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The Role of Government Contracts in Discretionary Reinsurance Markets for Natural Disasters

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Abstract

A recent surge in natural disaster losses in the United States has created widespread disruptions in the property insurance market and generated calls for federal protection against natural disaster risk. This article examines the market for disaster insurance in the United States and finds that insurance markets are limited in their ability to intertemporally diversify catastrophic risk. In a targeted response, this article proposes a new form of federal reinsurance based on the auctioning of multiple peril catastrophe call spread options that cover industry losses in the range of $25–$50 billion. This article argues that the sale of these catastrophe excess-of-loss contracts utilizes the unique intertemporal diversification capabilities of the federal government to expand the market for natural disaster risk while enhancing the private market equilibrium for insurance.

Introduction

With the recent rise in catastrophic disaster losses and the resulting impact on insurance company financial solvency, the insurance industry is calling for some form of federal assistance in meeting disaster claims. Most of these requests, including previous versions of the industry-sponsored Natural Disaster Protection Act, incorporate some form of all-hazard federal reinsurance program. This article examines the prospective role of federal reinsurance in providing protection for the insurance industry and argues that the lack of federal regulatory authority in the insurance industry; the prevalence of moral hazard, adverse selection, and other opportunities for risk-shifting; and the well-documented inability of the federal gov-

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ernment to set adequate premiums to control for these costs make any traditional federal reinsurance program problematic.

Instead, this article considers the role of federal reinsurance in the context of a risk management system, whereby risks originate at the individual level, are ceded to primary insurers through insurance contracts, and are further spatially diversified through private reinsurance mechanisms. The effectiveness of reinsurance in this risk management system directly impacts the supply of primary insurance for natural disaster risks. Essentially, when reinsurance can more efficiently diversify risks, the ceding of risks to reinsurers reduces the cost of primary insurance. Because of the highly correlated and idiosyncratic nature of natural disaster risks, however, private reinsurance companies have not been able to fully diversify disaster risk in the system. As a result, the existing insurance and reinsurance markets have experienced stress from an "overexposure" to disaster risk. To fully diversify this disaster risk and alleviate this stress requires a mechanism that facilitates greater intertemporal diversification. This article focuses on whether the federal government can help create such a mechanism.

This article also analyzes the conditions necessary for the private reinsurance market for natural disasters to achieve an efficient equilibrium in the presence of a federal reinsurance program. A key feature of risk of loss arising from catastrophic natural disasters is the large uncertainty over the probability of a catastrophic event. Both parties to a reinsurance contract (primary insurer and reinsurer) have imperfect information about this probability. As a result, reinsurers must charge an incremental premium, or risk load, to compensate for this "distribution uncertainty" when writing a "spot" or one-period reinsurance contract. This premium compensates the reinsurer for the probability that, in the event a catastrophe does occur, the *ex ante* estimate was too low.

A more efficient equilibrium can be achieved in the private market when the insurer and reinsurer develop an implicit long-term contract. In an efficient market equilibrium without bankruptcy risk, the reinsurer can price this contract without a "distribution uncertainty" premium, provided that the insurer promises to compensate the reinsurer by paying higher premiums after a disaster has occurred. It may seem that this promise would not be credible, because the insurer would have an incentive to defect from the agreement after a disaster has occurred. The equilibrium is sustainable, however, if all reinsurers can punish a defecting insurance company by refusing to write future reinsurance coverage for that company under the terms of an implicit long-term contract. As long as the net value of reinsurance remains positive, the primary insurance company will continue to purchase reinsurance, making its promise credible.

If the federal government were to offer a *competitive* reinsurance contract, however, it would have an adverse impact on the spot reinsurance market and a devastating impact on the implicit long-term reinsurance market. Instead of punishing defecting companies, a competitive federal reinsurance program would offer coverage to these firms—increasing the benefits of defection and reducing the value of long-term implicit contracts. Therefore, the efficient equilibrium would break down, and all private contracts would have to be priced on a spot basis. If, instead, the federal government offers a *complementary* product (at very high levels of loss) where private reinsurers do not write coverage, the product would enhance the stability of the long-term (and spot) reinsurance equilibrium, and the net value of reinsurance will rise.

Responding to these concerns, this article proposes a form of federal reinsurance that is complementary to existing insurance and reinsurance products and narrowly targeted on diversifying large disaster losses over time, but limits the federal government's exposure to losses.[1] Specifically, the federal government would sell per-occurrence excess-of-loss contracts to private insurers and reinsurers, where both the coverage layer and the fixed payout of the contract are based on insurance industry losses, not company-specific losses. That is, the federal government would be selling earthquake/volcano and hurricane catastrophe call options to the insurance industry to cover catastrophic losses in the range of \$25–\$50 billion. This article argues that this form of limited per-occurrence excess-of-loss contract is a preferred reinsurance mechanism for the federal government because it would expand the capacity and stability of the insurance industry, while capping and fully funding the taxpayers' exposure to the insured event: a catastrophic disaster. Furthermore, this policy is narrowly formulated to take advantage of the unique capabilities of the federal government to diversify intertemporally, to respect the limited abilities of the federal government to monitor state regulated insurance companies (by offering industry-based as opposed to company-specific reinsurance), and to facilitate the private sector in providing efficient coverage whenever feasible (by offering a complementary reinsurance vehicle which does not compete with the private sector).

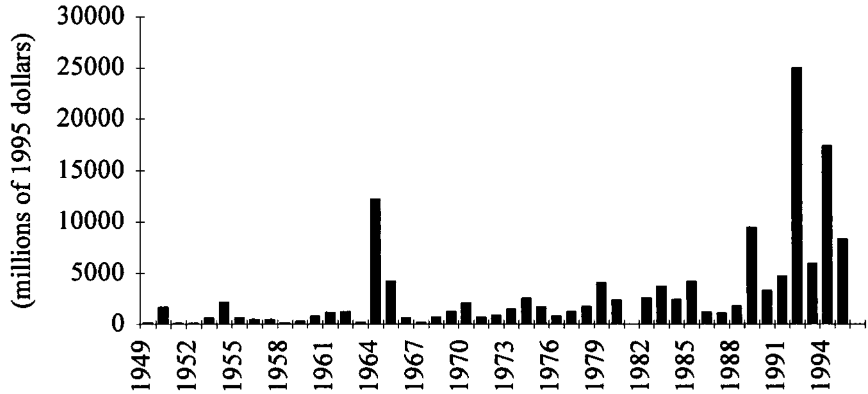
The next section provides a brief overview of the recent disaster experience in the insurance industry. Then, an analysis of two potential mechanisms for managing risks—insurance and securities markets—is considered, and the concept of a risk management system is discussed. We analyze the factors influencing the price of, and demand for, reinsurance protection and outline the mechanisms by which reinsurance expands the capacity and stability of primary insurance markets. The article analyzes the informational problems that private sector companies must address in writing disaster reinsurance and describes how efficient reinsurance contracts are feasible through implicit long-term contracts. We develop a framework for analyzing the role of the federal government in promoting reinsurance coverage. And, finally, we propose a federal reinsurance mechanism based on the provision of disaster call spread options for catastrophic disaster risk, formulate the terms of these contracts, and outline the advantages of this form of federal reinsurance.

[1] The operating assumption in this article is that the establishment of a federal reinsurance program does not include the provision of a taxpayer subsidy, which is viewed as a political decision outside the realm of this analysis.

Background on Recent Disasters

At first glance, the insurance industry's growing interest in a federal disaster insurance program seems surprising given the industry's long history of fighting federal involvement. However, examining the magnitude of insurance industry losses associated with recent natural disasters clarifies the industry's desire for a federal program. Combined, Hurricane Andrew in 1992 ($15.5 billion) and the Northridge earthquake in 1994 ($12.5 billion) resulted in $28 billion in insured industry losses, and caused the failure of nine insurance companies.[2] The magnitude of insurance industry losses associated with these two recent disasters is unprecedented. As shown in Figure 1, the next largest insurance industry loss associated with a natural disaster was the $2 billion in losses associated with Hurricane Hugo. In fact, property inflation adjusted insured disaster losses over the last 10 years totaled almost $75 billion, about one-third more than the cumulative total for the prior 40 years (Property Claims Services, 1995).

Figure 1
Insured Disaster Losses, 1949 Through 1995



Source: Property Claims Services.

More troubling is the possibility that these two events may not represent "outlier" years. Recent research on the frequency and magnitude of hurricanes and earthquakes, as measured by the Saffir-Simpson and Richter scales indicates a strong potential for increased disaster activity over the next 20 years (see Gray, 1990). In addition, given the 69 percent increase in insured coastal property values in the United States since 1988 (to $3.15 trillion), the future losses associated with hurricanes are likely to be more severe than historical experience. Thus, the probability of disasters with losses at least as large as Hurricane Andrew and the Northridge earthquake over the coming years is significant.

