Insuring Against Catastrophes

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Insuring Against Catastrophes[1]

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1. Introduction

The terrorist attacks of 9/11 and the hurricanes in the Gulf Coast have raised a number of questions regarding the role that insurance can or should play in providing protection against catastrophic risks. This chapter focuses on the role that information about potential adverse events plays in both the supply and demand for insurance where there is considerable uncertainty regarding the likelihood of the event occurring and the resulting consequences. Our focus will be on how insurers and those at risk react to events which can cause catastrophic losses to them.

Natural hazards are an example of a known risk (K) which have the potential of causing catastrophic losses to insurers and where there is considerable data to estimate the likelihood and consequences of these events for those residing in hazard-prone areas. Terrorism illustrates an unknown (u) event which also has the potential to cause severe losses to insurers but where the likelihood of a terrorist attack and its consequences are not well specified because there are limited data available. In neither case is the probability distribution well specified; however, the degree of uncertainty with respect to the risk and the ways to reduce the likelihood and magnitude of future losses differ between the two cases.

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An unknowable (*U*) risk is one where the probability cannot be determined through past data and scientific information, so that individuals are not able to form any beliefs (other than the "insufficient reason" default) about probabilities.[4] Insurers often refuse to cover such risks if they focus their attention on them; however, if they are not on their radar screen, they may fail to exclude them explicitly, and the policyholder may be protected by default. Thus, an insurer might consider excluding a risk such as a war or insurrection because it is difficult to estimate either the premium or its consequences but they might not exclude an event such as an out-of-control sports celebration, in which case the policyholder will be financially protected against damages caused by it.

In some situations, there is a fine line that one can draw between an unknowable and unknown risk. With respect to the events of 9/11, to our knowledge there was not an insurer or reinsurer in the world who had conceived of the possibility that a plane crashing into the World Trade Center could cause the structure to collapse. In this sense, such a risk would be considered unknowable. However, by writing contracts that promised coverage for perils not excluded, insurers were agreeing to provide coverage against losses from unknowable events, for at least the first time they occur—after which they presumably become knowable, and then may be explicitly priced or explicitly included or excluded from coverage. This seems to be what happened with the type of terrorism risk associated with 9/11.

This paper will focus on known (*K)* and unknown risks (*u)* facing insurers using natural hazards and terrorism as illustrative examples of these two cases. With respect to natural disasters, Hurricane Katrina is the most costly disaster in the history of the insurance industry to date, with total claims at $46.3 billion. The previous year's Hurricanes Charley, Frances, Ivan and Jeanne that hit Florida in the fall of 2004 produced a combined total loss of $29 billion. Each of these disasters was among the top 20 most costly insurance losses in the world from 1970-2008 (Kunreuther and Michel-Kerjan, 2009).

Regarding terrorism, the attacks of September 11, 2001 killed over 3,000 people from more than 90 countries and injured about 2,250 others. These attacks inflicted damage estimated at nearly $80 billion, approximately $32.4 billion of which was

[4] This case is termed complete ignorance by Camerer and Weber (1992) in their classification of risks.

covered by about 120 insurers and reinsurers. Of the total insured losses, those associated with property damage and business interruption are estimated at $22.1 billion (Wharton Risk Center, 2005). The insured losses from 9/11 illustrate the high degree of risk correlation between different lines of insurance coverage. Indeed, these attacks not only affected commercial property and caused business interruption, but also led to significant claims from other lines of coverage: workers' compensation, life, health, disability and general liability insurance.

This paper proceeds as follows. The next section examines conditions of insurability so that one can better understand why it is difficult to insure catastrophic events in general, and why some pose more severe and longer-lasting problems than others. Section 3 shows how catastrophic losses from hurricanes, earthquakes, floods and terrorism have impacted insurers' willingness to provide coverage against these risks. Section 4 examines the demand for coverage against these risks so that one has a better understanding as to the challenges in providing protection against catastrophic losses. Section 5 then examines the types of private-public partnerships for reducing losses and providing protection against low-probability, high-consequence events. The concluding section suggests future research in this area.

2. Factors Influencing the Supply of Insurance

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 a 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 on a set of identical homes each valued at $100,000. Based on past data, the insurer estimates there is a 1/1000 chance that a home will be destroyed by fire. Assuming this is the only event that can occur during the year, the expected annual loss for each home would be $100 (i.e. 1/1000 x $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. As the number of policies issued, *n*, increases, the variance of the expected annual loss per exposure, 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 $n = 1{,}000$ the variance is $0.10. It is thus not necessary to issue a very large number of policies to significantly reduce 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 since the assumptions of independence and ability to estimate probabilities and losses are satisfied. Risks that can cause catastrophic losses normally do not satisfy the above conditions, so they are more difficult to insure.

Before insurance providers are willing to offer coverage against an uncertain event at premiums anywhere close to the risk of loss they expect, 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. (An unreasonable premium for a buyer here would be one that is very close to the maximum value of the loss the buyer might experience.) 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 mdels.

Catastrophe models were introduced in the mid-1980s but did not gain widespread attention until after Hurricane Andrew hit southern Florida in August, 1992 causing insured losses of over $23.7 billion (in 2007 prices) (Kunreuther and Michel-Kerjan, 2009). 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 felt that they needed to estimate and manage their natural hazard risk more precisely, and turned to the modelers of catastrophe risks for decision support. Obviously, the data they had before the event was insufficient to protect them.

Use of Exceedance Probability Curves[5]

Based on the outputs of a catastrophe model, the insurer can construct an exceedance probability (EP) curve that specifies the probabilities that a certain level of total 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 residential earthquake policies in Long Beach, California. 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. Based on these estimates, one can construct the EP curve depicted in Figure 1. Suppose the insurer focuses on a specific loss L_i. One can see from Figure 1 that the likelihood that insured losses will exceed L_i is given by p_i. The *x-axis* measures the loss to the insurer in dollars and the *y-axis* depicts the probability that losses will exceed a particular level.

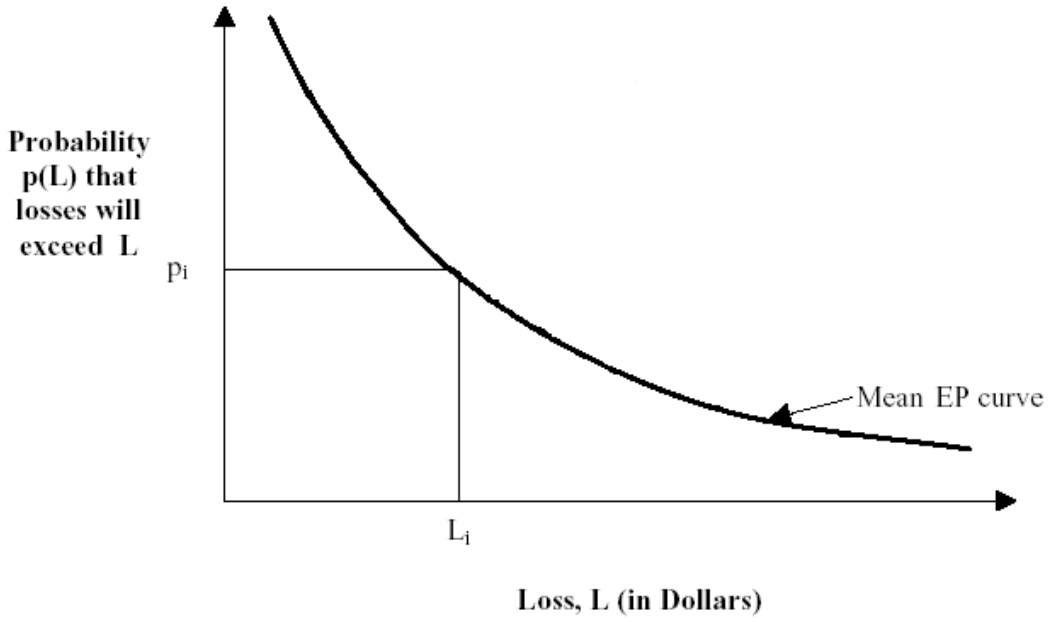

Figure 1: Example of an Exceedance Probability Curve

[5] The material in this subsection draws on chapter 2 in Grossi and Kunreuther (2005).

