Risk Transfer and Insurance: Insurability Concepts and Programs for Covering Extreme Events

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RISK TRANSFER AND INSURANCE: INSURABILITY CONCEPTS AND PROGRAMS FOR COVERING EXTREME EVENTS

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Abstract: This article discusses factors that determine the insurability of a risk and the extent of coverage offered by the private sector to provide protection against events where there is a low probability of a catastrophic loss. Such extreme events include natural disasters, catastrophic industrial accidents, and large-scale terrorism. We begin the discussion by focusing, for several reasons, on insurance for natural hazards, such as earthquakes, hurricanes, and floods. First, natural disasters have been studied for many years. Second, the concepts that define insurability of natural disasters are also applicable to other disasters. The article then discusses how federal and state governments in the United States have contributed to supplementing private insurance in dealing with catastrophe risks.

Keywords: insurance; coverage; natural disasters; catastropic loss; risks; premiums

1 INTRODUCTION

The United States has extensive experience with natural catastrophes. But the hurricanes that occurred in the Gulf Coast during the 2004 and 2005 seasons have changed the landscape forever. Coupled with the terrorism attacks of September 11, 2001, there is

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recognition by both the public and private sectors that one needs to rethink our strategy for dealing with these low probability but extreme consequence events.

The 2002 White House National Strategy defines homeland security as "the concerted effort to prevent attacks, reduce America's vulnerability to terrorism, and minimize the damage *and* recover from attacks that do occur". To succeed, homeland security must be a national and comprehensive effort. Moreover, that definition must apply to technological and natural disasters as well.

While protecting residential and commercial construction and critical infrastructure services (transportation, telecommunications, electricity and water distribution, etc.) in risky areas may limit the occurrence and/or the impacts of major catastrophes, we know that major disasters will still occur. In these situations one must provide adequate emergency measures and rapidly restore critical services. The question as to who will provide financial protection to victims (residents and commercial enterprises) will take center stage. The insurance infrastructure will then play a critical role [1].

This article discusses some fundamentals of the operation of insurance as well as some of the insurance programs that have been established in the United States to cover economic losses due to large-scale catastrophes.

2 HOW DOES INSURANCE WORK AND DOES NOT WORK

2.1 Determining Premiums and Coverage

2.1.1 Basic Concepts The insurance business, like any other business, has its own vocabulary. A *policyholder* is a person who has purchased insurance. A *premium* is the amount that a policyholder pays in return for the promise of a payment from the insurer should he suffer a loss covered by his policy. The term *benefit* denotes the payment by the insurer to the policyholder given that he has suffered a reduction in wealth due to a loss. A *claim* means that the policyholder is seeking to recover financial payments from the insurer for damage covered by the policy. A claim will not result in a payment by the insurer if the amount of the insured's financial loss is below the stated *deductible* (i.e. the amount or proportion of an insured loss that the policyholder agrees to pay before any recovery from the insurer) or if the loss is subject to policy exclusions (e.g. war or insurrection). However, insurers will still incur expenses for investigating the claim.

Insurer *capital* represents the net worth of the company (assets minus liabilities). Capital enables the insurer to pay any losses above those that were expected. It serves as a safety net to support the risk that an insurer takes on by writing insurance and helps ensure that the insurer will be able to honor its contracts. As such, it supports the personal safety nets of homeowners, business owners, workers, dependents of heads of households, and others who rely on insurance to provide financial compensation to rebuild their lives and businesses after covered losses occur. Insurer capital is traditionally referred to as *policyholders' surplus*. Despite the connotation of the term *surplus*, there is nothing superfluous about it—it is, in fact, an essential component supporting the insurance promise. The cost of that capital is an insurer expense that must be considered in pricing insurance, along with expected losses, sales, and administrative expenses for policies written.[1]

[1]Consider, for example, insurance for property damage caused by hurricanes. An insurer's expected losses are relatively low, because in a typical year, the policyholder will not suffer a hurricane loss. However, it is possible that losses will be quite high—far in excess of those expected at the time policies are priced. In the event of a serious hurricane, a substantial portion of the loss must be paid from insurer capital. For terrorism coverage, maximum losses are extremely high relative to expected losses, so the capital issue is critical.

The capital needed by an insurer varies directly with the risk that the insurer takes on. If an insurer wishes to take on more risk, it must have capital to support that risk. *Insurance regulators* and *rating agencies* in their efforts to assure policyholders that insurers will be able to pay their losses, devote significant efforts toward evaluating the adequacy of insurer capital relative to the amount and types of risk they are taking on. Holding an adequate level of capital is critical to the continued viability of an insurer.

Insurance markets function best when the losses associated with a particular risk are independent of each other and the insurer has accurate information on the likelihood of the relevant events occurring and the resulting damage. By selling a large number of policies for a given risk, the insurer is likely to have an accurate estimate of claim payments it expects to make during a given period of time. To illustrate this point with a simple example, consider an insurer who offers a fire insurance policy to a set of identical homes each valued at \$100,000. Based on past data, the insurer estimates that the likelihood that the home will be destroyed by fire next year is 1/1000 and that this is the only loss that can occur. In this case the expected annual loss for each home would be \$100 (i.e. $1/1000 \times \$100{,}000$).