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[2] Total disaster costs associated with these two disasters are now estimated at just under $65 billion. Insolvencies are as reported by the Insurance Services Office (1996).

The realization of this increased risk exposure has sent reverberations throughout the insurance markets, especially in Florida and California. Reinsurance companies have raised rates rapidly, in many cases by as much as 150 percent. Following suit, primary insurers have submitted requests for large rate increases to state insurance commissioners. However, most of these rate increases have been pared down by states before being approved, allegedly creating a disconnect between reinsurance rates and primary insurance rates for a given risk.[3] Thus, the recent jump in expected disaster claim severity and frequency and the resulting recognition of the inadequacy of insurance premiums has prompted the industry to look to the federal government for some form of assistance, typically through a reinsurance mechanism.

INSURANCE VERSUS SECURITIES MARKETS IN MANAGING RISK

In a world of perfect information, where there is a full set of state-contingent Arrow-Debreu securities, individuals can diversify the risks in their portfolios by holding (long and short positions in) state-contingent securities that eliminate portfolio risk. In the absence of the Arrow-Debreu world, there are two primary mechanisms for managing risk in the economy—the trading of market-based securities and the provision of insurance. Each of these mechanisms is used extensively in the management of risk.

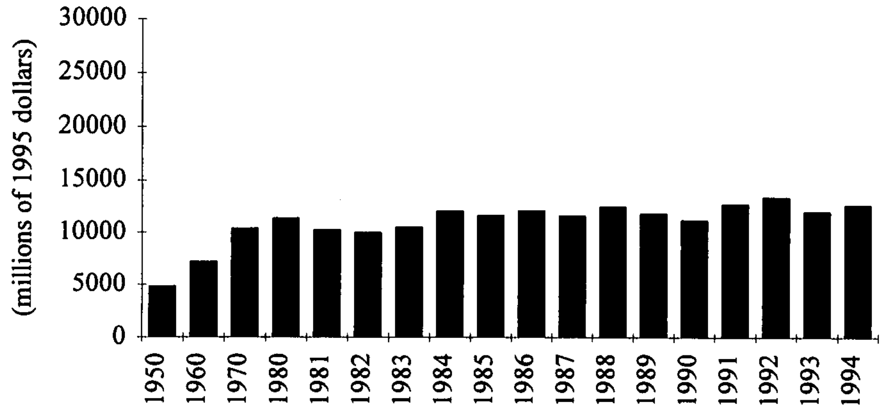
The advantages and disadvantages of using the insurance or securities markets for managing risk relate to the characteristics of the underlying risk. The securities model of managing risk is most appropriate when the critical information necessary to value the risk is public (or at least not asymmetrically distributed) and a market for the trading of the risk exists. Of course, in order for a market to exist for a specific risk, there must be a counterparty willing to take the opposite position in the risk being hedged. For many risks, a natural counterparty exists and the creation of a liquid securities market is feasible. For example, in many commodities markets (e.g., oil) the producers and consumers of the product can diversify the risk of price shocks through transactions in futures contracts. When a natural counterparty does not exist, liquid securities markets can still exist as long as private agents are willing to speculate on the underlying risk, eliminating any price inefficiencies through arbitrage.

The insurance model, on the other hand, is more appropriate for providing protection against a large and undiversified risk of an individual—a risk covered through an insurance contract. The insurance company holding this contract then diversifies this risk by creating a large portfolio of these independent and identically distributed risks, so that (by the law of large numbers) the variance of mean risk in the portfolio becomes small. The effect of this portfolio diversification can be seen by examining the annual losses for fire risks in the United States (see Fig-

[3] Testing the existence of state "rate suppression" or "rate stickiness" with respect to catastrophe loads is outside the scope of this article. However, it should be noted that the existence of state "rate stickiness" can only account for the failure of insurance rates to adjust to higher levels in the post-disaster environment in California, since rates in the state were not pre-approved before 1990.

ure 2). In the insurance model, the insurance company performs an important function—discovering information and appropriately pricing the risk being insured. For many risks covered by insurance contracts, information on the underlying insured risk is not public knowledge. As a result, insurance companies are needed to identify and segment risks into appropriate risk categories. This information-intensive risk evaluation process is accomplished through explicit insurer screening mechanisms, offering a menu of contracts that enable different risk groups to self-select the best available contract given their own private information, and continuous monitoring of the underlying risk.

Figure 2
U.S. Fire Losses, 1950 Through 1994



Source: Insurance Information Institute (1996).

The contrast between these two mechanisms should be apparent. Securities markets require public (or at least symmetric) information and have low transaction costs. Insurance is more costly to provide, but it includes mechanisms to address asymmetric information between the insurer and the insured. Thus, the appropriateness of each market for a specific risk depends on the fundamental tradeoff between the cost of providing the coverage and the extent of information processing required for understanding the underlying risk. Furthermore, while securities can be used to diversify idiosyncratic risks in the market, insurance companies diversify risks through the creation of a pool of like risks.

Unfortunately, in isolation, neither the insurance nor securities model is sufficient for diversifying the risk of loss arising from a large scale natural disaster. In the case of a natural disaster, losses mainly occur in traditional property insurance policies where information on the properties at risk is not generally publicly available and is asymmetrically distributed in favor of the insured (i.e., the property maintenance, the quality of building construction, and the enforcement of building codes). As a result, protection against loss for property traditionally has been provided through insurance products.

The losses associated with a natural disaster, however, are not independent and identically-distributed but are geographically correlated within a risk pool. Furthermore, a comparison of Figures 1 and 2 shows that the losses arising from large natural disasters are also idiosyncratic through time in the aggregate and, hence, not diversifiable through the creation of a large portfolio of like risks. This creates stress on an insurance-based risk management mechanism because, as the size of the event increases beyond some level, the underlying loss characteristics of disaster risk diverge from the characteristics best served by the insurance model. On the other hand, the magnitude of loss that arises from a given event depends in large part on the quality of construction of individual property units—information that is not publicly available and which is asymmetrically distributed in favor of the insured. Thus, disaster risk cannot be solely diversified through the trading of securities.

Therefore, in the context of disaster insurance, a model of a risk management *system* should be considered. Risks are first monitored and priced through the insurance mechanism. The risks are then aggregated and diversified spatially (to the extent feasible) through pooling and reinsurance transactions. Finally, assuming counterparties exist, higher layers of risk are diversified intertemporally through securities transactions. This system retains the advantages of insurance in its information processing capabilities while also utilizing the strengths of securities transactions to diversify idiosyncratic risks.

The shortcoming of this system, however, is that, given the infrequency and magnitude of losses from natural disasters, catastrophe risks need to be diversified intertemporally as well as spatially. For insurance and reinsurance firms, the existence of limited liability and bankruptcy costs prevents them from fully diversifying this type of intertemporal risk. Private securities markets (where private agents also have limited liability) often lack natural counterparties willing to hold this type of risk. Consequently, these markets fail to exist for high levels of disasters. The key question addressed by this article is: Given an apparent lack of natural counterparties for upper levels of disaster losses, can the federal government create an efficient "reinsurance" mechanism to complete the market for these risks without interfering with the private sector insurance system?

PRICE OF REINSURANCE AND DEMAND FOR REINSURANCE

In the framework of the risk-management system introduced in the previous section, the underlying risk originates with an individual property at risk of loss from a natural disaster. This risk is transferred to an insurance company through the purchase of an insurance contract. Since losses from natural disasters are highly correlated geographically and because insurance companies tend to have regional concentrations of risk from these losses, primary insurance companies frequently seek reinsurance to manage their exposure to natural disaster losses.

This section reviews the reasons why reinsurance is of value to primary insurers. Many of these reasons center on the ability of the reinsurance company to bear the risk of loss at a lower cost than that of the primary insurance company. As such, by efficiently transferring risk to the reinsurer, a reinsurance contract reduces the cost of writing primary insurance, ultimately expanding primary insurance capacity.

Price of Reinsurance

In a reinsurance contract, the ceding insurer transfers a portion of its exposure to loss from a particular risk to a reinsurer in exchange for a premium. The reinsurer accepts this risk transfer as long as its premium covers the expected loss of the transferred risk, adjusted for internal expenses and a required rate of return. That is, assuming no ceding commission or brokerage fees, the reinsurer's pricing formula simply can be expressed as follows:

$$\text{Premium} = \frac{f\,(\text{Expected Loss Distribution})}{(1-\text{EL})\ (1-\text{TER})}, \tag{1}$$

where EL represents the reinsurer's internal expense loading as a percent of premium, and TER represents the reinsurer's target economic return (Patrick, 1990).[4] The term f(·) in equation (1) prices the risk of the insured portfolio based on the expected loss distribution. At a minimum, this function incorporates the mean value and variance of the expected claims distribution. However, to more accurately define the probability of events under the tails of the distribution, an insurer also will incorporate higher moments of a parameterized loss distribution. For insuring against catastrophic events, which by definition occur in the tail of the loss distribution, the variance of the loss process and higher moments of the loss distribution become critically important in estimating the insurer's exposure.

