardless of cause and, second to keep the notion of a catastrophe hedge but remove the more perverse edges. The first approach is to treat the lower boundary as either redundant or carrying perverse incentives and thus to discard it. The upper bound is more problematic since the counter-party might wish to limit its liability. A more friendly structure can be envisioned in which the option is not annihilated when losses penetrate the barrier, but rather the payout is capped at a level B in Figure 2. Allowing for the discard of both loss bounds, the payoff structure is shown in Figure 1 as $NPxQ$. This payout structure can be replicated by a portfolio comprising a long put with exercise price x ; a short put with exercise price B^U ; and a short position in a bond valued at N .¹⁰

The second approach is to retain the notion of a catastrophe trigger but to avoid the payout discontinuities. This can be achieved by having a "floating" exercise price equal to the share price immediately before the defined catastrophe that triggers payout. The upper discontinuity can be avoided by simply capping the payout rather than terminating it entirely when the upper threshold is exceeded.

IV. INDEMNITY versus INDICES versus INSTRUMENTS

Perhaps the most important innovation that has emerged from the flurry of recent activity is that indemnity contracts may not be optimal for managing catastrophe risk. The catastrophe puts are non indemnity contracts that address post-loss capital needs directly rather than providing a direct hedge against the ceding insurer's cat losses. The CBOT options, and the proposed Bermuda Exchange options both seek liquidity and control of moral hazard by using industry, or sub industry, indices. Moreover, at least some of the catastrophe bonds have been indexed. The gain from indexing, as discussed above, is that it ameliorates the moral hazard problem. I will finish by discussing further some of the design options that can be used and how some recent visible transactions fair against these choices.

¹⁰This portfolio also suggests a pricing scheme since each component can be priced separately.

The basic idea in using a non indemnity contract is to define the contract payoff in relation to some instrument variable that is correlated with insurer losses but over which the insurer has little or no control. In choosing such an index there is a further trade off between liquidity (which favors standardization) and moral hazard. Industry indices have the advantage of standardization but, since they include the hedging firm, there can be residual moral hazard which depends on market share. Another standardized approach is to define an index of a sub set of insurers who are representative but not dominant. There is no potential for manipulation by insurers not included in the index. Non standardized approaches may be preferable for tailored transactions. Two approaches that have some appeal are a model payoff and a tariff. The model payoff can be structures as follows. The independent models, described in the introduction, can be re-run after a given cat event to estimate the claims that event should cause to a given insurer. The insurer buys a hedge based not on actual claims, but on the model's post-loss forecast of the claims that should result given the physical event parameters (hurricane wind-speeds, track, diameter, etc). If other parameters are fixed there should be no *ex post* moral hazard. The final variation is a fixed tariff of contract payoff defined purely as a function of the physical event (e.g. \$x for a force 4 hurricane hitting zip codes a, b, c, etc). The array of possible instruments permits considerable flexibility in trading off basis risk, liquidity and moral hazard.

Several insurers have made limited use of the indexed CBOT catastrophe options though the size of this market is still modest (the size of the private market is unknown). Use of cat bonds is rarer. The most visible example lies in a recent USAA issue \$400 million dollar issue that would be forgiven on the issuer's own loss experience. This strategy does not avoid moral hazard since the issuer's gain from reducing its losses is offset by a reduction in the debt. Thus, like reinsurance provisions are set up to resolve incentive conflicts (auditing of underwriting and claims plus coinsurance). Moral hazard and its mitigation are similar to reinsurance and, in this respect, the issue hardly seems innovative. These features may partly explain the high cost of the issue to USAA. Given USAA's book of business is concentrated at military establishments, the basis risk from an industry index would be large. However, alternatives were available to trade basis risk for moral hazard. For example, a modeled payoff would mitigate moral hazard without necessarily taking on excessive basis risk. Indeed it is not clear that a modeled payoff would involve more basis risk than the coinsured 20%.

An alternative use of cat bonds is exemplified by a recent Swiss Reinsurance issue. Here the idea seems to be that the reinsurer will issue an indexed instrument in order to expand capacity to offer conventional reinsurance. Intermediating the basis risk is known as "transforming". The potential advantage is that reinsurers have an alternative vehicle for accessing capital. But, by expanding conventional reinsurance, moral hazard is not resolved. Undoubtedly, reinsurance will continue to be used for some insurers for whom basis risk will continue to be high and who benefit from monitoring and other services reinsurers can provide. But for other insurers, the real benefit of innovation will come when they accept the use of instruments such as indices and modeled payoffs to redress the high transaction costs in traditional reinsurance hedges.

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