If the insurer issued only a single policy to cover the full loss from a fire, then there would be a variance of approximately \$100 associated with its expected annual loss.[2] As the number of policies issued, n, increases, the variance of the expected annual loss, or the mean loss per policy, decreases in proportion to n. Thus, if $n = 10$, the variance of the mean loss will be approximately \$10. When $n = 100$ the variance decreases to \$1, and with $n = 1000$ the variance is \$0.10. It is thus not necessary to issue a very large number of policies to reduce significantly the variability of expected annual losses per policy if the risks are independent. This model of insurance works well for risks such as fire, automobile, and loss of life where the above assumptions of independence and ability to estimate probabilities and losses are satisfied. As will be shown below, terrorism risk does not satisfy the above conditions, so it is more problematic to insure.

2.1.2 Catastrophe Models[3] Before insurance providers are willing to offer coverage against an uncertain event they feel they must be able to identify and quantify, or at least partially estimate the chances of the event occurring and the extent of losses likely to be incurred. Such estimates can be based on past data (e.g., loss history of the insurer's portfolio of policyholders, loss history in a specific region) coupled with data on what experts know about a particular risk through the use of catastrophe models.

The four basic components of a catastrophe model are hazard, inventory, vulnerability, and loss, as depicted in Figure 1, and illustrated for a natural hazard such as a hurricane. First, the model determines the risk of the *hazard* phenomenon, which in the case of a hurricane is characterized by its projected path and wind speed. Next, the model characterizes the *inventory* (or portfolio) of properties at risk as accurately as possible. This is done by first assigning geographic coordinates such as latitude and longitude to a property based on its street address, zip code, or another location descriptor, and then determining how many structures in the insurer's portfolio are at risk from hurricanes of different wind speeds and projected paths. For each property's location in spatial terms, other factors that characterize the inventory at risk are the construction type, the number of stories in the structure, and its age.

[2]The variance for a single loss L with probability p is $Lp\,(1-p)$. If $L = \$100{,}000$ and $p = 1/1000$, then $Lp(1-p) = \$100{,}000\ (1/1000)(999/1000)$, or \$99.90.

[3]This section is based on [2].

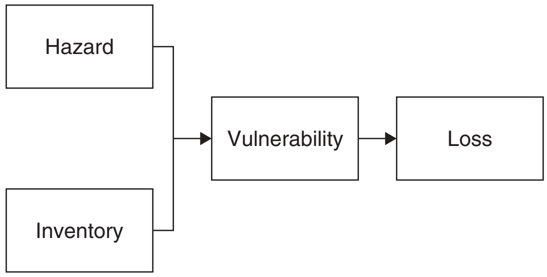

FIGURE 1 Structure of catastrophe models.

The hazard and inventory modules enable one to calculate the *vulnerability* or susceptibility to damage of the structures at risk. In essence, this step in the catastrophe model process quantifies the physical impact of the natural hazard phenomenon on the property at risk. How this vulnerability is quantified differs from model to model. On the basis of this measure of vulnerability, the *loss* to the property inventory is evaluated. In a catastrophe model, loss is characterized as direct or indirect in nature. Direct losses include the cost to repair and/or replace a structure. Indirect losses include business interruption impacts and relocation costs of residents forced to evacuate their homes.

Catastrophe models were introduced in the mid1980s but did not gain widespread attention until after Hurricane Andrew hit southern Florida in August, 1992, causing insured losses of over $21.5 billion (in 2004 prices). Until 9/11 this was the largest single loss in the history of insurance. Nine insurers became insolvent as a result of their losses from Hurricane Andrew. Insurers and reinsurers thought that, in order to increase the chances of remaining in business, they needed to estimate and manage their natural hazard risk more precisely. Many companies turned to the modelers of catastrophe risks for decision support.

2.1.3 Exceedance Probability Curves[4] On the basis of the outputs of a catastrophe model, the insurer can construct an exceedance probability (EP) curve that specifies the probabilities that a certain level of losses will be exceeded. The losses can be measured in terms of dollars of damage, fatalities, illness, or some other unit of analysis.

To illustrate with a specific example, suppose one were interested in constructing an EP curve for an insurer with a given portfolio of insurance policies covering wind damage from hurricanes in a southeastern US coastal community. Using probabilistic risk assessment, one would combine the set of events that could produce a given dollar loss and then determine the resulting probabilities of exceeding losses of different magnitudes. On the basis of these estimates, one can construct a mean EP curve such as the one depicted in Figure 2. The x-axis measures the loss to insurer in dollars and the y-axis depicts the probability that losses will exceed a particular level. Suppose the insurer focuses on a specific loss L_i. One can see from Figure 2 that the likelihood that insured losses exceed L_i is given by p_i.

An insurer utilizes its EP curve for determining how many structures it will want to include in its portfolio given that there is some chance that there will be hurricanes causing damage to some subset of its policies during a given year. More specifically, if the insurer wanted to reduce the probability of a loss from hurricanes that exceeds L_i

[4]This section is based on material in [3].

