The Role of Insurance in Managing Extreme Events: Implications for Terrorism Coverage

Howard Kunreuther*
Center for Risk Management and Decision Processes
The Wharton School
University of Pennsylvania
Philadelphia, PA 19107

Visiting Research Scientist
Columbia University

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* **Comments on the paper should be e-mailed to kunreuther@wharton.upenn.edu**

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1. Introduction

A key question being raised since September 11th is the appropriate role of the private and public sectors in reducing losses and offering insurance protection against extreme risks such as natural disasters, technological accidents and terrorist activities. The following scenario illustrates the challenges and opportunities facing the insurance and reinsurance industry in this regard:

Scenario: Over the past 10 years the AllRisk (AR) Insurance Company has provided $500 million in coverage to Big Business (BB) Inc. against risks to its plant including terrorism. AR covers $100 million itself and has purchased an excess of loss reinsurance contract from Reinsurance Enterprise (RE) to cover the remaining $400 million. Given the events of Sept. 11th RE has decided that terrorism will no longer be included in its coverage because of the uncertainties associated with the risk. BB needs terrorism coverage since the bank that holds its mortgage requires this as a condition for the loan. AR must decide whether or not to continue providing BB with the same type of insurance as it has had previously and if so how much coverage it is willing to offer.

This scenario raises the following questions that this paper will address:

1. What factors determine whether the risk is insurable?
2. How much capital will AR require in order to provide protection against extreme events?
3. What role can and should the public sector play in providing protection against extreme events?

The next section addresses **Question 1** by showing that uncertainty regarding the risks is likely to raise the premiums considerably particularly if one is concerned with the potential of large losses. Section 3 addresses **Question 2** by focusing on the illustrative example depicted in the scenario and showing that large amounts of capital are required to provide protection against uncertain events with large potential losses. In Section 4 I turn to **Question 3** and contend that today there is a more important role for the public sector to play than ever before because of the uncertainties of the risks and the externalities associated with them. The paper concludes with a set of open questions for future research.

2. Insurability of Risks[1]

What does it mean to say that a particular risk is insurable? This question must be addressed from the vantage point of the potential supplier of insurance who offers coverage against a specific risk at a stated premium. The policyholder is protected against a pre-specified set of losses defined in the contract.

Two conditions must be met before insurance providers are willing to offer coverage against an uncertain event. Condition 1 is the ability to identify and quantify, or estimate, the chances of the event occurring, and the extent of losses likely to be incurred when providing different levels of coverage. Condition 2 is the ability to set premiums for each potential customer or class of customers. This requires some knowledge of the customer's risk in relation to others in the population of potential policyholders. If Conditions 1 and 2 are both satisfied, a risk is considered to be insurable. But it still may not be profitable. In other words, it may impossible to specify a rate for which there is sufficient demand and incoming revenue to cover the development, marketing and claims costs of the insurance and yield a net positive profit. In such cases the insurer will opt **not** to offer coverage against this risk.

Condition 1: Identifying the Risk

To satisfy this condition, estimates must be made of the frequency at which specific events occur and the extent of losses likely to be incurred. Such estimates can use data from previous events, or scientific analyses of what is likely to occur in the future. One way to reflect what experts know and do not know about a particular risk is to construct a loss exceedance probability (EP) curve.

A loss EP curve depicts the probability that a certain level of loss will be exceeded on an annual basis. The loss can be reflected in terms of dollars of damage, fatalities, illness or some other measure. To illustrate with a specific example suppose one was interested in constructing an EP curve for dollar losses to structures in Paris from the flooding of the Seine. Using probabilistic risk assessment (PRA), one combines the set of events that could produce a given dollar loss and then determines the resulting probabilities of exceeding losses of different magnitudes. Based on these estimates, one can construct the mean EP depicted in Figure 1. By its nature, the EP curve inherently incorporates uncertainty in the probability of an event occurring and the magnitude of dollar losses. This uncertainty is reflected in the 5% and 95% confidence interval curves in Figure 1.

[1] A more detailed discussion of insurability conditions can be found in Freeman and Kunreuther (1997). Gollier (2000) examines the various factors that may make certain risks uninsurable.

