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# Insurer Ambiguity and Market Failure

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*Abstract*

A series of studies investigate the decision processes of actuaries, underwriters, and reinsurers in setting premiums for ambiguous and uncertain risks. Survey data on prices reveal that all three types of these insurance decision makers are risk averse and ambiguity averse. In addition, groups appear to be influenced in their premium-setting decisions by specific reference points such as expected loss and the concern with insolvency. This behavior is consistent with a growing analytical and empirical literature in economics and decision processes that investigates the role that uncertainty plays on managerial choices. Improved risk-assessment procedures and government involvement in providing protection against catastrophic losses may induce insurers to reduce premiums and broaden available coverage.

**Key words:** insurer ambiguity, uncertainty, market failure, decision making

## 1. Introduction

Recently, the difficulties of obtaining insurance coverage against events ranging from accidents at day care centers to environmental impairment liability damage have been reported with increasing frequency in the media. These failures of insurance markets present a puzzle for economics. Insurance protection is the classic example of a contingent claim. In theory, individuals have an opportunity to purchase a policy at a premium $z$ that will yield claim payments to cover prespecified losses if a particular state of nature occurs (e.g., an earthquake). If the insurer is able to estimate the probability of the given state of nature and the distribution of resulting losses, then it should be possible to determine what premium to charge. In a world with perfect capital markets, the insurer will attempt to maximize expected profits and set premiums accordingly.

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During the past few years, economists have been searching for explanations as to why there have been large price increases, coverage reductions, and for many clients unavailability of insurance since the mid-1980s. Winter (1991) suggests that a principal reason for the insurance crisis is that limited liability of insurers imposes a constraint on the amount of coverage that they can credibly offer. In addition, there are imperfect capital markets, because managers have better information on the characteristics of their firms' operations than do the outside suppliers of equity.

These two features will lead to new market equilibria in which prices are higher and coverage reduced if insurers experience very large losses so their capacity is significantly affected. Firms with multiple lines will tend to restrict coverage and revise prices on those risks that are most uncertain. Doherty and Posey (1992) suggest that rationing occurs on those lines of insurance where it is most difficult to estimate future and unsettled claims. Here again, those lines where either the probability or loss is most uncertain will be the ones where prices will be increased the most for a given amount of coverage.

This article complements these recent studies by examining how uncertainty affects the premium-setting decisions of actuaries, underwriters, and reinsurers. Surveys of these three groups reveal that their recommended premiums are considerably higher if there is increasing ambiguity with respect to the probability of a given loss and/or there is larger uncertainty with respect to the actual loss itself should a specific event occur. The data also suggest that insurers utilize simplified rules, such as the safety-first model, in determining what premiums to set. Furthermore, a number of respondents voluntarily indicate that they would prefer not to provide insurance against risks where there is considerable ambiguity and uncertainty.

If insurance is to be a useful policy instrument for providing protection against specific risks, then our results suggest that issues related to uncertainty and ambiguity need to be addressed directly. We suggest two types of solutions. One involves improving risk assessments. The other involves creating new institutional arrangements whereby risks are shared between potential clients, insurers, and government bodies. Otherwise, individuals and businesses may have to go bare and declare backruptcy or rely on federal assistance should a disaster occur. Today this problem is significant in a number of different areas involving natural and technological hazards.

To set the stage for the empirical findings, consider four general classes of risk for which insurers may be asked to provide coverage. This classification is based on the ambiguity and uncertainty conditions depicted in table 1. A well-specified probability ($p$) refers to a situation in which there are considerable past data on a particular event so that "all experts agree that the probability of a loss is $p$." An ambiguous probability ($Ap$) refers to the case where "there is wide disagreement about the estimate of $p$ and a high degree of uncertainty among the experts." A known loss ($L$) indicates that all experts agree that, if a specific event occurs, the loss will equal $L$. An uncertain loss ($UL$) refers to the situation where the experts' best estimate of a loss is $L$, but estimates range from $L_{min}$ to $L_{max}$.

As shown in table 1, well-known risks for which large actuarial data bases exist (e.g., life and automobile) fall into the ($p$,$L$) category. Other events, such as playground accidents, are more appropriately classified as ($p$,$UL$). These are risks where there are

*Table 1.* Classification of risks

| Probability | Loss: Known | Loss: Uncertain |
|---|---|---|
| Well specified | *p,L*<br>Life, auto | *p,UL*<br>Playground accidents |
| Ambiguous | *Ap,L*<br>Satellite, new products | *Ap,UL*<br>Earthquake, underground storage tanks |

considerable data on the chances of an event occurring but much uncertainty about the potential size of the loss (e.g., magnitude of potential liability awards). Risks such as satellite losses or new product defects fall into the (*Ap,L*) class. The chance of a loss occurring is highly ambiguous because there is little past experience against which to estimate probabilities, but the insurers feels confident that they know what the magnitude of the loss will be should the event occur. The risks which are most problematic for the insurance industry are those in the (*Ap,UL*) class. Examples include earthquake damage and environmental damage from waste facilities such as underground storage tanks.