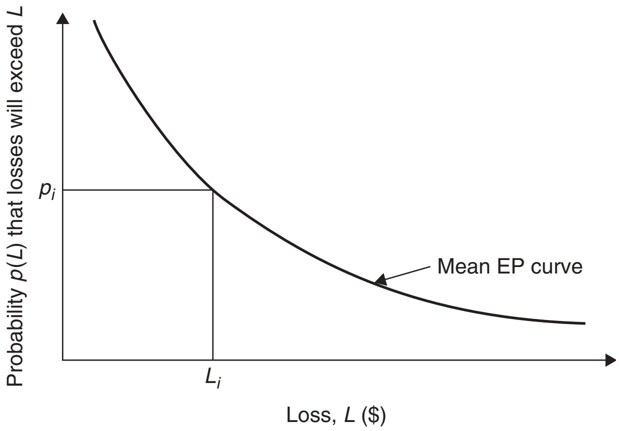

FIGURE 2 Sample mean exceedance probability curve.

to be less than p_i it will have to determine what strategy to follow. The insurer could reduce the number of policies in force for these hazards, decide not to offer this type of coverage at all (if permitted by law to do so) or increase the capital available for dealing with future hurricanes that could produce large losses.

Federal and state agencies may want to use EP curves for estimating the likelihood that losses to specific communities or regions of the country from natural disasters in the coming year will exceed certain levels in order to determine the chances that it will have to provide disaster assistance to these stricken areas. At the start of the hurricane season in 2004, Florida could have used an EP curve to estimate the likelihood of damage exceeding $23 billion. Although this probability would have been extremely low, we now know that a confluence of events (i.e., Charley, Frances, Ivan, and Jeanne) produced an outcome that exceeded this dollar value.

The uncertainty associated with the probability of an event occurring and the magnitude of dollar losses of an EP curve is reflected in the 5 and 95% confidence interval curves in Figure 3. The curve depicting the uncertainty in the loss shows the range of values, $L_i^{0.05}$ and $L_i^{0.95}$ that losses can take for a given mean value, L_i, so that there is a 95% chance that the loss will be exceeded with probability p_i. In a similar vein one can determine the range of probabilities, $p_i^{0.05}$ and $p_i^{0.95}$ so that there is 95% certainty that losses will exceed L_i. For low probability-high consequence risks, the spread between the 5 and 95% confidence intervals depicted in Figure 3 shows the degree of indeterminacy of these events.

The EP curve serves as an important element for evaluating risk management tools. It puts pressure on experts to make explicit the assumptions on which they are basing their estimates of the likelihood of certain events occurring and the resulting consequences.

2.2 Determining Whether to Provide Coverage

On the basis of their knowledge of likelihood and outcome, an insurer has to make a decision as to whether to cover the risk (unless they are required to do so by law). In his study on insurers' decision rules as to when they would market coverage for a specific risk, Stone [4] develops a model whereby firms maximize expected profits subject to

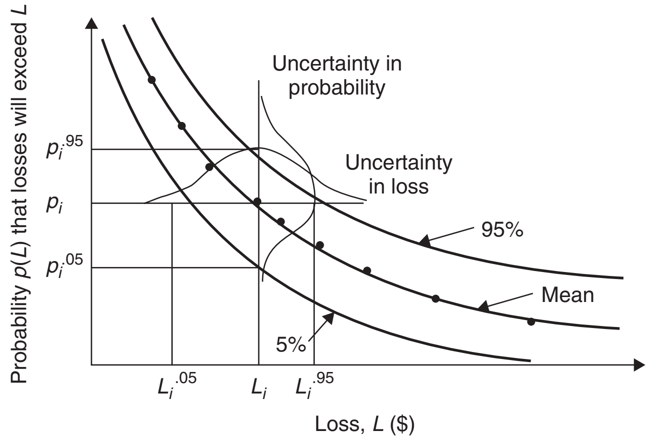

FIGURE 3 Confidence intervals for a mean exceedance probability (EP) curve.

satisfying a constraint related to the survival of the firm.[5] An insurer satisfies its survival constraint by choosing a portfolio of risks with an overall expected probability of total claims payments greater than some predetermined amount (L^*) that is less than some threshold probability, p_1. This threshold probability reflects the trade-off between the expected benefits of another policy and the costs to the firm of a catastrophic loss that reduces the insurer's surplus by L^* or more. This threshold probability does not necessarily correspond to what would be efficient for society. The value of L^* is determined by an insurer's concern with insolvency and/or a sufficiently large loss in surplus that will lead a rating agency to downgrade its credit rating.

A simple example illustrates how an insurer would utilize its survival constraint to determine whether a particular portfolio of risks is insurable with respect to hurricanes. Assume that all homes in a hurricane-prone area are identical and equally resistant to damage such that the insurance premium, P, is the same for each structure. Furthermore assume that an insurer has S dollars in current surplus and wants to determine the number of policies it can write and still satisfy its survival constraint. Then, the maximum number of policies, n, satisfying the survival constraint is given by Eq. (1):

$$\text{Probability [claims payments } (L^*) > (n \cdot P + S)] < p_1 \qquad (1)$$

The insurer will use the survival constraint to determine the maximum number of policies it is willing to offer, with possibly an adjustment in the amount of coverage and premiums, and/or a transfer of some of the risk to others in the private sector (e.g. reinsurers or capital markets). It may also rely on state or federal programs to cover its catastrophic losses.