One can also incorporate uncertainty in the analysis by constructing confidence intervals around the mean EP curve as shown in Figure 2. The curve depicting the uncertainty in the loss shows the range of values, $L_i^{.05}$ and $L_i^{.95}$ that losses can take for a given mean value, L_i , so that there is a 95 percent chance that the loss will be exceeded with probability p_i. To illustrate, suppose that experts were asked to estimate a 95 percent confidence interval characterizing the losses from a hurricane hitting New Orleans with probability p_i. Their analysis might reveal that $L_i^{.05}$ = \$40 billion and $L_i^{.95}$ = \$200 billion with L_i. = \$90 billion. In a similar vein, one can determine the range of probabilities, $p_i^{.05}$ and $p_i^{.95}$ so that there is 95 percent certainty that losses will exceed L_i. Using the above illustrative example, experts might conclude that $p_i^{.05}$ = 1/5,000 and $p_i^{.95}$ = 1/300 that a hurricane would hit New Orleans where damage would exceed L_i = \$90 billion.

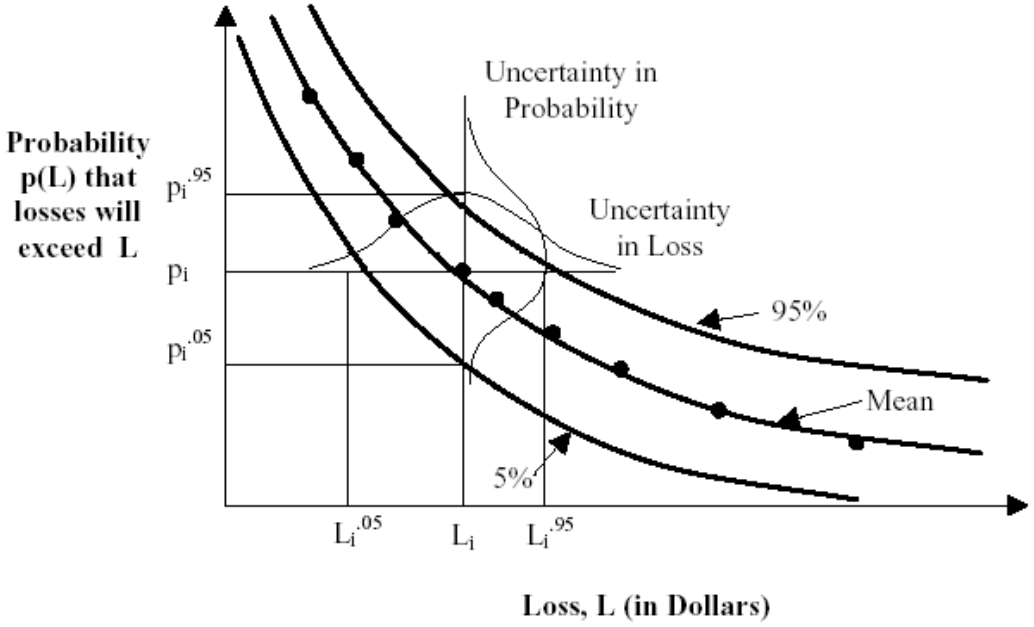

Figure 2: Confidence Intervals for a Mean Exceedance Probability (EP) Curve

It is much easier to construct an EP curve for natural disasters than it is for terrorist activities. But even for these more predictable events, there may be considerable uncertainty regarding both the likelihood of their occurrence and the resulting damage. For low-probability, high-consequence risks, the spread between the three curves depicted in Figure 2 shows the degree of indeterminacy of these events. Providing

information on the degree of uncertainty associated with risk assessments should increase the credibility of the experts producing these figures. The uncertainty arises largely from the experts' lack of confidence in the models they used to generate the curve. If they feel very uncertain about the models, the confidence interval will be large.

Insurability Conditions

Consider a standard insurance policy where premiums are paid at the start of a given time period to cover losses during this interval. Two conditions must be met before insurance providers are willing to offer coverage at reasonable premiums against an uncertain event. One must first be able to identify and quantify, or estimate at least partially, the chances of the event occurring and the extent of losses likely to be incurred. Such estimates can be based on past data or catastrophe loss modeling, coupled with data on what experts know about a particular risk. For example, the data might tell us that experts know almost nothing about this particular risk, but that they know a great deal about some other risks. The insurer can then construct an exceedance probability (EP) curve that depicts the probability that a certain level of loss will be exceeded on an annual basis.[6] The second condition is the ability to set different premiums for each potential customer or class of customers facing different probabilities of suffering a loss and/or the magnitude of that loss.

If both conditions are satisfied, a risk is considered to be insurable. But it still may not be insured (even if it is theoretically insurable) because it is not profitable to do so. In other words, it may be impossible to specify a rate at which some customers will buy insurance for which there is sufficient demand and incoming revenue to cover the development, marketing, operating and claims processing costs of the insurance and yield a net positive profit over a prespecified time horizon. In such cases, the insurer will opt not to offer coverage against this insurable risk.

[6] It is not necessary to have a precise estimate of the probability for a risk to be covered by insurance (Eeckhoudt and Gollier, 1999). For example, the first U.S. satellite launch (Explorer I in 1958) was covered despite the lack of historical data and the difficulty of calculating the risk of failure (Doherty, 1987).

Determining Whether to Provide Coverage

In his study on insurers' decision rules as to when they would market coverage for a specific risk, Stone (1973) develops a model whereby firms maximize expected profits subject to satisfying a constraint related to the survival probability of the firm.[7] Even if insurance against a particular risk is assumed to yield a positive expected profit, the insurer will decide not to add this coverage to its portfolio if by doing so the *survival constraint* is violated.[8]

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 is affected by the tradeoff between the expected benefits of another policy and the costs to the insurer of a catastrophic loss that reduces its surplus by L^* or more. This threshold probability does not necessarily bear any relationship to what would be efficient for society or what would prevail in capital markets. The value of L^* is determined by concerns with insolvency and/or a sufficiently large loss in surplus, perhaps based on the fear that the insurer's credit rating will be downgraded, making it more costly for the insurer to raise capital in the future.

A simple example illustrates the method by which an insurer that pays attention to its survival constraint would determine whether a particular portfolio of risks is insurable with respect to hurricanes. Assume that all homes in a hurricane-prone area are equally resistant to damage so that the insurance premium, z, is the same for each structure. Furthermore, assume that an insurer has A 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:

$$\text{Probability [Claims Payments } (L^*) > (n \cdot z + A)] < p_1 \qquad (1)$$

[7] Stone also introduces a constraint regarding the stability of the insurer's operation. However, insurers have traditionally not focused on this constraint in dealing with catastrophic risks.