The next section describes two specific types of ambiguous risks for which insurers are reluctant to provide coverage. After a brief description of the relevant institutional arrangements surrounding the insurance pricing decision, in section 3 we examine the decision processes of different actors in insurance firms. A number of behavioral and organizational considerations may lead prices for ambiguous and uncertain risks to be higher than one would anticipate in a competitive market where firms maximize expected profits. The empirical data in section 4 provide evidence consistent with this conjecture and suggests that the market for insurance for these types of risks is likely to be thin. The concluding section suggests ways of correcting for market failure through better risk assessment and alternative institutional arrangements such as federal reinsurance to cover catastrophic losses.

## 2. Two problems

### *2.1. Earthquakes*

Severe earthquakes can produce losses far greater than any other natural hazard. Estimates of property damage from major earthquakes in the Los Angeles and San Francisco areas (in 1990 dollars) are in the $45 billion range, considerably higher than the worst-case projections from hurricanes along the East Coast (Litan 1991). Although earthquake insurance is available today, and has been profitable to date, most insurers are reluctant to provide widespread coverage, claiming that a catastrophic quake would cause insolvency both for themselves and for many other companies. Empirical evidence supporting this concern has been documented by Doherty et al. (1991).

Until recently, few homeowners have had an interest in voluntary earthquake coverage, and financial institutions have normally not required such insurance as a condition for a mortgage. In 1976 less than 5% of the homeowners residing in California were covered by an earthquake policy. This percentage rose to about 20% 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). Today most insurance firms favor a program whereby the federal government would provide reinsurance against a catastrophic earthquake. In return for this protection, firms would offer coverage to homeowners at much lower premiums than are currently available (Earthquake Project, 1990).

### *2.2. Underground storage tanks*

In the U.S., there are approximately 1.5 million regulated Underground Storage Tanks (USTs) containing petroleum or hazardous chemicals. The EPA estimates that 25% or more of all USTs have corroded and are leaking hazardous substances (Duus and Telsey 1990). Regulations specifying the inspection requirements and use of USTs are covered by the 1984 Resource Conservation and Recovery Act (RCRA). All existing tanks must be protected from corrosion or removed by 1999 and, as of 1993, all new tanks must be tested for leaks and have leak-detection equipment installed (Ouellette and Maestri, 1990).

Many owners, particularly small businesses, have been reluctant to incur the costs of testing (approximately $1000) and cleaning up after a leak (ranging from $7500 for a small leak to more than $1 million for major damage including third-party liability claims). For this reason, the Superfund Amendments 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 deteriorating tanks or to cover cleanup and bodily-injury and property-damage claims following 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.

Few insurers have offered coverage against potential leaks from underground tanks.[2] Without regular inspections, it is difficult to estimate the probability of a leak, and if one should occur, the resulting environmental liability is highly uncertain. The president of an insurance-consulting firm testified at Congressional hearings in 1983–1984 that insurance companies are reluctant to provide pollution coverage on USTs. He indicated that a principal reason for this lack of interest is that "it is an unknown risk and we really don't know what to expect" (*Ground Water Contamination,* 1983–1984). Today there are a few companies who offer limited coverage against UST risks. Most insurers prefer not to get involved.

Due to this lack of interest by private insurers, state funds have been set up to help 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 tank owners or commercial lenders would want to purchase private insurance is to protect themselves against the chance that the state fund itself will not be able to cover losses, and therefore the company itself would be held liable.

Both these problems illustrate reluctance by insurers to offer coverage against risks where the probabilities of a loss are ambiguous and the magnitudes of potential claims are uncertain and may be large. Under these conditions, the prices charged by insurers are higher than would be implied by their expected losses (e.g., earthquake insurance) or coverage is normally not offered (e.g., protection against UST leakage).

## 3. Pricing an insurance policy

The process of insuring a risk with catastrophic potential, such as losses from earthquakes and UST leaks, involves actuaries and underwriters in a primary insurance company and underwriters in reinsurance firms.[3] Using past data as a guide, the actuary provides the primary-insurance underwriter with a recommended pure premium, which does not include loading factors such as marketing and administrative expenses. The underwriter utilizes this information to determine whether coverage should be offered to the potential client and what premium should be charged. To the extent that primary underwriters do not recognize that the prices of actuaries may already include adjustments for ambiguity and uncertainty, they may recommend a premium that reflects their concerns with these factors.