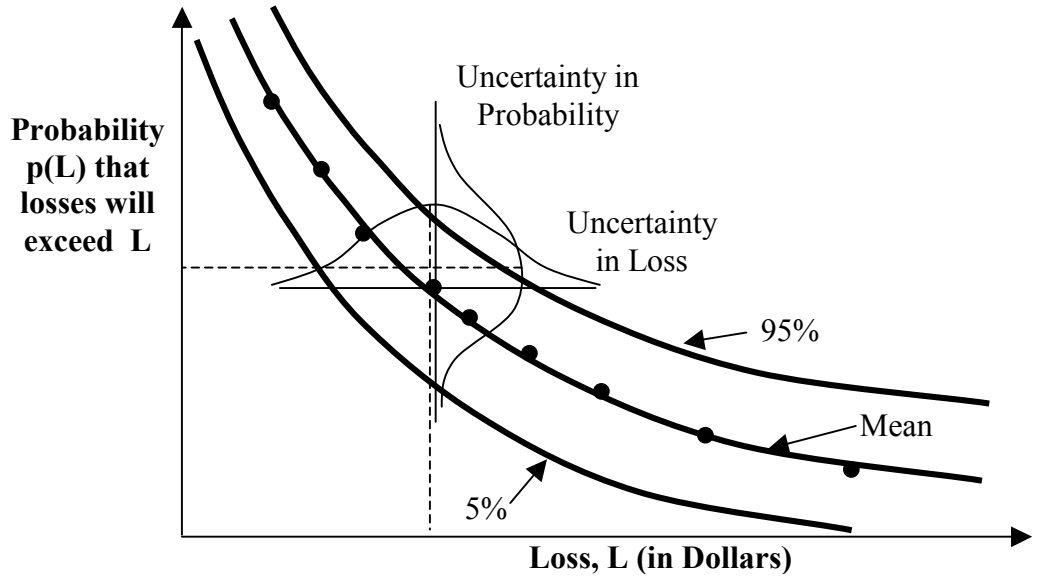

Figure 1. Example of Exceedance Probability Curves

The EP curve is the key element for evaluating a set of risk management tools. The accuracy of the EP curves depends upon the ability of the scientific and engineering community as well as social scientists to estimate the impact of events of different probabilities and magnitudes using the different units of analysis. These units normally include quantifiable measures such as dollar damage, number of people injured or killed and business interruption losses.

When dealing with extreme events the key questions that need to be addressed when constructing an EP curve is the degree of uncertainty with respect to both the probability as well as the consequences of the event. It is a lot easier to construct an EP curve for natural disasters and chemical or nuclear power plant accidents than it is for terrorist activities. But even for these events there is considerable uncertainty with respect to both the probability of occurrence and the damage from these events. Here are a few questions in this regard that we may want to ponder:

- What are the chances that Paris will have severe flooding of the Seine next year and what will be the resulting damage and indirect losses?
- What is the likelihood of a severe nuclear power accident somewhere in France and what would be the resulting impacts?
- What are the chances that an airplane will crash into the business district in Paris in the next year and how serious would the consequences be?
- What are the chances that there will be a smallpox epidemic in Europe in the next five years and how many people would be affected?

Condition 2: Setting Premiums for Specific Risks

Once the risk has been identified, the insurer needs to determine what premium it can charge to make a profit while not subjecting itself to an unacceptably high chance of a catastrophic loss. There are a number of factors that play a role in determining what prices companies would like to charge. In the discussion which follows we are assuming that insurers are free to set the premiums at any level they wish. In reality, state regulations often limit insurers in their rate-setting process.

Ambiguity of Risk Not surprisingly, the higher the uncertainty regarding the probability of a specific loss and its magnitude, the higher the premium will be. As shown by a series of empirical studies, actuaries and underwriters are so averse to ambiguity and risk that they tend to charge much higher premiums than if the risk were well specified.

Kunreuther, et al, (1995) conducted a survey of 896 underwriters in 190 randomly chosen insurance companies to determine what premiums would be required to insure a factory against property damage from a severe earthquake. The survey results examine changes in pricing strategy as function of the degree of uncertainty in either the probability and/or loss. A probability is considered to be well-specified where there is enough historical information on an event that all experts agreed that the probability of a loss is p. When there is wide disagreement about the estimate of p among the experts, this ambiguous probability is referred to as Ap. L represents a known loss — that is, there is a general consensus about what the loss will be if a specific event occurs. When a loss is uncertain, and the experts estimates range between L_{min} and L_{max}, this uncertain loss is denoted as UL.

