"Ambiguity and Underwriter Decision Processes"

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Abstract

This paper provides empirical evidence that risk and ambiguity affect underwriters' decisions on pricing insurance. A field study of primary-insurance underwriters in a random sample of commercial property-and-casualty insurance companies reveals that premiums are significantly higher for risks when there is either ambiguity regarding the probability of a particular event occurring and/or uncertainty about the magnitude of the resulting loss. The paper suggests economic and organizational rationales for this behavior and offers several explanations as to why insurers in a competitive market can charge higher prices for ambiguous risks which promise to yield excess profits in the long run.

Ambiguity and Underwriter Decision Processes

1. Introduction

When an organization has to price a product under conditions of uncertainty the final decision may reflect the relevant manager's attitudes toward risk and ambiguity. This paper explores how underwriters price insurance when they face either ambiguity regarding the probability of a particular event occurring and/or uncertainty about the magnitude of the resulting loss.

Recent research in several disciplines has provided a theoretical and empirical foundation for this study. Economists have developed principal-agent models which examine the differences between managers' and owners' goals and the effect of asymmetries of information between these two groups on managers' choices (Holmstrom, 1979; Shavell, 1979; Grossman and Hart, 1983; and Rogerson, 1985). The models explore ways to design controls such that potential conflicts cannot hurt firm performance. This work has generally been highly theoretical. Few attempts have been made to examine how real-world constraints affect actual agent behavior.[1]

Management scientists and psychologists have studied managerial decision making under risk and uncertainty through both controlled laboratory studies and field surveys in order to determine under what circumstances decisions deviate from those predicted by normative models of choice such as expected profit maximization or

[1] An excellent summary of recent developments in the economic theory of the firm can be found in Holmstrom and Tirole (1989). Kreps (1990 Ch. 19 and 20) discusses the formal theory of the firm and the need for new methods to address some of the weaknesses in current approaches.

expected utility theory (Payne et. al., in press; MacCrimmon and Wehrung 1986; March and Shapira 1987).

To gain insight into the effects of ambiguity and uncertainty on agents in a real-world setting we have conducted a series of studies of premium-setting behavior by executives in the insurance industry (Kunreuther 1989; Hogarth and Kunreuther 1989; 1991). As a context for research on risk this industry has several advantages. First, there is a large theoretical literature on optimal pricing decisions by insurers (Dionne and Harrington 1992). Predictions from this literature can be compared with actual agents' behavior. Second, because profitability and survival of insurance firms depend on good pricing decisions, premiums set by agents matter in the marketplace. If firm and market incentives counteract "irrational" risk behavior, this should occur in this context. Finally, underwriters make pricing decisions regularly as part of their jobs; they are expert, experienced risk evaluators.

Our previous work examined premium-setting decisions by actuaries. Actuaries perform a staff function in an insurance firm; they provide advice about prices, primarily for risks where there are considerable statistical data (e.g. life and automobile insurance). By contrast, underwriters are line managers in insurance companies; they are the agents who make final pricing decisions.

This paper reports on a study of underwriters making pricing decisions for several different types of risk involving low-probability events. The findings suggest that underwriters set higher premiums than would be predicted by standard economic theory because of special concerns with both ambiguity of probability and uncertainty of losses. Higher prices can reduce the demand for insurance and lead to market failure for some risks. The paper explores economic and organizational rationales for

the risk and ambiguity aversion exhibited by underwriters. In the concluding section we speculate as to why higher product prices reflecting these attitudes can exist in some market settings and lead to market failure in others.

2. Theoretical Framework

Loss Uncertainty and Premium Setting Economists have recently described several practical reasons why uncertainty about potential losses may affect expected profits and, hence, cause managers to be risk averse in their behavior. Smith, Smithson, and Wilford (1990) point out that if the provisions of the corporate tax code yield a convex tax function for low levels of taxable income and a linear function for taxable income above some threshold, a company can reduce its expected tax liability by reducing the variance of pre-tax income. By this reasoning, if two losses have the same expected value, the one with the greater variance would normally trigger a higher premium.

