“Ambiguity and Government Risk-Bearing for Low Probability Events”

91-05-02

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Paper Prepared For
The Conference on Government Risk-Bearing
Federal Reserve Bank of Cleveland

May 30-31, 1991

Many of the ideas in this paper are based on joint work with colleagues and students. In particular, the discussion on earthquake risks reflects research jointly undertaken with Ann Butler, Neil Doherty, Anne Kleffner and Jack Morrison; Carrie Ericson helped summarize the legislative and regulatory history associated with the underground storage tank risk. This research was partially supported by NSF Grant No. SES88-09299 and a grant from the Russell Sage Foundation.
Ambiguity and Government Risk-Bearing for Low Probability Events

I. Introduction

What is the appropriate role for the federal government to play in dealing with ambiguous risks where there is a reluctance on the part of the insurance industry to offer coverage and there is limited interest by homeowners and businesses in voluntarily adopting loss reduction measures? This question is of increasing importance today because of the potentially high costs to society from these low probability events. Two examples illustrate these developments:

Earthquakes — Catastrophic earthquakes have the potential of producing losses far greater than any other natural hazard. Estimates of property damage from major quakes in the Los Angeles and San Francisco areas (in 1990 dollars) are in the $45 billion range, more than 5 times as high as the worst case projections from hurricanes along the East Coast. (Litan 1991). With respect to financial protection, earthquake insurance has been widely available in California since 1916 (Steinbrugge, McClure and Snow 1969). In recent years it has been written by private insurers throughout the United States, although most policies are purchased in California.
Few homeowners have had an interest in voluntarily purchasing protection and financial institutions have normally not required such coverage as a condition for a mortgage. In 1976 less than 5 percent of the homeowners residing in California were covered by an earthquake policy. This percentage has risen to about 20 percent in 1990 after the California State legislature passed a ruling that insurance companies were required to inform all policyholders with homeowners coverage that they could add an earthquake rider to their policy for an additional charge. (Palm et. al. 1990). The insurance industry is reluctant to provide coverage on a widescale level, claiming that a catastrophic quake would cause insolvency of a number of companies. A recent study using the thrift crisis as an analogy supports the insurance industry's concern. (Litan 1990).

On the consumer side there has been limited interest by individuals in adopting loss mitigation measures against earthquakes. In a 1974 survey of 1000 California homeowners in earthquake prone areas, only 12 percent adopted protective measures against earthquake damage (Kunreuther et. al. 1978). In a 1989 survey of 3500 homeowners in four California counties subject to earthquake damage, the percentages were even lower, ranging from 5 to 9 percent (Palm et. al 1990). The most important reason given for not adopting these loss prevention measures was that it was too expensive relative to the benefits that could be reaped.
Underground Storage Tanks In the United States there are approximately 1.5 million regulated Underground Storage Tanks (UST) containing petroleum or hazardous chemicals. The EPA estimates that 25 percent or more of all USTs have corroded and are leaking hazardous substances into the groundwater. (Duus and Telsey 1990). Regulations covering the inspection and use of USTs are covered by the 1984 Resource Conservation and Recovery Act (RCRA). All tanks must be tested for leaks and have leak detection equipment installed by 1993 and all existing tanks must be protected from corrosion or removed by 1999. (Ouellette and Maestri 1990).

Many owners, particularly small businesses, have been reluctant to incur the costs of testing (approximately $1000) and cleaning up the tank (ranging from $7500 for a leak to more than $1 million for major damage including third party liability claims). For this reason the Superfund Amendments and Reauthorization Act (SARA) requires that the EPA develop financial responsibility requirements for owners and operators of USTs to ensure that they have sufficient funds to upgrade leaking tanks or cover cleanup, bodily injury and property damage claims from leaks.¹ Commercial lenders also run the risk of being identified by the courts as a responsible party if they are actively engaged in the management of a property containing leaking tanks.

¹ Deadlines have been postponed by the EPA for compliance with these financial responsibility requirements. Those owning between 13 and 99 tanks were required to meet these requirements by April 26, 1991; those with fewer than 13 tanks have until October 26, 1991 as do local governments who own and operate USTs. State governments and the federal government are immune from the rules. (Schachner 1990).
Few insurers have offered coverage against potential leaks from underground tanks. A principal reason for this lack of interest by the private sector is that state funds have been set up for helping UST owners meet their $1 million financial responsibility requirements. These funds are financed by taxes on gasoline distributors and fees paid by tank owners and operators. It has been estimated that the implied premiums are 10% of what commercial insurers would charge for similar risks (Shalowitz 1990). Given the existence of these state funds, the only reason why a tank owner or commercial lender would want to purchase private insurance is to protect himself against the chance that the state fund itself will not be able to cover losses and the company would then be held liable.

