“Reducing Losses from Technical and Natural Hazards: The Need for Public-Private Sector Partnerships”

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Reducing Losses from Technical and Natural Hazards:
The Need for Public-Private Sector Partnerships

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ABSTRACT

Society faces large challenges in how we will deal with the increasing losses from natural, technological and environmental hazards. There is grave concern by the insurance and reinsurance industry that they cannot provide protection against these catastrophic risks without exposing themselves to the danger of insolvency or significant loss of surplus. Furthermore there is a reluctance on the part of property owners to invest in cost-effective loss reduction measures due to underestimation of the probability of a loss, short time horizons (myopia) and budget constraints. This paper explores the importance of insurance coupled with other policy instruments, such as regulations and standards, and interested parties (e.g. banks and financial institutions) to encourage loss reduction measures and provide financial protection against these hazards.

In order for the risks from natural disasters and catastrophic accidents to be insurable, there is a need to develop better risk estimates and allow insurers to set rates based on the risk. 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. To encourage investment in cost-effective loss reduction measures there is a need for well-enforced building codes as well as financial incentives such as long-term loans tied to an insurance policy. 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. (Kunreuther and Roth, Sr. 1998).

Consider the following two 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)] in the United States 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. 1998)

The purpose of this paper is to explore how insurance can be combined with other policy instruments, such as mitigation measures, building codes and well-specified standards, to better manage safety and reduce losses from catastrophic risks from technological and natural hazards. In particular, there is a need for a public-private partnership for dealing with these challenging issues. The principal focus here will be on the reducing losses from natural disasters, but the concepts and principles discussed below are relevant for dealing with safety systems for technical risks. Three recent developments provide the ingredients for rethinking the way society deals with these risks:
(1) There has been an emergence of new capital market instruments, such as catastrophe bonds, for dealing with catastrophic losses from these risks. Although the volume of business to date in these instruments is relatively small, they offer promise for protection in the future, both in the developed countries as well as emerging economies. [Insurance Services Office (1999)]

(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 low probability-high consequence (LP-HC) events. Today 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 (Kunreuther and Roth Sr. 1999).

(3) Mitigation measures promise to reduce losses from natural disasters and catastrophic accidents. In particular, there are many benefits which have traditionally not been considered as part of the standard benefit-cost analysis. These benefits may make mitigation extremely attractive to all of the concerned parties. (Heinz Center, in press; Mileti, 1999)

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

Since 1989 insurance and reinsurance firms have suffered losses from disasters that have wreaked havoc with their balance sheets. Figure 1 depicts the magnitude of the catastrophic losses experienced by the insurance industry in the United States from 1949 to 1997. The drastic
change from 1989 to 1997 is obvious. Prior to Hurricane Hugo in 1989 (where insured losses were over $4 billion), the insurance industry had never suffered any loss of over $1 billion from a single disaster. Since that time they have had 10 disasters which exceeded this amount. Commercial development has followed the population's movement to coastal areas, and this has increased the potential economic losses from natural disasters in this part of the country.

INSERT FIGURE 1 HERE

To analyze the impact of catastrophic risks on society it is important to consider the following elements:

*Population and Property at Risk.* One way to characterize who is at risk is to construct a community or region consisting of homes, businesses and other properties which are subject to future disasters. One needs to know the design of each structure, whether specific mitigation measures are in place or could be utilized, and the property's location in relation to the hazard. (e.g., distance from an earthquake fault line or proximity to the coast in a hurricane-prone area) as well as other risk-related factors.

*Risk Assessment and Potential Damage*  The potential damage to a community is determined by estimating the probability that disasters of specific magnitudes will occur and specifying the resulting losses to structures in harm's way. Relatively sophisticated models of catastrophic losses have been developed in recent years to model these distributions. (Dong et al., 1996). Consider the earthquake hazard. Scientists have been working to reduce the ambiguity and uncertainty in predicting the location, severity, frequency of occurrence, and physical effects of
earthquakes by examining geologic records, looking at actual events, and conducting experiments on how the ground responds to earthquake processes.¹

Engineers have focused on the nature, distribution, and level of damage from earthquakes. Such investigations have increased our understanding of the performance of various types of buildings and structures in earthquakes of different magnitudes. Hazard risk maps have been drawn for earthquakes, but they only provide rough guidelines as to the likelihood and potential damage from specific events. A case in point is the medium-intensity Northridge earthquake, where the predicted damage was considerably less than the actual losses (Scawthorn, 1995).

