"Mitigating Losses and Providing Protection Against Catastrophic Risks: The Role of Insurance and Other Policy Instruments"

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Mitigating Losses and Providing Protection Against Catastrophic Risks
The Role of Insurance and Other Policy Instruments

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ABSTRACT

There is grave concern by the insurance and reinsurance industry that they cannot provide protection against catastrophic risks from natural, technological and environmental hazards without exposing themselves to the danger of insolvency or significant loss of surplus. This paper explores the role insurance can play coupled with other policy instruments, such as regulations and standards, to encourage loss reduction measures and provide financial protection against these hazards. The challenge is to find ways to make these catastrophic risks insurable. New advances in information technology and risk assessment coupled with the emergence of new financial instruments for covering large losses provide the ingredients for rethinking the way society deals with catastrophic risks. The paper proposes a program for rethinking how we manage these risks in which insurance plays a key role but which requires the involvement of other stakeholders and policy instruments. The natural hazard problem is the principal example used to illustrate these points, but the concepts have relevance to technological and environmental risks, as indicated in the concluding section of the paper.
1. Introduction

There is grave concern by the property and casualty insurance and reinsurance industry that they cannot continue along their current path of providing protection against certain risks or taking on additional risks without exposing themselves to the danger of insolvency or significant loss of surplus which will threaten the availability of future coverage. (BestWeek 1996).

Consider the following three illustrative examples:

**Natural hazards**: Insured losses from Hurricane Andrew, which swept ashore along the Florida coastline in August 1992, topped $15 billion. If the storm had taken a more northerly track so it would have hit downtown Miami and Miami Beach, total insured damage could have approached $50 billion. (Insurance Research Council and Insurance Institute for Property Loss Reduction 1995). Insured damage from the Northridge earthquake in southern California exceeded $12 billion. Had a similar quake hit central Los Angeles, the insured bill could have been over $50 billion. A large quake in central Tokyo could have cost over $800 billion. (Giles 1994)

**Technological risks**: The explosion of Union Carbide’s chemical tank at Bhopal in 1984 killed thousands of residents in the community and injured or created health problems for countless others. (Shrivastava 1987). The Clean Air Act Amendments of 1990 (Sect. 112(r)) requires that chemical facilities must develop risk management plans including emergency response measures and “worst case scenarios” with respect to substances that might cause major chemical accidents. To date, the insurance industry is reluctant to provide specific coverage for any of these substances. (Er et. al. 1996)

**Environmental risks**: Leaking underground storage tanks may create damage to municipal water supplies and adversely affect groundwater. In the United States alone there have been 185,000 confirmed releases with the total cost of remediation estimated to be between $30 and $40 billion. (Freeman and Kunreuther in press). Providing insurance against leaking USTs does not appear to lead to catastrophic losses since each tank is independent of each other. On the other hand, the combination of precedent setting court judgments which may be retroactive in nature violates this independence assumption. (Priest 1987). For example, suppose there were rulings next year which required a more stringent cleanup of land contaminated by USTs. Then insurers would find that their costs on all leaking USTs to be much higher than they had anticipated when setting a premium. Legislative initiatives, such as Superfund, have created new forms of liability which were never anticipated at the time that pollution insurance contracts were written and have caused pollution insurance to practically disappear. (Doherty 1991).
(1) There has been an emergence of new financial instruments, such as Act of God Bonds and catastrophe futures and options, for dealing with the potentially large losses from these risks. Although the volume of business to date in these instruments is relatively small, they may offer promise for protection in the future, particularly if traditional insurance and reinsurance has only a limited role to play (Russell and Jaffee 1995).

(2) New advances in information technology (IT) and risk assessment offer an opportunity to estimate the chances and potential losses of future disasters and catastrophic events more accurately than in the past. On the IT side, the development of faster and more powerful computers enables one to examine extremely complex phenomena in ways that were impossible even five years ago. Scientific advances in risk assessment have reduced the uncertainty associated with predicting the chances and consequences of these LP-HC events. Insurers and reinsurers can more accurately estimate the premiums for providing protection against these risks and develop strategies for managing their portfolios so as to avoid sufficiently large losses which cause an unacceptable loss of surplus (Walker 1996).