These examples suggest two policy questions with respect to the role of the government in dealing with low probability high consequence events:

(1) What type of loss protection (if any) should the government provide to insurers to encourage them to offer coverage in cases where the risks are ambiguous and potential losses may be catastrophic?

(2) What is the appropriate role of regulations forcing homeowners and businesses to take protective action for reducing potential losses from the hazard in question?

This paper argues that the government may want to bear some of the risks for catastrophic disasters, such as an unusually severe earthquake in a populated portion of California because of the limited financial capacity of the insurance
industry to cover the resulting claims if most of the victims were insured. In return for this protection loss prevention measures should be required to reduce potential damage should a severe disaster occur.

On the other hand, it is much less clear whether the public sector should offer protection against individual risks where there is no catastrophic potential, such as a leaky underground storage tanks, particularly if the insurance industry has the interest and capacity to cover these losses. The key issue in these cases is how to deal with the claim by small businesses that they are unable to pay for private insurance and hence are willing to go unprotected rather than buying coverage. Forced inspections and financial responsibility requirements may be necessary to reduce the health risks from hazards which would otherwise be undetected.

In the next section of the paper we will examine the impact that ambiguity of probability and loss has on the supply of insurance by summarizing the results of a survey of underwriters who were asked to price earthquake and UST insurance policies and a related survey of actuaries. Contrary to the predictions of expected utility theory both underwriters and actuaries charge much higher premiums for ambiguous than non-ambiguous risks.

Section III examines the role of individuals or businesses facing the potential risk of earthquake or UST losses. We will develop a simple benefit-cost model depicting what type of protective actions individuals should want to take regarding mitigation and insurance and examine reasons why they do not follow these guidelines in practice. The final sections of the paper examine the policy implications of these
findings and proposes a joint private-federal program for dealing with risks such as 
earthquake and underground storage tanks.

II Insurer Decision Making Under Ambiguity

A. Theoretical Considerations

The decision regarding what premium an insurance company should set for a 
given risk is made by the underwriters with advice from actuaries. Until recently it 
was assumed by economists that agents acting on behalf of firms are risk neutral and 
hence make choices that maximize their firms' expected profits. This assumption 
has been challenged by Greenwald and Stiglitz (1990) who suggest that managers 
(e.g. underwriters) may be risk averse because they will suffer substantial personal 
costs if their company becomes insolvent. Hence they have strong incentives to 
reduce the probability of bankruptcy to a point that is lower than the one which is 
optimal for stockholders. Supporting empirical evidence on this point in the case of 
insurers has been provided by Mayers and Smith (1983, 1989) in their studies of 
corporate demand for insurance and reinsurance.

Consider the premium setting decision for a risk averse underwriter facing a 
single risk with known probability p and known outcome L. He wants to determine 
the premium r where he is indifferent between offering insurance coverage or 
maintaining the status quo. To simplify the exposition without loss of generality 
assume that the underwriter is offering a full insurance policy to his client. If A 
represents the insurance company's assets prior to providing coverage and U is the
underwriter's Von Neumann - Morgenstern utility function then \( r \) is determined by setting

\[
U(A) = p U(A-L+r) + (1-p)U(A+r)
\]  

(1)

It should be clear from (1) that as the variance of the loss around a given mean \( L \) increases then the indifference premium \( r \) will also increase due to risk aversion by the underwriter. If there is ambiguity or uncertainty on the probability then this should not affect the premium for a single risk. To see this consider the case where there are \( k \) different expert opinions of the probability of a given loss occurring within a specified time period. These probability estimates are denoted by \( p_1 = 1, \ldots, k \) with the underwriter estimating the probability of a loss to be \( f(p_1, \ldots, p_k) \). As long as this probability estimate is the same as \( p \), then the premium should not change from \( r \) given by (1).

For a portfolio of risks the problem becomes more complicated because the underwriter now has to determine the degree of independence between the individual policies. A somewhat counterintuitive theoretical result based on expected utility maximization is that probability ambiguity will lead the underwriter to charge a higher premium for independent identically distributed risks but not for perfectly correlated risks. (Hogarth and Kunreuther 1991).