**Key Stakeholders**  The many interested parties concerned with natural disaster damage their principal roles, and their linkages with each other are depicted in Figure 2. Although the United States is used as an illustrative example here, the basic structure is likely to be the same in most developed countries.² At the top of the figure are the reinsurance industry, the capital markets and government agencies, each of whom have special roles to play with respect to providing protection against catastrophic losses. For example, the Federal Emergency Management Agency (FEMA) and other federal agencies have stressed the importance of building codes and enforcement of regulations to reduce losses from natural disasters in the United States.

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¹ One should make the distinction between aleatory and epistemic uncertainties in estimating risk. Epistemic uncertainty is the result of our limited knowledge about a hazard; epistemic uncertainty typically manifests itself as differences among experts in estimating the probabilities of a disaster and/or their consequences. Aleatory uncertainty refers to statistical uncertainty surrounding these estimates. Epistemic uncertainty can be reduced by obtaining better knowledge of the hazard (e.g., through research or better data), while aleatory uncertainty is an inherent aspect of the randomness of hazards. Both need to be considered in the risk estimation process. For more details on these two types of uncertainties, see (Hanks and Cornell, 1994).

² In developing countries where the insurance industry does not exist the key stakeholders and their interaction with each other may differ from Figure 2.
Reinsurers relate to insurers in the same manner that insurers do to property owners. They provide protection to primary insurers by insuring a portion of their claims in exchange for a premium. For all but the largest insurance companies, reinsurance is a prerequisite to offering insurance against natural disasters when there is a potential for catastrophic losses. As pointed out above, the capital markets have recently provided private insurers access to funds in the form of catastrophic bonds. The insurer borrows from investors or an institution at higher than normal interest rates to cover extreme losses from hurricanes and earthquakes that exceed a trigger amount. If this amount is exceeded then the interest on the bond, the principal, or both, are forgiven.³

The primary insurance companies, as shown in Figure 2, provide direct insurance coverage to residential and commercial sectors for losses such as those caused by fires (including those resulting from earthquakes) and wind damage from tornadoes and hurricanes. Primary insurance companies offer this coverage through the standard homeowners' policies normally required as a condition for a mortgage, and through commercial multi peril policies.

A number of other interested parties play key roles in the design and enforcement of insurance and damage mitigation requirement. They include financial institutions, through specific requirements as a condition for a mortgage; the construction industry, by designing safer structures; state and local governments, through ordinances and building codes; and the real estate sector through provision of information on hazards to potential buyers and owners.

**Decision Processes** An understanding of the decision processes of the property owner and insurer provides guidance for developing a set of strategies for reducing losses from future

³ For more details on these catastrophic bonds and other financing and hedging instruments see Doherty (1997).
natural hazards. If residents in hazard-prone areas are reluctant to voluntarily adopt mitigation measures that are cost-effective, then this provides a rationale for developing and enforcing building codes. The involvement of municipalities, contractors, third party inspectors and other key stakeholders is essential if this measure is to work. Similarly, if insurers are willing to give premium discounts for adopting mitigation measures, then there is an opportunity for banks and financial institutions to partner with the insurers to develop a financially attractive mitigation loan/insurance package.

**Policy Implications** One question that needs to be addressed in developing strategies for managing catastrophic risks is the appropriate roles of the private and public sectors in financing the cost of large-scale disasters. To the extent that private insurance markets provide protection against catastrophe risk, policymakers must decide how these markets should be regulated. They must also determine the role of regulations (e.g. restricting developments through land-use restrictions) and standards (e.g. well-enforced building codes) and the extent to which private choice and incentives will guide hazard mitigation efforts. Within the realm of public choice, decisions also must be made with respect to the delegation of authority among the different levels of government and its agencies. In evaluating these options, policymakers must consider how various governmental actions affect the behavior of firms and individuals in responding to catastrophe risk.