2. Framework for Analyzing Catastrophic Risks: The Case of Natural Disasters

The basic elements which characterize how society should deal with catastrophic risks are depicted in Figure 1. Initially one needs to delineate the nature of the problem and its importance. Given the interest in insurance as a key policy instrument, the next phase is to determine whether the risk is insurable. The third element is an analysis of risk management tools which can supplement insurance to encourage the adoption of loss reduction measures and offer protection in the event of a major catastrophe.
Nature of the Problem

Natural disasters are now on the societal radar screen where they previously have received relatively little notice and attention, except after a catastrophic event. In the United States there has been increasing concern about the expenditures following recent disasters as illustrated by the following comment by two U.S. Congressmen:

Over the past five years the cost of natural disasters has been rising at an alarming rate. In that time, 11 catastrophes have cost the nation more than $1 billion each. Hurricane Andrew and California’s Northridge earthquake together cost more ($24 billion) than what the government spends annually on running the federal court system, aiding higher education and pollution control, combined (Emerson and Stevens 1995).

Although the insurance industry has suffered record losses from natural disasters in recent years, most of the damage from these events are covered from other sources of funds. In 1995 total estimated losses from natural disasters around the world accounted for $150 billion which exceeded ten times the insured losses ($14.6 billion). More than half of this amount was accounted for by the Kobe earthquake where total damage was estimated at over $82 billion, although insured losses were only $2.5 billion. (Sigma 1995 pp. 3-6).

Evaluating Insurability

As shown in Figure 1 one first has to characterize the Population at Risk to determine whether a risk is insurable. For the natural hazards problem this would require one to construct a community or region consisting of homes, businesses and other property which are subject to future disasters. More specifically, one would want to know the design of each structure, whether specific mitigation measures were in place or could be utilized and its precise location.
A risk can be made more insurable by encouraging mitigation measures to reduce losses suffered by individual structures and hence the catastrophic potential from a disaster. This approach is widespread in other lines of insurance, such as fire and automobile coverage, but has had limited appeal to date when it comes to reducing losses from natural disasters. In fact, there has been a reluctance by the insurance industry to embrace the concepts of mitigation for natural hazards and provide premium reductions should certain measures be adopted (Walker 1996).²

The **Insurability Issue** is the critical element that determines the supply of coverage by the private sector. In theory, an insurer will examine the nature of the risk and determine how much coverage it will offer at different premiums so that its expected profit from insuring this risk is non-negative and its chance of becoming insolvent from an unusually large disaster is below some acceptable probability threshold. The insurability issue and the its impact on the supply of insurance is analyzed in Section 4.

**Risk Management Tools**

The management of catastrophic risks requires a much broader set of policy tools than just insurance. Building codes that are enforced promise to reduce the loss potential from future large-scale disasters. New financial instruments which supplement reinsurance may alleviate the immediate financial problems faced by insurers in the aftermath of a catastrophic disaster or accident. A program for managing natural disasters which incorporates these and other policy tools is proposed in Section 5. These concepts have relevance to technological and environmental risks as well as natural disasters. Section 6 illustrates their application to these two

² One of the reasons for this is that insurers have felt that, due to regulatory restrictions, current rates for these disasters are inadequate. If they promote a loss control measure and reduce premiums to reflect the decrease in risk, they would actually be encouraging residents in hazard-prone areas to purchase coverage. This would result in an increase in their future expected losses.
city had never experienced a severe earthquake since its existence. Following the recent severe
earthquakes in California during the past decade, voluntary demand for insurance increased
because residents in affected areas are now concerned about future damage from these disasters
(Palm 1995).

Figure 2 depicts a model of choice for an individual's decision process. There is likely
to be a threshold probability $p^*$ below which a person will not want to buy coverage because
the attention costs of thinking about the event as well as the transaction costs of collecting
information on insurance and making a decision on how much coverage to buy is too high. The
higher these costs the larger will be $p^*$. Those who feel $p > p^*$ are likely to seek out friends and
neighbors for information on where to buy coverage. (Kunreuther et. al. 1978; Weinstein 1987).