If the final insurance package includes reinsurance, the underwriter also has to consider what risks reinsurers will be willing to underwrite and what price they will be likely to charge the insurer.[4] If reinsurers charge higher prices and/or narrow their layers of protection when there is considerable uncertainty, then underwriters will raise premiums and/or reduce the amount of coverage they are willing to offer. Should reinsurance be unavailable for certain risks, primary insurers are likely to withdraw these types of policies from the market. To the extent that underwriters recognize ambiguity and risk aversion among reinsurers, this may tend to legitimate and reenforce their own ambiguity-averse pricing tendencies.

Each decision maker concerned with pricing insurance has his or her own set of goals and objectives that may differ from those of the owners of the firm. Each also may have different information than the owners. Economists have recognized potential goal conflicts and information asymmetries between owners and managers and have developed principal-agent models to examine the effects of such differences on actual choices (Holmstrom, 1979; Shavell, 1979; Grossman and Hart, 1983; Rogerson, 1985). Management scientists and psychologists have undertaken controlled laboratory studies and field surveys to examine how different goals and objectives influence managerial decision making under risk (Payne et al., 1992; MacCrimmon and Wehrung, 1986; March and

Shapira, 1987). These models and studies suggest several propositions about insurer behavior, including predictions regarding pricing of risks.

**Hypothesis 1.** Insurance managers are risk averse.

If an insurance manager charges a higher premium for risks when there is uncertainty about the potential size of losses than for risks when the potential magnitude of losses are known, other things being equal, this individual is considered *risk averse.*

*Example 1.* Consider two risks with different characteristics regarding probabilities ($q_i$) of different losses ($L_i$) occurring, as shown in the two trees in figure 1. Both risks have the same expected loss ($q \times L = EL = -100$) If a loss occurs in risk 1, it is certain to be $L = -1000$. In case of risk 2, the loss is either $L = -600$ or $L = -1600$. A risk-averse insurer will charge a higher premium for risk 2 than risk 1.

Recent empirical and theoretical studies suggest that actuaries and underwriters are risk averse in their behavior. Mayers and Smith (1990) contend that the transaction costs associated with bankruptcy can make risk-averse behavior rational and may explain the demand for reinsurance by property/liability companies. Greenwald and Stiglitz (1990) argue that managers suffer grave damage to their personal career prospects when their companies become insolvent and that they cannot diversify this risk as owners can. Underwriters would, by this logic, price insurance higher than the owners of the firm would view as desirable.

**Hypothesis 2.** Insurance managers are ambiguity averse.

*Example 2.* Consider an insurer who is setting premiums for each of the following two risks with known loss $L = -1000$. Risk 1 has known probability $p = .2$. For risk 2 there

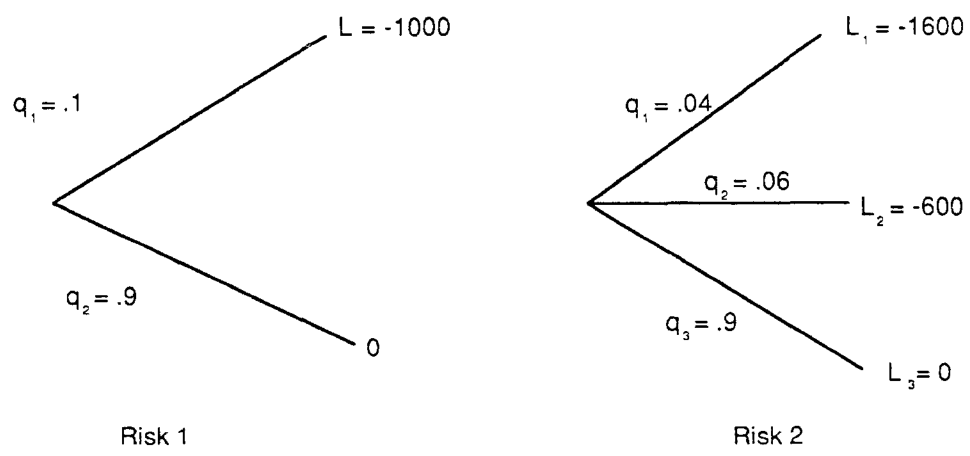


*Figure 1.* Two risks with different characteristics regarding probabilities ($q_i$) of different losses ($L_i$) occurring.

are two different expert opinions of the probability $p$. Expert A estimates $p_\alpha = .1$, and expert B estimates $p_\beta = .3$. The insurance manager accords equal weight to each expert (i.e., $w_i = .5, i = \alpha, \beta$) so that his or her estimate of the ambiguous probability $Ap = .2$

The trees depicting these two situations are shown in figure 2. An ambiguity-averse insurer will charge a higher premium for risk 2 than risk 1, even though $p = Ap$.[5]

If an insurance manager sets a higher premium for a risk when the probability is ambiguous ($Ap$) rather than well specified ($p$), other things being equal, this individual is considered *ambiguity averse* in the loss domain.