Combining the degree of probability and loss uncertainty leads to four cases which are shown in the Table 1 along with a set of illustrative examples of the types of risks that fall in each category.

INSERT TABLE 1 HERE

To see how underwriters reacted to different situations, four scenarios were constructed as shown by the columns in Table 2. Where the risk is well specified, the probability of the earthquake is either .01 or .005; the loss, should the event occur, is either $1 million or $10 million. The premium set by the underwriter is standardized at 1 for the non-ambiguous case; one can then examine how ambiguity affects pricing decisions.

Table 2 shows the ratio of the other three cases relative to the non-ambiguous case (p, L) for the four different scenarios, which were distributed, randomly to underwriters in primary insurance companies. For the highly ambiguous case (Ap,UL), the premiums were between 1.43 to 1.77 times higher than if underwriters priced a non-ambiguous risk. The ratios for the other two cases were always above 1, but less than the (Ap,UL) case.

INSERT TABLE 2 HERE

Adverse Selection[2] If the insurer sets a premium based on the average probability of a loss, using the entire population as a basis for this estimate, those at the highest risk for a certain hazard will be the most likely to purchase coverage for that hazard. In an extreme case, the poor risks will be the only purchasers of coverage, and the insurer will lose money on each policy sold. This situation, referred to as adverse selection, occurs when the insurer cannot distinguish between the probability of a loss for good- and poor-risk categories.

Moral Hazard[3] Providing insurance protection to an individual may lead that person to behave more carelessly than before he or she had 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.

Moral hazard refers to an increase in the probability of loss caused by the behavior of the policyholder. Obviously, it is extremely difficult to monitor and control behavior once a person is insured. How do you monitor carelessness? Is it possible to determine if a person will decide to collect more on a policy than he or she deserves by making false claims?

Correlated Risk Correlated risk refers to the simultaneous occurrence of many losses from a single event. As pointed out earlier natural disasters such as earthquakes, floods, and hurricanes produce highly correlated losses: many homes in the affected area are damaged and destroyed by a single event.

If a risk-averse insurer faces highly correlated losses from one event, it may want to set a high enough premium not only to cover its expected losses but also to protect itself against the possibility of experiencing catastrophic losses. An insurer will face this problem if it has many eggs in one basket, such as providing earthquake coverage mainly to homes in Los Angeles County rather than diversifying across the entire state of California.

To illustrate the impact of correlated risks on the distribution of losses, assume that there are two policies sold against a risk where $p = .1$, $L = \$100$. The actuarial loss for each policy is \$10. If the losses are perfectly correlated, then there will be either two losses with probability of .1, or no losses with a probability of 9. On the other hand, if the losses are independent of each other, then the chance of two losses decreases to .01 (i.e., .l x .1), with the probability of no losses being .81 (i.e., .9 x .9). There is also a .18 chance that there will be only 1 loss (i.e., .9 x .1 + .1 x .9).

[2] For a survey of adverse selection in insurance markets see Dionne and Doherty (1992)
[3] See Winter (1992) for a survey of the relevant literature on moral hazard in insurance markets.

The expected loss for both the correlated and uncorrelated risks is $20.[4] However, the variance will always be higher for correlated than uncorrelated risks if each have the same expected loss. Thus, risk-averse insurers will always want to charge a higher premium for the correlated risk.

Insurability Conditions and Demand for Coverage

The above discussion suggests that in theory insurers can offer protection against any risk that they can identify, and for which they can obtain information to estimate the frequency and magnitude of potential losses as long as they have the freedom to set premiums at any level. However, due to problems of ambiguity, adverse selection, moral hazard, and highly correlated losses, they may want to charge premiums that considerably exceed the expected loss. For some risks the desired premium may be so high that there would be very little demand for coverage at that rate. In such cases, even though an insurer determines that a particular risk meets the two insurability conditions discussed above, it will not invest the time and money to develop the product.

More specifically, the insurer must be convinced that there is sufficient demand to cover the development and marketing costs of the coverage through future premiums received. If there are regulatory restrictions that limit the price insurers can charge for certain types of coverage, then companies will not want to provide protection against these risks. In addition, if an insurer's portfolio leaves them vulnerable to the possibility of extremely large losses from a given disaster due to adverse selection, moral hazard, and/or high correlation of risks, then the insurer will want to reduce the number of policies in force for these hazards.