Smith, Smithson, and Wilford also suggest that the transaction costs associated with bankruptcy can make risk-averse behavior rational. The probability of insurer insolvency is in part a function of the variance of losses; companies with higher variance in their financial performance are more likely to become insolvent. Risk aversion may also partially explain the demand for reinsurance by property/liability insurance companies (Mayers and Smith 1989).

Regulation of insurance firms may lead to other costs associated with loss volatility. An insurer's premium-to-surplus ratio, R, is treated as an important indicator of financial stability by the National Association of Insurance Commissioners; it is considered an early-warning indicator of potential insolvencies because it suggests whether a firm has overcommitted itself by writing too many policies in relation to its

assets. When R>3 regulators may become concerned and examine the financial status of the firm in some detail (Committee for Economic Development 1989). Insurers are thus more likely to charge higher premiums for uncertain risks in order to reduce the chances of being scrutinized by regulators, incurring the associated transactions costs, and having their reputation impaired.

Greenwald and Stiglitz (1990) provide yet another rationale for risk-averse behavior by agents of a firm. They suggest that managers suffer substantial damage to their personal career prospects when their companies become insolvent. Managers who face these nondiversifiable career risks may be risk averse in situations where stockholders, who can diversify their portfolio may be risk neutral. Thus, managers may seek to reduce the probability of bankruptcy to a point that is lower than is in the best interests of stockholders.

If the above observations are correct, an expected-utility model may be a more appropriate characterization of underwriter behavior than the standard expected-profit maximization model used by economists. According to expected-utility theory, a risk-averse underwriter will charge a higher premium as the variance of losses around a given mean increases (Goovaerts and Taylor 1987).

In the context of this study, consider two risks. For risk 1 experts estimate that there is a probability p of a known loss L. Let r_1 be the premium charged for fully insuring this risk. For risk 2 the probability of the event is still p but the potential loss is uncertain, although it is estimated by experts as being bounded by L_{min} and L_{max} (normally the insurance policy limit). The resulting insurance premium, r_2, is determined by:

$$U(A) = p\sum_{i=L_{min}}^{L_{max}} q_i\, U(A- L_i + r_2) + (1-p)\, U(A+r_2) \quad (1)$$

where q_i is the probability that the insured loss will be L_i, A is the insurer's assets and U is the underwriter's utility function. Suppose the expected value of the loss of this distribution is the same as the known loss L. In this case, the premium r_2 will be higher than r_1 for risk-averse underwriters.

Ambiguity about Probabilities Now consider a situation where there is ambiguity or uncertainty about the probability of a given event occurring. To make this concept operational, suppose the underwriter has k different expert opinions of the probability of a specific loss within a given time period.[2] Let the experts' probability estimates be denoted by p_i, i=1....k. The underwriter's best forecast of the probability of a loss is a point estimate, $p = f(p_1.....p_k)$.

Expected utility theory implies that, when insuring a single risk, ambiguity should not affect the premium charged by the underwriter if the underwriter believes the experts' estimates (Hogarth and Kunreuther 1989). To see this, define r_3 to be the premium when probability is ambiguous[3] with a best approximation, $p^* = f(p_1....p_k)$ and loss varying between L_{min} and L_{max}. To operationalize p^* assume that n experts

[2] In discussions with underwriters we were told that data on probabilities associated with specific risks are often provided by outside experts or actuaries in the firm.

[3] Budescu and Wallsten (1987) prefer to use the term "vague uncertainty" rather than "ambiguity" to characterize any situation in which uncertainty cannot be expressed as a point probability estimate or second-order distribution over probability values.

disagree and that a linear weighting rule is utilized for combining their different probability estimates. Any other procedure that results in the same estimate of p^* for the ambiguous probability will lead to the same qualitative predictions as those described below (Hogarth and Kunreuther, 1992).

Consider the case where k different expert opinions need to be combined so that p_i represents the estimate by expert i (=1,....k) of the probability that a loss will occur. If each expert's estimate is given a weight w_i with $\sum w_i = 1$, then a linear weighting rule yields an estimate $p^* = \sum w_i p_i$ with the weights chosen so that $p^* = p$. If one substitutes p^* for p in equation(1), $r_3 = r_2$.