3. **Why Is There Limited Interest In Mitigation?**
The decision on whether to adopt risk mitigation measures (RMMs) to reduce losses from catastrophic accidents or natural disasters can be framed in a very straightforward manner. There is an upfront cost of the mitigation measure which will either reduce the probability of the accident or disaster occurring or the magnitude of the loss should the event take place. The benefits of the mitigation measure will be reaped for the length of time (T) that the entity is in place. In the case of homeowners adopting a loss-reduction measure, T is defined by how long the property is used as a residence. In the case of a firm facing technical risks, T is defined as the length of time that the business is in operation.

For simplicity, and without loss of generality, assume that there is a single type accident or disaster that can occur and that the probability of such an event and the resulting losses are constant over time. Using very simple notation to characterize the problem let us define the following terms:

\[ C = \text{upfront cost of mitigation measure} \]
\[ p = \text{annual probability of disaster causing house to collapse without mitigation measure} \]
\[ (\text{e.g. } p = .05) \]
\[ p^* = \text{annual probability of disaster causing house to collapse with mitigation measure} \]
\[ (p^* \leq p) \]
\[ (\text{e.g., } p^* = .025) \]
\[ L = \text{loss reduction from mitigation measure} \]
\[ (\text{e.g. } L = 20,000) \]
\[ r = \text{annual discount rate} \]
\[ (\text{e.g. } r = .10) \]
\[ T = \text{relevant time horizon} \]
\[ (\text{e.g. } T = 10 \text{ years}) \]

The decision as to whether or not to invest in an RMM is determined by comparing the cost of mitigation (C) with the expected benefits [E(B)]. Assume that if a disaster or accident occurs
within the T year time horizon the house will be restored to its pre-disaster condition and be functional again as it was prior to the disaster. Then \( E(B) \) can be characterized as follows:

\[
\sum_{t=1}^{T} (p^* - p)(L)/(1+r)^t \quad (1)
\]

To illustrate with a simple example, consider the figures presented with the notation above.

Equation (1) now becomes:

\[
\sum_{t=1}^{T=10} (0.05 - 0.25)(20,000)/(1.10)^t \quad (2a)
\]

\[
\sum_{t=1}^{T=10} 500/(1.10)^t = 3,380. \quad (2b)
\]

On the average the mitigation will yield $500 worth of direct expected benefits each year so that over the 10 year time horizon it will yield total discounted expected benefits of $3380. If the mitigation measure costs less than $3380, then it is cost-effective for the business or homeowner to adopt it. This example and the discussion which follows assumes that the value of the property will not be increased at all by the investment in the mitigation measure. To the extent that mitigation gets translated into a higher property value, then this provides an additional reason to make this investment.

In reality there are a number of reasons why a firm or individual will decide not to invest in such measures:

**Underestimation of Probability** Some individuals may perceive the probability of a disaster causing damage to their property as being sufficiently low that the investment in the protective
measure will not be justified. For example they may relate their perceived probability of a disaster (p) to a threshold level (p*), which they may unconsciously set, below which they do not worry about the consequences at all. If they estimate p < p*, then they assume that the event "will not happen to me" and take no protective actions. This decision to ignore events where p < p* may be justified by individuals who claim that there is a limited amount of time available to worry about protecting oneself against hazards facing us. By setting a threshold level p*, individuals can devote their attention to events that where p is sufficiently high to be a source of worry and concern. Such a rule is also easy to explain and justify to others because of its simplicity.

**Short Term Horizons** Individuals may have relatively short time horizons over which they want to recoup their investment in an RMM. Even if the expected life of the house is 25 or 30 years, the person may only look at the potential benefits from the mitigation measure over the next 3 to 5 years. They may reason that they will not be residing in the property for longer than this period of time and/or that they want a quick return on their investment.

The need for a quick return is also consistent with having a high discount rate regarding future payoffs. Loewenstein and Prelec (1992) propose a behavioral model of choice whereby the discount function is hyperbolic, rather than exponential. Their model appears to explain the reluctance of individuals to incur the high immediate cost of energy-efficient appliances in return for reduced electricity charges over time (Hausman, 1979; Kempton and Neiman, 1987).