3. Capital Required by Insurers for Providing Protection

One of the key issues that has been discussed recently is the amount of capital required by an insurer or reinsurer to provide protection against an extreme event. Cummins Doherty and Lo (2002) have undertaken a series of analyses that indicate that U.S. property-liability insurance industry could withstand a loss of $40 billion with minimal disruption of insurance markets. According to their model a $100 billion loss would create major problems for the insurance industry by causing 60 insolvencies and leading to significant premium increases and supply side shortage.

In the context of the terrorism attack of September 11th there has been a severe shortage of capital so reinsurers will not want to provide protection against this event for the immediate future. Hence for insurers to provide firms with the coverage they have offered in the past, they must find capital from different sources. The cost of this protection can be so high that the demand for coverage will dry up. To illustrate this point it is useful to focus on a concrete example such as the Scenario in the introductory section

[4] For the correlated risk the expected loss is .9 x $0 + .1 x $200 = $20. For the independent risk the expected loss is (.81x$0) + (.18x$100) + (.01x$200) = $20.

that involves whether the AR Insurance Company can provide terrorism coverage to BB Inc.

Situation Prior to September 11th

Recall from the Scenario in the introduction that there was a potential loss to BB of $500 million with a probability equal to .01. Prior to September 11th AR was able to obtain $ 400 million worth of reinsurance from RE so that it only had to cover $100 million of any losses that BB may have experienced.

Here is the relevant data on which RE based its premium to AR for reinsurance coverage:

Loss to BB (L =$500 million)
Probability of loss to BB (ρ= .01)
Reinsurance coverage by RE to AR (L_{RE} =$400 million)
Expected Loss to RE (ρL_{RE} = .01 ($400)= $4 million)
RE loading factor (λ_{RE} = 1)
Reinsurance premium charged by RE to AR [Z_{RE} = (1+ λ_{RE}) ρ L_{RE} = 8]

Assume that AR has a loading factor of λ_{AR} =.5 so it charges BB a premium to cover the $500 million loss of $Z_{AR} = (1+ \lambda_{AR}) [\rho(L- L_{RE}) + Z_{RE}]$. In other words AR charges BB a premium Z_{AR} = [.01 (100) + 8](1.5) =13.5 for $500 million coverage and purchases $400 million worth reinsurance from RE.

Situation After September 11th

Now that RE has decided to eliminate terrorist coverage in its reinsurance policies, AR has to determine how much protection it can offer BB Inc. and what price to charge for this coverage. The first concern of underwriters at AR is on the firm's safety with profit maximization taking second place.[5] Stone (1973) formalized these concepts by suggesting that an underwriter will first focus on keeping the probability of insolvency below some threshold level (α):

$$\Pr(\text{Loss} > \text{Premiums} + \text{Surplus}) \leq \alpha$$

For AR to offer BB $500 million in coverage, it now has to raise an additional $400 million in capital from different sources.

One possibility would be for an investment bank to issue a $400 million catastrophe bond to cover the losses from a terrorist attack.[6] A cat bond requires the investor to provide money up front that will be used by the firm if some type of triggering

[5] Roy (1952) first proposed a safety-first model of firm behavior. Such a model explicitly concerns itself with insolvency when making a decision regarding maximum amount of coverage and premiums to charge.
[6] See the papers in Froot (1999) for a more detailed discussion of new developments in providing capital for dealing with catastrophic risks.

event occurs such as a terrorist attack. In exchange for a high return on investment, the investor faces the possibility of losing either a portion or its entire principal investment. The amount paid out to the firm (*i.e.* the ceding company) depends on how the cat bond is constructed and this amount is specified in advance of the triggering event.[7] If investors are risk averse because of the uncertainty associated with the terrorist risk they will require a much larger than average return on their investment in order to cover the risk of losing their principal. Given the unusually high premiums on cat bonds for natural hazards risks[8], where there is considerably less ambiguity and uncertainty than a terrorist attack, this should not be surprising.