Following the series of natural disasters that occurred at the end of the 1980s and in the 1990s, insurers focused on the survival constraint to determine the amount of catastrophe coverage they were willing to provide because they were concerned that their aggregate

[5]Stone also introduces a constraint regarding the stability of the insurer's operation. Insurers have traditionally not focused on this constraint in dealing with catastrophic risks but reinsurers have, as discussed in the next article.

exposure to a particular risk did not exceed a certain level. Rating agencies, such as A.M. Best, focused on insurers' exposure to catastrophic losses as one element in determining credit ratings, so insurers paid attention to this risk.

2.3 Setting Premiums

If the insurer decides to offer coverage, it needs to determine a premium rate that yields a profit and satisfies its survival constraint given by Eq. (1). State regulations often limit insurers in their rate-setting process. Competition can play a role as well as to what premium can be charged in a given marketplace. Even in the absence of these influences, an insurer must consider problems associated with the *ambiguity of the risk*, asymmetry of information (*adverse selection* and *moral hazard*), and degree of *correlation* of the risk in determining what premium to charge. We briefly examine each of these factors in turn.

2.3.1 Uncertainty of the Risk The infrequency of major catastrophes in a single location implies that the loss distribution is not well specified. The ambiguities associated with the probability of an extreme event and with the outcomes of such an event raise a number of challenges for insurers with respect to pricing their policies. As shown by a series of empirical studies, actuaries and underwriters are averse to ambiguity and want to charge much higher premiums when the likelihood and/or consequences of a risk are highly uncertain than if these components of risk are well specified [5].

Figure 4 illustrates the total number of loss events from 1950 to 2000 in the United States for three prevalent hazards: earthquakes, floods, and hurricanes. Events were selected that had at least $1 billion of economic damage and/or over 50 deaths [6]. Looking across all the disasters of a particular type (earthquake, hurricane, or flood), for this 50-year period, the median loss is low while the maximum loss is very high. Given this wide variation in loss distribution, it is not surprising that insurers are concerned about the uncertainty of the loss in estimating premiums, or even providing any coverage in certain hazard prone areas.

The 2004 and 2005 seasons have already dramatically changed the upper limits in Figure 4. Hurricane Katrina is estimated to have caused between $150 billion and $170 billion in economic losses, more than four times higher than the most costly hurricane between 1950 and 2000. On the other hand, no hurricane hit the US landfall this year, despite predictions earlier in the year indicated higher than normal intensive season.

2.3.2 Adverse Selection If the insurer cannot differentiate the risks facing two groups of potential insurance buyers and each buyer knows his/her own risk, then the insurer is likely to suffer losses if it sets the same premium for both groups by using the entire population as a basis for this estimate. If only the highest risk group is likely to purchase coverage for that hazard and the premium is below its expected loss, the insurer will have a portfolio of "bad" risks. This situation, referred to as *adverse selection*, can be rectified by the insurer charging a high enough premium to cover the losses from the bad risks. In so doing, the good risks might purchase only partial protection or no insurance at all because they consider the price of coverage to be too expensive relative to their risk[6].

[6]For a survey of adverse selection issues, see [7].

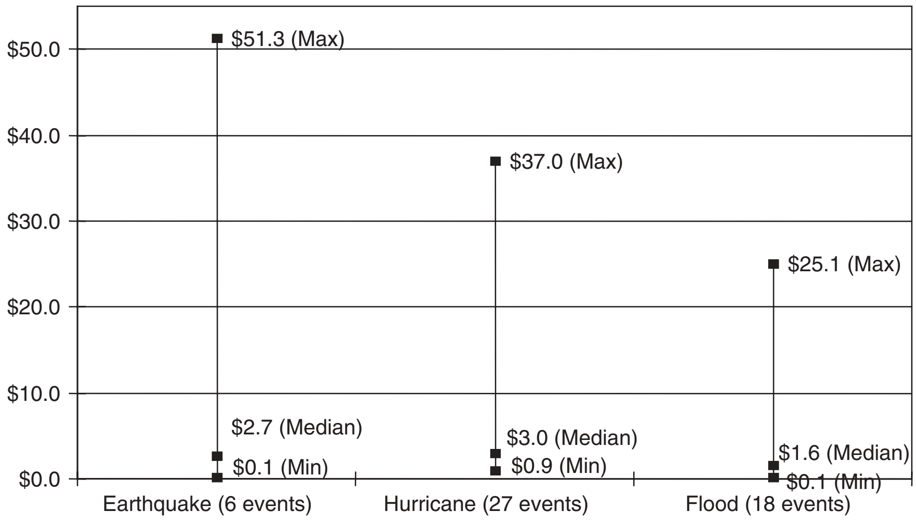

FIGURE 4 Historical economic losses in $ billions versus type of significant US natural disaster for the 50-year period from 1950 to 2000.

This was the argument made by private insurers regarding the noninsurability of flood risk that led to the creation of the National Flood Insurance Program (NFIP). Indeed, insurers thought that family who had lived in a specific flood-prone area for many years had a much better knowledge of the risk than any insurer would have unless it invested in costly risk assessment tools.