There is considerable evidence from controlled laboratory studies that individuals are ambiguity averse. Einhorn and Hogarth (1985; 1986) characterized choice under ambiguity as the result of an anchoring-and-adjustment process and conducted experiments showing that individuals are averse to ambiguity in the domain of losses for small probabilities. Heath and Tversky (1991) contend that individuals' attitudes toward ambiguity depend on how competent they feel in understanding the particular situation they face.[6] Insurance managers are likely to feel less confident and therefore to be more ambiguity averse when trying to estimate the risk of low-probability, difficult-to-predict events such as earthquakes.

Curley, Yates, and Abrams (1986) found greater ambiguity aversion in situations where individuals knew their decisions would be scrutinized by others. In the context of insurance-pricing decisions, each key actor is responsible to others (e.g., actuaries to underwriters, underwriters to other insurance executives). Anticipated scrutiny and judgment may induce ambiguity aversion.

**Hypothesis 3.** Insurance managers utilize constraints and reference points in making pricing decisions.

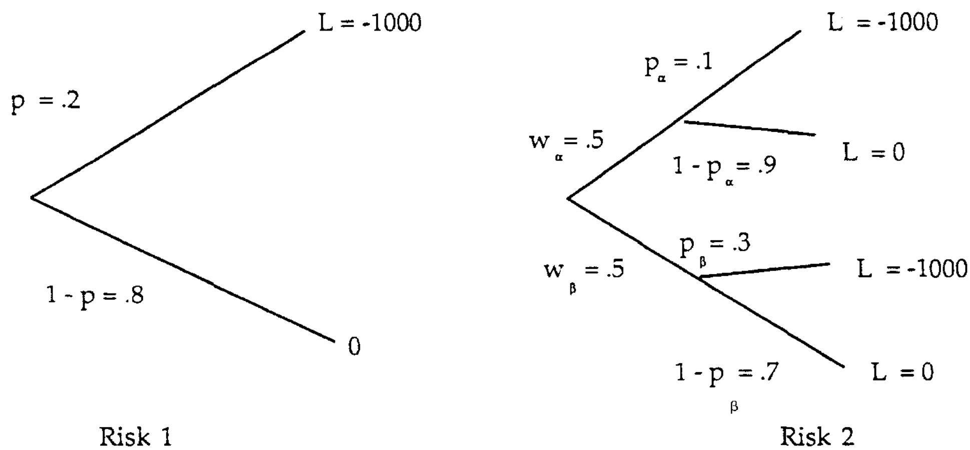


*Figure 2.* Two risks with known loss $L = -1000$.

The analysis of the underwriting decision process by Stone (1973) indicates that two types of constraints influence insurers' behavior: stability and insolvency constraints. Stability constraints reflect a firms' concern with specific financial ratios. For example, regulators treat the premium-to-surplus ratio, $R$, as an early warning signal of potential insolvencies because it suggests that a firm may have written too many policies in relation to its assets. A ratio of $R > 3$ may lead to closer examination of a company by regulators (Committee for Economic Development, 1989). Both insurers and reinsurers are likely to charge higher premiums for more uncertain risks in order to lower the probability of $R$ exceeding 3.

An insolvency or "safety-first" (Roy, 1952) constraint is a prespecified probability, $p^*$, that represents the maximum probability of insolvency that the firm will tolerate. In determining whether to add another risk to its portfolio, an insurer will choose a premium such that the enlarged portfolio has a probability of insolvency less than $p^*$. When firms use this type of constraint, Berger and Kunreuther (1991) have shown that premiums will be higher than when the insurer do not explicitly set a value of $p^*$.

At a broader level than insurance, March and Shapira (1992) have explored how reference points and constraints affect managerial behavior when making decisions under risk. They have pointed out in an earlier paper (March and Shapira, 1987) that reference points such as $p^*$ and $R$ are likely to be particularly important when the available information is ambiguous or poorly specified. Lemaire (1986) has reviewed the procedures utilized by actuaries in setting premiums and has indicated that they utilize expected value as a reference point. Actuaries recommend inflating prices above expected value if there is ambiguity about probability and/or uncertainty about losses.