A simple example illustrates these differences and compares the behavior of a risk
neutral and risk averse underwriter. Consider the situation where there are two experts 1 and 2 each of whose estimates of the probability of a known loss L are considered equally credible. Expert 1 estimates $p_1 = .1$ and Expert 2 estimates $p_2 = .3$, so that $f(p_1, p_2) = .2 = p$ (the well specified probability). The underwriter is considering insuring two risks each of which has the same potential loss, $L = 100$. With respect to the underwriter's utility function let $U(A) = 0$ and $U(A - 100) = -1$. A risk neutral underwriter would set $U(A - 200) = -2$ while a risk averse underwriter would set $U(A - 200) < -2$, say $U(A - 200) = -3$.

Figure 1 depicts the decision trees required to determine the indifference premium specified by the underwriter for four different cases based on the nature of the probability and loss conditions. When the premium is zero, the resulting expected utilities reveal that a risk neutral underwriter will find that $E(U) = -.4$ for all four cases. This implies that the indifference premium remains the same whether or not probability is ambiguous and losses are independent or perfectly correlated. When the underwriter is risk averse and losses are independent then his expected utility with a zero premium will be lower if probability is ambiguous [$E(U) = -.45$] than if probability is well-specified [$E(U) = -.44$] thus implying that the indifference premium must be higher for the ambiguous case. For a perfectly correlated risk (which is really the same as a single risk) then the expected utilities remains the same whether or not the probability is ambiguous [$E(U) = -.6$]. Due to risk

\[2\text{The indifference premium to charge for the risk neutral case is } r = .2. One can easily determine that at this value the expected utility equals 0, the same as if no insurance policies had been issued.\]
Figure 1: Decision Trees and Expected Utilities for Two Risks Under Different Probability and Loss Conditions
aversion by the underwriter this implies that catastrophic losses will require higher indifference premiums than independent losses.

B. Underwriter Survey

Recent empirical data on underwriter behavior suggests that these managers have a strong aversion to probability ambiguity as well as uncertainty on losses. (Kunreuther, Hogarth, Meszaros and Spranca (1991)). A questionnaire was mailed to underwriters in 190 randomly chosen insurance companies of different types and sizes to determine what pure premiums\(^3\) they would set for three different types of losses or risk contexts: neutral, earthquake and underground storage tanks. The earthquake scenario involved insuring a factory against property damage from a severe quake; the hazardous waste scenario provided liability coverage to the owners of an underground storage tank containing toxic chemicals against damages caused by leakage from the tank. The neutral risk, which acted as a reference point for the two context based scenarios, described only a probability and loss level for an unnamed peril.

Each questionnaire included two scenarios, the neutral risk plus either the earthquake or underground tank context. A scenario consisted of four cases representing uncertainty and ambiguity conditions specified in Table 1 below:

\(^3\)The questionnaire instructions stated that pure premiums should exclude "loss adjustment expenses, claims expenses, commissions, premium taxes, defense costs, profits, investment return and the time valuation of money".
Loss

<table>
<thead>
<tr>
<th>Known</th>
<th>Uncertain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well-Specified</td>
<td>p, L</td>
</tr>
<tr>
<td>Ambiguous</td>
<td>Ap, L</td>
</tr>
</tbody>
</table>

The p, L case reflects the case where both p and L are well-specified (e.g. p=0.01, L=$1 million). In the Ap,L case the probability is ambiguous meaning that there is a high degree of uncertainty around some given value of p such as p=0.01. In the p,UL the best estimate of loss is given (e.g. $1 million) but the uncertainty associated with loss is indicated by specifying a minimum and maximum loss equidistant from the best estimate. An illustrative set of scenarios for the neutral risk is presented in Appendix A.

One measure that provides a perspective on how underwriters feel about

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4 If the best estimate is $1 million then the respective minimum and maximum values might be $0 and $2 million.
probability and loss uncertainty is the coverage per dollar of premium charged (c/\$). As premiums increase, then c/\$ decreases. This standardized measure enables one to compare premiums across risks of different magnitudes. For example, suppose that L=$1 million and p=.01. An actuarially fair pure premium would be r=$10,000 which would imply a c/\$ =100. This value acts as a reference point for determining how underwriters feel about uncertainty and ambiguity. Table 2 depicts different values of c/\$ for the different experimental conditions of our questionnaire survey.