INSERT FIGURE 2 HERE

The factors which determine the amount of insurance to purchase when individuals have
the freedom to specify coverage limits is still not well understood, although recent controlled
experimental studies provide insight into consumer decision processes for some types of
coverage. I will assume that individuals who can voluntarily determine how much insurance to
purchase will make some type of benefit-cost tradeoffs that will maximize their expected
utility. The appendix presents a simple expected utility model for examining the
relationship between the premium charged and the perceived probability of a disaster to

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1 It may also have been the case that residents in Kobe were not able to purchase earthquake insurance without
some time and effort in finding an insurer willing to offer coverage.

2 For example, Johnson et al. (1993) conducted a recent set of experiments on insurance purchase decisions but did
not examine the actual process of choice.

3 The seminal study on the factors influencing the demand for insurance is by Arrow (1971). A comprehensive
review of the literature appears in the paper by Dionne and Harrington (1992) as well as other papers in the
volume edited by the two (Dionne and Harrington ed. 1992).
determine how much insurance will be demanded if the individual has reached this stage in his or her decision process.

The model of consumer choice depicted in Figure 2 has the following implications regarding the demand for insurance:

(1) The optimal amount of coverage decreases when there is an increase in the ratio of the premium per unit coverage ($z$) to the perceived probability of a disaster. If $z < \pi$, then the individual will want to purchase full insurance. When $z > \pi$, then the individual will only purchase partial coverage. Should the ratio of $\frac{z}{\pi}$ be sufficiently high, then no coverage will be demanded even if the individual is somewhat risk-averse.

(2) If individuals use friends and neighbors to determine from which insurers to purchase coverage, then one would expect to find a clustering of policies with the companies who have successful regional agents. These insurers face larger losses from a catastrophe than if a random search process had been utilized by consumers.\textsuperscript{5}

\textsuperscript{5} It would be interesting to examine data from insurance companies to determine whether such a clustering effect is found in practice.
Table 1

Optimal Value of \( x \) as a Function of Probability of Disaster and Time Horizon

\[
L(x) = L - 100 \log(x)
\]

\[
U(W) = W - r
\]

Discount rate \( r = 0.10 \)

<table>
<thead>
<tr>
<th>Probability of Disaster</th>
<th>Time Horizon (T)</th>
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<tr>
<td></td>
<td>1 year</td>
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<td>1/20</td>
<td>4.3</td>
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<td>1/100</td>
<td>0.9</td>
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measures. For this reason, certain investments will not be viewed as cost-effective by those residing in hazard-prone areas, even though they are deemed as financially attractive by the insurer who takes into account the expected length of the life of the structure in evaluating specific mitigation measures.

A third factor, which may limit the ability of the homeowner or businessman to invest in a protective measure, is budget constraints. If the cost to reinforce one's structure is $1500 and the savings on one's annual insurance premium is only $500, then the investment may be viewed as unaffordable even if the expected benefits over a 5 year time horizon would more than justify the cost.

Summary

There is a general lack of interest by individuals in voluntarily purchasing insurance because they underestimate the probability of the event occurring, use sequential models of choice and may misestimate the losses. There is an increase in the demand for coverage following disasters because the event is salient in many people's minds, so that its perceived probability exceeds the threshold level of concern. Those who do consider purchasing coverage often rely on friends and neighbors for information on which to base their decision.

With respect to the adoption of mitigation measures, relatively few residents of hazard-prone areas invest in cost-effective LRM s. Their reluctance to consider loss prevention measures appears to be due to short planning horizons, underestimates of probability of the disaster and/or

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8 A set of experiments by Lowenstein (1987) on willingness to pay for items where the benefits were delayed revealed that the implied discount rates are considerably higher than market rates, particularly in situations where the expected savings over time are small relative to the upfront expenditure.

9 With a discount rate of r=0.10, the expected benefits from investing in the measure would be over $1,800 with p=1/20.
loss. One commonly used formula for determining a premium is \( z = (1 - \lambda) \mu \) where \( \mu \) = expected loss (i.e. \( p \times L \)) and \( \lambda > 0 \) is a factor reflecting ambiguity and uncertainty independent of any adjustment to cover administrative costs [Lemaire (1986)].