To illustrate, in our field survey of actuaries (Hogarth and Kunreuther, 1992), 15 respondents who were asked to set premiums for specific scenarios explicitly and spontaneously mentioned that they anchored on expected value and adjusted the recommended price upward if there was ambiguity about the probability and/or uncertainty about the loss. For example, one actuary who was asked to quote a premium for a \$100,000 loss with Ap = .01 used the following written line of reasoning:

"$.01(100{,}000) = 1{,}000 / \times (100/70) = 1{,}429 = \Rightarrow 1450.$"

This implies that the actuary first calculated expected value, then adjusted this figure upward by a factor of 100/70 to yield 1429. The actual quoted premium was rounded up to \$1450.

Another actuary was asked to quote premiums for two scenarios. There was a .35 probability of a \$100,000 loss in both, but the probability was ambiguous in one scenario and well specified in another. The notes attached to the ambiguous scenario were

"$100 \times .35 \times 1.25 = 43{,}750$"
↑
"Conf factor"

The suggested premium was \$43,750.

For the nonambiguous scenario, the actuary wrote:

"100,000 × .35 × 1.0"

and recommended a premium of $35,000 exactly equal to the expected value of the loss.

Figure 3 depicts the interactions of actuaries, underwriters, reinsurers, and regulatory bodies in specifying premiums for specific risks. For risks with ambiguous probabilities and/or uncertain losses, actuaries will suggest pure premiums. Regulators provide reference points and stability and insolvency constraints, such as the Premium/Surplus ratio ($R$). Reinsurers determine what types of coverage they will provide and what price they will charge for this protection. All this information filters to the underwriter, who then decides whether to offer coverage and, if so, what price to charge.

## 4. Empirical data on premium-setting behavior

The results of three surveys of insurance managers—actuaries, primary insurance underwriters, and reinsurance underwriters—illustrate that uncertainty about losses and ambiguity about probability lead to higher prices. These surveys and their key findings are briefly described below.

### *4.1. Actuary survey*[7]

A mail survey of professional actuaries, members of the Casualty Actuarial Society, was conducted. Of the 1165 individuals who were sent questionnaires, 463 (40%) returned valid responses. Each of the actuaries evaluated several scenarios involving hypothetical risks where the probability of a loss was either known or ambiguous.[8] One of these scenarios 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. Each actuary was asked to specify premiums for both ambiguous and nonambiguous conditions when losses were either independent or perfectly correlated.

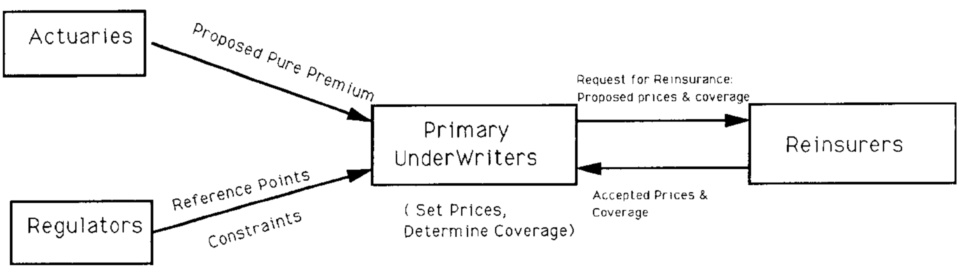


*Figure 3.* Interactions in insurance pricing decisions.

One measure that provides a perspective on how actuaries feel about ambiguous probabilities is the coverage per dollar of premium charged (*c*/$).[9] As premiums increase, *c*/$ 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 $10,000, which would imply a *c*/$ = 100.[10] If actuaries offer *c*/$ below 100, they are asking a price that is higher than can be justified by expected value alone.

The values of *c*/$ presented in table 2 indicate that actuaries specified considerably higher premiums for perfectly correlated risks than for independent risks when 100,000 units were insured, thus indicating that they are risk averse. They are ambiguity averse as well. When $p = .01$, the actuarially fair *c*/$ value = 100. The data in table 2 reveal that when losses are perfectly correlated and $p$ is well specified, the median *c*/$ is 82; it is only 9 when the actuary faces an ambiguous probability. The true probability would have to be $p = .111$ instead of $p = .01$ for the median *c*/$ based on an ambiguous probability to be actuarially fair.