In the context of hurricane, however, it is not clear whether there is any adverse selection. Indeed, there is no evidence that those at risk have an informational advantage over the insurer. In fact, the opposite might be true: if insurance companies spend a lot of resources estimating the risk (what they actually do) they might gain an informational advantage over their policyholders who cannot afford or want to do so. Over the past 5 or 6 years, there has been a growing literature studying the impact of insurers being *more* knowledgeable about the risks than the insured themselves. Research in this field reveals that insurers might want to exploit this “reverse information asymmetry”, which results in low risk agents being optimally covered while high risks are not [8].

2.3.3 Moral Hazard This refers to an increase in the expected loss (probability or amount of loss conditional on an event occurring) caused by insurance-induced changes in the behavior of the policyholder. An example of moral hazard is more careless behavior *vis-à-vis* natural hazards or other types of risk as a result of purchasing coverage. Providing insurance protection may lead the policyholder to change behavior in ways that increase the expected loss from what it would have been without coverage. If the insurer cannot predict this behavior and relies on past loss data from uninsured individuals to estimate rates, the resulting premium is likely to be too low to cover losses.

Even after the insurer is aware that people with insurance have higher losses, its inability to observe loss-enhancing behavior may create problems of moral hazard. The introduction of specific deductibles, coinsurance or upper limits on coverage can be useful tools to reduce moral hazard by encouraging insureds to engage in less risky behavior, as they know they will have to incur part of the losses from an adverse event.

2.3.4 Correlated Risks For extreme events, the potential for high correlation between the risks will have an impact on the tail of the distribution. In other words, at a predefined probability p_i, the region below the EP curve is likely to expand for higher correlated risks covered by insurers. This requires additional capital for the insurer to protect itself against large losses. Insurers normally face spatially correlated losses from large-scale natural disasters. State Farm and Allstate Insurance paid \$3.6 billion and \$2.3 billion in claims, respectively, in the wake of Hurricane Andrew in 1992 due to their high concentration of homeowners' policies in the Miami/Dade County area of Florida. Given this unexpectedly high loss, both companies began to reassess their strategies of providing coverage against wind damage in hurricane-prone areas [9].

Hurricanes Katrina and Rita that devastated the US Gulf Coast in August and September 2005 impacted dramatically on several lines, including life, property damage, and business interruption. Edward Liddy, chairman of Allstate, which provided insurance coverage to 350,000 homeowners in Louisiana, Mississippi, and Alabama, declared that "extensive flooding has complicated disaster planning ... and the higher water has essentially altered efforts to assess damage. We now have 1100 adjusters on the ground. We have another 500 who are ready to go as soon as we can get into some of the most-devastated areas. It will be many weeks, probably months, before there is anything approaching reliable estimates" [10].

2.3.5 Role of Capital Costs The importance of capital and its need to secure an adequate rate of return is often not sufficiently understood. In particular, the prices charged for catastrophe insurance must be sufficiently high to cover the expected claims costs and other expenses, but must also cover the costs of allocating risk capital to underwrite this risk. Moreover, because the large amounts of risk capital are needed to underwrite catastrophe risk relative to the expected liability, the capital cost built into the premium is high, often dominating the expected loss cost. Thus, an insurer usually needs to charge high prices relative to its loss expenses, simply to earn a fair rate of return on equity and thereby maintain its credit rating.

To illustrate, we construct a hypothetical example that is somewhat conservative by ignoring taxes. Consider a portfolio that has 1000 in expected liabilities, $E(L)$. Since actual losses will not equal expected losses, the insurer needs to hold considerable capital. Here we will assume that \$1 of capital is needed for each \$1 of expected liability to maintain the insurer's credit rating. Thus the insurer needs capital, $E(L) = 1000$. In addition to paying claims, the insurer has an additional 200 in upfront-expected expenses that include commissions to agents and brokers, and underwriting expenses. Moreover, given the risk characteristics of the portfolio, investors require a rate of return (ROE) of 15% on their investment to compensate for risk. The insurer invests its funds in lower risk vehicles that yield an expected return, r, of 10%. What premium P would the insurer have to charge to secure a return of 15% for its investors?

The formula for the premium can be expressed as a function of the cash flows, the return on investment and the required return on equity (k is the ratio of equity to expected losses)

$$P = \frac{X(1+r) + E(L)}{(1+r) - k(ROE - r)}$$

$$P = \frac{200(1+0.05) + 1000}{(1+0.05) - 1(0.15 - 0.05)} = 1210$$

Premiums need to be 1210 to generate this required 15% return on equity.

This calculation is very sensitive to the ratio of capital to expected liability, k, needed to preserve credit. In the above example, the ratio was one dollar of capital for one dollar of expected liability. This ratio is in the ballpark for many property liability insurers for their combined books of business. However, for catastrophe risk, with its very high tail risk (which severely affects credit risk), the capital to liability ratio needs to be considerably higher. Indeed, the capital to liability ratio depends on volatility (particularly, the downside or tail risk) of the catastrophe liability and its correlation with the insurer's remaining portfolio. For higher layers of cat risk, the expected loss is often quite low and the volatility very high. At these layers, the required capital to liability ratio can be considerably greater than unity as shown in this example. An increase in the capital to liability ratio will increase the premium required to generate a fair return on equity.