In the case of cat bonds for providing funds should a terrorist attack occur, suppose investors require a 20% annual rate of return[9] for them to put money in a cat bond. Suppose the normal annual return on investments is 8%. In this case the annual cost to AR of obtaining $400 million through issuing a cat bond would be

$$(.20 - .08)\$400 = .12\ (\$400) = \$48 \text{ million} = C$$

For AR to offer BB insurance for next year given their additional costs of capital would be $(pL_{AR} + C)\ (1+ \lambda_{AR}) = (\$1 + 48)\ (1.5) = 73.5$ which would be considerably more than BB would be willing to pay for $500 million worth of coverage. Under these conditions terrorist coverage is uninsurable.

Note that even if investors only required a 12% return on the cat bond, AR would have to pay C= (.12-.08)($400) = $16 in which case its premium would be ($1+16)(1.5)=$25.5, still a very high price for BB Inc. to have to pay for property insurance.

4. Role of Public and Private Sectors for Dealing with These Problems

The analyses of this scenario raises a set of key questions as to what the roles of the public and private sectors should be in providing protection against extreme events. There are three issues that will be addressed in this section:

- What type of federal reinsurance protection would be appropriate for dealing with the terrorism risk?
- What is the experience of the UK in dealing with terrorism protection?
- What role should the public sector play in encouraging protection against extreme events?

[7] See Standard and Poors (2000) on the structure of recent cat bonds.
[8] For more detail on the high interest rates required by investors for these cat bonds see Bantwal and Kunreuther (2000).
[9] The figure of 20% is based on recent discussions with insurers who are trying to raise capital for covering terrorist risks.

Role of Federal Reinsurance

If it is really true that investors are unwilling to provide capital to insurers or reinsurers for coverage against terrorism without obtaining a very high return as shown in the previous section, then there may be a need for some type of public sector involvement at least in the short-run.

A key question that needs to be addressed in developing some type of federal reinsurance program is who should pay for the costs while this system is in operation. If terrorism is viewed as a national problem with the costs borne by all taxpayers rather than just those who suffer losses, then some type of tax on all citizens might be appropriate. Alternatively all property owners who purchased insurance would have to pay a special *terrorism surcharge* to cover losses that have occurred.

If on the other hand, the Government feels that the costs of terrorism should be borne by those who are at risk, then insurers who provide terrorism coverage should have to cover the cost of reinsurance. Suppose that the Government set up a Terrorism Reinsurance Fund (TRF) to cover losses above a certain amount.

Looking at the scenario introduced at the beginning of the paper, the AR Insurance Company would either have to pay TRF for reinsurance just as it was paying RE before Sept. 11th. Its actual premium would depend on estimates of the probability of future terrorist attacks (ρ) and the resulting claims that AR would have to pay (L). Instead if after a terrorist attack the Government created TRF to cover any losses above a certain amount through some type of loan arrangement, then insurers who required these funds would have to be the ones to repay them to TRF.

Experience of the UK with Terrorism Coverage

It may be useful to study the experience that the United Kingdom (UK), the one country that established some type of private/government partnership for dealing with the terrorism risk. More specifically, at the beginning of 1993 the insurance community and the Government established a mutual insurance organization (Pool Re) to accommodate claims following terrorist activities. The motivation for forming Pool Re came from two terrorist bomb explosions in the City of London in April 1992 and an announcement seven months later by British insurers that they would exclude terrorism coverage from their commercial policies (Fleming 1993).

Pool Re charges a separate, optional premium for terrorism cover that is calculated as a percentage of the total fire and accident coverage. This premium is collected by the primary insurer and passed on to Pool Re. If a claim is made which exhausts the premiums collected, each primary insurer faces a levy of up to 10 percent of the premiums it has paid into the pool. If this amount cannot cover the cost of the claim then the balance is met out of the public purse. (CII Journal 1993).

The premiums established by Pool Re are based on the risks with the highest rates in Central London and the second highest in the rest of the city. The lowest rates are in the rural parts of Scotland and Wales. Since this coverage is voluntary there were a number of businesses in the high risk areas of London who were uninsured because they felt the premiums were too high. (CII Journal 1993).

Role of Government in Providing Protection

Let me now turn to the question that has been preoccupying the United States in recent weeks: What is the appropriate role of the public and private sectors in providing protection against terrorism? Prior to September 11th, there was certainly a concern with terrorism but there was also a feeling that "it will not happen in my backyard". The private sector was expected to finance protective measures rather than relying on government for any assistance.