### *4.2. Underwriter survey*[11]

Recent empirical data on underwriter behavior suggest that these managers have a strong aversion to ambiguity about probability as well as to uncertainty about losses. A questionnaire was mailed to underwriters in 190 randomly chosen insurance companies of different types and sizes to determine what pure premiums[12] 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 earthquake. The hazardous-waste scenario involved liability coverage to the owners of an underground storage tank containing toxic chemicals against damages if the tank leaks. 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.

The data reveal that underwriters recommend pure premiums that are higher than the expected loss even in the absence of ambiguity and uncertainty. One explanation for this might be that, contrary to instructions, the underwriters were thinking about the

*Table 2.* Actuaries'[a] estimates of coverage per dollar premium *c*/$ for computed scenarios with nonambiguous probabilities [*p*] and ambiguous probabilities [*Ap*] (median values)[b]

| | Independent risks | | | Perfectly correlated | | |
|---|---|---|---|---|---|---|
| | $p = 0.001$ | $p = 0.01$ | $p = 0.10$ | $p = 0.001$ | $p = 0.01$ | $p = 0.10$ |
| Actuarially fair | 1000 | 100 | 10 | 1000 | 100 | 10 |
| $p$ | 909 | 95 | 10 | 1000 | 82 | 8 |
| $Ap$ | 200 | 50 | 8 | 100 | 9 | 4 |

[a]The number of actuaries responding to each of these scenarios ranged from 14 to 22.
[b]100,000 units insured; $L$ = $100.
Source: Hogarth and Kunreuther (1992).

premium-setting process in the context of a portfolio of other existing risks rather than in terms of adding a single risk to an existing healthy portfolio. This behavior would then be consistent with reference-point-driven behavior such as the safety first and insolvency models or stability reference points (e.g., minimum surplus levels) described under hypothesis 3.

Each questionnaire included two scenarios, the neutral risk plus either the earthquake or underground storage tank (UST). For each scenario, four cases representing each of the uncertainty and ambiguous conditions specified in table 1 were presented. Uncertainty about loss was defined by providing a best estimate of loss (e.g., $1 million) but specifying that losses could range between a minimum and maximum loss (e.g., $0 and $2 million), which were set equidistant from the best estimate. Ambiguity about probability was similarly established by providing a best estimate (e.g., $p$ = .01) and then stating "that there is wide disagreement about the estimate of p and a high degree of uncertainty among the experts." One hundred seventy-one questionnaires (a 19.1% response rate) were received from 43 companies (22.6% of those solicited).

Table 3 depicts the values of *c*/$ derived from our survey of underwriters for the case where $p$ = .01 and L = $1 million.[13] It is clear from these figures that underwriters charge a much higher premium when probabilities are ambiguous and/or losses are uncertain. To illustrate, consider the UST scenario where $p$ = .01 and $L$ = $1 million, so that the expected loss is $10,000. For case 1 (*p,L*), the average *c*/$ = 57, which implies a premium of $17,500. For case 2 (*Ap,L*), the average *c*/$ drops to 37, implying a premium of $27,000. For case 3 (p, UL) the value of C/$ = 41 which implies a premium of $24,400. For case 4 (Ap,UL), the value of *c*/$ = 31 which translates into a premium of $32,300. Both the neutral and earthquake scenarios yielded the same pattern of premiums across the four cases as did the USTs, although the premiums for these scenarios were generally lower. This may reflect a greater uncertainty by underwriters about the nature of the UST risk relative to the other two policies. There were no significant differences in subjects' responses based on which version of the questionnaire they received (i.e., neutral plus earthquake or plus UST), nor were significant order effects found for order of presentation of scenarios, uncertainty conditions, or ambiguity conditions.

*Table 3.* Values of *c*/$ from the survey of underwriters.
p = .01, L = $1 million
Actuarially Fair c/$ = $100

| | p, L | Ap, L | p, UL | Ap, UL | N |
|---|---|---|---|---|---|
| Neutral | 63 | 41 | 56 | 37 | 24 |
| Earthquake | 51 | 43 | 42 | 34 | 23 |
| UST | 57 | 37 | 41 | 31 | 32 |

UST: Underground Storage Tank
N = Number of Respondents
Source: Kunreuther, Hogarth, Meszaros and Spranca (forthcoming).