There is considerable experimental evidence suggesting that individuals treat ambiguous probabilities differently than probabilities that are well specified. Ellsberg's classic paper (1961) revealed that, for events that involve gains, individuals prefer lotteries with well-specified probabilities over ones with ambiguous probabilities unless the chances of winning are small. A number of experiments have confirmed Ellsberg's hypothesis (Becker and Brownson 1964; Slovic and Tversky 1974; Yates and Zukowski 1976; MacCrimmon and Larson 1979). Schoemaker (1989) provides experimental evidence that individuals appear to use heuristics in which second order probabilities matter in determining the value of additional information on the probability of a gain or loss. In the domain of potential losses, where underwriters operate, experimental studies imply that subjects are averse to ambiguity when probabilities are small but not when they are large (Einhorn and Hogarth 1985, 1986; Hogarth and Einhorn 1990).

Recently, theorists have incorporated ambiguity formally into subjective

expected utility models either by employing nonadditive probabilities (Gilboa 1987; Hazen and Lee 1989; Fishburn 1988; Schmeidler 1989) or factoring ambiguity into the utility function (Sarin and Winkler 1990). Fishburn (1990) has developed a theory which treats ambiguity as a primitive concept without direct reference to likelihood, subjective probability, preference or decision.[4]

Psychologists, too, are attempting to understand ambiguity aversion. Einhorn and Hogarth (1985; 1986) developed and tested a behavioral theory which characterizes choice under ambiguity as the output of an anchoring and adjustment process. Heath and Tversky (1991) contend that individuals' attitudes toward ambiguous situations depend upon their feelings of competence as measured by their general knowledge or understanding of the relevant context.[5] Psychological hypotheses about what might cause ambiguity aversion include anticipation of how others might judge you if a bad outcome occurs (Curley, Yates and Abrams 1986) and the presumption that ambiguity is more likely to be resolved against you than in your favor (Ellsberg 1961).

In summary, the above discussion implies several different predictions regarding underwriter behavior which depend on their attitudes toward risk and ambiguity. If underwriters acted as if they were expected utility maximizers, then the following two predictions hold:

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[4] For a comprehensive survey of recent developments in modelling preferences under uncertainty and ambiguity see Camerer and Weber (1992).

[5] Frisch and Baron (1988) provided a similar explanation of behavior when there is ambiguity about the probability.

Prediction 1: Risk averse underwriters will set higher premiums for an uncertain loss than for a known loss with the same expected value (i.e. $r_2 > r_1$).

Prediction 2: Risk averse underwriters will charge the same premium for a single risk whether the probability is non-ambiguous, p, or ambiguous, p^*, provided $p = p^*$.

If, on the other hand, underwriters show aversion to ambiguity, then the following prediction which is not consistent with expected utility maximization will be borne out:

Prediction 3: Underwriters will charge a higher premium for a single risk with ambiguous probability, p^*, than for a risk with non-ambiguous probability $p = p^*$.

The next section describes the findings from a study of underwriter behavior designed to examine these predictions.

3. A Survey of Underwriter Behavior

Questionnaire Design A questionnaire was designed to ask primary-insurance underwriters what minimum pure premium[6] they would charge in order to add certain single risks to an otherwise healthy portfolio. The risk contexts presented were:

[6] The specific instructions for each scenario stated that underwriters should provide their estimates of the "pure premium," not the price the firm should charge for each risk. It was stated that pure premium should exclude "loss adjustment expenses, claims expenses, commissions, premium taxes, defense costs, profits, investment return, and the time valuation for money. In other words, the premiums you set should be based only on potential losses." This is the common meaning of the term pure premium in the insurance industry.

insuring a factory against property damage caused by a severe earthquake; the underground tank scenario described liability coverage against damages caused by leakage from an underground storage tank containing toxic chemicals; the neutral scenario asked for coverage for an unnamed peril.

Table 1 outlines the four different combinations of ambiguity and uncertainty that might exist for a specific risk. The p,L case reflects a situation where both the probability (p) and loss (L) are well specified (e.g., p=.01 and L=$ 1 million). In the Ap,L case the probability is ambiguous, which means that there is a high degree of uncertainty about the reliability of estimated probabilities. In the p,UL case, loss is uncertain within a prespecified range. The Ap,UL case reflects a situation in which probability is ambiguous and loss is uncertain.