It is clear from these figures that underwriters charge a much higher premium when there is either probability ambiguity and/or loss uncertainty. To illustrate, consider the Underground Tank scenario where p=.01 and L=$1 million and the actuarially fair premium is $10,000. Even for case 1 (p,L), the average c/\$=57 which is equivalent to a premium of $17,500. For case 2 (ap,L) the average c/\$ drops to 37 implying that the premium has increased to $27,000. For case 4 (ap,UL), the average value of c/\$=31 which translates into a premium of $32,300. Both the neutral and earthquake scenarios showed the same pattern between the four cases as the underground tank case, although the premiums were generally lower. This may reflect a greater uncertainty by these underwriters on the nature of the UST risk.

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5Since the underwriters are providing full insurance in all case, coverage is the same as the actual loss.

6In general, c/\$=1/p for an actuarially fair pure premium. Thus whenever p=.01 c/\$=100; if p=.005 then c/\$=200 no matter what the loss is.

7For the case where loss was uncertain (UL) we utilized the best estimate of loss (which by definition was L) to determine c/\$.
### Table 2

**Mean Coverage per Dollar of Premium (c/\$) for Different Scenarios and Experimental Conditions**

*Underwriter Survey*

\[
p = 0.005, \ L = \$1 \ million \\
Actuarially Fair c/\$ = $200
\]

<table>
<thead>
<tr>
<th></th>
<th>p,L</th>
<th>Ap,L</th>
<th>p,UL</th>
<th>Ap,UL</th>
<th>n</th>
</tr>
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<tbody>
<tr>
<td>Neutral</td>
<td>127</td>
<td>87</td>
<td>94</td>
<td>74</td>
<td>29</td>
</tr>
<tr>
<td>EQ</td>
<td>115</td>
<td>90</td>
<td>97</td>
<td>65</td>
<td>17</td>
</tr>
<tr>
<td>HW</td>
<td>105</td>
<td>55</td>
<td>59</td>
<td>38</td>
<td>12</td>
</tr>
</tbody>
</table>

\[
p = 0.005, \ L = \$10 \ million \\
Actuarially Fair c/\$ = $200
\]

<table>
<thead>
<tr>
<th></th>
<th>p,L</th>
<th>Ap,L</th>
<th>p,UL</th>
<th>Ap,UL</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral</td>
<td>129</td>
<td>100</td>
<td>100</td>
<td>58</td>
<td>31</td>
</tr>
<tr>
<td>EQ</td>
<td>143</td>
<td>109</td>
<td>111</td>
<td>90</td>
<td>8</td>
</tr>
<tr>
<td>HW</td>
<td>121</td>
<td>79</td>
<td>83</td>
<td>61</td>
<td>17</td>
</tr>
</tbody>
</table>

\[
p = 0.01, \ L = \$1 \ million \\
Actuarially Fair c/\$ = $100
\]

<table>
<thead>
<tr>
<th></th>
<th>p,L</th>
<th>Ap,L</th>
<th>p,UL</th>
<th>Ap,UL</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral</td>
<td>53</td>
<td>41</td>
<td>56</td>
<td>37</td>
<td>24</td>
</tr>
<tr>
<td>EQ</td>
<td>51</td>
<td>43</td>
<td>42</td>
<td>34</td>
<td>23</td>
</tr>
<tr>
<td>HW</td>
<td>57</td>
<td>37</td>
<td>41</td>
<td>31</td>
<td>32</td>
</tr>
</tbody>
</table>

\[
p = 0.01, \ L = \$10 \ million \\
Actuarially Fair c/\$ = $100
\]

<table>
<thead>
<tr>
<th></th>
<th>p,L</th>
<th>Ap,L</th>
<th>p,UL</th>
<th>Ap,UL</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral</td>
<td>67</td>
<td>44</td>
<td>53</td>
<td>37</td>
<td>47</td>
</tr>
<tr>
<td>EQ</td>
<td>83</td>
<td>60</td>
<td>72</td>
<td>58</td>
<td>6</td>
</tr>
<tr>
<td>HW</td>
<td>60</td>
<td>44</td>
<td>44</td>
<td>29</td>
<td>11</td>
</tr>
</tbody>
</table>

Source: Kunreuther, Meszaros, Hogarth and Spranca (1991)
relative to the other two policies.

C. Actuary Survey

The underwriter survey focused on a single risk so that no conclusions could be drawn between the impact of independence or correlation on the premiums charged. In an earlier survey, 489 actuaries were exposed to different scenarios where the probability of a loss was either known or ambiguous (Hogarth and Kunreuther 1989). One of these scenarios, Computeez, involved a manufacturing company that wants to determine the price of a warranty to cover the $100 cost of repairing a component of a personal computer. In this scenario the actuaries were asked to specify premiums when losses were independent or perfectly correlated.