[8] The survival constraint is rather similar to the concept of Value at Risk (VaR), widely used in the risk management of banks and insurance companies. The VaR is a tolerance level set on the possible loss of capital. For example, a VaR of $100 million at the 1% level means that there is a 99% certainty that the capital loss will not exceed $100 million.

The insurer will use the survival constraint to determine the maximum number of policies (*n**) it is willing to offer. It can also make an adjustment in premiums and/or a transfer of some of the risk to others in the private sector (e.g., reinsurers or capital markets) or rely on state or federal programs to cover catastrophic losses. It will still offer coverage against this risk only if (*n**) yields a positive expected profit.

Following the series of natural disasters that occurred at the end of the 1980s and in the 1990s, insurers may have focused on the survival constraint given by equation (1) to determine the amount of catastrophe coverage they were willing to provide. 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 the likelihood of a large loss that might threaten their current standing.

Setting Premiums

For an insurer to want to offer coverage against a particular risk it needs to determine a premium that yields a positive expected profit and avoids an unacceptable probability and level of loss. State regulations often limit insurers in their rate-setting process, and competition can play a role in what may be charged in a given marketplace. Even in the absence of these influences, there are two other issues that an insurer considers in setting premiums for catastrophic losses: uncertainty in loss and highly correlated risks.[9]

Uncertainty in Loss Catastrophic risks pose a set of challenging problems for insurers because they involve potentially high losses that are extremely uncertain. Figure 3 illustrates the total number of loss events from 1950 to 2000 in the United States for three prevalent natural hazards: earthquakes, hurricanes and floods. Events were selected that had at least $1 billion of economic damage and/or over 50 deaths.

[9] There are two other problems insurers face with respect to setting premiums with respect to risks: adverse selection and moral hazard. Neither appears to be a major problem with respect to catastrophic risks such as natural disasters. Adverse selection occurs when the insurer cannot distinguish (or does not discriminate through price) between the probabilities of a loss for different categories of risk, while the insured, possessing information unknown to the insurer, selects a price/coverage option more favorable to the insured. Moral hazard refers to an increase in the probability of loss caused by the behavior of the policyholder.

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. The 2004 and 2005 seasons have already dramatically changed the upper limits in Figure 3. Hurricane Katrina is estimated to have caused between $150 billion and $170 billion in economic losses, more than four times that of the most costly hurricane between 1950 and 2000. Given this wide variation in loss distribution, it is not surprising that there is a need for catastrophe models to aid insurers and reinsurers in estimating their potential claims from events that have not yet occurred but are scientifically credible.

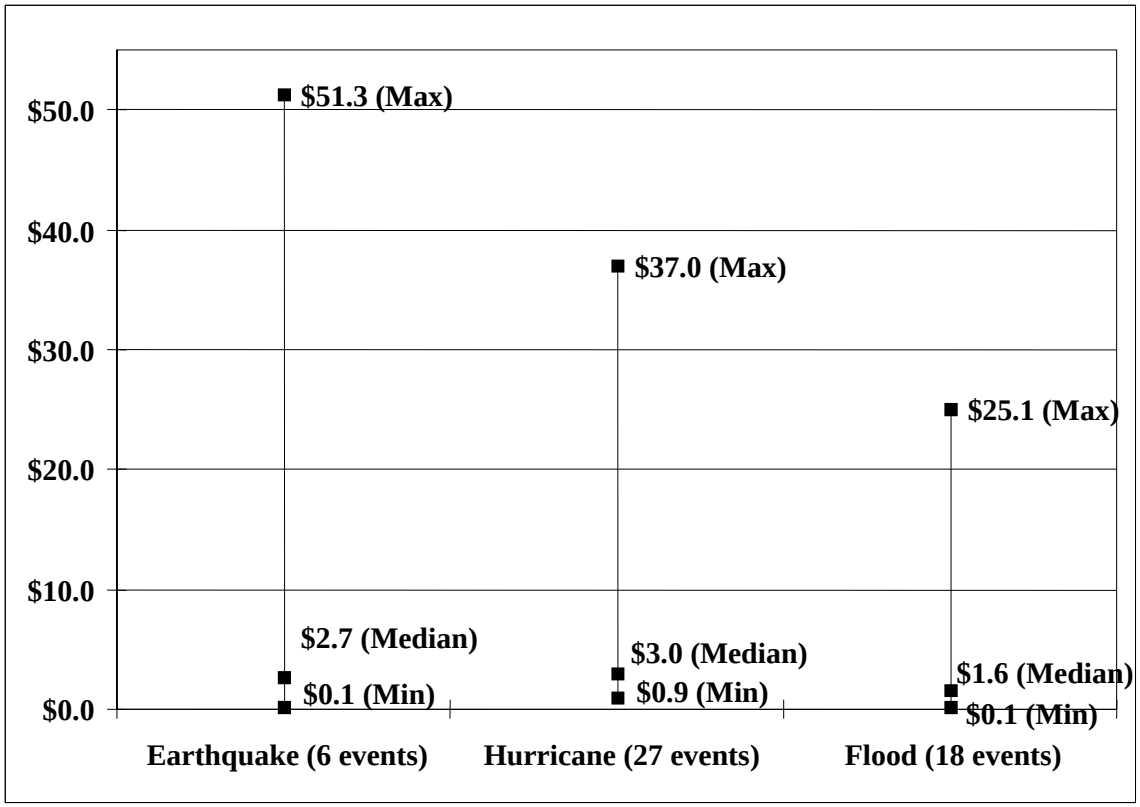

Figure 3: Historical economic losses in $ millions versus type of significant U.S. natural disaster 1950-2000

(Source: American Re 2002)

Highly Correlated Risks Catastrophic risks involve spatially correlated losses or the simultaneous occurrence of many losses from a single natural disaster event. For example, a major hurricane or earthquake can cause damage to many properties in a relatively small geographic area. If an insurer sells a block of residential policies in a neighborhood, it could potentially experience a large (spatially correlated) total loss should a disaster occur in the region.

The possibility of catastrophic losses due to high correlation of risks requires insurers to be highly capitalized to deal with the tail risk implied by equation (1). In particular, the prices charged for catastrophe insurance must be sufficient to cover the expected claims costs and other expenses, but also must cover the costs of allocating risk capital to underwrite this risk. Moreover, because the levels of risk capital needed to underwrite catastrophe risk are usually high relative to the expected liability, the capital cost built into the premium is high, often dominating the expected loss claim cost. Thus, insurers usually need to set prices that are high relative to the loss expenses, simply to earn a normal rate of return on equity and thereby maintain their credit rating (Merton and Perold, 1993).

3. Role of Catastrophic Losses on Supply of Insurance

There is considerable empirical evidence that, following a catastrophic disaster, insurers who suffered large losses are reluctant to continue providing coverage. In theory, one should treat these events as outcomes in the tail of a distribution of possible losses that require the insurer to replenish its surplus by going to the capital market for funds. In practice it is not so easy for insurers to raise large amounts of capital following a large-scale realized loss, presumably because the possibility of a similar event occurring in the future makes many investors reluctant to provide capital. Insurers have faced such difficulties following large-scale losses from natural disasters and the terrorist attacks of 9/11.