- Insert Table 1 here -

Each respondent received a questionnaire that included two scenarios, the neutral risk plus either the earthquake or underground tank context. For each scenario, four hypothetical policies were presented corresponding to the four conditions specified in Table 1.

The design was a repeated-measures study with five experimental variables. Four of these---loss magnitudes, loss uncertainty, probability ambiguity, and type of scenario---were varied within subjects. Potential losses were either $1 million or $10 million. When there was uncertainty about losses the underwriters were told potential losses could range from either $0 to $2 million or from $0 to $20 million with expected values of $1 and $10 million respectively. Probability level was varied between

subjects. The probability of a loss was set at either .01 or .005. The order of scenarios, order of ambiguity and uncertainty conditions, probability and loss levels were completely crossed in a Latin-square design. A sample of neutral-scenario questions is included as Appendix A.

Ambiguity and uncertainty conditions were established in the following manner. For a well-specified probability (p), underwriters were told that "all experts agree that the probability of loss is [p]." Ambiguity (Ap) was established by indicating that experts' best estimate of the probability of a loss is [p] but "there is wide disagreement about this estimate and a high degree of uncertainty among the experts." For a known loss (L), the underwriters read that "all experts agree that if a loss occurs it will equal [L]." When the potential size of the loss was uncertain (UL), the underwriters were told that the "experts' best estimate is that if a loss occurs it will equal [L]. However, estimates range from L_{min} to L_{max}."

Sampling Plan The questionnaire was developed with assistance from the American Institute for Property and Liability Underwriters and pretested on a sample of 70 underwriters secured through that organization.[7] After pretesting, 896 questionnaires were mailed to 190 randomly chosen commercial property-and-casualty insurance firms identified through the A.M. Best Company's "Total" database for 1987. The set of companies was balanced so that approximately equal numbers of questionnaires would be returned from small, medium, and large companies. Packets of questionnaires with cover letters and stamped, return envelopes were sent to the chief

[7] We are grateful to Norm Baglini and his colleagues at the American Institute for Property and Liability Underwriters for critiquing the questionnaire and facilitating a pilot study.

underwriters at each company. The chief underwriters were asked to distribute these to property-and-casualty underwriters reporting to them. Follow-up phone calls were made and follow-up letters were sent after two and three weeks respectively.

The final sample consisted of 171 questionnaires (a 19.1% response rate) from 43 companies (22.6% of those solicited). Seventy percent of the companies in the sample were stock companies; 26% were mutuals; and 5% were Lloyds-type companies. According to the Best "Total" database, the national distribution of property and casualty companies that write commercial business is 60% stock; 36% mutual; and 4% Lloyds. Respondents had an average age of 43; an average of 17 years of work experience; 78% had at least a college degree.

Descriptive Findings Underwriters were asked to specify the minimum pure premium they would charge for a particular risk. For purposes of analysis, premiums were normalized by expected value (EV) to yield a measure, Price/EV, that could be compared across different loss and probability levels. Since expected value is by definition equal to the actuarially fair pure premium, the ratio Price/EV provides a way of determining if the percentage increases in premiums are due to ambiguity about probability and/or uncertainty about losses. For example, a Price/EV ratio of 1.5 means that the price charged is 50 percent higher than the actuarially fair pure premium.

Table 2 presents the geometric means for Price/EV[8] for the main

[8] Geometric means are employed in order to counteract the disproportionate effects of several extreme outliers. The geometric means of Price/EV are equal to the antilogs of Log(Price/EV), which is the dependent measure employed in the ANOVA analyses.

experimental conditions in the survey.[9] In general, the underwriters were risk averse since the mean Price/EV was greater than 1 in all conditions of all scenarios.[10] To take an example, in the p,L condition for the neutral scenario, underwriters charged a premium which was 63 percent above the pure premium. Mean premiums and percentage increases above the pure premium were even higher for the other three conditions.