Underwriters make their decision regarding whether a risk is insurable by utilizing the actuary's recommended premium \( z \) as a reference point and then focus on the impact of a major disaster on the probability of insolvency. In other words, underwriters are first concerned with the firm's safety and then with profit maximization. Stone (1973 a, b) formalized these concepts by suggesting that an underwriter who wants to determine the conditions for a specific risk to be insurable will first focus on keeping the probability of insolvency below some threshold level \( (q^*) \). More specifically, suppose that the insurer expects to sell \( m \) policies, each of which can create a loss \( L \). Then the underwriter will recommend a premium \( z' \) so that the probability of insolvency would be less than \( q^* \). Risks with more uncertain losses or greater ambiguity will cause underwriters to want to charge higher premiums for a given portfolio of risks. The situation will be most pronounced for highly correlated losses, such as earthquake policies sold in one region of California. A more formal model for the underwriter's decision process is specified in the appendix.

A safety-first model of underwriter behavior is consistent with the Mayers and Smith (1990) rationale as to why insurance firms want to purchase reinsurance. In fact, a rule that focuses on keeping the chances of insolvency below \( q^* \) explicitly recognizes the role that risk

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12 A safety-first model of firm behavior was first proposed by Roy (1952). Such a model can be contrasted with a value maximization approach to firm behavior. Safety-first models explicitly concerns itself with insolvency when making a decision regarding maximum amount of coverage and premiums to charge. A value maximization model recognizes that firms are risk averse so that premiums will have to be higher to reflect the chances of a catastrophic loss. It does not explicitly focus on keeping the probability of insolvency below some prespecified level.

13 A more detailed discussion of the decision processes utilized by actuaries and underwriters in insuring ambiguous risks can be found in Kunreuther (1989).
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. [Kunreuther et al. (1995)]

**INSERT TABLE 2 HERE**

An analysis of these and other data on underwriter's responses to questions such as these suggests that a safety-first model characterizes their behavior. [Berger and Kunreuther (1994)]. Interview data with several insurance companies in the United States concerned with the impact of recent natural disaster losses on their future activity provides additional evidence that firms follow a safety first model. Prior to Hurricane Andrew (1992) and the Northridge earthquake (1994), these insurers were not worried about the potential impact of losses to their portfolio from severe hurricanes and earthquakes and hence did not attempt to restrict coverage and/or make the case for higher premiums because of the likelihood that they would become insolvent. Hence they did not focus on the survival constraint in their insurance decisions.

In the aftermath of these two disasters, company executives have modified their view and are concerned that they cannot survive a future catastrophe given their current portfolio and the amount of reinsurance coverage that they can obtain at a reasonable price. In other words they feel that the chances of insolvency based on their current portfolio exceeds their threshold level of concern (q*). Hence they either want to reduce the number of policies they write in catastrophic-prone areas, raise their per unit premium z, and/or obtain more reinsurance coverage. In the United States insurers have had problems undertaking these actions for the following reasons:

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16 These observations are based on a series of personal interviews with insurers and reinsurers conducted by Jacqueline Meszaros as part of a National Science Foundation study to the University of Pennsylvania on "The Role of Insurance and Regulation in Dealing with Catastrophic Risk".
Regulatory Constraints: In Florida, for example, the percentage of homeowners policies that an insurer can cancel or non-renew in any one year is required to be less than 5 percent statewide and 10 percent in any one county until November 1996. Insurers who offer coverage in Florida are also forced to share in the future losses of those individuals who buy coverage from a Residential Joint Underwriting Association (JUA). These JUAs were set up to provide coverage to those homeowners who could not purchase or renew their policy from a private insurer. Hence they generally represent a higher risk and their premiums may not reflect this (Insurance Information Institute 1995).  

Limited Reinsurance: Insurers have had a difficult time finding enough reinsurance to protect themselves against catastrophic losses. Today an individual company can purchase at most $300-$400 million in reinsurance to cover catastrophes at premiums that they are willing to pay. This may be sufficient to cover smaller firms but will be insufficient to cover companies such as State Farm which stands to lose about $10 billion in a $50 billion catastrophe. (Mooney 1995). On a broader level there is great concern in the industry with the potential impact of a future catastrophic earthquake or hurricane where insured damage could be over $100 billion. The insurance and reinsurance industry feels it will not have enough capacity to cover future losses from such an earthquake. Although the total annual capacity worldwide is hard to estimate, it is unlikely to be more than $50 billion. (Valery 1995)  

Limited Enforcement of Building Codes: The other problem that insurers face in setting premiums for structures in hazard-prone areas is not knowing whether or not the house

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17 State regulators have come under increasing pressure to maintain oversight of insurers' solvency and market practices in recent years. For a more detailed discussion of the changing role of the state regulator given these pressures and recent reforms that have been undertaken see Klein (1995).
higher premiums. Since they are restricted from doing this either by regulatory authorities, they want to withdraw from hazard-prone areas (e.g., hurricane-prone in Florida and earthquake-prone in California). In other words, given the current climate these insurers consider such risks to be uninsurable.