Empirical Evidence from Natural Disasters

Insurers provided coverage against earthquakes, hurricanes and floods without any public sector involvement until they suffered severe losses from major disasters. In

the case of earthquakes, the Northridge, CA earthquake of January 1994 caused $18.5 billion in private insured losses while stimulating considerable demand for coverage by residents in earthquake-prone areas of California. Insurers in the state stopped selling new homeowners' policies because they were required by state regulations to offer earthquake coverage to those who demanded it. This led to the formation of the California Earthquake Authority (CEA) in 1996 which raised the deductible from 10 percent to 15 percent and limited the losses that insurers can suffer from a future earthquake (Roth, 1998).

Flood insurance was first offered in 1897 by a newly established stock company in Cairo, Illinois but was discontinued in 1899 when flooding from the Mississippi and Missouri Rivers completely wiped out the home office. It was not offered again until the mid 1920s when thirty American fire insurance companies issued flood coverage and were congratulated by the American insurance magazines on having placed this coverage on a sound basis. However, the losses experienced by insurers following the 1927 Mississippi floods and severe flooding in the following year led all companies to discontinue coverage by the end of 1928 (Manes, 1938). Few private companies offered flood insurance over the next forty years.

In 1968, Congress created the National Flood Insurance Program (NFIP), making the federal government the primary provider of flood insurance for homeowners and small businesses. Private insurers market coverage and service policies under their own names, retaining a percentage of premiums to cover administrative and marketing costs. Communities that are part of the program are required to adopt land-use regulations and building codes to reduce future flood losses (Pasterick, 1998). Private insurers provide coverage for larger commercial establishments.

Coverage from wind damage is provided under standard homeowners' and commercial insurance policies. Following Hurricane Andrew, some insurers felt that they could not continue to provide coverage against wind damage in hurricane-prone areas in Florida. Many felt that insurance rate regulation would prevent them from charging the high rates that would be required to continue writing coverage with a positive expected profit. Insurers who wrote sizeable amounts of coverage in Florida were also concerned about experiencing catastrophic losses following the next hurricane to make landfall in

the area. For example, State Farm and Allstate Insurance paid $3.6 billion and $2.3 billion in claims respectively in the wake of Hurricane Andrew due to their high concentration of homeowners' policies in the Miami/Dade County area of Florida. Both companies and other insurers began to reassess their strategies of providing coverage against wind damage in hurricane-prone areas (Lecomte and Gahagan, 1998).

This concern led to the formation of the Florida Hurricane Catastrophe Fund (FHCF) in November 1993 which reimburses a portion of insurers' losses following major hurricanes (Lecomte and Gahagan 1998). The FHCF is a state-run catastrophe reinsurance program, and participation is mandatory for every residential property insurer writing covered policies in the state of Florida. The purpose of the fund is to improve the availability and affordability of property insurance in Florida by providing reimbursements to insurers for a portion of their catastrophic hurricane losses. Each company is required to pay a premium into the fund based on its hurricane exposure.

In 2004, the total claims-paying capacity of the fund was expanded from $11 billion to $15 billion and increased to $27 billion in 2007 for a "temporary" period of three years. Losses associated with the 2004 and 2005 hurricane seasons left the FHCF with payment obligations of $8.45 billion. These loss payouts led to a funding shortfall that in turn led the FHCF to issue $1.35 billion in revenue bonds to cover the shortfall and $2.8 billion in pre-even notes to provide liquidity for the 2006 storm season (Florida Hurricane Catastrophe Fund, 2007).

Provision of Terrorism Insurance

Prior to September 11, 2001, terrorism exclusions in commercial property and casualty policies in the U.S. insurance market were extremely rare (outside of ocean marine), presumably because losses from terrorism had historically been small and, to a large degree, uncorrelated. Attacks of a domestic origin were isolated, carried out by groups or individuals with disparate agendas. Thus the United States did not face a concerted domestic terrorism threat, as did countries such as France, Israel, Spain and the UK.

In fact, insurance losses from terrorism were viewed as so improbable that the risk was not explicitly mentioned nor priced in any standard policy and it was never excluded from so-called "all-risk" policies with the exception of some marine cargo, aviation and political risk policies. Even the first attack on the World Trade Center (WTC) in 1993[10] and the Oklahoma City bombing of 1995[11] were not seen as being threatening enough for insurers to consider revising their view of terrorism as a peril worth considering when pricing a commercial insurance policy. Since insurers and reinsurers felt that the likelihood of a major terrorist loss was below their threshold level of concern, they did not pay close attention to their potential losses from terrorism in the United States (Kunreuther and Pauly, 2005).

Following the terrorist attacks of 9/11, insurers warned that another event of comparable magnitude could seriously strain the capacity of the industry (U.S. GAO, 2005). Furthermore, they contended that the uncertainties surrounding large-scale terrorism risk were so significant that the risk was uninsurable by the private sector alone. As a result, many insurers excluded terrorism damages from their "all causes" commercial policies. Those firms demanding insurance protection against such losses were forced to purchase a policy that added terrorism as a specific cause. They often had difficulty finding an insurer offering such coverage at a premium they were willing to pay, and sometimes could not find a seller who was willing to provide terrorism insurance at any price.

When coverage was offered, the prices were likely to increase significantly over what they were prior to 9/11 and coverage limits were reduced. For example, prior to 9/11, Chicago's O'Hare airport had $750 million of terrorism insurance coverage at an annual premium of $125,000. After the terrorist attacks, insurers offered the airport only $150 million of coverage at an annual premium of $6.9 million. The airport purchased this insurance as it was required to have insurance in order to operate (Jaffee and Russell, 2003). Golden Gate Park in San Francisco, CA was unable to obtain terrorism coverage

[10]The 1993 bombing of the WTC killed 6 people and caused $725 million in insured damages. See Swiss Re (2002).

[11] Prior to September 11, the Oklahoma City bombing of 1995, which killed 168 people, had been the most damaging terrorist attack on domestic soil, but the largest losses were to federal property and employees and were covered by the government.

and its non-terrorism coverage was reduced from $125 million to $25 million. Yet the premiums for this reduced amount of protection increased from $500,000 in 2001 to $1.1 million in 2002 (Smetters, 2004).

The paradox is this: before 9/11, coverage against losses due to terrorism was indeed provided by insurers in the predominant "all perils" policy form, at apparently nominal additional premiums. There was also little or no attention given by regulators to the impact that a terrorist loss would have on insurer reserves or viability. Six months after the terrorist attacks of September 11, forty-five states permitted insurance companies to exclude terrorism from their coverage, except for two types of coverage: workers' compensation insurance policies where occupational injuries are covered without regard to the peril that caused the injury, and fire policies in states that have a law where losses from fire are covered no matter what the cause.[12] The price of coverage for the few insurers that continued to offer terrorism protection went from almost zero to a very high level.

What accounts for this enormous shift? The most plausible explanation is that the events of 9/11 greatly increased insurer uncertainty about terrorism losses in additional to increasing the expected value. As described earlier, greater uncertainty leads to higher premiums, at least for a time. Terrorism also has features that make estimating the likelihood of catastrophic events more challenging than for other low-probability, high-consequence risks. In contrast to natural disasters, where the likelihood of an event is determined by natural forces, terrorists are likely to determine what actions to take based on what their adversaries are doing to protect themselves.