**Aversion to Upfront Costs** If people have budget constraints then they will be averse to investing in the upfront costs associated with protective measures simply because they feel they cannot afford these measures. It is not unusual for one to hear the phrase “We live from payday to payday” when asked why a household has not invested in protective measures. (Kunreuther et al. 1978).
Truncated Loss Distribution  Individuals may have little interest in investing in protective measures if they believe that they will be financially responsible for only a small portion of their losses should a disaster occur. If their assets are relatively limited in relation to the potential loss, then these individuals may feel they that they can walk away from their destroyed home without being financially responsible. Similarly if residents anticipate liberal disaster relief from the government should they suffer damage, then they would have less reason to invest in an RMM.

4. Empirical Studies on Adoption of Mitigation Measures

The empirical data on studies of mitigation adoption in hazard-prone areas of the United States suggest that individuals are not willing to invest in RMMs despite the rather large damage that either they and/or their friends and neighbors suffered from recent disasters. For example, after Hurricane Andrew in Florida in 1992 most residents in hurricane-prone areas appear not to have made cost-effective improvements to existing dwellings that could reduce amount of damage from another storm at relatively low cost. A July 1994 telephone survey of 1241 residents in six hurricane-prone areas along the Atlantic and Gulf Coasts revealed that 62 percent indicated that they had not installed hurricane shutters, used laminated glass in windows, installed roof bracing and/or made sure that side walls were bolted to the foundation either before or after Hurricane Andrew. (Insurance Institute for Property Loss Reduction 1995).

Measures, such as strapping a water heater with simple plumbers tape, can normally be undertaken by property owners at a cost of under $5 in materials and one hour of their own time. (Levenson 1992). This RMM can reduce damage by preventing the heater from toppling during an earthquake, creating gas leaks and causing a fire. Yet these and other mitigation investments are not being adopted by residents in earthquake-prone areas in the United States. A 1989 survey of
3,500 homeowners in four California counties subject to the hazard reported that only between 5 and 9 percent of the respondents reported adopting any loss reduction measures (Palm et al. 1990). This behavior suggests that individuals do not believe that investing in the RMM will increase their residence’s property value or that they have either short time horizons and/or severe budget constraints which either reduce their perceived net benefits from RMMs or simply prevent them from making the investment (Kunreuther 1996).

Turning to the relationship between insurance and mitigation some interesting findings emerge from recent surveys undertaken by Risa Palm and her colleagues. Palm and Carroll (1998) report that that those who had adopted mitigation measures were also more likely to buy earthquake insurance than those who had not taken these loss reduction measures. This raises the interesting question as to whether certain types of individuals and managers want protection for reasons that have less to do with their perception of the risk than their intrinsic worries and concerns.

To determine individual decision processes with respect to RMMs and how much an individual is willing to pay for investing in such measures, a set of controlled experiments were conducted in Pennsylvania and California (Kunreuther, Onculer, and Slovic 1998). One example of a question posed to individuals participating in this survey was to specify their maximum willingness to pay (WTP) for bolting the structure to its foundation if they planned to reside in their house for exactly 5 years given that the expected annual reduction in damage from the RMM was approximately $500. They were then asked to specify their maximum WTP if they
expected to live in the house for exactly 10 years. In other words their time horizon (T) for residing in their house was doubled but nothing else in the experiment was changed.\footnote{No statement was made about the impact that mitigation would have on the value of the property. From informal discussions with subjects participating in the experiment, there was no indication that anyone even considered that mitigation would increase their property values.}

Table 1 presents the distribution of these WTP figures for 84 students at the University of Pennsylvania. Half of these students were not told what the RMM cost to install and the other half were told that the price of installing the RMM was $1500. As shown in the illustrative example presented in Section 3 \[\text{[see equation (2b)]}\], a risk-neutral person should be willing to pay as much as $3380 if their annual discount rate was 10\% and they expected to live in their house for 10 years.\footnote{A person who is averse to risk should want to pay even more than $3380.} Yet only 7\% of the subjects who were not given the price chose to spend more than $3,000; the percentage increases to 17\% for this group when the price was specified to be $1,500. Almost half of the individuals participating in the experiment did not change their maximum WTP when the time horizon was doubled from 5 to 10 years. These results suggest that individuals have extremely high discount rates and/or use a decision process that differ from those suggested by cost-benefit analysis. RMMs may need to be very cost effective indeed if they are to be adopted voluntarily by individuals residing in hazard-prone areas.