Also important for the reinsurer are the errors in the parameterization of the loss distribution utilized. The main estimation errors that any reinsurance contract must address are process risk, parameter risk, and timing risk. Process risk is the risk represented by the use of a specific loss distribution to characterize and project the future losses associated with the covered exposure. Parameter risk is the risk associated with estimating the parameters specifying these loss distributions. Finally, timing risk represents the risk associated with the timing of loss payments (Berger, Cummins, and Tennyson, 1992). These estimation errors are especially significant in the provision of catastrophe insurance, where claim frequency is low; claim severity is high; and estimates are sensitive to changes in new information, experience, and parameterization. Loss severity inflation only adds to this uncertainty risk.

To compensate for estimation errors, however, a reinsurer's targeted economic return includes both a normal return to capital for the reinsurance company and a *risk load* associated with any riskiness in the reinsurance product not captured in the numerator of equation (1), including estimation uncertainty. Because the reinsurance company does not have perfect information about the underlying

[4] Most excess-of-loss coverages do not include a ceding commission, and the existence of a brokerage commission is, of course, dependent on the existence of a reinsurance broker in the transaction.

distribution of events, it must be compensated for the cost of bearing this "distribution uncertainty." In spot markets, where the primary insurer and reinsurer pair up each period and agree to a contract based on price, the reinsurance company must charge a distribution uncertainty premium or risk load on top of the normal reinsurance premium to cover the *ex ante* risk of underestimating future losses. When implicit long-term contracts are feasible, the reinsurance company may reduce (or eliminate) this premium by incorporating a credible *ex post* compensation scheme once *ex ante* estimation errors are realized.

Demand for Reinsurance

At the same time, a reinsurance transaction simply represents an equal transfer of risk and premium from the insurer to the reinsurer. Therefore, the question arises: why do primary insurance companies demand reinsurance? That is, why would a primary insurance company find it advantageous to purchase reinsurance instead of retaining the risk, especially when financial theory tells us that reinsurance is redundant in the conditions of capital market equilibrium for diversified, widely-held firms (Doherty and Tinic, 1981)?

The most obvious explanation is that many small and regional primary insurance companies do not have well-diversified portfolios. For these firms, reinsurance allows the firm to diversify its underlying loss exposure beyond its internal risk pool. Second, many insurance companies (i.e., mutual insurance companies) are not owned by diversified investors capable of diversifying the residual nonsystemic risk inherent in an insurance company's portfolio through positions in their personal investment portfolio (Mayers and Smith, 1990). As a result, reinsurance provides an alternative mechanism for further reducing the nonsystemic risk to shareholders of the insurance firm. Finally, for widely-held, diversified insurers, the redundancy of reinsurance identified by efficient markets theory may disappear once such factors as taxes, bankruptcy costs, regulation, real service advantages, and overinvestment decisions are incorporated. Berger, Cummins, and Tennyson (1992) and Mayers and Smith (1990) discuss the impact of these factors and show that reinsurance can facilitate optimal diversification even for insurance firms with relatively diversified insurance portfolios.

Reduce volatility. Insurers have an incentive to use reinsurance to reduce the volatility in reported earnings. Reinsurance is an effective tool for reducing the variance of an insurer's retained loss distribution from a particular line of insurance. As a result, reinsurance can reduce the reported earnings volatility for insurance companies. Reflecting this relationship, Hoerger, Sloan, and Hassan (1990) and Garven (1990) show a positive relationship between the riskiness of insured lines and the demand for reinsurance. For catastrophe coverage, which is a highly volatile line, reinsurance can be especially beneficial.

Minimize taxes. By reducing income volatility and lowering the value of reported earnings, reinsurance also can enable insurers to minimize taxes (Cummins and Grace, 1994). This incentive is especially strong for companies or product lines with high income volatility and for companies that do not belong to an insurance group where earnings can be redistributed to lower taxes (Mayers and Smith, 1990).

Regulatory constraints. Reinsurance also provides a tool for primary insurers to expand coverage in the face of state regulatory constraints. Since state regulators normally constrain insurer premium writings on the basis of the relationship between net premiums written (net of reinsurance) and equity capital, reinsurance can be used to support an expansion in direct premiums written without requiring additional capital (Doherty and Tinic, 1981). In fact, many insurers use reinsurance to maintain a premium to surplus ratio of less than three. Premium to surplus ratios of greater than three are viewed as undesirable by the National Association of Insurance Commissioners (NAIC) and A. M. Best's Ratings Services.

Underinvestment incentive. Research by Myers (1977), Mayers and Smith (1987, 1990), and Cummins and Danzon (1996) implies that, in certain cases, the purchase of reinsurance could counteract an underinvestment incentive for primary insurers. This factor easily can be related to the context of disaster insurance. If an insurance company experiences an unusually large loss that reduces the value of both equity and the value of outstanding policies, the equityholders of the company may reject offering new (positive net present value) coverage because the benefits would accrue to existing policyholders and not equityholders. If reinsurance had been purchased, however, the loss would have been indemnified and the underinvestment incentive reduced. This "underinvestment" problem may partially explain the reluctance of California insurers to issue new earthquake policies.

Costs of insolvency. Insurance firms must be concerned with the probability of ruin, that a run-up in insurance claims will force the firm into insolvency. Managers will be especially concerned about insolvency risk if they are risk averse and are concerned with the high search costs associated with finding another job if their company fails. Further, the risk of insolvency imposes explicit and implicit costs on the firms (Hoerger, Sloan, and Hassan, 1990). These costs include the increase in a firm's cost of funds as the risk of insolvency increases. Doherty and Tinic (1981) show that, as in other forms of corporate risky debt, there is a positive correlation between the insurer's bond rating and the quality-premium on the insurer's policies. As a firm's rating declines, the price at which it can sell its policies falls, increasing its costs of funds. Other costs are those of regulatory intervention and restructuring. Insurance companies face a risk that state insurance regulators will proactively close weak firms in order to maximize the protection of policy claimants, extracting a cost on equityholders of the firm. Cummins, Harrington, and Niehaus (1994) show that the risk that a company will be seized by the regulator while its net worth is still positive may have been increased by the new risk-based capital system adopted by the NAIC.

Real service advantages. Finally, given its broader risk pool coverage, a reinsurer may have "real-service" efficiencies in the diversification of risk associated with low probability events. In this case, the reinsurer can actually provide the primary insurer with valuable information on pricing and adjusting claims (Mayers and Smith, 1990). In addition, reinsurers may have an information advantage over the capital markets in evaluating the financial status of the primary insurer and, in particular, in evaluating the primary insurer's risk of loss from catastrophic events.

The impact of most of these factors on an insurer's demand for reinsurance can be seen in the simple reinsurance pricing equation model presented above. Real service advantages of reinsurance directly lower the expense loading factors of the ceding insurer. All other factors raise the ceding insurer's required rate of return relative to the reinsurer's required rate of return, making reinsurance more attractive. That is, for an exogenously given (and mutually shared) expected loss distribution, each of these factors creates a cost-of-funds advantage to using reinsurance.

How Reinsurance Increases Primary Insurance Capacity

Through a reinsurance contract, primary insurance companies can share in the cost advantages enjoyed by reinsurers and support a higher volume of direct written premiums for existing levels of capital. That is, reinsurance can be used as a relatively inexpensive substitute for capital. This section examines this link between the availability of reinsurance and primary insurance capacity by examining the market equilibrium in the reinsurance market in terms of the reinsurance premium defined in equation (1).

As noted above, the target economic return for a primary insurer or a reinsurer can be expressed as a function of the return on a riskless asset (RR) and a risk premium (RP). The risk premium represents the excess return required to compensate the insurer/reinsurer for any uncertainty associated with pricing and accepting the risk inherent in the underlying portfolio. This risk premium includes a risk load associated with distribution uncertainty—the risk that the *ex post* realization of losses may exceed *ex ante* estimates. The cost advantages identified above, however, lower the risk premium required by reinsurers for a given risky portfolio relative to the risk premium required by primary insurers. The differential in target economic return (Δ) between primary insurers (p) and reinsurers (r) creates a cost-of-funds advantage for reinsurance.

$$\Delta = f\,(RPp - RPr), \tag{2a}$$

where

$$\Delta = \Delta\,(t, k, hp, reg, s_l). \tag{2b}$$

In equation (2b), t represents the tax advantages of reinsurance, k represents the differential in the cost of capital for primary insurers and reinsurers based largely on default risk, hp is the hurdle rate for new projects (the underinvestment problem), reg is the regulatory advantages of reinsurance, and s_l is the claims volatility associated with the insurer's portfolio. The cost-of-funds advantage for using reinsurance is positively related to each of these factors.