This harder private market led to a call for some type of federal intervention (U.S. Congress Joint Economic Committee, 2002). At the end of 2002, Congress passed the Terrorism Risk Insurance Act (TRIA) as a temporary measure to increase the availability of risk coverage for terrorist acts (U.S. Congress 2002b). TRIA is based on risk sharing between the insurance industry and the federal government. The Act expired on

[12] See Section 5 for more details on the nature of workers' compensation insurance and fire policies as they relate to terrorism losses.

December 31, 2005, was renewed in a modified form for another two years, and then extended for another seven years in December 2007.

Under TRIA, with its requirement that insurers offer coverage to commercial firms, sufficient insurance coverage is available today at moderate cost for commercial and residential properties in most of the country where the threat of a terrorist attack is not viewed as extremely high, and/or where the resulting damage is not anticipated to be major. The principal problems related to demand remain for large metropolitan areas where insurers must manage their concentrations of risk so as not to expose their firm to a ruinous financial loss. Due to the unknown probabilities of terrorism losses, insurers determine the extent of coverage that they are willing to offer by determining their aggregate exposure under an assumed scenario (e.g., an explosion of a 5-ton truck bomb in New York City) that will not exceed a certain percentage of its policyholders' surplus.

4. Demand for Insurance Protection

Individuals faced with the possibility of a catastrophic loss tend to ignore the event until after it occurs, at which point they are extremely interested in protecting themselves. This section discusses key factors that are important to homeowners in hazard-prone areas in deciding whether to purchase insurance and then develops a sequential model of choice to explain their behavior. Empirical evidence is presented in support of such a model from studies of homeowners' behavior with respect to natural disasters. We then turn to why firms might not purchase terrorism insurance and provide supporting evidence from surveys of firms following 9/11.

Determining Whether to Insure Your Home Against Natural Disasters

Most residents in hazard-prone areas have limited probabilistic knowledge of the hazard. There is considerable evidence from field studies and controlled experiments that prior to a catastrophe, individuals underestimate the chances of such a disaster occurring. In fact, many potential victims perceive the costs of getting information about the hazard and costs of protection to be so high relative to the expected benefits that they do not obtain such information, and therefore do not consider investing in loss reduction measures or purchasing insurance (Kunreuther and Pauly, 2004).

This reluctance to voluntarily invest in protection may be compounded by perceived short-term *budget constraints*. For lower-income individuals, insurance is considered a discretionary expense that should be incurred only if they have money left over after taking care of what they consider the necessities of life. In focus groups on the topic, a typical reaction of such a homeowner living in a hazard-prone area to the question "Why don't you have flood or earthquake insurance?" is "I live from pay-day to pay-day," That the homeowner could have purchased a less expensive house and saved enough to cover insurance premiums out of their paycheck is not considered. The above quote thus reflects how people think about insurance, not with the actual constraints on their resources. The riskiness of buying a more costly house than one can afford has, of course, been highlighted by the turmoil in housing markets during the 2008-2009 financial crisis.

Another factor that has been purported to limit homeowners from wanting to purchase insurance is the expectation of liberal disaster assistance following a catastrophic event. Federal disaster assistance creates a type of Samaritan's dilemma: providing assistance *ex post* (after hardship) reduces parties' incentives to manage risk *ex ante* (before hardship occurs).[13] To the extent that parties expect to receive government assistance after a loss – a form of free or low-cost insurance – they might have less incentive to engage in mitigation or buy insurance before a disaster occurs. Because less insurance is purchased, the government's incentive to provide assistance after a disaster is reinforced or amplified.

The empirical evidence on the role of disaster relief suggests that individuals or communities have **not** generally based their decisions on whether or not to invest in mitigation measures by focusing on the expectation of future disaster relief. Kunreuther et al. (1978) found that most homeowners in earthquake and hurricane prone areas did not expect to receive aid from the federal government following a disaster. Burby et al. (1991) found that local governments that received disaster relief undertook more efforts

[13] For more details on the relationship between *ex ante* protective behavior and *ex post* expectations of disaster assistance see Kunreuther, H. et al. (1978); Kaplow, L. (1991); Harrington, S. (2000); Browne, M.J. and Hoyt, R.E. (2000); Ganderton et al. (2000); and Moss, D. (2002)

to reduce losses from future disasters than those that did not. This behavior seems counter-intuitive and the reasons for it are not fully understood.[14]

A Sequential Model of Choice

One possible explanation for the lack of interest in insurance and ignoring the possibility of disaster relief is that individuals utilize a sequential model of choice when dealing with low-probability, high-consequence events. As a first stage in such a process, individuals relate their perceived probability of a disaster (p) to a threshold level of concern (p^*), which they may unconsciously set. If $p < p^*$ they do not even think about the consequences of such a disaster by assuming that the event "will not happen to me." In this case they do not take protective actions. Only if $p > p^*$ will the individual or family consider ways that they can reduce the risk of future financial losses.

The contingent weighting model proposed by Tversky, Sattath and Slovic (1988) provides a useful framework for characterizing individual choice processes with respect to this lack of interest in purchasing insurance voluntarily. In this descriptive model, individuals make tradeoffs between the dimensions associated with alternatives such as probability and outcomes. The weights they put on these dimensions are contingent, because they may vary depending on the problem context and the way information is presented.

The decision to ignore events where $p < p^*$ may be justified if a homeowner claims that there is limited time available to worry about the vicissitudes of life, and a manager focuses on events that constitute a meaningful threat to the firm's operations. Residents and decision makers in firms need some way of determining what risks they should pay attention to. If they perceive the likelihood of some event to be sufficiently low that it is not on their radar screen, then only the occurrence of the disaster will cause the individual to address it seriously.

[14] To our knowledge there is no empirical evidence whether firms take into account the likelihood of receiving federal aid when determining whether or not to invest in protective measures and/or purchase insurance.

Empirical Evidence from Natural Disasters

Data supporting such a sequential model of choice has been provided through homeowners' surveys of insurance purchase decisions in flood, hurricane and earthquake-prone areas undertaken over 25 years ago (Kunreuther et al., 1978). Data from surveys of homeowners in California lend further confirming evidence to such a process. Four mail surveys undertaken since 1989 examine the spatial and demographic characteristics of those homeowners who had purchased earthquake insurance. The findings indicate that insurance purchase is *unrelated* to any measure of seismic risk that is likely to be familiar to homeowners. Rather, past experience plays a key role in insurance purchase decisions (Palm 1990; Palm 1995).

To illustrate, consider the Loma Prieta earthquake of 1989, which caused substantial damage to property in Santa Clara County, and to a lesser extent, Contra Costa County, California. In these counties, there were major differences in responses to the 1989 and 1990 survey. In 1989, prior to the earthquake, about 34 percent of the uninsured respondents in both counties felt that earthquake insurance was unnecessary. One year later, only about 5 percent gave this response. This finding suggests that a disaster causes individuals to think about ways they can protect themselves from the next event and that insurance now becomes an attractive option.

There is also empirical evidence that many homeowners who purchase insurance are likely to cancel policies if they have not made a claim over the course of the next few years (Kunreuther, Sanderson and Vetschera, 1985). In the case of flood insurance, this finding is particularly striking since the NFIP requires that homes located in Special Flood Hazard Areas (SFHAs) purchase insurance as a condition for federally-backed mortgages. To determine the extent to which residents of these areas took advantage of the program, FEMA examined applications for disaster assistance from 1,549 victims of a flood in August 1998 in northern Vermont and found that 84 percent in SFHAs did not have insurance, 45 percent of whom were required to purchase it. A study by *Geotrac* revealed that more than one-third of the properties damaged in a 1999 flood in Grand Forks, North Dakota were non-compliant with the mandatory insurance purchase

requirement (Tobin and Calfee, 2005).[15] With respect to earthquake insurance, eight years after the creation of the California Earthquake Authority (CEA) in 1996, the take-up rate for coverage was down from 30 percent to 15 percent (Risk Management Solutions 2004).