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These general conclusions were reinforced in a follow-up survey of 252 individuals visiting the Exploratorium Museum in San Francisco who were more likely to face the earthquake hazard than those participating in the Pennsylvania survey. Now three different time horizons (T) for residing in the house were utilized: 5 years, 10 years and 20 years for obtaining the maximum
WTP when the price of the quake RMM was given at $1500. As in the earlier experiment, a significant proportion of the respondents had either high annual discount rates (the mean value varied between 67% and 74% depending on the values of T) or did not change their maximum WTP as the time horizon for residing in the house was increased. For the case where the length of time in the house was extended from 5 to 10 years, 45% of the subjects did not change their expressed WTP for the protective measure (Kunreuther, Onculer and Slovic, 1998).

In summary, many property owners are reluctant to invest in cost-effective RMMs because they do not make the implied tradeoffs between spending money now in return for potential benefits over time. Such non-adoption behavior may be further exacerbated by developers who may believe (perhaps correctly) that they are unable to recover the costs of RMMs in increased selling prices for the structures.

5. Improving the Estimates of the Risk

Suppose homeowners and businesses were to voluntarily adopt cost-effective mitigation measures and insurers were to set premiums which reflected the reduction in losses from RMM to their insured structures. This would take us a long way toward reducing disaster losses to those in hazard-prone areas as well as reducing the probability of insurer insolvency. An important next step in achieving this objective is to improve our estimates of the risks associated with natural and technological disasters.

There are two principal reasons why insurers will benefit from improved estimates of the risk associated with catastrophes. By obtaining better data on the probabilities and consequences of these events, they will be able to more accurately set their premiums and tailor their portfolio to reduce the chances of insolvency. Providing more accurate information on
the risk also reduces the asymmetry of information between insurers and other providers of capital such as reinsurers and the financial investment community. Investors are more likely to supply capital if they are more confident in the estimates of the risks provided to them by the insurers.

In setting rates for catastrophic risks insurers have traditionally looked backwards by relying on historical data to estimate future risks. Such procedures are likely to work well if there is a large data base of past experience which forms the basis for extrapolation into the future. Low probability-high consequence events generally have a relatively small historical data base. In fact, many technological and environmental risks are associated with new processes, so that past performance data are lacking. One thus has to rely on scientific modeling and epidemiological data to estimate these risks. Fortunately there is considerable scientific work undertaken in the areas of natural, technological and environmental hazards to provide estimates of the probabilities and consequences of events of different magnitudes.

For example, with respect to earthquakes, a discussion of new advances in seismology and earthquake engineering can be found in Federal Emergency Management Agency (1994) and Office of Technology Assessment (1995). Regarding technological hazards, the Wharton Risk Management and Decision Processes Center is now compiling a very comprehensive data base on the impact of large-scale catastrophic accidents on health and safety risks. (Kleindorfer, Lowe and Rosenthal 1997). With respect to environmental risks to health, such as groundwater contamination, data bases have been assembled which open up opportunities for providing insurance protection on risks that recently had previously been considered uninsurable by firms in the industry. (Freeman and Kunreuther 1997).
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. 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 1996).

Today there are a growing number of catastrophe models that have been utilized to generate data on the likelihood and expected damage to different communities or regions from disasters of different magnitudes or intensity. Each model uses different assumptions, different methodologies, different data and different parameters in generating their results. Hence the need for a better understanding as to why these models differ and attempts to reconcile these differences in a more scientific manner than has been done up until now.

6. **Broadening Protection Against Catastrophic Losses**

New sources of capital from the private and public sectors could provide insurers with funds against losses from catastrophic events, which would alleviate insurers’ concerns that the next major disaster might leave them insolvent. They range from capital market instruments to insurance pools to federal solutions.