### *4.3. Reinsurer survey*[14]

We mailed 1390 questionnaires to reinsurance and excess-and-surplus lines underwriters across the nation, essentially soliciting a census of the industry. Only 123 valid responses were returned, a response rate of 9%. Systematic follow-up to assess nonresponse bias was not possible because respondents had been promised anonymity. Table 4 shows mean *c*/$ recommended by the reinsurance underwriters, all of whom evaluated three types of risks: neutral, earthquake, and a defective product scenario for $p = .005$. Ambiguity and uncertainty conditions in the reinsurance survey were established in essentially the same way as in the underwriter survey, but reinsurers were asked to price a layer of excess, rather than primary coverage. As with the primary-insurance underwriters, the pricing patterns of reinsurance underwriters imply ambiguity aversion and risk aversion. These findings support a recent study of reinsurers that suggest that they are risk averse and are likely to decrease their supply of coverage and raise their prices if they experience unexpectedly high losses (Berger, Cummins, and Tennyson 1992).

Because the survey response rate was so low, we supplemented it with a series of interviews aimed at understanding reinsurance underwriters' decision processes. Preliminary results indicate that some types of ambiguity may lead to unavailability of coverage while others may lead to higher prices. If there is ambiguity (about something important) in the form of "there is something you don't know that could make a difference" or " it is not clear how good this information is," reinsurance underwriters will tend to decline to write at any price. Since these two expressions of ambiguity are so directly related to adverse selection, this is understandable. If there is ambiguity of the form "experts disagree about the probabilities" or "this is an unfamiliar risk," reinsurers indicate that they will likely write the policy but may charge a higher price. To reinsurance underwriters, one important source of ambiguity centers on the credibility of the primary underwriter.

## 5. Implications for policy

The data from the surveys of underwriters, actuaries, and reinsurers show a consistent pattern. The recommended premiums increase considerably when the probability is ambiguous and/or the loss uncertain. These findings provide additional confirming evidence for the recent study by Doherty and Posey (1992) showing that severe capacity constraints will have the greatest impact on those risks that are most uncertain. The

*Table 4.* Mean coverage per dollar of premium (*c*/$) (reinsurance underwriter survey)

| | Actuarially fair | *p,L* | *Ap,L* | *p,UL* | *Ap,UL* |
|---|---|---|---|---|---|
| Neutral | 200 | 237 | 158 | 162 | 123 |
| Earthquake | 200 | 145 | 115 | 130 | 102 |
| Defective batch | 200 | 118 | 70 | 81 | 59 |

results also point to the value of reducing uncertainty and ambiguity by utilizing risk-assessment procedures to obtain more accurate estimates of the probability and consequences of specific events (e.g., leakage of different types of underground storage tanks). To the extent that there is potential for catastrophic losses, as in the earthquake risk, there may be an appropriate role for the government to play in providing reinsurance. Finally, there may be organizational changes that can be implemented to aid insurers in their pricing decisions. We now examine each of these three avenues in more detail.

### *5.1. Employing risk assessment procedures*

The loss-related uncertainty associated with a risk appears to be the principal reason for the reluctance of the insurance industry to provide coverage against earthquake damage (Earthquake Project, 1990) and leaks from underground storage tanks (USTs) (Wasserman and Craig 1990). In the case of earthquake risks, there are 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 risk-assessment studies that have enabled them to characterize more accurately the risks associated with 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. To the extent that better information reduces uncertainty for risk-averse underwriters, these efforts should have the intended effects of lowering prices.

For USTs, insurers can require owners to have an inspection or environmental audit to determine the current condition of their tanks and the nature of the risk. These data should improve the ability of the insurance industry to estimate the probability that a tank will leak and the potential damage this would cause, and should therefore reduce perceived ambiguity and uncertainty for the whole class of risk as well as for the individual risks. In addition, insurers can develop risk-classification methods utilizing feature rating and experience rating (Abraham 1988). Feature rating focuses on the nature of the insured's operations, such as the types of magnitudes of the hazardous materials it handles and stores. If a firm reduces the waste it stores, then its insurance rates should be reduced accordingly. Experience rating encourages firms to introduce new hazard-reduction methods, such as specially lined USTs. Expected future losses and, hence, insurance premiums should be lowered. These methods can reduce perceived ambiguity and uncertainty on a policy-by-policy basis.

### *5.2. Government involvement in insurance*

Some type of federal government involvement may also help lower premiums by reducing ambiguity and uncertainty. In the case of catastrophic losses, it appears that ambiguous information about probability will lead to higher premiums.

A consortium of insurance companies has recommended that the government set up a new federal earthquake corporation to collect premiums and cover losses from an earthquake (Litan, 1991). A principle motivation for this program is to reduce uncertainty regarding maximum size of losses to private insurance firms by providing federal reinsurance if the claims from an earthquake exceed a prespecified limit. In addition, a federal corporation would not be taxed on reserves for large earthquakes, as private companies are.