Insurance is thus likely to be treated by many individuals as an investment rather than a protective measure, so that those who purchase coverage and do not collect on their policies over the next few years may feel that their premium payments have been wasted. In the case of flood insurance, this finding also indicates that some banks which were expected to enforce the requirement that individuals in high-hazard areas purchase flood coverage looked the other way.

Why Firms May Not Purchase Terrorism Insurance Voluntarily

The choice not to purchase terrorism insurance may sometimes be considered rational from a corporate risk management perspective. Most large public companies are owned by investors who have diversified portfolios. These investors are unlikely to be severely affected financially if the terrorism loss affects only one or two firms in their holdings. Likewise, large firms own many assets, and they will have low demand for insurance against events that will affect only a small number of those assets. If the premium for insurance is well above their perceived expected loss, it may be cost-effective for them to forego purchasing coverage.

Another reason why firms may not have purchased terrorism insurance is that their managers are not concerned about the risk. There is considerable empirical evidence on managerial decision-making that firms develop simplified decision rules to determine whether or not to undertake certain protective measures (Russo and Schoemaker, 1990). The sequential model of choice discussed above that implies that if the probability of a disaster that will seriously affect the firm financially is below a level of concern, it is not worth worrying about (Camerer and Kunreuther, 1989). Data from a leading brokerage firm (Marsh) from 2007 reveals that four out of ten companies decided not to buy terrorism coverage, either because they think they are not at risk ("it will not happen to

[15] With the passage of the 1994 National Flood Insurance Reform Act lenders who fail to enforce the flood insurance requirement can be fined up to $350. Prior to that time no penalties were imposed.

us") or because they have limited resources to spend on insurance other than standard property coverage, or for both reasons (Michel-Kerjan et al., 2009).

Finally, as elaborated in the work of Kydland and Prescott (1977) for which they received the Nobel Prize in Economics, the federal government cannot credibly commit *ex ante* to refuse to bail out noninsured firms in the aftermath of an attack. If a firm believes that the government will provide financial relief to those in need after another attack, they will have less interest in purchasing insurance coverage than if they were on their own. This *Samaritan's dilemma* arises when society extends assistance to others and by so doing, leads those at risk not to take appropriate *ex ante* actions that would have reduced their need for *ex post* assistance.

Empirical Evidence on Terrorism

There are significant differences across industrial and retail sectors in the degree of diversification of risk across corporate assets and facilities. Figure 4 shows the differences in take-up rates for a sample of Aon accounts in 11 sectors that renewed their terrorism coverage (both TRIA and combined coverage) during the period October 1, 2003 to September 30, 2004. Sectors like entertainment, financial services/real estate and healthcare exhibit high take-up rates, while basic materials, manufacturing and pharmaceutical/chemical sectors exhibit much lower take-up rates.

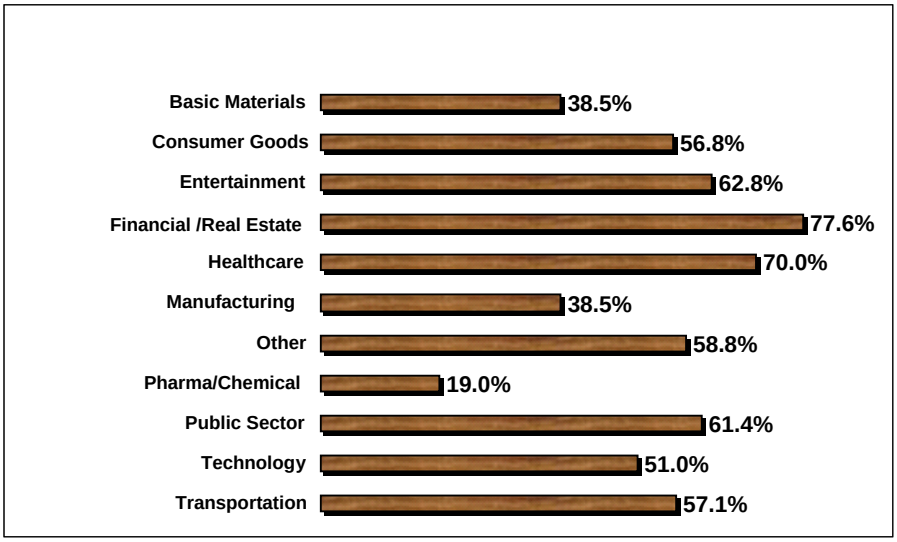

Figure 4: Take-up Rate by Industry
Source: Aon 2004

Corporate demand for insurance depends upon, among other things, the price of the coverage, the degree of risk aversion of firms in the sector, the buyer's expectations of losses, and the level of diversification of risks in a company's portfolio. In addition, other factors influence firms' decision processes, such as perceived responsibility for mitigating and responding to terrorist attacks, interdependencies with other actors, spillover effects from these sectors resulting in indirect losses, and synergies with other risks faced by competitors. For example, we see in Figure 4 that the take-up rate for terrorism coverage among retailers in the consumer goods sector is more than 20 percent lower than for the financial/real estate sector. This is partly because the effects of diversification are more fully recognized in retailing, with its largely dispersed, low-rise structures, than in the real estate sector, which often faces loan covenants by its lenders that require terrorism coverage.

The chemical sector is an interesting case. Given the hazards involved in this sector, one might expect a relatively high demand for terrorism coverage. The problem in the chemical sector is that hundreds of facilities in the U.S. already have non-terrorism worst-case scenarios that could cause death and injury to more than 100,000 people, thus exceeding any reasonable possibility of having private insurance at the corporate level provide coverage for these many possible events. According to the Aon (2004) report, the demand for terrorism insurance in the chemical sector has been minimal, largely because two decades of retrenchment for the larger companies towards self-insurance has already occurred (Aon 2004). This explains the very low take-up rate of 19 percent for the pharma/chemical sector depicted in Figure 4.

In interviews conducted as part of a study (Wharton Risk Center, 2005), larger chemical companies claim that they have "owned" the risk from major accidents, whatever their cause, for some time and can provide cheaper risk-bearing capital to cover these risks than going to a pure outside solution. Some have portfolios of insurance placed with both outside insurers and captives. Smaller chemical companies cannot make this claim, and may well be going bare because they perceive an attack will not occur against them and/or they do not have sufficient resources to afford to buy the

coverage. Should they suffer a large loss from a terrorist attack, they may be forced to declare bankruptcy and then start over again.

5. A Private-Public Partnership for Insuring Against Catastrophic Risks

In this section we sketch out the elements of an insurance program for dealing with catastrophic risks and suggest ways it can be combined with other public-private sector initiatives to reduce future disaster losses. This general framework applies both to known risks with ambiguous probabilities and to unknown risks (where by definition, the probabilities relevant to insurer decisions are ambiguous). We comment at the end on whether the unknown case is different in degree or kind from the known case.