Through this cost-of-funds differential, reinsurance allows a ceding insurer to lessen its budget constraint and extend more coverage for a given primary insurance premium. In fact, Berger, Cummins, and Tennyson (1992) have shown that the amount of coverage provided in the primary insurance market is directly related to the supply of reinsurance available at a given insurance premium. That is, for a given level of primary insurance premiums, reinsurance increases the level of direct written premiums supported by a primary insurer's level of capital. This addresses the reasons why primary insurers demand reinsurance and how reinsurance expands primary insurance capacity.

At the same time, analyzing the reinsurance market equilibrium requires an examination of the available supply of reinsurance for catastrophic levels of risk. As in primary insurance, the supply of reinsurance is an increasing function of the reinsurance premium or, synonymously, an increasing function of the reinsurer's risk premium for this insurance coverage. The demand for reinsurance, *ceteris paribus*, is a decreasing function of the reinsurance premium. The demand for reinsurance, however, is zero if the reinsurance premium is equal to or more than the primary insurance rate plus the transactions costs. Thus, if the current risk premium for reinsurance is too high relative to primary insurance premiums, reinsurance is unavailable for primary insurers at "affordable" rates.

This situation may be indicative of the current market for catastrophic natural disaster risk. The recent rise in disaster losses in Florida and California represented an exogenous (upward) shock to the loss distributions of both primary insurers and reinsurers. Reinsurers were able to translate this adjustment in exposure directly into reinsurance rates. Primary insurance rates, constrained by state regulation, have failed to keep pace—creating a rift between primary and reinsurance rates. State regulation also prevented many primary insurers from exiting the market. In addition, the magnitude of some of the rate increases by reinsurance firms suggests that reinsurers simultaneously increased their targeted economic return for underwriting catastrophe coverage, reflecting the increased uncertainty of reinsurers in pricing reinsurance coverage. The net result may have been that reinsurers set prices well above levels supportable by primary insurance rates.

Obviously, the natural way to shift the reinsurance market equilibrium to provide additional reinsurance for catastrophic coverage is to allow primary insurance rates to rise commensurate with the new expectation of disaster risk—a process that is evolving slowly at the state level. In addition to affecting the demand for reinsurance through primary rate increases, the supply of reinsurance can be expanded by reducing the risk premia, lowering transactions costs, or increasing the real service advantages of catastrophic reinsurance. The question before policy-makers is whether a federal reinsurance program is needed to accomplish this task.

The Private Reinsurance Market Equilibrium

The discussion in the previous section implicitly assumes that all parties to the reinsurance contract have equal access to information about the nature of the risk being insured. Unfortunately, this is not the case. In reality, there exists significant asymmetric and imperfect information that affects the equilibrium character of the reinsurance contract between the primary insurer and the reinsurance company.

This section describes how these issues are addressed through a private market equilibrium utilizing both spot and implicit long-term reinsurance contracts. This analysis is important if one of the objectives in designing a federal reinsurance program is to complement—not disrupt—existing reinsurance markets.

Adverse Selection and Moral Hazard

In a reinsurance contract, the primary insurance company cedes risk to the reinsurance company for a layer, or tranche, of risk. Even if the underlying distribution of risk is known with certainty by both parties (a condition which fails to hold and which will be addressed below), these two parties will have different information about the risk being ceded from the primary insurance company. The primary insurance company should possess superior information about the quality of the risk of the properties it insures in its portfolio. For example, the primary insurance company may know that the *enforcement* of the building codes in the communities it serves are lax, and so the structures it insures could suffer disproportionate damage in the event of a natural disaster. This is the problem of hidden information and it results in adverse selection, whereby a primary insurer holding a portfolio of bad risks is more likely to purchase reinsurance.

Second, the primary insurer can actively alter the distribution of risk in its portfolio such that the risks are concentrated at a microlevel; for example, by insuring a high percentage of properties in individual neighborhoods. This can alter the distribution of losses for the primary insurer and increase the likelihood that a catastrophic event will trigger reinsurance payments. This is the problem of hidden action or moral hazard. Zeckhauser (1996) characterizes this form of moral hazard as "distribution distortion hazard."

While the problems of adverse selection and moral hazard will be present in any reinsurance transaction, they will be most prevalent in spot transactions. If instead the two parties contract with each other over a number of periods, the reinsurer has greater incentives to monitor the portfolio of the primary insurer. Learning will take place. The reinsurer can study the quality of management, investigate the book of business, etc., and over time the extent of information asymmetry will be reduced.

Imperfect Information

Even if the primary insurer and reinsurer share common information (and hence there is no problem of adverse selection or moral hazard), the two parties do not have perfect information about the nature of the risk involved. In particular, the two parties share only imperfect information about the underlying distribution of a catastrophic event taking place (i.e., the probability of a hurricane or earthquake striking a densely populated area). In the absence of an effective ability to commit to long-term contracts, this imperfect information introduces a potentially important cost in the natural disaster reinsurance market—a cost that can be seen in the relative size of the risk loads required for spot catastrophe coverage. This cost creates an advantage for a market equilibrium characterized by long-term relationships between primary insurers and reinsurers, a reinsurance premium structure that adjusts with the arrival of new information on disaster risk, enforceable compensation schemes to correct for *ex ante* mispricing, and the sanctioning of primary insurance companies who drop reinsurance coverage in the aftermath of a disaster.

Spot versus Long-Term Reinsurance Contracts

As discussed above, in a one-period reinsurance contract, the reinsurer bears the risk associated with "distribution uncertainty" in estimating the underlying loss process and charges an additional risk load to compensate for this risk. In most contract periods, no event occurs, relatively little new information is revealed, and the reinsurance contract appears overpriced. But when an event occurs, significant new information is often discovered, with the usual result that this new information exposes errors in the *ex ante* information set. This new information is unknown at the time the contract is written and what will be learned from the new event can only be characterized by a high degree of uncertainty. The *ex ante* price charged for reinsurance must include a component that compensates the reinsurer for this uncertainty over the costs that *will be exposed* when an event occurs. Thus, the price of the reinsurance contract will be greater than if the insurer and reinsurer simply used their best estimates of expected losses.

The Infeasibility of Explicit Long-Term Contracts

Of course, if the primary insurer and reinsurer could write explicit long-term contracts for disaster risk, then the reinsurer could be explicitly compensated for this imperfect information risk by provisions of the contract, and the *ex ante* price would not include a premium for "distribution uncertainty." If a perfect Arrow-Debreu state-contingent contract could be written that explicitly describes how the reinsurer would be compensated for any realization of the distribution uncertainty, *and* the reinsurer had 100 percent probability that the terms of the contract would be fulfilled, then no incremental premium would be required. That is, the value of the contractual compensation scheme would fully offset the need for a reinsurance risk premium.

Thus, explicit contracts face two challenges. The first is how to price the transfer of risk in future periods, after new information has been revealed by an event. The second is how to explicitly determine how to compensate the reinsurer for the revealed cost of "distribution uncertainty" that becomes apparent once the event has occurred.

Unfortunately, there are two additional obstacles hindering the enforceability of explicit long-term contracts—bankruptcy risk and defection risk. Bankruptcy risk arises because the primary insurance company could fail as a result of the event and hence would not honor the terms of the contract. Defection risk in the explicit long-term contract is the legal risk that the primary insurer may be solvent, yet refuse to honor the contract, and that the legal system may not enforce the contract.

In the presence of bankruptcy and legal risk, the *ex ante* reinsurance premium for disaster reinsurance will continue to include a positive risk load for distribution uncertainty. However, the risk load required on an explicit long-term reinsurance contract would be significantly smaller than the risk load on a spot transaction. The significantly lower risk load results from the fact that the explicit long-term contract includes a compensation scheme that provides a collateral offset to the reinsurance risk load. The offset is substantial but not complete because the value of the compensation is now conditional on the survival of the ceding insurer and the enforceability of the contract.

Unfortunately, given the high degree of uncertainty over the information ultimately revealed by a catastrophic event, writing explicit long-term contracts is infeasible. It would be nearly impossible to specify explicitly how the price of future reinsurance contracts should change in response to an event. (For example, after Hurricane Andrew, insurers discovered lax enforcement of building codes in many communities, and, after the Northridge earthquake, the magnitude of structural damage to steel buildings was discovered.) The space of possible information revealed is too large to write explicit contracts for all contingencies (e.g., estimating undiscovered fault lines). Similarly, it would be impossible to explicitly characterize how the reinsurer should be compensated for mispricing based on the inaccurate *ex ante* information used in the period when the event occurred.