Take the airline industry, for example. Before the World Trade Center and Pentagon attacks, if an airline wanted to invest in more secure cockpits or armed guards on the flight they would have had to incur these expenses themselves. Each company decided there was no incentive for it to take this action on its own, in part because they may not have felt the risks warranted such action but also because of competitive pressures. If one airline had invested in these protective measures, it would have incurred higher costs than the others. Furthermore there would have been little, if any, appreciation by the flying public as to why these measures were even necessary. Hence passengers would have been reluctant to pay higher ticket prices necessary to cover these additional expenses. In short, increased airline protection was a losing proposition for a single company.

The world has changed in the last twelve weeks. The United States Government now feels it has to bail out the airline industry given that many companies are on the verge of bankruptcy. There is now recognition that an airplane can be used to kill many more people than just the passengers and crew, and create havoc by damaging property and causing large-scale business interruptions. This recognition and the resulting "fear of flying" by many people has created a demand for safer planes and increased security at airports. In the future much, if not all, of the costs of these protective measures is likely to be absorbed by the federal government.

On a more general note, the terrorist attacks offer an opportunity to reassess the role of the public and private sector with respect to providing protection. One needs to recognize that for many situations there may be a need for the public sector to take the lead role.

To illustrate this point, consider Airline A that is considering whether to institute a system to check their incoming bags, knowing that none of the other airlines have instituted such a system. Hence there is some chance that an unchecked bag from Airline B, C, D or E could be transferred to one of Airline A's planes. It turns out that if there is

a relatively high chance that such an event will occur then there is little incentive for Airline A to undertake this protective measure under the current liability and insurance systems (Heal and Kunreuther 2001). It is thus not surprising that the US government has recently required that all baggage be checked by the airlines.

6. Conclusions and Open Issues

This paper has addressed the question as to the appropriate role of the public and private sectors in reducing the likelihood and consequences of future extreme events through protective measures as well as providing insurance to cover losses should a disastrous event occur.

There are a number of open questions that need to be addressed to deal with the problem of managing extreme events. The paper concludes by raising some of them as it applies to the terrorism problem:

- Can one develop meaningful scenarios to estimate the probability of future terrorist activities occurring (e.g. chances of a plane crashing into another building; chance of an individual contracting anthrax and recovering from the disease or dying from the disease)?

- Can one develop estimates of the losses from these events for which the insurer will be held responsible (e.g. property damage and business interruption from another terrorist attack; hospital expenses for individuals contracting anthrax)?

- How much extra premiums will the insurer want to charge due to the ambiguity of the terrorist risk?

- Is there an adverse selection problem associated with terrorism? (i.e. only those in the high risk category want insurance and the insurer cannot distinguish between high and low risks?)

- Is there a moral hazard problem associated with terrorism? (i.e. those who buy insurance behave more carelessly than those who don't?)

- High likely is that losses from terrorist activities will be highly correlated? (e.g several planes crashing simultaneously; a smallpox epidemic)

- Will the premiums charged by insurers be affordable by those who are demanding terrorist coverage?

- What roles should the government and private sector play in providing protection against terrorism activities?

There are no easy answers to these questions but they need to be addressed by insurers, reinsurers and the public sector to determine under what conditions private companies can provide protection against terrorism and other extreme events. We also need to determine what roles the private sector and government should play in reducing the likelihood of these events occurring in the future and making them insurable risks.

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Table 1

Classification Of Risks By Degree Of Ambiguity And Uncertainty

		LOSS
	KNOWN	***UNKNOWN***
PROBABILITY		
	Case 1	*Case 3*
WELL-SPECIFIED	p, L	p, UL
	Life, auto, fire	Playground accidents
	Case 2	*Case 4*
AMBIGUOUS	Ap, L	Ap, UL
	Satellite	Earthquake, Bioterrorism

Table 2

Ratios of Underwriters Actuarial Premiums for Ambiguous and/or Uncertain Earthquake Risks Relative to Well-Specified Risks

SCENARIO	CASES			
	1	**2**	**3**	**4**
	p,L	Ap,L	p,UL	Ap,UL
p=.005 L=$1 million pL=$5,000	1	1.28	1.19	1.77
p=.005 L=$10 million pL=$50,000	1	1.31	1.29	1.59
p=.01 L=$1 million pL=$10,000	1	1.19	1.21	1.50
p=.01 L=$10 million pL=$100,000	1	1.38	1.15	1.43

Source: Kunreuther et al 1995