Setting Risk-Based Premiums

If one believes that those residing in hazard-prone areas should be responsible for bearing their own financial burden after suffering losses from a catastrophe, then insurance rates should reflect the risk. Such a pricing policy will promote more rational decisions on housing investment and mitigation. In the case of natural disasters, property owners residing along the Gulf Coast should pay considerably more for insurance against wind and water damage from hurricanes than in other parts of the country. Individuals residing in areas where floods, tornadoes and hurricanes are rare should pay next to nothing for insurance that covers these hazards. Those who face earthquake hazard should pay premiums that reflect this risk. Such a system of risk-based premiums encourages individuals in low-risk areas to buy coverage and prevents the problems of adverse selection.

The challenge in implementing a risk-based rating program for catastrophic events is that the premiums charged to those residing in the highest risk areas would likely be considerably greater than they are today. In fact, many states regulate rates so that premiums do not reflect the actual risks borne. In addition some residences in high-risk areas are owned by low-income families who cannot afford the costs of insurance or

the costs of reconstruction should their house suffer damage from a disaster.[16] A risk-based insurance program with subsidies to low-income individuals would enable insurers to set the appropriate rates over time and still achieve fairness goals, unless they are prevented from doing so by state regulation.

Given the existing system of state rate regulation and the need for special treatment for low-income residents in high hazard areas, there are political challenges in implementing the proposed program. The use of catastrophe models and exceedance probability curves can be extremely useful in this regard for legitimizing the types of rates that should be charged. An open question is whether regulators will use these models in determining what rates they are willing to approve.

A Multi-Layered Insurance Program

In order to encourage those at risk to take protective measures while at the same time providing protection to private insurers against catastrophic losses we propose a multi-layered program that involves both the public and private sectors.

The *first level* of disaster losses would be borne by the victims themselves in order to encourage them to adopt safer measures and to avoid moral hazard problems that might otherwise occur if individuals behaved more carelessly because they knew they were fully protected against the risk. This form of self-insurance is equivalent to having a deductible on an insurance policy. The magnitude of the deductible could vary depending on the amount of coverage in place (e.g., a percentage deductible), the needs of those at risk and their willingness to trade off a lower price for less protection against small losses.

Losses in *Layer 2* would be covered by private insurers with the amounts of coverage based on their surplus, their current portfolio and their ability to diversify across risks. Firms with limited assets that insure policyholders in only one region of the country will want to take on a much smaller book of business than large insurers with policies written in many states and/or protect themselves through risk transfer mechanisms.

[16] One could pose the following question regarding these uninsured low-income residents: "If you cannot afford the insurance, how can you afford the house? You could downsize your ownership of assets until you can protect those assets with insurance."

Layer 3 would consist of private sector risk transfer mechanisms that include reinsurance and catastrophe bonds with the proportion of funds allocated by insurers to each of them depending on the prices and the available coverage. The capital markets have recently emerged as a complement to reinsurance for covering large losses from disasters. Through new financial instruments known as catastrophe bonds, an insurer or reinsurer can access needed funds following a disaster. If the losses exceed a pre-specified amount, then the interest on the bond, the principal, or both, are forgiven. To justify the risks of losing their principal and/or interest, capital market investors demand a large enough risk-adjusted return to invest in these bonds. This comes in the form of a higher than normal interest rate when no disaster occurs.

Catastrophe bonds have been on the market since 1997. Figure 5 illustrates the evolution of risk capital issued and outstanding, and the number of bonds issued between 1997 and December 2007. The market recorded total issuance of over $4.7 billion in 2006 (twenty new issuances, almost twice as many as in 2005), a 125 percent increase over the $2.1 billion in 2005. This was is a new record high, and a 75 percent increase over the $1.14 billion issued in 2004, and a 20 percent increase over the $1.73 billion issuance in 2003 (the previous record). The risk capital issued during 2005 and 2006 was equal to the total issued during the preceding five years. Bonds outstanding increased significantly as well, which reflects the issuance of multiyear bonds in previous years. At the end of 2006, outstanding risk capital continued to significantly grow significantly, to $8.7 billion, with nearly $4.7 billion of that being issued. In 2007, twenty-seven new catastrophe bonds were issued for a total of $7 billion in capital and $14 billion was outstanding. The 2008 financial crisis had an impact on this market in the sense that no new cat bonds were issued between September and December 2008. Total cat bond volume for 2008 was $2.7 billion (Kunreuther and Michel-Kerjan 2009, chapter 8).

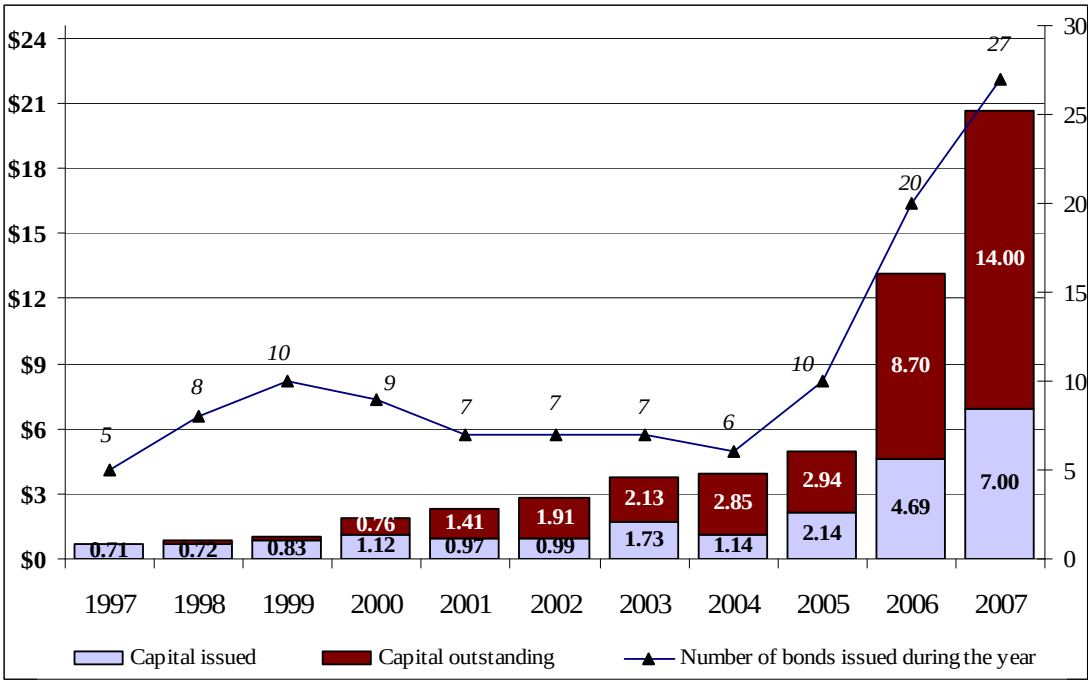

Figure 5: Natural Catastrophe Bonds: Capital Risk Issued and Outstanding 1997-2007 (in $ billion)

Sources: Data from Swiss Re Capital Markets, Goldman Sachs, and Guy Carpenter

Regulatory, accounting and tax issues are preventing the cat bonds from being used more widely. Another impediment to the widespread use of cat bonds is that it requires specialized knowledge and skills. Investors without these attributes are likely to allocate their funds elsewhere (Jaffee, 2005).

Layer 4 would cover large-scale losses. It could take the form of multi-state pools for providing coverage in certain regions of the country subject to particular hazards, such as hurricanes in the Gulf Coast states. The federal government could also offer catastrophe reinsurance contracts and/or provide pre-funded federal reinsurance for mega-catastrophes.