The Implicit Long-Term Contract Market Equilibrium

Implicit long-term contracts are much more feasible than writing explicit long-term contracts and are used in the reinsurance industry. In the implicit long-term contract, the primary insurer agrees to transact with the same reinsurer every period into the future. In theory, the reinsurer charges a price for its coverage that reflects all known information at the time, but does not charge an incremental premium to compensate it for "distribution uncertainty." In order for the reinsurer to be willing to offer reinsurance at this lower *ex ante* price, it must be assured that the primary insurer will compensate it *ex post*. The mechanism for how this *ex post* compensation is credible will be discussed shortly.

Because the contract price is determined each period, the two parties are free to incorporate all available information on the loss distribution into the current price of the contract. That is, in the period after a catastrophic event takes place, the information revealed by the event will be known and freely incorporated into the price of the next contract. (This solves the first challenge of writing explicit long-term contracts.) Second, after the event has occurred, its impact on the best estimates of the underlying distribution are known as well, facilitating a more precise calculation of the *ex post* compensation that the primary insurer must pay to the reinsurer for an upward reestimation of the insured risk. For a period of time after the event, the primary insurer will then pay an *ex post* premium. Once the two parties are fully compensated, the price will no longer include any premium associated with "distribution uncertainty" and the reinsurance premium will adjust.

If we compare the implicit contract equilibrium to the spot market, in general, the primary insurance company will receive reinsurance at a lower price because the price does not include a premium for "distribution uncertainty." However, in the aftermath of a disaster, the price will be higher because the primary insurance company must compensate the reinsurer *ex post.* This creates an incentive for the primary insurer to defect during the *ex post* compensation phase by not purchasing reinsurance or by purchasing reinsurance from another company.

In a market equilibrium, however, the primary insurer cannot defect as long as all reinsurance companies in the market punish a defecting primary insurance company by refusing to write reinsurance under the terms of an implicit long-term contract. In all likelihood, a primary insurance company that defects from its original implicit long-term contract also would defect from any subsequent agreement as well. Therefore, the only alternative reinsurance available to the primary insurer would have to be priced on a spot basis, where the primary insurer pays the "distribution uncertainty" premium in the *ex ante* price. This would remain true, not just during the immediate aftermath, but in all periods in the future. As long as the net value of reinsurance (under the terms of the implicit contract) is positive during the compensation phase, the primary insurer will continue to purchase reinsurance, and the implicit long-term contract is credible.

If the reinsurer had perfect assurance that the primary insurer would fulfill its obligation to pay *ex post* compensation, then the *ex ante* price would not need to include any premium to compensate it for "distribution uncertainty" under an implicit long-term reinsurance contract. As in the analysis of explicit long-term contracts, however, implicit long-term contracts are subject to both solvency risk and defection risk. Solvency risk has already been discussed, but it is important to emphasize that defection risk is greater in *implicit* long-term contracts than it would be under *explicit* contracts. With explicit contracts, the reinsurer would have recourse through the legal system to enforce the agreement. Under implicit contracts, it is the primary insurer's incentive compatibility constraint that binds it to the agreement. After a disaster, the primary insurer compares the benefits of paying *ex post* compensation in the short run and then having lower costs of reinsurance in the long run to simply purchasing reinsurance under spot terms in all periods or self-insuring. Thus, the implicit long-term contract will include a premium that compensates the reinsurer for solvency and defection risk. This premium will be less than the premium on a spot reinsurance product but more than the risk load charged under the theoretical explicit long-term reinsurance contract.

Of course, exogenous future events can impact the spot and implicit long-term reinsurance market equilibriums in fundamental ways. For example, entry by a more efficient competitor who specializes in spot transactions will alter the incentives of the primary insurer to make good on the terms of the implicit contract. On the other hand, if a third party were able to offer an otherwise neutral product that reduces the bankruptcy risk in implicit long-term contracts, the advantages of the implicit contract model would be enhanced. Thus, the implementation of any federal program must be carefully scrutinized to avoid creating adverse effects within the market.

POLICY FRAMEWORK FOR EVALUATING ANY FEDERAL REINSURANCE INITIATIVE

The analysis of this article thus far has examined how risk of loss arising from natural disasters can be managed as a part of a risk management system. Risks are ceded from individuals to primary insurance companies and these aggregated risks can be ceded to reinsurance companies to create spatial diversification. Because of the highly correlated nature of natural disaster risk, however, the aggregate risk still retains significant volatility over time. The most effective mechanism to diversify this risk intertemporally is through the purchase of market-based securities, as was discussed above, but at present this market fails to exist due to a lack of natural counterparties. This section develops a framework for analyzing any federal program designed to address this market failure.

The preceding discussion manifests the advantages of creating an "efficient" mechanism for diversifying upper layers of disaster risk intertemporally—where, in this context, an "efficient" mechanism is one that does not distort the existing private market equilibrium by mispricing the risk absorbed through the contract.[5] Given its trivial bankruptcy risk, the federal government is a likely candidate for offering such a mechanism. At the same time, the discussion of the primary insurance and reinsurance markets highlights the intricacies of the existing insurance market equilibrium. Therefore, any proposal to assist the insurance industry's ability to smooth disaster claims over time must complement and not compete with the private insurance and reinsurance sectors. This section establishes a policy framework for judging the relative value of any federal initiative in terms of its ability to (1) narrowly address the missing market for upper layers of disaster insurance, (2) complement and not distort the private insurance-reinsurance equilibrium, and (3) be financially solvent (actuarially-sound) on a risk-adjusted basis.

Addressing the "Market Failure"

In the area of disaster insurance, the existence of high bankruptcy costs prevents private insurance agents from adequately diversifying catastrophic losses intertemporally. At the same time, bankruptcy costs and the existence of asymmetric information with respect to the loss exposure of the underlying properties hinder the development of securities markets in this layer of catastrophe risk. Thus, reinsurance mechanisms for large natural disaster losses do not exist in the private sector—clearly a missing market.

Since the federal government does not share the same bankruptcy constraint as private firms, the risk premia required by a federal reinsurer for upper layers of catastrophic risk, even using risk-based rates, would be significantly below the premia required by private reinsurers. Thus, it is feasible that a federal program

[5] Although the policy framework in this section is not based explicitly on a general equilibrium analysis of welfare effects, the objective of this article is to design an efficient, nonredundant reinsurance security that private sector agents may purchase to increase their capacity. As long as the contract is efficient and appropriately priced, the creation of a new security should leave the private sector equilibrium at least no worse off than the current equilibrium, for private agents could always choose not to participate.

explicitly aimed at alleviating the bankruptcy constraint faced by the private sector in high layers of disaster risk would improve the market equilibrium in the insurance sector by helping to complete the upper end of the disaster insurance market. That is, if this cost-of-capital advantage exceeds any efficiency losses associated with the federalization of this layer of reinsurance, a federal program could expand the supply of reinsurance and the capacity of the primary insurance market. Of course, assuming the initiative can be adequately targeted to the upper end of disaster claims, the critical issue becomes the market efficiency of the proposed federal initiative and its ability to avoid interfering in the private market's ability to provide insurance and reinsurance.

Complement the Existing Private Sector Equilibrium

In justifying any federal intervention in the credit or insurance markets, it is not sufficient to argue that a proposal "fixes" a private market failure or imperfection. A federal program also must demonstrate the ability to result in a new equilibrium at least as good as the (albeit imperfect) free market equilibrium. Given the insurer-reinsurer relationships described above, a federal reinsurance program will be efficient and add value to the existing insurance market equilibrium only if it complements the private insurance and reinsurance sectors. If the federal government were to offer reinsurance in competition with private reinsurers, the effect on the market equilibrium in both the spot and long-term reinsurance markets would be disastrous. In the spot reinsurance market, a competitive federal reinsurance product would crowd out private reinsurance firms, creating a deadweight loss to society as taxpayers absorbed risk that was better insured in the private financial markets. In the implicit long-term contracts market, the disruption would essentially destroy the market.

The implicit long-term contract market is only feasible when a ceding insurance company credibly will pay *ex post* compensation in the aftermath of an event. This, in turn, depends on the credibility of the punishment by the other reinsurance companies of a defecting primary insurance company (charging a defection premium). If the federal government were to offer competitive reinsurance, it would not be able to discriminate and charge a differential price to primary insurers who defected in the past. (More realistically, the federal government would end up with a portfolio of clients who consist mostly of defectors from private agreements.) If both primary insurers and reinsurers know that the federal government will not punish a defector, the *ex post* compensation scheme is no longer credible, and the private sector reverts to the spot market. Since any federal reinsurance program should also be neutral to the type of reinsurance offered in the private market, this structure is clearly inefficient. That is, a federal reinsurance program should not create an exogenous bias in favor of one form of reinsurance (e.g., spot reinsurance) vis-à-vis another (e.g., implicit long-term contracts), or in favor of one reinsurance market (federal reinsurance) vis-à-vis another (private reinsurance markets).