With respect to capital market solutions, in the past couple of years investment banks and brokerage firms have shown considerable interest in developing new financial instruments for protecting against catastrophic risks. Their objective is to find ways to make investors comfortable trading new securitized instruments covering catastrophic exposures, just like the
securities of any other asset class. In other words, catastrophe exposures would be treated as a new asset class. (Insurance Services Office 1999)

In June 1997 the insurance company, USAA, floated act-of-God bonds that provided them with protection should a major hurricane hit Florida. A 2 year CAT bond was put together by Swiss Re Capital Markets and Credit Suisse First Boston in July 1997. The loss triggers were tied to California insurance industry earthquake losses based on the Property Claims Insurance index for the state. Other financial arrangements, such as catastrophic insurance futures contracts and call spreads introduced by the Chicago Board of Trade (CBOT) in 1992 enable an insurer to hedge against its underwriting risk by attracting capital from insurance and non-insurance segments of the economy. (Cummins and Geman, 1995; Harrington, et al., 1995). The Catastrophic Risk Exchange (CATEX) creates a marketplace where insurers, brokers, and the self-insured can swap units of their catastrophe risks by region and peril. For example, an insurer could swap units of California earthquake for Florida windstorm (Insurance Services Office, 1996).

Turning to the role of the public sector, Lewis and Murdoch (1996) developed a proposal 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. Insurers, reinsurers, and state and national reinsurance pools would be eligible purchasers. Another proposed option is for the federal government to provide reinsurance protection against catastrophic losses. Private insurers would build up the fund by being assessed premium charges in the same manner that a private reinsurance company would levy a fee for excess-loss coverage or other protection. The advantage of this approach is that resources at the federal government’s disposal enable it to cover
catastrophic losses without charging insurers the higher-risk premium that either reinsurers or
capital market instruments would require. If one views the private sector as the first line of attack
on the problem, then one would only want to resort to federal reinsurance as last resort.

6. Policy Implications: Need For A Public-Private Partnership

As pointed out in the introduction, the key to a successful hazard management program is to
design ways for reducing losses while providing protection should a disaster occur. The
empirical data suggests that there is a need for new public-private partnerships to address this
problem. Today most property owners have limited interest in investing in loss reduction
measures. Insurers have little reason to encourage mitigation in hazard-prone areas since they
feel that the rates they are allowed to charge are inadequate. They prefer to charge the same rates
with and without mitigation and hope that some policyholders decide not to renew their
insurance policy. (Kunreuther and Roth 1998).

In this section three types of public private partnership programs are proposed that
can reduce losses from future disasters: (1) building codes, (2) premium reductions linked with
long-term loans for mitigation (3) insurers offering lower deductibles for those investing in
mitigation. In order to successfully implement these programs there needs to be a better
understanding of the nature of the probabilities and consequences from these hazards, as
indicated in Section 5 and insurance rates should reflect these risks.

Role of Building Codes Building codes mandate that property owners adopt mitigation
measures. Such codes may be desirable when property owners would otherwise not adopt cost-
effective RMMs because they either misperceive the benefits from adopting the RMM and/or
underestimate the probability of a disaster occurring. For example, suppose the property owner believes that the losses from an earthquake to the structure is $20,000 and the developer knows that it is $25,000 because it is not well constructed. There is no incentive for the developer to relay the correct information to the property owner because the developer is not held liable should a quake cause damage to the building. If the insurer is unaware of how well the building is constructed, then this information cannot be conveyed to the potential property owner through a premium based on risk. Inspecting the building to see that it meets code and then providing it with a seal of approval provides more accurate information to the property owner.

Cohen and Noll (1981) provide an additional rationale for building codes. When a building collapses it may create externalities in the form of economic dislocations and other social costs that are beyond the economic loss suffered by the owners. These may not be taken into account when the owners evaluate the importance of adopting a specific mitigation measure. For example, if a building topples off its foundation after an earthquake, it could break a pipeline and cause a major fire that would damage other homes not affected by the earthquake in the first place. In other words, there may be an additional annual expected benefit from mitigation over and above the reduction in losses to the specific structure adopting this RMM. All financial institutions and insurers who are responsible for these other properties at risk would favor building codes to protect their investments.

If a family is forced to vacate its property because of damage that would have been obviated if a building code had been in place, then this is an additional cost that needs to taken into account when determining the benefits of mitigation. Suppose that the household is expected to need food and shelter for 50 days at a daily cost of $100. Then the additional expense from not having mitigated after a disaster occurs is $5000. If the annual chances of the disaster occurring is p
= 1/100, then the annual expected extra cost to the taxpayer of not mitigating is 1/100 x $5000 = $50. Although this may not appear to be a very large dollar amount, it gives rise to an expected discounted cost of over $560 for a 30-year period if an annual interest rate of 8% were utilized. Should there be a large number of households that need to be provided with food and shelter, these costs could mount rapidly.