The median values of c/$ presented in Table 3 indicate the actuaries specified considerably higher premiums for perfectly correlated risks than independent risks when 100,000 units are insured. This behavior suggests that they are extremely risk averse. Contrary to the predictions of expected utility theory, they reacted by increasing the premium (i.e. reducing c/$) for the perfectly correlated case. For example when p=.01, the actuarially fair c/$ value = 100. The data in Table 3 reveal that when losses are perfectly correlated and p is well-specified, the median value is 82; it decreases to 9 when the actuary faces an ambiguous probability. The true probability would have to be p=.111 for this median premium to be actuarially fair.

These findings provide strong empirical evidence that both underwriters and
Table 3


(Median Values)

100,000 units insured
L = $100

<table>
<thead>
<tr>
<th></th>
<th>Independent Risks</th>
<th>Perfectly Correlated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p = 0.001</td>
<td>p = 0.01</td>
</tr>
<tr>
<td>Actuarially</td>
<td>1000</td>
<td>100</td>
</tr>
<tr>
<td>Fair</td>
<td></td>
<td></td>
</tr>
<tr>
<td>p</td>
<td>909</td>
<td>95</td>
</tr>
<tr>
<td>Ap</td>
<td>200</td>
<td>50</td>
</tr>
</tbody>
</table>

** The number of actuaries responding to these scenarios ranged from 14 to 22

Source: Hogarth and Kunreuther (1990)
actuaries are concerned with ambiguity and uncertainty when setting premiums for certain risks. There are a number of possible explanations for this behavior ranging from a concern about having to justify their pricing decisions to others (Tetlock (1985); Curley Yates and Abrams (1986)), the use of safety first models which are motivated by stability and insolvency constraints (Stone 1973) and the use of anchors and reference points to set premiums (March and Shapira 1987).

The empirical results also suggest that if these managers are able to accurately assess the risk associated with a particular hazard then this will considerably reduce the premium charged to the client. To the extent that there is information available on the probability of a defective UST and the expected replacement cost then private insurers may feel more comfortable providing coverage against this event. Earthquakes provide fewer possibilities in this regard since they are relatively infrequent and whatever data exists on past quakes has been published and collected by the insurance industry. However, there may be opportunities to collect more detailed data on the nature of damage to different structures. We will return to this area in the concluding section of the paper.

III Protective Actions by Homeowners and Businesses

We now turn to the decision making process of a consumer or business who is considering purchasing protection against a particular risk. There are two types of protective options: voluntarily purchasing insurance and adopting loss prevention measures. Each will be considered in turn:
A. Voluntarily Purchasing Insurance

We will consider the following case where the prospective buyer has the option of buying full coverage or remaining unprotected. Figure 1 depicts a decision tree for the case where the buyer has wealth W and faces a loss L with probability p. If the individual purchases insurance then her wealth is decreased by the premium z. If she decides to remain unprotected then if an accident or disaster occurs she either loses L or declares bankruptcy (if W<L).

There are several reasons why an individual may not want to purchase insurance coverage. People may underestimate the probability of a disaster or the magnitude of the loss so that they perceive the premium to be too high relative to the potential benefits. (Zeckhauser and Viscusi 1990). A related form of behavior is the use of very simple heuristics or rules of thumb for coping with low probability high consequence events. These rules reflect individuals discomfort with probability as well as their limited ability to process information.

Tversky, Sattath and Slovic (1988) concluded that individuals use a contingent weighting model in dealing with uncertainty. More specifically individuals make biased tradeoffs between the different the probability and outcome dimensions associated with different alternatives. For some problems the perceived probability of an accident or disaster is the critical dimension. In such cases people may decide not to purchase insurance because they feel the chances of their suffering a loss or injury is below a given threshold value. For example, if a person's threshold probability level was $p^* = .01$ then if they perceived the chances of an earthquake
occurring next year to be less than .01 then they would behave as if the event "cannot happen to me".

If the individual or business has limited wealth then he may not be able to afford insurance due to budget constraints and/or conclude that he would prefer to take his chances that an accident will not occur and if it does declare bankruptcy. Ringlieb and Wiggins (1990) have provided empirical evidence that since 1967 large firms have attempted to avoid liability for long-term latent hazards such as groundwater contamination by vertically divesting production tasks associated with these risks. Should specific consequences from such hazards be discovered then these small firms will declare bankruptcy when suits are filed. There is thus no incentive for these firms to purchase insurance against these risks. For example, a small business with assets of $500,000 may prefer not to purchase voluntarily UST insurance of $1 million for covering cleanups and third party liability should a leak be discovered in its underground storage tank.