Financially Solvent (Actuarially-Fair) and Capped

The federal government also must be concerned with limiting its risk of loss to the insured events for which it collects premiums. In the private reinsurance markets, reinsurers manage their risks of loss by conducting a thorough evaluation of the ceding insurer's management ability, financial solvency, franchise value, and overall need for reinsurance. Once satisfied that the ceding insurer is worthy of a long-term financial relationship, the reinsurer evaluates the ceding insurer's historical underwriting performance, primary pricing adequacy, marketing ability, and claims-processing capacity (Patrick, 1990). Thus, reinsurers manage their exposure through a combination of pricing, close monitoring, and the ability to reject reinsurance requests for new reinsurance or renewals, should the primary insurer pursue unsound underwriting standards. This is how the reinsurer can combat the dual problems of adverse selection and moral hazard.

For the federal government, however, this model of reinsurance is problematic because the approach would require a federal reinsurer to evaluate the underwriting performance of each ceding insurer and have the regulatory authority to monitor and control this risk. Under the current legal structure of the insurance industry, however, all industry regulation resides with state governments. As a result, the federal government would have no ability to regulate and control the risks that it was reinsuring. In addition, as discussed in Merton and Bodie (1992), pricing alone is an ineffective tool for controlling risk. Alternatively, requiring a single federal reinsurer to audit the underwriting standards of all insurance and reinsurance companies would be inefficient, and may even lead to increases in reinsurance rates as the result of an increased expense loading by the federal reinsurer. In short, if the federal government were to write company-specific reinsurance, adverse selection and moral hazard would make it impossible for the federal government to set reinsurance rates that accurately reflect the amount of risk being transferred to the government. To avoid the creation of this contingent liability, federal reinsurance only should be provided to cover losses at the industry level.

Furthermore, the reinsurance vehicle developed by the federal government should be capped and bounded. As discussed above, the federal program should not crowd out private insurance and reinsurance firms—suggesting the use of a lower floor on the federal coverage that is set above coverage levels offered in the private market. In addition, a federal reinsurance program should not provide reinsurance against mega-catastrophic events that are truly uninsurable (i.e., not able to be priced with some degree of confidence) and for which the federal government will want to retain some flexibility in response. Of course, this suggests an upper limit or cap on the amount of coverage provided by the federal program based on what layers of disaster risk are "insurable."

Finally, the federal program should be priced using a market, risk-based reinsurance premium. To prevent undercutting existing or prospective insurance or reinsurance providers, this premium should incorporate all information concerning the loss distribution associated with offering upper layers of disaster reinsurance, an expense loading covering the full costs of the program (no administrative expense subsidy), and an adjustment to reflect the private market's expected return on "normal reinsurance"—as opposed to the low return required by federal subsidy estimates. In addition, the program should create a mechanism for extracting additional information from the private market on the appropriate value for the risks being insured.

Summary

This framework clearly defines a set of boundaries around any possible federal reinsurance program. The program should use market-based securities to intertemporally diversify large-scale losses from natural disasters. The reinsurance should be provided at the industry, as opposed to the company-specific, level so as not to compete with the private sector reinsurance industry. The coverage should be targeted at high layers of losses, but with capped liability. Finally, mechanisms should be put in place so that the private sector can ultimately provide coverage at this level, should private counterparties be willing to write this coverage.

FEDERAL EXCESS-OF-LOSS REINSURANCE

If the federal government is able to utilize its unique position to diversify claims intertemporally while designing a reinsurance mechanism that complements the private sector's provision of insurance, the federal government will expand reinsurance capacity. Furthermore, this expansion of capacity directly increases the capacity of primary insurance companies to expand coverage. To the extent that the federal government's program enhances the welfare gains associated with implicit, long-term reinsurance contracts, this expansion in primary insurance capacity may even exceed the direct expansion in coverage offered by the federal program. Of course, the natural question is whether a federal initiative meeting this framework exists. This section proposes such an initiative.

To meet the criteria established in the previous section, only federal reinsurance proposals that provide coverage based on industry losses, offer capacity at levels above what is being provided in the private market, are capped and fully-funded, and are market neutral are worthy of consideration. Unfortunately, no existing reinsurance product precisely meets these policy criteria. By drawing on innovations in several markets, however, this section describes in detail a reinsurance product that does meet these requirements: a proposal that can expand the capacity of the primary insurance market for natural disasters without creating disruptions in the current insurance-reinsurance market equilibrium and without adverse impact on the federal budget.

To begin, we return to an examination of the transfer of liability induced by the reinsurance contract. The objective of catastrophic excess-of-loss reinsurance is to provide per risk, per occurrence protection for losses (L) that exceed some trigger level (T) based on what the insurer can absorb. By design, once an event exceeds this trigger, the reinsurance pays (some fixed proportion of) disaster losses (L) usually up to some predetermined cap (C) on the reinsurer's exposure. Therefore, if losses are less than the trigger, the contract pays nothing. If losses fall in the range between the trigger and the cap, the contract pays out L − T. If losses exceed the cap, the contract pays out the difference between the cap and the trigger, or C – T. Using this basic structure, one can specify the payout (P) of the reinsurance as follows:

$$P = \text{Max}\ [0, \text{Min}\ (L - T, C - T)] \tag{3a}$$

or

$$P = \text{Max}\ [0, L - T] - \text{Max}\ [0, L - C]. \tag{3b}$$

As expressed in equation (3b), the reinsurance contract is simply the difference between a put option and a call option written on the underlying exposure of the insured event, or a call spread option. While this specification is by no means novel (see the discussion of the CBOT options in the Appendix), it provides a financial framework for addressing the federal reinsurance role. That is, if the federal government is going to accept a contingent liability for a portion of disaster losses through excess-of-loss reinsurance, a federal reinsurer will be best able to control this liability and fund a reinsurance program by directly selling narrowly-defined contingent claims.

Specifically, the federal government should directly write and sell contingent claims against the upper (capped) layers of catastrophic disaster losses on a per risk and per occurrence basis. These contingent claims, hereafter referred to as excess-of-loss (XOL) contracts, would be available for qualified insurance companies, pools, and reinsurers and would cover industry losses from a disaster in the \$25–\$50 billion layer of coverage—a layer currently unavailable in the private market.[6] The federal government could write either a multiple peril contract or provide individual hurricane and earthquake/volcano contracts. For a discussion of pricing and hedging techniques for XOL contracts, see Cummins, Lewis, and Phillips (1996).

Like private catastrophe coverage, the basic XOL contracts would provide coverage for a single event, not an aggregation of losses over a fixed period.[7] However, like the CBOT options, the reinsurance trigger and cap would be based on insured industry losses to minimize the problems associated with company-specific reinsurance. The payout function on these single-occurrence XOL contracts also would be a function of industry losses and would be fixed at the time the contract is issued. Thus, the expected payout of the contract would be re-expressed as follows:

[6] Industry losses are defined as aggregate direct insurance losses in qualified lines of insurance in the United States, occurring as a result of a catastrophic event within the contract period and paid within 18 months of the event date.

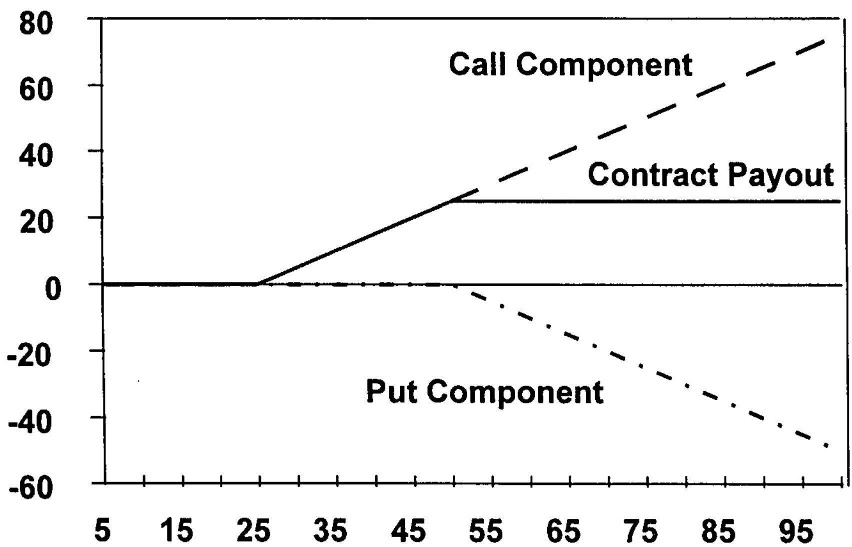
[7] Given the intractable problem of creating a renewal provision for these contracts that meets insurers' needs for continuous coverage without providing "free" insurance, the federal government could offer multiple-occurrence XOL contracts. Multiple-event XOL contracts would cover disaster losses from up to two or three disasters in the \$25–\$50 billion range. The contracts would not aggregate losses over disasters, but would treat each event "as if" it was covered by a separate contract. In return for the expanded coverage, the federal government would incorporate a higher up-front risk-based premium in the reservation price for the multi-XOLs to compensate for the extra coverage.

$$P = \text{Max}\,[0, \delta\,(L - T)] - \text{Max}\,[0, \delta\,(L - C)], \qquad (4)$$

where $\delta(\cdot)$ represents the payout function of the contract, which depends on the difference between the level of total industry losses and the contract trigger or strike price.