These concerns by insurers raise the question as to the future role of the private market in providing financial protection against losses from catastrophic events. Property owners who are interested in buying insurance or who are required to purchase coverage as a condition for a mortgage are now having difficulty obtaining policies at affordable rates. Insurers are now taking steps to withdraw from certain markets because they feel the premiums they are forced to charge are too low and the number of policies they are required to provide in hazard-prone areas is too great. They believe that this combination places them in a precarious financial position should another catastrophic disaster occur in these areas.

5. A Proposed Program for Dealing with Catastrophic Risks

We need a fresh approach for dealing with the catastrophic risks from natural and technological hazards. Fortunately, it is possible for us to think more broadly about managing these risks in the future due to the advances in information technology for analyzing and managing data, and the availability of new financial instruments for supplementing traditional reinsurance. These developments suggest a strategy which consists of the following elements to be discussed in more detail below: (1) Improving Risk Estimates. (2) Role of Audits and Inspections and (3) Broadening Protection Against Catastrophic Losses.

Two general observations should be made before outlining the details of such a program:
contention among the experts as to the potential risks from hazards or technologies. For example, scientific knowledge on the probability of earthquakes of different magnitudes has been growing rapidly since the 1960s and there is still no widely agreed upon information what figures should be the basis for seismic probability maps. (Mittler, Taylor and Petak 1995). On the other hand, it should be possible to construct statistical confidence intervals for characterizing these risks, even though they may be quite high.

The advances in information technology have encouraged catastrophe modeling because it is possible to simulate a wide variety of different scenarios which reflect the uncertainties in these estimates of risk. (Walker 1996) For example, it is feasible to evaluate the impact of different exposure levels by insurers on both expected losses as well as maximum possible losses by simulating a wide range of different estimates of seismic events used the data generated by scientific experts. Similar studies can be undertaken to evaluate the benefits and costs of different building codes and loss prevention techniques (Insurance Services Office 1994).

Role of Audits and Inspections

In order to avoid problems of moral hazard and adverse selection while at the same time rewarding those who undertake loss reduction measures (LRMs), it is often necessary to undertake audits and inspections. With respect to properties at risk, one way to encourage the adoption of cost effective LRM's is to have them incorporated in building codes and provide a seal of approval to each structure that meets or exceeds these standards.  

Kunreuther and Kleffner (1992) provide a rationale for strengthening building codes by analyzing the factors which lead individuals to avoid investing in mitigation measures even if they have accurate information on the risk.
Many poorly constructed homes are owned by low-income families who cannot afford the costs of mitigation measures on their existing structure nor the costs of reconstruction should their house suffer damage from a natural disaster. Equity considerations argue for providing this group with low interest loans and grants for the purpose of adopting cost-effective LRMVs or for them to relocate their home to a safer area. Since low income victims are likely to receive federal assistance after a disaster, subsidizing these mitigation measures can also be justified on efficiency grounds.

Broadening Protection Against Catastrophic Losses

New sources of capital from the private and public sectors have the possibility of providing insurers with funds against losses from catastrophic events so as to alleviate their concerns that they may be insolvent from the next major disaster. This section briefly examines some options currently on the table.

New Financial Instruments: Over the past few years a number of new financial instruments in the form of derivatives have been developed for dealing with catastrophic losses, although to date they have had limited market penetration (Culp 1996). These instruments infuse the insurer with additional capital should there be a catastrophic loss. In this sense they represent diversification of assets over time rather than across geographical boundaries. Each of the instruments could be priced using models which incorporated the risk and magnitudes of the disaster and the amount of coverage provided. Furthermore, insurers could supplement traditional reinsurance with these guaranteed sources of funds in order to relieve the safety first constraint which may be restricting their ability to offer coverage in high risk areas.\(^{25}\)

\(^{24}\) A derivative is a bilateral contract in which one party has an obligation to another if certain conditions occur (e.g. a disaster where insured losses exceed some prespecified dollar figure). For more details on the nature of derivatives see Culp (1996) pp. 4-10.