In the case of underground storage tanks there is another good reason for not buying coverage. Let $z =$ premium offered by a private company and $s =$ premium for joining a state fund. The premium $z$ normally consists of an annual fee per tank (e.g. $40) and a tax on the gasoline sold by the distributors who service the tank owner (e.g. 2 cents per gallon). If the tank owner is a small business with severe budget constraints he is likely to choose the cheapest policy (i.e the state fund) if required to show financial responsibility by the EPA. In making this decision he may recognize that the state fund has limited reserves, so that he may still have to
declare bankruptcy if his tank leaks. Larger businesses and commercial lenders may prefer to purchase private insurance coverage rather than taking the chance that the state fund will be unable to pay off a large future claim they might make.

B. Voluntary Loss Prevention Measures

The decision by a homeowner or a business to adopt a loss prevention measure is similar in spirit to a decision on whether to purchase insurance. There is a cost (M) of adopting the measure and there are benefits in the form of either a lower probability (p') of a disaster or accident occurring and/or the magnitude of the resulting loss (L'). The first case is illustrated by retrofitting a storage tank with corrosion protection, thus reducing the probability of a leak during the life of the tank. An example of the second case would be the installation of a leak-detection device on a UST so that any damage from a corrosive tank can be contained and hence the loss is limited to L'. In the case of earthquake measures there is little that an homeowner can do to reduce the probability of a quake short of moving his structure to a location further from the fault line. With respect to loss prevention measures the owner can strap appliances (e.g. gas water heaters) to the dwelling's structural frame to reduce the damage to L' should a quake occur.

To illustrate the tradeoffs associated with either type of loss prevention measure assume that the individual is risk neutral so that a simple benefit-cost comparison
can be made.\(^8\) If the structure is expected to last for \(T\) years then the annual amortized cost for the measure is determined by finding \(m\) so that

\[
\sum_{t=0}^{T} \frac{m}{(1+d)^t} = M
\]

For example if \(T=5\) years and \(M=\$1000\) then \(m=\$250.\(^9\)

For the case where the annual probability is reduced from \(p\) to \(p'\) then loss prevention measures would be viewed as desirable if \(m < (p-p') L\). For example if \(p=0.01\), \(p'=0.005\), and \(L=\$100,000\) then if \(m < \$500\) such a measure would be considered attractive. In the case where the action reduces losses from \(L\) to \(L'\) then the relevant comparison for adoption is that \(m < p (L-L')\). Thus if \(L=\$100,000\) \(L'=\$60,000\) and \(p=0.01\), a measure with a discounted cost \(m < \$400\) would be a desirable one to adopt.

As pointed out in the introduction there is considerable evidence that few homeowners adopt loss reduction measures for earthquakes and that a large

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\(^8\)If the person is risk averse then one has to compare utilities in different states of the world but the same type of tradeoff as described below will be appropriate.

\(^9\) This calculation is based on the assumption that will be no accident or disaster over the 5 year period, or that if there were a disaster the mitigation measure would be intact, so that the \$1000 cost would not have to be incurred if the structure were rebuilt.
number of USTs are currently leaking, implying that relatively few have been inspected. Some of the reasons that individuals have not adopted these measures may be similar to those which have led homeowners to remain uninsured: underestimation of p, threshold models of choice and budget constraints.

There is an additional reason why a homeowner or business may not adopt a protective measure. They may focus on the relatively large upfront expenditure associated with the measure (i.e. M), not recognizing that the potential benefits will be reaped as long as the structure is in place. If one thinks of the investment as reaping a return only over the coming year rather than over a longer time horizon, then the investment will often be viewed as unattractive. Recent empirical studies suggest that individuals are myopic and do not consider long-time horizons in their planning decisions. (Lowenstein and Prelac 1989).

Finally if insurance is purchased for protection against losses, then mitigation measures may be discouraged. In their seminal piece Ehrlich and Becker (1972) indicate that market insurance has two opposite effects on the incentive to adopt these measures. On the one hand, it discourages the adoption of protective activities by reducing the difference between the incomes in the disaster and non-disaster states of the world. On the other hand, it encourages individuals to adopt mitigation measures if the insurance premiums reflect the decrease in expected loss. The actual impact depends on the degree of risk aversion by the individual, the loading charge on insurance and the costs of the mitigation activity relative to the reduction in risk.
IV Implications for Policy

The above discussion indicates that the private market for insurance and mitigation against ambiguous risks such as quakes and underground storage tanks is likely to be very thin because of imperfections on both the supply and demand sides.