Another option, appropriate for either earthquakes or USTs, would be to mimic the German pharmaceutical pool and the nuclear-liability insurance protection pool in the United States. One proposal in this spirit is a three-tiered 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 businesses themselves, equivalent to a deductible on an insurance policy. This feature produces an incentive for the insured to adopt loss-mitigation measures beyond those that 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 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. This is the model followed by the German pharmaceutical pool, a group of insurers and reinsurers from all over Europe. It is also similar to two insurance pools formed in 1957 as part of the Price–Anderson Act to provide nuclear power plant operators with liability coverage. Mutual pools, however, are difficult to form because each potentially insured client tends to believe that he or she is the safest in the group and therefore would not be comfortable taking coverage from such a concern.

Finally, the third layer requires some type of government involvement for losses above some specified upper limit. 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 on the responsibility of the insurer for paying the costs of groundwater contamination from tank leaks. A government agency would be responsible for levying fees on the insurer for catastrophic earthquake losses or on the owners of the UST for covering losses which exceed the limits of layer 2.[15] The Price–Anderson Act offers a precedent for such an arrangement.

The program outlined above requires the government to bear some of the risk associated with catastrophic losses. Risk assessment is an important part of this process so that costs can be allocated appropriately. The purpose of these measures is to reduce ambiguity, uncertainty, and bankruptcy risks so insurers will have an incentive to sell coverage at affordable prices. This may be one way for insurance to be utilized as a meaningful policy tool in providing protection against losses from serious risks.

### 5.3. *Organizational or institutional solutions*

Since our survey results suggest that several actors in the pricing chain may adjust premiums upward due to uncertainty and ambiguity regarding the risk, firms might examine their organizational arrangements to satisfy themselves that they are appropriately guarding against redundant adjustments. Actuaries might, for example, be asked to reveal their adjustments to underwriters when recommending pure premiums. Underwriters might be encouraged to note their own ambiguity and uncertainty adjustments, opening these to company scrutiny and strategy analysis. This would make it easier for insurance firms to make strategic judgments about offering and pricing various types of ambiguous risks.

### *5.4. Concluding comments*

There are no easy answers to protecting consumers and firms against problems where there is considerable ambiguity and uncertainty. For some risks it may be extremely difficult to obtain data to undertake risk assessments, and there may be a reluctance on the part of the government to be an insurer of last resort. What we do know is that thin or nonexistent private insurance markets are likely to exist for highly uncertain and ambiguous risks. Future research should address the issue as to how other policy tools such as regulations and standards may have to be employed to deal with these risks.

## Notes

1. Deadlines for compliance with these financial responsibility requirements have been postponed by the EPA. Those owning between 13 and 99 tanks were required to meet these requirements by April 26,1991; those with fewer than 13 tanks had 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).
2. Johnson and Higgins has recently compiled a list of the insurers offering protection against USTs.
3. The following account is largely based on our interactions and interviews with executives in the insurance industry over the last few years. See Kunreuther and Hogarth (1992) for more details.
4. Reinsurance offers primary insurers protection against catastrophic losses. For the type of risks studied here, reinsurers normally offer excess-of-loss coverage in which they agree to cover losses that exceed a specified limit. This type of coverage offers protection to the primary insurer against possible insolvency (Berger, Cummins, and Tennyson, 1992).
5. Hogarth and Kunreuther (1992) have considered the case where there is more than one policy issued for a particular risk and the losses are independent. A risk-averse insurer will always set a lower premium for risk 1 with probability $p$ than for risk 2 with probability $Ap$ even if the manager is *not* ambiguity averse. However, if the losses are perfectly correlated, then the premiums should be the same unless the manager is ambiguity averse. Perfect correlation implies that there is only a single risk and that the situation is analogous to example 2 discussed above.
6. A similar explanation of behavior is provided by Frisch and Baron (1988) although they do not use the term competence.
7. For more details on the nature of this survey, see Hogarth and Kunreuther (1989; 1992).
8. Six of the actuaries sent back questionnaires indicating that they would refuse to insure the risks described. All six of these had received versions of the questionnaire with scenarios involving ambiguous probabilities of loss.
9. Since the underwriters are providing full insurance in all cases, coverage is the same as the actual loss.
10. In 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 amount of the loss.
11. More details on the results of this survey can be found in Kunreuther, Hogarth, Meszaros, and Spranca (forthcoming).

12. 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."
13. For the case where loss was uncertain ($UL$), we utilized the best estimate of loss (which by definition was $L$) to determine $c/\$$.
14. More details on the reinsurer survey can be found in Meszaros, Kunreuther, and Hogarth (1991).
15. The fee could be partially based on the degree of risk faced by the insurer or UST owner.

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