\(^{25}\) For a detailed description of these financial instruments see Russell and Jaffee (1995).
Insurance Pools and Public Sector Programs: Because of the magnitude of real
and potential disaster losses, and the consequent effects on the insurance industry and on
financial markets, legislatures have begun to provide some security and stability for financing
catastrophic losses experienced by insurers. State-mandated insurance pools for windstorm risks
have existed for some time in many coastal areas but they are limited in geographic coverage
and in their ability to provide financial assistance following a severe disaster. Furthermore they
are regulated by elected insurance commissioners so that the rate setting process and availability
of coverage to those in disaster areas are affected by political considerations.

The California Department of Insurance has proposed a California Earthquake Authority
(CEA) whereby a fund consisting of insurance industry capital, reinsurance capital and private
capital totaling $10.5 billion are used to cover a portion of the insured losses from quakes
exceeding this dollar magnitude. Even if they achieve their goals, however, these state efforts
are barely adequate for a limited disaster, let alone the mega-catastrophe that is well within the
range of probability.

A successful example of the use of an insurance pool is the coverage of catastrophic
losses from nuclear power plant accidents in the United States. A group of private insurers provides
coverage for losses up until $7.2 billion. The German Pharmaceutical pool, consisting of private
insurers and reinsurers from all over Europe, operates in a similar fashion by providing protection
against large risks by private drug manufacturers associated with new drugs. (Kunreuther 1989).

The National Economic Council (NEC) has developed a proposal recommending that the
federal government offer catastrophe reinsurance contracts that would be auctioned annually. The

\[24\] Russell and Jaffee (1995) pp. 16-18 provide a detailed analysis of the CEA.
6. Extensions to Other Hazards

Although natural hazards has been used as an illustrative example with the homeowner as a focal point, similar principles are relevant to firms which face technological and environmental risks. In this section I will examine some of the challenges that insurers face in these areas and the need to involve other interested parties using the two illustrative examples presented in the introductory section.

Technological Risks

Suppose that a chemical plant would like to purchase insurance protection against the losses from an explosion or major accident which could produce physical damage to the facility as well as cause losses, injuries and deaths to the surrounding area. The same type of questions discussed in Section 3 for natural hazards would arise for these technological risks.

The degree of uncertainty and ambiguity on the risk depends on the data available on previous accidents in chemical plants, the type of scientific modeling of causes of accidents of different magnitudes as well as the types of risk management plans that the company has implemented to reduce the chances and magnitudes of accidents. New advances in information technology should enable one to do a more complete analysis of alternative scenarios regarding these accidents in order to determine the range of expected losses as well as the nature of worst case scenarios.

Insurers are much more concerned with the liability that they face with technological risks than for natural disasters. In particular, they face the problem of public moral hazard, which refers to the public blaming “unexplained” adverse health effects following a chemical
number of industrial facilities, then it will be less concerned with the impact of a single accident on its surplus. However, the insurer may still want to arrange to have an infusion of capital in the spirit of the Nationwide-J.P. Morgan agreement, just in case it experienced an unusual number of accidents during a short period of time.

**Environmental Risks**

For environmental risks, such as leakage from underground storage tanks (USTs) or other forms of groundwater contamination, there is the basic question as to what the insurer would be expected to cover in terms of claim payments. The linkage between the magnitude of damage and the risk of illness or disease (e.g., cancer) is very tenuous for most chemicals so that it is difficult to determine any measure of the health effects based on toxicological studies. (Kraus et al. 1993)

Yet there is great concern from the public regarding the impact that hazardous waste will have on their lives and this has affected the decision process regarding the cleanup of hazardous waste. The results of a national opinion poll in which experts and citizens ranked environmental health risks revealed that hazardous waste sites were at the top of the public's ranking of risks while they were categorized as medium to low by scientific experts. (Sunstein 1996 p. 265).