The payment structure of these XOL contracts is depicted in Figure 3. As mentioned above, the XOL contract offered by the federal government would be analogous to writing a call option for the insurance industry that pays off when industry disaster losses exceed \$25 billion, where embedded in the call option is a put option held by the federal government such that industry losses in excess of \$50 billion are "put" back to the insurance industry. That is, the payout of the call option component of the XOL contract rises as a fixed proportion of industry losses in excess of \$25 billion once the \$25 billion threshold is reached. However, once industry losses exceed \$50 billion, the put component of the XOL contract provides an equal offset to any industry losses above \$50 billion. As a result, the federal government's exposure is limited to covering losses in the \$25–\$50 billion range, as shown in the payout of the XOL contract line.

Figure 3
Payout of Excess of Loss Contract
(in billions of dollars)



Other aspects of the XOL contracts include the following:

Maturity. The XOL contracts would be sold annually with a maturity of up to one year.

The excess of loss trigger (T). The trigger level of the contracts would be set at a level above where reinsurance coverage is being provided in the private markets. The company-specific nature of traditional reinsurance makes estimating this level difficult. However, based on evidence provided by private reinsurers and current activity in the CBOT market, we assume a trigger level (T) of $25 billion in industry losses. This trigger level of coverage could be adjusted to reflect the rate of property-value inflation, changes in private reinsurance supply, demographic changes in insured values, and changes in expected insurance losses.

The excess of loss cap (C). The cap on the XOL contracts is based on the ability of a federal reinsurer to estimate the probability of loss associated with catastrophic disaster risk with some degree of certainty. That is, while the actual distribution of expected contract losses is unknown and must be estimated with a given level of uncertainty, the uncertainty in estimating the parameters of the loss distribution cannot swamp the actual expectation of loss. Setting the federal reinsurance cap initially at $50 billion should help ensure that the federal government only provides coverage for layers of disaster risk that can be reasonably priced. Again, the level of the cap can be adjusted annually to reflect property-value inflation, with further adjustments permitted based on market conditions as discussed in indexing the contract trigger.

The payout function ($\delta(\cdot)$). The payout function of the XOL contract stipulates how much each individual contract will pay in the event the contract trigger is reached. As proposed, $\delta(\cdot)$ simply represents a scalar function relating industry losses to the desired denomination of each contract. That is, $\delta(\cdot)$ is set so that each contract pays out $1 million for every $1 billion by which industry losses exceed the trigger:

$$\delta(\cdot) = 1/1000\,(L - T). \tag{5}$$

This simple payout function, which by construction includes a contract payout cap equal to $25 million, would provide a total capacity of 1,000 contracts being sold annually. A more complicated specification for $\delta(\cdot)$ is, of course, possible. However, in specifying the payout function, special consideration should be given to the size of the contract denomination. If the contract denomination is too small, the transactions costs associated with purchasing a large number of contracts can offset the gains provided by the reinsurance coverage. On the other hand, if the denomination is too large, insurers with smaller portfolios could be squeezed out of the market. Thus, a careful balance must be reached between the contract size and the complexity of the payout formula.

Payout tail. Only reimbursable disaster losses paid during the 18-month period immediately following the disaster and reported to the Treasury within 21 months of the event date will be covered to limit the tail on the contract payout and prevent the accumulation of losses over a series of events. While helping to protect against fraud and abuse, this provision has the additional advantage of encouraging insurance companies to expedite the processing of claims in the wake of a disaster—a social good from a policy standpoint.

Qualified parties for purchasing the XOL contracts. Private reinsurance firms; primary insurance companies; and state, regional, and national pools would be eligible to purchase and exercise a federal XOL contract, as long as they are licensed or admitted to write property and casualty insurance or reinsurance in a state in the United States, are actively providing coverage for property located in the United States, and have registered with the government.

Qualified lines of insurance. Qualified lines of insurance for earthquake damage would include property losses in earthquake shake policies (written separately or as part of a homeowners policy), commercial multiple peril, and commercial inland marine coverage associated with earthquakes. For hurricane damage, property losses covered by homeowners, wind policies (written separately or as part of a homeowners policy), commercial multiple peril, fire policies, allied policies, farmowners policies, and commercial inland marine policies would be covered. With respect to volcanic activity damage, property losses covered by homeowners policies, commercial multiple peril policies, fire policies, allied policies, farmowners policies, and commercial inland marine policies would be included. For reporting purposes, estimates reported by the state insurance commissioners' office in each affected state would be used as an index of loss, with validation accomplished through year-end tax filings.

Linking Payouts to Firm Losses

To provide a more direct link between the payout of the XOL contracts and actual incurred disaster losses by a firm, the XOL contract would carry an additional payment condition that only firms with *reimbursable disaster losses* would be eligible to exercise the XOL contracts, and only in an amount up to the value of actual reimbursable losses at that company.[8] To enforce this condition, qualified purchasers must provide a certified account of reimbursable losses upon exercise and follow up with audited financial statements supporting their claims. Thus, to be considered a *qualified claimant*, a firm must be a qualified purchaser, have actual reimbursable disaster losses, and hold a valid XOL contract.

This provision is designed to eliminate one shortcoming of providing federal reinsurance through these excess-of-loss contracts—the potential for a firm with no disaster losses to receive a payout from these contracts in the wake of a disaster. For example, if a hurricane swept through New England causing over $25 billion in insured damage, regional insurers in the Southeast United States that purchased hurricane contracts would get paid. This potential outcome, while not an aberration from a financial hedging perspective, would create a political difficulty for the federal government. Further, when reviewing the accounting treatment of these contracts, this potential outcome may make it more difficult for states to accord XOL contracts the same regulatory status as traditional reinsurance.

In isolation, this condition would greatly increase the complexity of pricing the XOL contracts. Adding this exercise condition to the reinsurance contract

[8] Reimbursable losses are defined as insurance and reinsurance claims, including assigned claims and loss adjustment expenses, that (1) result from a catastrophic event, (2) reside in qualified lines of insurance, (3) are measured net of salvage and reinsurance recovered and recoverable, (4) cover losses in the United States, (5) are paid within 18 months of the event date and presented to the federal government within 21 months of the event date, and (6) are covered by a valid XOL contract.

would transform the valuation problem to that of pricing the difference between a *contingent* put option and a *contingent* call option. Solving this problem would require the federal reinsurer to calculate the correlation between industry disaster losses and each individual company's losses, leading to all of the same problems associated with company-specific reinsurance.

Transferability—Creating a Secondary Market

To avoid the complications arising from offering contingent put options, the XOL contracts could be made fully transferable among qualified purchasers. Furthermore, the collection "rights" of the contract can be made fully transferable and divisible (i.e., assigned losses). By allowing the rights of the contracts to be transferable, a secondary market will develop that will allow firms to trade reimbursement rights to the insurers with the greatest uncovered losses.

Initially, only companies whose portfolios correlate well with industry losses will purchase the XOL contracts. However, in the event that one of these companies does not incur losses in the wake of a disaster, the company can sell the contracts to other qualified purchasers in need of additional coverage or sell the reimbursement rights of their contracts to nonqualified purchasers. In this way, most, if not all, of the contracts will be exercised in the wake of a disaster, and the federal government can reasonably price these contracts "as if" all contracts will be exercised.

The development of this secondary market should improve the allocation of these reinsurance contracts across insurance firms and provide additional pricing signals for both the federal government's initial contract pricing and for individual firms.[9] If a firm purchased an XOL contract but did not experience losses from a qualifying event, the firm could easily transfer the rights of the XOL contract to a firm that did experience losses. Depending on the supply and demand for contracts after a qualifying disaster event, a firm that purchases the rights from the holder of the XOL contract will pay a substantial premium for these rights, possibly as high as the full nominal payout of the contract less transactions fees. Of course, since firms would realize the premium they would pay for *ex post* coverage under the XOL program, firms would anticipate their demand for coverage and bid for contracts during the auction process or purchase the rights from XOL contracts in the secondary market before an event actually occurs. Thus, while it is possible for companies to earn rents from purchasing XOL contracts and selling the rights to the contracts after an event, such a financing strategy is *ex ante* unprofitable, and any rents would be transitory.