Lewis and Murdock (1996) proposed that the federal government offer catastrophe reinsurance contracts, which would be auctioned annually. The Treasury would auction a limited number of excess of loss (XOL) contracts covering industry losses between $25 billion and $50 billion from a single natural disaster. Another option is for the federal government to provide reinsurance protection against catastrophic losses

that cannot be covered by the private sector. One advantage that the federal government has over private reinsurers is its financial ability through taxing and borrowing authority to cover a disaster that occurs in the next few years before sufficient funds are built up to cover these losses. There may be a special need for federal involvement for protection against terrorism where insurers cannot set rates based on risk and where coverage is required today for certain policies (e.g., workers' compensation in all states, fire following a terrorist attack in eighteen states).

Linking Insurance with Other Initiatives

For a catastrophic disaster insurance program to reduce losses from future events it needs to be linked with other private-public sector initiatives. The importance of well-enforced building codes and land-use regulations to control development in hazard-prone areas becomes an important part of such a program. If some states and the federal government are providing protection against catastrophic losses, they can also require these risk-reducing measures as part of such a private-public partnership.

One way to encourage adoption of cost effective mitigation measures is to have banks provide *long-term mitigation loans* that could be tied to the property. The bank holding the mortgage on the property could offer a home improvement loan with a payback period identical to the life of the mortgage. For example, a 20-year loan for $1,500 at an annual interest rate of 10% would result in payments of $145 per year. If the annual premium reduction due to the adoption of the mitigation measure is greater than $145 per year, an insured homeowner would have lower total payments by investing in mitigation (Kleindorfer and Kunreuther, 1999). In order for such a program to achieve its desired impact, insurance premiums must be risk-based so that the premium reduction for undertaking the mitigation measure exceeds the annual home improvement loan payment.

Building codes require property owners to meet standards on new structures but normally do not require them to retrofit existing structures. Often such codes are necessary, particularly when property owners are not inclined to adopt mitigation measures on their own due to their misperception of the expected benefits resulting from adopting the measure and/or their inclination to underestimate the probability of a disaster occurring. Cohen and Noll (1981) provide an additional rationale for building

codes. When a structure collapses, it may create externalities in the form of economic dislocations and other social costs that are beyond the financial loss suffered by the owners. For example, if a poorly designed structure collapses in a hurricane, it may cause damage to other buildings that are well designed and still standing from the storm. Knowing this, an insurer may offer a smaller premium discount than it would otherwise have given to a homeowner investing in loss reduction measures.

Communities can also offer *tax incentives* to encourage property owners to adopt mitigation measures. The city of Berkeley has encouraged home buyers to retrofit newly purchased homes by instituting a transfer tax rebate. The city has a 1.5 percent tax levied on property transfer transactions; up to one-third of this amount can be applied to seismic upgrades during the sale of property. Qualifying upgrades include foundation repairs or replacement, wall bracing in basements, shear wall installation, water heater anchoring, and securing of chimneys. (Earthquake Engineering Research Institute, 1998). Between fiscal years 1993-1994 and 2007-2008 the city of Berkeley provided $13.4 million in seismic rebates based on this tax incentive program.[17]

Open Issues

Voluntary or Required Coverage In developing an insurance program for catastrophic losses, one of the open issues is whether all property owners should be required to have this insurance coverage (and whether such a requirement could be enforced). Since banks normally require homeowners' coverage and commercial insurance as a condition for a mortgage, a sizable number of property owners would indeed have catastrophic protection. Of course, this requirement presumably reflects a bank's judgment that the expected profitability of a mortgage at a lower interest rate coupled with a requirement to pay for coverage is greater than the profitability of a mortgage with no requirement but a higher interest rate to offset the possibility of default.

There will be some individuals who either own their property outright or are not required by their bank to purchase insurance. They may decide to take their chances and not purchase coverage. If there are enough of these uninsured individuals and the past is a

[17] Personal correspondence with Heather M. Murphy, City of Berkeley Finance Department, April 7, 2009.

guide for the future, the federal government is likely to provide financial assistance following the next large-scale disaster. In this case, one would want to consider making insurance protection mandatory.

A related option would be for government at some level to levy a tax on all property in the United States with the payment based on the actuarial risk. The government would then cover the catastrophic losses from natural disasters. The local property tax would be the natural base to be surcharged, but the federal government often pays for the relief. If such a tax were imposed, then one would need to separate out the catastrophic portion of the loss from lesser damage that would continue to be covered by a homeowners' or commercial insurance policy.

Role of Regulation If insurance is to provide the appropriate signals to residents in hazard-prone areas, risk-based premiums must be charged. State insurance departments need to give insurers freedom to charge these rates subject to solvency concerns that regulators may have if unduly low premiums are proposed by some insurers. One of the advantages of a risk-based system is that it rewards individuals who undertake mitigation measures by providing them with lower premiums. If premiums are subsidized in high-hazard areas then the insurer has limited economic incentives to provide coverage to these property owners and no reason to reward them with a lower premium that fully reflects the expected benefit of adopting a loss reduction measure.

If one wants to encourage the use of capital market instruments to cover catastrophic losses, it would be useful to reexamine the current regulations and accounting practices that restrict the use of these instruments today. Jaffee (2005) has indicated three issues that deserve consideration. Accounting standards currently do not allow insurance firms to reflect the risk transfer achieved by non-indemnity catastrophe funds on their financial reports filed with state insurance regulators. A new Financial Accounting Standards Board proposal as it relates to Special Purpose Vehicles (SPVs) used in issuing cat bonds may also have detrimental effects on the cat bond market. A third area is whether one can gain more favorable treatment for the SPVs issuing a catastrophe bond.

Special Treatment for Lower- Income Families There are likely to be a number of low-income residents who reside in high-hazard areas. These individuals may not be willing or able to afford the relatively high premiums that they would be charged on their disaster insurance policy. They also may not have funds available to invest in mitigation measures even if offered a home improvement loan. Serious consideration should be given to special treatment for this group by public sector agencies at either the local, state and/or federal levels on both equity and efficiency grounds. There needs to be a more detailed analysis as to what proportion of the homes in high-hazard areas are occupied by low-income residents and the types of subsidies that should be offered them so they can afford insurance and invest in cost-effective mitigation measures.

Unknown Risks If insurance contracts continue to take the current form of promising coverage for all risks not specifically excluded (and therefore covering unknown risk), the framework we have proposed would still apply, with the various layers of coverage linked to the size of the loss. That is, the consumer might be expected to bear the full cost of a small loss from a previously unknown cause, the private market would cover the next layer, and government might play a role in covering losses which come from previously unknown causes and are catastrophic. Should insurers propose returning to an older form of contract in which only specified risks were covered, public policy issues might be raised, but thus far this has not happened.

6. Conclusions and Future Research

Modifying the demand side of catastrophe insurance is challenging but seems feasible. In contrast, modifying the supply side to deal with high loss but highly uncertain and unpredictable events is daunting, especially in a world in which the natural and political environments are unpredictable. Both the demand side and the supply side appear to be experiencing changes whose final impact is hard to predict. Market insurance can help with some risk pooling; in theory, government might help with other risks, but our expectations and optimism here need to be tempered with a realization that agents in both the public sector and private markets appear to have difficulty in correctly

detecting, conceptualizing, and arranging ways to deal with the unknown. Further experimentation in this area is needed for us to gain more insight into what program are likely to work in practice.

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