Consider the challenge in providing insurance coverage for leaking USTs discussed in the introductory section. One would need to know the probability of a leak from a tank of a particular age and type as well as the expected costs of cleaning up the contaminated waste from leaks of different magnitudes and the cost of replacing the tank. These data could form the basis for a private insurance program. To estimate the premium one would have to inspect the tank to determine its current condition. Regular inspections of the tank over time would reduce the
7. Conclusions and Suggestions for Future Research

This paper argues for a new approach for dealing with catastrophic accidents and disasters which takes advantage of recent developments in information technology and the emergence of new financial instruments to deal with non-diversifiable risks. These two major changes open up opportunities for residents and firms to undertake cost-effective loss protection measures while at the same time providing a financial cushion to insurers concerned with the possibility of insolvency.

There are a set of open questions as to the types of incentives insurers can provide to individuals who invest in loss mitigation measures, and what types of financial instruments insurers should purchase to supplement or replace traditional reinsurance coverage. A strategy for undertaking research in this area would involve the analysis of the impact of disaster or accidents of different magnitudes on a set of structures, industrial plants or their equipment (e.g. USTs).

In order to determine expected losses and the maximum probable losses arising from worst case scenarios, it may be necessary to undertake long-term simulations. For example, one could examine the impacts of earthquakes of different magnitudes on the losses to a community or region over a 10,000 year period. In the process one could determine expected losses based on the probabilistic scenario of earthquakes as well as the maximum possible loss during this period based on a worst case scenario.

By constructing large, medium and small representative insurers with specific balance sheets, types of insurance portfolios, premium structures and a wide range of potential financial instruments, one could examine the impact of different disasters on the insurer’s profitability.
APPENDIX

MODELING THE DEMAND FOR PROTECTION AND SUPPLY OF COVERAGE AGAINST CATASTROPHIC RISKS

Demand for Insurance

We will first consider the case where the individual does not consider investing in loss mitigation measures. The standard model for analyzing this problem is expected utility analysis\(^\text{31}\) where the potentially insured party wants to find the optimal amount of insurance \((I^*)\) which maximizes his or her expected utility \(E(U)\) given by:

\[
\max \ E(U) = \pi U(W - I - zI) - (1 - \pi) U(W - zI) \quad (1)
\]

where \(W\) is the individual's wealth, \(I\) is loss from a disaster, \(z\) is premium per dollar of insurance and \(\pi\) is perceived probability of a disaster by the homeowner and \(U\) is a von-Neumann Morgenstern utility function. The amount of insurance is restricted to \(0 \leq I \leq L\). Note that \(z\) is based on the insurer's perceived probability of a disaster \((p)\). Optimal coverage based on \((1)\) is determined by the following contingency price ratio \((R)\):

\[
R = \frac{(1 - \pi)z}{\pi(1 - z)I} = \frac{U'(W - I - (1 - z)I)}{U'(W - zI)}
\]

where \(U'\) is the marginal utility of a particular wealth level. When \(R < 1\) then the individual will always buy full insurance \(I = L\). When \(R > U'(W - L)/U'(W)\) then an individual will want \(I = 0\).

\(^{31}\) Machina (1995) has shown that when one utilizes generalized expected utility analysis, most of the results of expected utility theory with respect to the consumer demand for insurance coverage still hold.
Impact of Financial Instruments on Survival Constraint

Let $B$ be the amount of capital which an insurer receives should it negotiate some type of financial arrangement like a finite risk product or Act of God bond. Suppose $Z$ reflects the annual premium which the insurer pays to obtain these funds when a disaster occurs (e.g., the extra amount paid by the insurer in interest rate differential in return for $B$ dollars provided to the insurer following a catastrophic disaster). Then (3) becomes:

$$
\sum_{j=1}^{m} [\text{Probability} \{ (X - jL - B) > (A - mr - Z) \}] < q^* \tag{4}
$$

(4)

Note that as $B$ increases relative to $Z$ in (4), the insurer will feel less constrained regarding the number of policies $m$ it writes for the new type of risk. Furthermore, for any given value of $m$, the premium $r$ will now be decreased. Viewed in this way, the underwriter should then be able to specify the magnitude of the needed funds ($B$) in relation to the cost ($Z$) to provide coverage against a risk which has catastrophic potential.

Freeman, Paul and Kunreuther, Howard (in press) Managing Environmental Risk Through Insurance


Insurance Research Council and Insurance Institute for Property Loss Reduction (1995) Coastal Exposure and Community Protection; Hurricane Andrew’s Legacy [Wheaton, Ill (IRC) and Boston (IIPR)].