With respect to the supply side, underwriters and actuaries will want to place a surcharge on their premiums for risks where there is uncertainty in either $p$ and/or $L$. Data on underwriter and actuary pricing behavior suggests that both these agents will want to charge a high enough premium on ambiguous risks so they can justify offering coverage to themselves and others in the firm.

Regarding the demand for protection, most homeowners and firms are reluctant to purchase insurance coverage or adopt loss reduction measures because they do not perceive that the expected benefits from such actions are worth the costs. This could be due to a combination of factors ranging from misperceptions of the risk, the use of threshold models of choice, myopic behavior, and the knowledge that they can declare bankruptcy should they be personally responsible for repairing any damage or covering the loss from a specific event.

Why should we be concerned about the failure of the private market to provide adequate protection prior to a disaster? For one thing, there are risks which have the potential of creating severe financial and environmental disruption on a rather broad level. One only has to turn to the record of disaster relief in the mid 1960s to
the early 1970s for graphic evidence on the special measures that were passed to help uninsured victims of floods, earthquakes and hurricanes. For example, following Tropical Storm Agnes in 1972 the Federal government offered up to $5000 forgiveness grants and 1 percent loans to those uninsured homeowners and businesses who suffered damage and provided over $1.2 billion in loans and $544 billion in grants. (Kunreuther 1973). Flood insurance at highly subsidized rates had been available in many areas hit by the storm but very few policies had been sold.

There may be indirect losses from a disaster or accident which may not be part of an individual's calculation when determining whether to adopt mitigation measures voluntarily. In the case of earthquakes, losses due to injury, death or business interruption may be as great as the direct property losses.\textsuperscript{10} These factors are not part of property insurance coverage and hence the premium reduction from adopting mitigation measures will not reflect these elements. In the case of USTs there are severe health and environmental risks from the thousands of leaky tanks that have not been inspected by their owners for fear that they would have to be repaired or replaced at a cost that was viewed by the firm as prohibitively expensive.

V. A Proposed Private-Federal Insurance and Mitigation Program

A proposed program is outlined below designed to encourage the insurance industry to provide coverage against risks such as earthquake and USTs at lower

\textsuperscript{10} See Kunreuther and Kleffner (1991) for a comparison of the impact of two specific loss reduction measures on direct property losses as well as indirect losses.
rates than are currently available. At the same time it appears necessary for either the government or financial institutions to require homeowners and businesses to purchase insurance protection and adopt loss mitigation measures. To the extent data are collected on the status of USTs the insurance industry should be able to estimate the probability that a tank will leak and the potential damage this would cause.

**Improving risk assessment techniques.** The basic principle of insurance is to set premiums based on risk. In the case of the earthquake risk there is limited data on which to base premiums. In the past few years the insurance industry and the Federal Emergency Management Agency have undertaken a number of studies which has enabled them to more accurately characterize the risks of different structures (Earthquake Project 1990) and the impact of alternative mitigation measures on damage from a quake (Dames and Moore 1990). Insurance premiums should reflect these differences in risk so that consumers are paying a fair price and have incentives to adopt loss prevention measures. To the extent that data are collected on the status of USTs, the insurance industry should be able to estimate the probability that a tank will leak and the potential damage this would cause.

**Financial Responsibility or Mandatory insurance** In order to provide protection to victims from a natural disaster (earthquake) or environmental disaster (leakage of an UST) it is essential that the homeowner or business show financial responsibility to cover their losses. With respect to earthquakes, banks and financial institutions who issue federally-insured or reinsured mortgages can require
homeowners to purchase an earthquake rider that would be attached to their standard homeowner policy.\textsuperscript{11} This requirement would severely reduce the chances that the federal government would be forced to offer liberal disaster relief should a catastrophic quake occur.

In the case of USTs there is no reason why the financial requirements stipulated by EPA should be delayed any further. State Funds, need to provide a plan for covering losses from USTs if their limited reserves are exhausted; otherwise they should cease to exist as they are likely to provide a false sense of security to potential victims. There is a private insurance market for coverage against USTs and this type of protection should be encouraged.

**Require Mitigation Measures** In the case of earthquakes there are a number of cost-effective mitigation measures which can provide substantial benefits in the form of reduction in damage to property, saving lives and injuries and reducing disaster relief for such expenditures as temporary housing and business interruption. Few homeowners adopt these measures voluntarily and mandatory insurance will make them even less attractive than if the homeowners were uninsured. (Kunreuther and Kleffner 1991). Building codes and investment incentives (e.g. subsidized loans) may be necessary in order to avoid large scale damage and federal assistance following a catastrophic quake.