In addition to these temporary food and housing costs, the destruction of commercial property could cause business interruption losses and the eventual bankruptcy of many firms. The impact on the fabric of the community and its economic base from this destruction could be enormous (Britton 1989). In a study estimating the physical and human consequences of a major earthquake in the Shelby County/Memphis, Tennessee area, located near the New Madrid fault, Litan et al. (1992) found that the temporary losses in economic output stemming from damage to workplaces could be as much as $7.6 billion based on the magnitude of unemployment and the accompanying losses in wages, profits and indirect “multiplier” effects.

One way to encourage the adoption of cost-effective mitigation measures is for banks and financial institutions to provide a seal of approval to each structure that meets or exceeds building code standards. Under the Institute for Business Home and Safety (IBHS) Showcase Community Program structures that meet predefined criteria would receive a certificate of disaster resistance. Upon receipt of that certificate, there would be a set of incentives provided by banks (e.g. lower mortgage rates), contractors and insurers. (Personal Communication with Harvey Ryland, November 1997). The success of such a program requires the support of the building industry and a cadre of qualified inspectors to provide accurate information as to whether
existing codes and standards are being met. Insurers may want to limit coverage only to those structures that are given a certificate of disaster resistance.6

**Premium Reductions Linked with Long-Term Loans** Premium reductions for undertaking loss prevention methods can be an important first step in encouraging property owners to adopt these measures. The basic rule in this case is a simple one: if the premium reduction is less than the savings in expected claim payments due to mitigation, it is a desirable action for the insurer to promote. If homeowners are reluctant to incur the upfront cost of mitigation due to budget constraints, then one way to make this measure financially attractive to the property owner is for the bank to provide funds for mitigation through a home improvement loan with a payback period identical to the life of the mortgage. For example, a 20-year loan for $1500 at an annual interest rate of 10% would result in payments of $145 per year. If the annual premium reduction from insurance reflected the expected benefits of the mitigation measure (e.g., $500 in the example in Section 3), then the insured homeowner would have lower total payments by investing in cost-effective mitigation than not doing so (Kunreuther 1997).

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 RRM$s or for them to relocate 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.

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6 For more details on ways to make communities disaster-resistant see CUSEC 1997.
Lower Deductibles Tied to Mitigation

An alternative way to encourage consumers to adopt mitigation measures is to change the nature of their insurance coverage rather than reducing the premium. More specifically, the insurer could offer a lower deductible to those who adopt mitigation at the same or lower price than if they had decided not to invest in the RMM. Such a program is likely to be very attractive given the empirical and experimental evidence that suggests that consumers appear to dislike deductibles even though they offer considerable savings in premiums.

A graphic example of the aversion to higher deductibles is the outcry by consumers in Pennsylvania, when Herbert Denenberg, then the Insurance Commissioner of Pennsylvania, instituted a mandatory $100 deductible for automobile collision policies. Although the plan purportedly saved consumers millions of dollars, it was eventually rescinded (Cummins et al. 1978, p. 146). This attitude toward deductibles still prevails. Johnson et al. (1993) attribute the dislike for deductibles, in part, to loss aversion and provide evidence from controlled laboratory experiments to support this conjecture.

7. Extensions to Technological 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 risks. In this section I examine some of the challenges that insurers face in this area and the need to involve other interested parties.

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 above 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,*⁷ which refers to the public blaming “unexplained” adverse health effects following a chemical release on the accident even though the illness (real or imagined) was caused by other factors. If the insurer believes that they will be forced to cover these unfounded claims following an accident, the premium will have to reflect this risk.

As with natural hazards there are potential benefits to inspections of the chemical facility to both estimate the risk as well as determine what loss prevention measures have been undertaken. These audits can be undertaken by the insurer itself or a third party such as a certified inspector. The inspection process will enable important risk data to be collected, synthesized and analyzed so that one has better estimates of the risk. There are two factors which inhibit the use of these inspections:

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⁷ The term “public moral hazard” was suggested by Paul Kleindorfer. It is discussed in more detail in Er et al. (1996).
(1) the difficulty in determining what constitutes a safe facility and
(2) concern with liability by the inspector if there is an accident which occurs after
the facility is certified to be safe.