Federal Auction for the Excess-of-Loss Contracts

To allow for the development of a private market to crowd out these federal contracts and to limit the potential for underpricing, the federal government would

[9] Although important, the dynamics of how this secondary market would develop and value the XOL contracts in the wake of a disaster is outside of the scope of this article.

auction off a limited number of these contracts, starting from an initial reservation price (floor) using an auction.[10] The advantage of using an auction to sell the XOL contracts is the ability to marginally undersupply the market and extract private information on the value of the XOL contracts from private firms.

An advantage of short-selling the market is that the program generates additional premium revenue to cover the risks associated with mispricing the reservation price. To see this, recall that there are three basic information sets that the federal government must recognize when setting the appropriate premium for the XOL contracts—explicit information on risk available to the government, the explicit and intangible information reflected in the private market's valuation of the contracts, and any information that is currently unknowable but may be revealed at some point in the future.

The risk-based reservation price is set to reflect the federal government's best estimate of the loss distribution associated with providing coverage against this layer of catastrophic losses. Using an auction format provides a mechanism for extracting the private market's valuation of the risk covered by the contracts. If the federal government were able to ensure that the supply of contracts perfectly equaled the demand for contracts, the price would equal the marginal cost of risk—reflecting all currently available information on the magnitude of the risk. Since the government has imperfect knowledge on the level of the private sector's demand for the contracts, the program needs to marginally short-sell demand to extract information on the private sector's demand curve. However, by short-selling demand, the price of the XOL contracts should be marginally above the marginal cost of risk—providing at least partial protection against upward revisions in the assessment of risk.

Reservation price. The reservation price would include a *risk-based premium* for providing the reinsurance, a *cost-of-capital surcharge* to reflect the private reinsurance market's expected return on "normal" catastrophic reinsurance, and an *expense loading* to cover all administrative expenses of the program. Including a cost-of-capital adjustment in the reservation price allows for the development of a private reinsurance market to "crowd out" the federal government in the provision of these reinsurance coverage layers. Furthermore, the excess premium collected through the cost-of-capital surcharge can be redirected to efforts to increase loss mitigation activities that reduce the overall property losses from natural disasters.

Supply constraints. The contracts would be auctioned by the U.S. Treasury with only a limited number of contracts being supplied in any one year to capture implicit pricing information in the private market demand for the XOL contracts. For example, with a threshold of $25 billion, a cap of $50 billion, and a payout of

[10] With this structure, and an appropriately determined risk-based reinsurance premium, a federal reinsurance program will remain actuarially sound. Unlike other federal credit and insurance programs, the only contingent liability associated with the program is the potential liability that future events or states of the world will reveal information concerning increased program costs for which we currently have no information. That is, uncertainty risk whose current expected value is zero and whose variance is infinite.

A discussion of the appropriate auction format for the sale of the XOL contracts is left for future research.

$1 million for every $1 billion in industry losses above the threshold, there is a total capacity in the market for 1,000 contracts (1,000 contracts × $1 million per $1 billion in losses × 25 = $25 billion maximum payout). As a starting point, the Treasury would auction 25 percent of the total value of the contracts, or 250 contracts, in the first auction. The Treasury could then limit the value of XOL contracts offered for sale at subsequent auctions to be no larger than the greater of 90 percent of the total payoff value of the contract bids that were received at auction during the preceding year that exceeded the reservation price by at least 10 percent or the total payoff value of the contract bids that were received at auction during the preceding year. Furthermore, the Treasury could limit its exposure by placing an overall ceiling on the value of contracts available for sale in any year (e.g., 75 percent of the maximum value of contracts covered within the $25–$50 billion range).

CONCLUSION

In sum, this article has developed a concept for a risk management system for diversifying losses arising from large-scale natural disasters that relies on insurers, reinsurers, private securities markets, and the federal government. Losses are ceded from individuals to primary insurance companies that diversify risks spatially through the creation of risk pools. Primary insurance companies then utilize reinsurance and private securities markets to obtain a better geographic diversification of risk. Finally, because the losses from natural disasters remain highly correlated geographically in the aggregate and idiosyncratic over time, the federal government provides a new risk management mechanism for diversifying these risks intertemporally.

This article also outlines the role of private reinsurance in reducing the cost of primary insurance and expanding the capacity of primary insurers to offer coverage for natural disasters. In managing this role, many private reinsurers rely on the use of implicit long-term contracts to efficiently control natural disaster exposure. Therefore, to complement the existing insurance and reinsurance markets' ability to offer disaster coverage, we develop a policy framework for ensuring that any new federal program complements the existing market. Under this framework, any federal reinsurance mechanism must be narrowly targeted at the missing market for intertemporal diversification of large magnitude losses, based on industry (not company-specific) payouts, designed to complement existing private sector insurance and reinsurance mechanisms, and actuarially sound.

Finally, this article proposes an approach for the federal government to expand private insurance capacity through a form of excess-of-loss reinsurance that meets this policy framework. The federal government would sell tradeable excess-of-loss reinsurance contracts to qualified insurers for disaster losses in the range of $25–$50 billion. The proposal represents a targeted approach for enhancing the ability of the insurance markets to smooth large claims over time, without imposing direct or indirect losses on federal taxpayers. In addition, by covering layers of reinsurance currently unavailable in the private market and incorporating a cost-of-capital adjustment to offset the federal government's lower borrowing costs, this program should avoid any "crowding out" of private reinsurers.

Since the XOL contract is an efficient, nonredundant security offered on a voluntary basis, the contracts will not distort existing insurance-reinsurance relationships, but will enhance the private market equilibrium by providing the private market with an additional choice of reinsurance that leaves the market at least as well off as without the initiative. Furthermore, the XOL contract directly complements the development of new financial market tools (CBOT options, act-of-God bonds) being developed to cover lower levels of disaster risk or the exposure of individual companies by enabling the provider of these contracts to reduce their upside exposure.

The program is also designed to enable the private sector to "crowd out" the federal government if it becomes proficient at insuring this layer of disaster risk. The price of the federal contracts will be determined using a cost of capital that is adjusted to reflect private sector costs encouraging private sector competition. Furthermore, as this model of intertemporal risk diversification through the purchase of call-spread options on industry losses becomes established, private sector firms can offer or expand their efforts at providing coverage for different levels of risk.

Of course, expanding private reinsurance capacity is not a complete solution for improving the nation's societal approach to natural disaster risk. Unless consumers, state and local governments, businesses, and the federal government begin to internalize natural disaster risk in their purchasing and building decisions, federal reinsurance will provide only a modest improvement in the ability of the nation to handle catastrophe risk. Thus, this type of federal reinsurance program, while feasible as a stand-alone option, is best incorporated into a larger federal initiative addressing hazard mitigation, the encouragement of private insurance, and reforming the provision of federal post-disaster relief. It is in the context of these larger reforms that this federal reinsurance proposal will prove effective.

APPENDIX
CBOT FUTURES AND OPTIONS

In the futures and call-spread options being traded on the floor of the Chicago Board of Trade, protection is provided to cover a percentage of natural disaster losses occurring in layers of exposure for all events within the six-month contract period. In the CBOT market, coverage is provided in levels of exposure of up to 200 percent of industry-written premiums. Thus, based on current premiums, these contracts are providing coverage for aggregate disaster loss levels of up to $25 billion. This type of protection is similar to aggregate excess treaties used by traditional reinsurers or Asian options traded in many commodity exchanges (Cummins and Geman, 1995). For a more detailed discussion of the CBOT futures and options markets, see D'Arcy and France (1992, 1993), Niehaus and Mann (1992), and Cummins and Geman (1995).

In the case of CBOT catastrophe futures and options, moral hazard and adverse selection risk is minimized by benchmarking the payout of each contract to an index of industry losses. Making the contract's payout a function of industry losses largely eliminates the ability of primary insurers to pass moral hazard and adverse selection risk to the financial counterparty (the "reinsurer") in the transaction.[11] Of course, the success of this mechanism is highly dependent on the ability to construct an industry loss index that is independent of individual insurer behavior. That is, no single insurer should be able to exert a large influence on the level of the loss index.

The CBOT futures and options markets, while an extremely important risk management tool for insurers, do not represent a complete solution to the problem of reinsuring upper levels of catastrophe risk. The primary problem with the CBOT market is a lack of natural counterparties willing to assume a long position in insurers' catastrophic risk. In addition, it is doubtful that speculators in the catastrophe risk market will constitute a large and stable capital base for this risk.

Finally, unlike traditional catastrophe coverage provided in the reinsurance markets, CBOT options do not provide per occurrence reinsurance. Instead, the contracts cover the estimated losses associated with natural disasters in each region over the entire contract period (see Cummins and Geman, 1995). Although this method of insurance adds income stability for the purchasing firm, it also exposes the "reinsuring" counterparty to noncatastrophic disaster losses that are included in the loss index.

[11] However, this does not eliminate the moral hazard and adverse selection problems faced by primary insurers.

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