\textsuperscript{11}A homeowner policy is normally required as a condition for a mortgage to protect the bank against fire, wind and other potential losses to the property and contents.
For USTs, insurers can require each small business to have an inspection or environmental audit to determine the current condition of their tanks and the nature of the risk. If certain tanks need to be repaired or removed, then EPA must enforce these regulations. Many small businesses claim that they cannot afford these expenditures and may have to declare insolvency if such action is required. In such a situation the choices facing the EPA and other federal agencies are not easy ones: if they want to preserve these small businesses they could institute a long-term low interest loan program to assist them if their balance sheet indicate a need for funds. Their other alternative is to call the firm's bluff and see whether it can scrape up enough money to repair or replace the tank.

Federal Involvement in Insurance  Given the impact that ambiguity and uncertainty has on the insurance pricing decision process, some type of federal government involvement may help reduce premiums over what they would otherwise be. In the case of catastrophic losses it appears that probability ambiguity will lead to much higher premiums than if the chances of a disaster were well-specified. A consortium of insurance companies have recommended that the government set up a new federal earthquake corporation to collect premiums and cover losses from an earthquake. (Litan 1991). A principal motivation for this program is to reduce the rates from their current levels partially because ambiguity will become less of an issue and also because the federal corporation would not be taxed on reserves for the big quake, as private companies are.
Another option that could be considered for either earthquakes or USTs includes elements of the German pharmaceutical pool and nuclear liability insurance protection pool in the United States. This proposed three-tiered system involves a well-specified risk-sharing arrangement between the insured party, the insurer(s) and the federal government. (Doherty et al. 1990). As in the German pool the first layer of protection is self-insurance by the homeowners or business itself, equivalent to a deductible on an insurance policy. This feature produces an incentive for the insured to adopt loss mitigation measures beyond those which are required if it determines that by taking these steps it can reduce the losses it will have to bear. In addition, the deductible reduces or eliminates moral hazard problems.

The second layer can be offered by private insurers and mutual insurance pools. A consortium of insurance companies could form an earthquake pool and combine their premiums received from mandatory coverage to build up reserves for a catastrophic quake. Similarly an insurer could form a mutual company consisting of UST owners, all of whom contribute to a fund for covering potential losses. Precedence for such an arrangement comes from the German pharmaceutical pool, a group of insurers and reinsurers from all over Europe, and from the two insurance pools formed in 1957, as part of the Price Anderson Act, to provide nuclear power plant operators with liability coverage. Mutual pools are difficult to form because of the concern by each potentially insured client that she is the safest on the block and therefore would not be comfortable taking coverage from such a concern. Hence premiums need to be based on risk and the operations of the
insured should be closely monitored and controlled to reduce moral hazard potential.

Finally the third layer requires some type of government involvement for losses above a specified limit in Layer 2. For example, in the case of earthquakes the limit could be a catastrophic quake exceeding $10 billion. For a UST there would be a limit (currently between $500,000 and $2 million depending on the scale of the operation) on the insurer’s responsibility for paying the costs of groundwater contamination from tank leaks. A government agency would be responsible for levying fees on the insurer for catastrophic quake losses or on the owners of the UST for covering losses which exceed the limits of layer 2. The Price Anderson Act offers a precedent for such an arrangement. The fee would be partially based on the degree of risk faced by the insurer or UST owner.

The principal objective of Layer 3 is to provide compensation to victims. The incentives for encouraging risk reduction measures by homeowners and businesses lie in the first two layers of coverage and the required mitigation measures.

VI. Conclusions

The two examples presented in this paper illustrate the impact that ambiguity and uncertainty have on the failure of the private market to allocate risk between key stakeholders. Insurers are reluctant to provide insurers except at highly inflated
premiums; homeowners and businesses behave as if the event in question will not happen to them. The costs of protection are generally viewed as too high relative to the expected benefits in the form of reduced losses or insurance coverage.

The program outlined above has a carrot and stick quality to it. The government assumes some of the risk-bearing with respect to catastrophic losses while imposing requirements for homeowners and businesses to reduce the chances of such large losses occurring. Risk assessment is an important part of the program so that costs can be allocated appropriately across the different interested parties. Each particular problem has its own institutional arrangements which need to be recognized in designing the detail of any specific program. The challenge is in finding an appropriate mix of public and private sector involvement for dealing with risks where there is considerable ambiguity and uncertainty.
References


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