A second issue with catastrophe risk is that it can be expensive to underwrite since it requires extensive modeling. Many companies will buy commercial models and/or use their own in-house modeling capability. If we rework the above premium calculation now with the transaction costs set at 100% of expected losses and 4:1 capital to expected liability ratio the required premium is now 3154:

$$P = \frac{1000(1 + 0.05) + 1000}{(1 + 0.05) - 4(0.15 - 0.05)} = 3154$$

For very high layers even more capital may be needed, thus further increasing the premium. There are other considerations that can dramatically leverage upwards the capital cost, notably the impact of double taxation. [11] have simulated the tax burden over many parameterizations and show that tax costs alone can reasonably be as much as the claim cost and lead to further increases in premiums. When we account for all these factors (i.e. high capital inputs, transaction costs, and taxes), catastrophe insurance premiums often are several multiples of expected claims costs.

2.4 Role of Rating Agencies

During the past few years, rating agencies have played increasing attention to the impact that catastrophic risks will have on their view of the financial stability of insurers and reinsurers. The rating given to a company will affect their ability to attract business and hence their pricing and coverage decisions.

To illustrate how ratings are determined consider A.M. Best. It undertakes a quantitative analysis of an insurer's balance sheet strength, operating performance, and business profile. Evaluation of catastrophe exposure plays a significant role in the determination of ratings, as these are events that could threaten the solvency of a company. Projected losses of disasters occurring at specified return periods (a 100-year windstorm/hurricane or a 250-year earthquake) and the associated reinsurance programs to cover them are two important components of the rating questionnaires that insurers are required to complete.

For several years now, A.M. Best has been requesting such information for natural disasters. Their approach has been an important step forward in the incorporation of catastrophe risk into an insurer's capital adequacy requirements. Up until recently the rating agency has been including probable maximum loss (PML) for only *one* of these severe events (100-year windstorm/250-year earthquake, depending on the nature of the risk the insurer was mainly exposed to) in its calculation of a company's risk-adjusted capitalization. In 2006 A.M. Best introduced a second event as an additional stress test.

The PML used for the second event is the same as the first event in the case of hurricane (a 1-in-100 year event; the occurrence of one hurricane is considered to be independent of the other one). If the main exposure facing the insurer is an earthquake, the second event is reduced from a 1-in-250 year event to a 1-in-100 year event [12]. These new requirements have increased the amount of risk capital that insurers have been forced to allocate to underwrite this risk and have made them more reluctant to provide this coverage unless they are able to raise premiums sufficiently to reflect these additional costs.

In March 2006, Standard and Poor's, another rating agency, indicated that it would revise criteria for measuring cat risk which has traditionally been based on premium charges. But the new criteria will measure catastrophe risk based on exposure of the insurer. This will include an exposure-based capital charge for insurers similar to what it does for reinsurers based on net expected annual aggregate property losses for all perils at 1-in-250 year return period. There will be a 6–12 month phase period to allow companies to adjust risk profiles [13].

2.5 Role of Market State Regulation

In the United States, insurance is regulated at the state level with the principal authority residing with insurance commissioners. Primary insurers are subject to solvency regulation and rate and policy form regulation, whereas domestic reinsurers are subject only to solvency regulation (the price and terms of reinsurance transactions are not subject to regulation). Solvency regulation addresses the question as to whether the insurer or reinsurer is sufficiently capitalized to fulfill its obligations if a significant event occurs and inflicts major losses on its policyholders.

Insurance commissioners regard solvency as a principal objective even if it means requiring higher premiums or other insurer adjustments (e.g. reducing their catastrophe exposures). On the other hand, insurance regulators face political pressure to keep insurance premiums "affordable" and coverage readily available. In balancing solvency and consumer protection goals, insurance regulators are required by state laws to ensure that rates are adequate but not excessive and not unfairly discriminatory. Regulators' assessment of insurers' rates and other practices involves some degree of subjectivity that can result in rate restrictions that reduce the supply of insurance or cause other market problems and distortions. "Parameter uncertainty" and different opinions on the level of risk of loss can lead to disagreements between insurers and regulators over what constitutes adequate rates and appropriate underwriting practices.[7]

State legislatures, governors, and the courts also play a significant role in the regulation of insurers and insurance markets. Consequently, insurance regulators are subject to a number of constraints on their authority and discretion and the other branches of state government may impose their preferences on how state laws, regulations, and policies govern insurers and insurance markets. Ultimately, all elected officials and their appointees are subject to the will of the voters—if government officials act contrary to the preferences of voters, they are subject to being replaced by people who will obey the voters, even if their actions are economically unsound.

[7] See [14–16] for more detailed discussions of insurance regulatory policies in general and specific to natural disaster risk.

3 US FEDERAL AND STATE CATASTROPHE PROGRAMS

We now turn to the important role that the federal and state governments in the United States play in supplementing or replacing private insurance with respect to natural disasters, nuclear accidents, and other catastrophic losses. This section provides a brief overview of several of these programs to illustrate the types of public–private partnerships that have been implemented in the past.