For both these reasons it may be necessary to specify standards and requirements
which guide the process. A good example of a case where third party inspections have worked
extremely well is in the regulation of steam boilers where 43 states in the U.S. require boiler
inspections on a regular basis. Statutory codes have been specified by an industry trade
association and serve as the basis for judging the performance of the boiler. (Er 1996)

If the insurer faces a potentially large loss from a catastrophic accident in relation
its surplus then it is in the same boat as with the natural hazards risk. It will require some form of
protection through a combination of reinsurance/new financial instruments or government
assistance. To the extent that the insurer provides coverage against accidents facing a large
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 new financial instruments such as Act of God Bonds, just in case it experienced
an unusual number of accidents during a short period of time

8. 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.

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 and accidents on the insurer’s profitability, solvency and performance through a simulation. Such an analysis may also enable one to evaluate the risks associated with different types of financial instruments provided to different sized insurers with a given portfolio. These data could be used to determine the return an investor would require to provide capital for supporting each instrument. The selling prices of different types of financial instruments would reflect both the expected loss and variance in these loss estimates to capture risk aversion by investors. One could also examine
the role of the public sector in regulating rates and providing protection against catastrophic losses.\footnote{An example of the application such an approach to a model city in California facing an earthquake risk can be found in Kleindorfer and Kunreuther (1999).}

Two very important outcomes would emerge from such simulations. It should be possible to rank the importance of different financial instruments for different type firms. Thus small firms may prefer finite risk products while larger ones may want to rely on excess loss reinsurance due to a more attractive price for a pre-specified amount of protection. These simulation results could be compared with analytic studies of the performance of these instruments. If there are major differences it would be important to understand why they exist. Secondly investors could determine whether the market price which emerged from this simulation would be sufficiently attractive for them to provide investment capital to support certain instruments.

Future studies could examine the following issues:

- **Regulatory Issues**: What impact would rate restrictions on premiums that insurers are allowed to charge in hazard-prone areas have on the availability of coverage and their incentive to encourage mitigation?

- **Uncertainty Issues**: There is considerable uncertainty in estimating the probability of disasters of different magnitudes occurring and the magnitude of the resulting losses. How can one incorporate these uncertainties in an analysis of which mitigation measures are cost-effective?

- **Tradeoffs Between Reinsurance and Mitigation**: How much reinsurance would have to be purchased to provide sufficient protection to the insurer as a function of the amount of mitigation in place?

- **Impact of Mitigation on Capital Market Instruments**: How will loss reduction measures impact on the ability of the insurance industry to provide coverage without relying extensively on funds from the capital market? Will mitigation reduce the uncertainty of future losses, so that these new financial instruments could be more easily marketed to investors?
This is a very exciting time for the insurance and reinsurance industry to explore new opportunities for dealing with catastrophic risks. If insurance can be used as a catalyst to bring other interested parties and new financial instruments to the table, it will have served an important purpose in helping both the industry and society deal with the critical issue of reducing losses and providing protection against natural, technological and environmental disasters.
REFERENCES


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 (IIPLR)].


### TABLE 1

**DISTRIBUTION OF MAX WILLINGNESS TO PAY (WTP)**

% Individuals in Each Category

<table>
<thead>
<tr>
<th></th>
<th>Price Not Given</th>
<th></th>
<th>Price Given=$1,500</th>
<th></th>
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<tr>
<td></td>
<td>5 Years</td>
<td>10 Years</td>
<td>5 Years</td>
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<td>7%</td>
<td>4%</td>
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<td>7%</td>
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<td>16%</td>
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<td>19%</td>
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<td>2%</td>
<td>7%</td>
<td>12%</td>
<td>17%</td>
</tr>
</tbody>
</table>

Number of Subjects = 42

Source: Kunreuther, Onculer and Slovic (1998)
Figure 1: Insured Catastrophe Losses (1949-1997) (in 1997 dollars)
Source: Insurance Services Office
Figure 2: Roles of Interested Parties Concerned with Hazard Mitigation and Insurance in the United States