3.1 Flood and Hurricane Insurance

3.1.1 Flood Insurers have experimented over the years with providing protection against water damage from floods, hurricanes, and other storms. After the severe Mississippi Floods of 1927, they concluded that the risk was too great, and refused to provide private insurance again. As a result, Congress created the NFIP in 1968, whereby homeowners and businesses could purchase coverage for water damage. Private insurers market flood policies, and the premiums are deposited in a federally operated Flood Insurance Fund, which is then responsible for paying claims. The stipulation for this financial protection is that the local community makes a commitment to regulate the location and design of future floodplain construction to increase safety from flood hazards. The federal government established a series of building and development standards for floodplain construction to serve as minimum requirements for participation in the program. The creation of the Community Rating System in 1990 has linked mitigation measures with the price of insurance in a systematic way [17].

The number of claims paid by the NFIP differs from year to year, but between 1980 and 2002 was never higher than 62,400, which was the count in 1995. The severity of flood losses from the 2004 hurricane season led to 75,000 claims, a new record in the history of the program. The breach in the New Orleans levees from Hurricane Katrina coupled with the flood losses from Hurricanes Katrina, Rita, and Wilma triggered some 239,000 claims with the NFIP in 2005, 80% of which were from Hurricane Katrina. It is estimated that the NFIP will pay in excess of $23 billion in flood claims for the 2005 hurricane season, the equivalent of 10 years of premiums. This raises major questions regarding the future of the program. Two bills are currently being discussed in Congress as to how modify its operation so it fits better with this new loss dimension.

3.1.2 Hurricane Insurance The need for hurricane insurance is most pronounced in the state of Florida. Following Hurricane Andrew in 1992, nine property-casualty insurance companies became insolvent, forcing other insurers to cover these losses under Florida's State Guaranty Fund. Property insurance became more difficult to obtain as many insurers reduced their concentrations of insured property in coastal areas. During a special session of the Florida State Legislature in 1993 the Florida Hurricane Catastrophe Fund (FHCF) was created to relieve pressure on insurers to reduce their exposures to hurricane losses. The FHCF, a tax-exempt trust fund administered by the State of Florida, is financed by premiums paid by insurers that write policies on personal and commercial residential properties. The fund reimburses a portion of insurers' losses following major hurricanes (above the insurer's retention level) and enables insurers to remain solvent [10]. The four hurricanes that hit Florida in the fall of caused an estimated $29 billion in insured losses, with only about $2.6 billion paid out by the fund. Each hurricane was considered a distinct event, so that retention levels were applied to each storm before insurers could turn to the FHCF.

As this article goes to press, the future of hurricane and flood insurance in the United States is being analyzed as part of a research initiative between the Wharton School, Georgia State University, and the Insurance Information Institute, in partnership with over 15 insurers and reinsurers, trade associations, and federal agencies.

3.2 Earthquake Insurance

The history of earthquake activity in California convinced legislators that this risk was too great to be left in the hands of private insurers alone. In 1985, a California law required insurers writing homeowners coverage on one to four unit residential buildings to also offer earthquake coverage. Since rates were regulated by the state, insurers felt they were forced to offer coverage against older structures in poor condition, with rates not necessarily reflecting the risk. Following the 1994 Northridge earthquake, huge losses on insured property created a surge in demand for coverage. Insurers were concerned that if they satisfied the entire demand, as they were required to do by the 1985 law, they would face an unacceptable level of risk and become insolvent following the next major earthquake. Hence, many firms decided to stop offering coverage or restricted the sale of homeowners' policies in California.

In order to keep earthquake insurance alive in California, the State legislature authorized the formation of the California Earthquake Authority (CEA) in 1996. The CEA is a state-run insurance company that provides earthquake coverage to homeowners. The innovative feature of this financing plan is the ability to pay for a large earthquake while committing relatively few dollars up front. There is an initial assessment of insurers of $1 billion to start the program and then contingent assessments to the insurance industry and reinsurers following a severe earthquake. Policyholders absorb the first portion of an earthquake through a 15% deductible on their policies [18]. However, 8 years after the creation of the CEA, the take-up rate for homeowners is about 15%, down from 30% when the California State Legislature created the CEA [19]. It is questionable how effective this program will be in covering losses should a major earthquake occur in California.

3.3 Nuclear Accident Insurance[8]

The Price-Anderson Act, originally enacted by Congress in 1957, limits the liability of the nuclear industry in the event of a nuclear accident in the United States. At the same time, it provides a ready source of funds to compensate potential accident victims, which would not ordinarily be available in the absence of this legislation. The Act covers large power reactors, small research and test reactors, fuel reprocessing plants, and enrichment facilities for incidents that occur through plant operation as well as transportation and storage of nuclear fuel and radioactive wastes.

Price-Anderson sets up two tiers of insurance. Each utility is required to maintain the maximum amount of coverage available from the private insurance industry—currently $300 million per site. In the United States, this coverage is written by the American Nuclear Insurers, a joint underwriting association or "pool" of insurance companies. If claims following an accident exceed that primary layer of insurance, all nuclear operators are obligated to pay up to $100.59 million for each reactor they operate payable at the

[8]For more details on nuclear accident insurance see Nuclear Energy Institute "Price-Anderson Act Provides Effective Nuclear Insurance at No Cost to the Public", February 2005.

rate of $10 million per reactor, per year. As of February 2005, the US public had more than $10 billion of insurance protection in the event of a nuclear reactor incident. More than $200 million has been paid in claims and costs of litigation since the Price-Anderson Act went into effect, all of it by the insurance pools. Of this amount, approximately $71 million has been paid in claims and costs of litigation related to the 1979 accident at Three Mile Island.

In February 2003, Congress extended the law for power reactors licensed by the Nuclear Regulatory Commission (NRC) to the end of 2003.[9] Coverage for facilities operated by the Department of Energy has been extended until the end of 2006 in a separate legislative action. Congress is now considering further extension of the law as part of comprehensive energy legislation.

3.4 Federal Aviation Administration Third Party Liability Insurance Program

Since the terrorist attacks of September 11, 2001, the US commercial aviation industry can purchase insurance for third party liability arising out of aviation terrorism. The current mechanism operates as a pure government program, with premiums paid by airlines into the Aviation Insurance Revolving Fund managed by the Federal Aviation Administration (FAA).

As the program carries a liability limit of only $100 million, losses paid by government sources in the event of an attack will almost surely exceed those available through the current insurance regime. In that case, either the government would need to appropriate additional disaster assistance funds as it did in the aftermath of September 11th, or victims would be forced to rely on traditional sources of assistance [20].

3.5 International Terrorism Risk Insurance Program (TRIA)

Although the United States has been successful since 9/11 in preventing terrorist attacks on its own soil, the impact on the economy of another mega-attack or series of coordinated attacks will cause serious concerns to the government, the private sector and citizenry ([21, 22]). With security reinforced around federal buildings, the commercial sector constitutes a softer target for terrorist groups to inflict mass casualties and stress on the nation. These threats require that the country as a whole develops strategies to prepare for and recover from a (mega-)terrorist attack. Insurance is an important policy tool for consideration in this regard.

Quite surprisingly, even after the terrorist attack on the World Trade Center in 1993 and the Oklahoma City bombing in 1995, insurers in the United States did not view either international or domestic terrorism as a risk that should be explicitly considered when pricing their commercial insurance policy, principally because losses from terrorism had historically been small and, to a large degree, uncorrelated. Thus, prior to September 11, 2001, terrorism coverage in the United States was an unnamed peril included in most standard all-risk commercial and homeowners' policies covering damage to property and contents.

The terrorist attacks of September 11, 2001, killed over 3000 people from over 90 countries and inflicted insured losses currently estimated at $32.5 billion that was shared

[9] Although the existing law has technically expired, its provisions are "grandfathered" and continue to apply to all existing NRC licensees, that is to say, to power reactor operators with operating licenses issued prior to the expiration date. Personal Correspondence with John Quattrocchi July 21, 2005.

by nearly 150 insurers and reinsurers worldwide. Reinsurers (most of them European) were financially responsible for the bulk of these losses. These reinsurance payments came in the wake of outlays triggered by a series of catastrophic natural disasters over the past decade and portfolio losses due to stock market declines. Having their capital base severely hit, most reinsurers decided to reduce their terrorism coverage drastically or even to stop covering this risk.

In response to such concerns, the Terrorism Risk Insurance Act (TRIA) of 2002 was passed by Congress and signed into law by President Bush on November 26, 2002.[10] It constitutes a temporary measure to increase the availability of risk coverage for terrorist acts.[23] TRIA is based on risk sharing between the insurance industry, all policyholders (whether or not they have purchased terrorism insurance) and the federal government (taxpayers) up to $100 billion of insured losses on US soil. President Bush signed into law a 2-year extension of TRIA on December 22, 2005, the Terrorism Risk Insurance Extension Act (TRIEA) that expanded the private sector role and reduced the federal share of compensation for terrorism insured losses. Since TRIA was passed prices have stabilized in most industries and take-up rate continuously increased. Today, over 60% of large commercial firms have some type of terrorism insurance coverage.[24] As we write this article in January 2007, it is unclear what type of long-term terrorism insurance program, if any, will emerge at the end of 2007 for dealing with the economic and social consequences of terrorist attacks.

4 CONCLUDING REMARKS

The past 5 years have demonstrated that the United States can suffer today catastrophic losses from disasters that far exceed those from events that occurred prior to 2000. Insurance has played a critical role in the recovery process, but these recent catastrophes have raised questions as to under which conditions the private sector can continue to provide coverage (and will want to) and the role that the public sector should play in dealing with these events. One limiting factor of the programs we discussed in this article is that the premiums they charge are often not based on risk, reducing the economic incentive to invest in cost-effective mitigation measures. Implementing reforms that will have premiums based on risk is certainly one way to start.

Also, so far, the country has responded by developing specific programs for each type of catastrophes. Whether this is the best way to go remains an open question. Other countries have developed some coverage that protects homeowners and businesses against all types of disasters: wind, flood, terrorist attacks, and so on [25]. This idea has been proposed for the United States many years ago [26] and has been resurrected following Hurricane Katrina[11]. Whether a risk-based all-hazard disaster insurance is now more appropriate given the events of the past 5 years is an issue for the new US Congress to study in more detail.

[10]The complete version of the Act can be downloaded at: http://www.treas.gov/offices/domestic-finance/financial-institution/terrorism-insurance/claims process/program.shtml.
[11]For a more detailed discussion of this proposal see [27].

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