- Insert Table 2 here -

The patterns of prices in Table 2 support Prediction 1. Prices rise significantly when uncertainty about L increases. That is, the difference between the price charged in the p,UL condition is significantly higher than that charged in the p,L condition ($p<.001$ in all scenarios). The results also support Prediction 3, since premiums are also significantly higher ($p<.001$ in all scenarios) when ambiguity about probability is introduced (i.e., difference between prices in the Ap,L versus the p,L condition). In other words, the principal findings of this survey strongly suggest that ambiguity about probability and increasing uncertainty about losses lead underwriters to charge higher premiums.

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[9] For the cases where loss was uncertain (UL), the best estimate of loss (which, was stated in the questionnaire to be L) was used in calculating Price/EV.

[10] In 17 percent of the cases premiums for the p,L condition were set below EV, suggesting a risk-seeking rather than risk-averse pricing strategy.

Results: Analyses of Variance (ANOVA) Repeated measures ANOVAs were performed to test the statistical significance of price differences between the ambiguous and nonambiguous probability conditions, and between the uncertain and known loss conditions. The three scenarios were treated as semi-independent replications of the tests, so a separate analysis was performed for each.

Each respondent was presented with four different risks for each scenario, representing a complete crossing of the ambiguous probability factor (Ap vs. p) and the uncertain loss factor (UL vs. L). The levels of probability and the levels of loss were held constant across the four risks for a single scenario for each subject. Thus, the analysis involved repeated measures, with uncertainty about loss and ambiguity about probability being evaluated within subjects, and loss and probability levels evaluated between subjects. In addition, the analysis tested whether the structure of the underwriter's firm (stock, mutual, or Lloyds), a between-subjects factor, influenced the underwriters' responses to uncertainty and ambiguity.

The analysis was designed to reveal whether Price/EV varied as a function of these five factors. However, because the distribution of prices was highly skewed by a number of extremely high outlying prices, the natural logarithm of Price/EV was employed in these analyses. The log transformation yielded a good approximation to the normal distribution for this dependent variable.

The results of the three ANOVAs are shown in Table 3. Consistent with the pattern of results discussed above, uncertainty about L (UL) and ambiguity about p (AP) were each significantly related to log(Price/EV). For each of the three scenarios, the main effects for AP and UL were significant at $p<.01$. Highest prices were reported when both probability was ambiguous and loss uncertain.

- Insert Table 3 here -

Loss was a significant predictor in the earthquake and underground tank models. Normalized prices were higher for lower losses, implying that the underwriters in our study offered better bargains for policies covering larger losses. This result makes sense if underwriters demand a threshold or minimum price for insuring any low-probability risk, an explanation that corresponds to certain industry practices. In interviews, underwriters sometimes expressed the opinion that they do not like to accept low-priced, low-probability policies because the profit margins are not high enough. Some insurers' reinsurance treaties also specifically mandate a minimum premium for difficult, low-probability potentially high loss risks, like earthquake and underground tank, even if the stated coverage is relatively low.

Probability level was not a significant predictor in any of the models. In other words, p only affected prices to the extent that it was incorporated as a component of the normalization variable, EV. No interaction effects between any of the variables were found to be statistically significant. Order of presentation of scenarios and of risk and ambiguity conditions were evaluated in a separate set of ANOVA analyses and also found <u>not</u> to be significant.

A series of ANOVA tests was conducted to examine whether variability among underwriters from the same company was lower than variation across companies. If only one underwriter responded from a particular company, that company had to be excluded from these analyses. Eighteen responses had to be excluded for this reason. F tests indicated that variation within a company was not

significantly different from variation between firms. The ANOVA results suggest that corporate structure accounts for significant variation in the underground tank model. Underwriters from mutual companies offered lower prices than did underwriters from stocks for this type of coverage.

The sample included underwriters from small ($20-100 in annual property-and-casualty premium), medium ($100-500 million), and large (>$500 million) companies. In order to see whether company size affected underwriters' pricing behaviors or their responses to ambiguity, a separate series of ANOVA analyses were conducted in which within-subject variation, which is highly collinear with company size, was not included in the model. Size was not found to be a significant predictor of pure premium for any of the scenarios, nor was the interaction of size with ambiguity.

Summary of Findings. Patterns of increased prices in the face of ambiguity and uncertainty were consistent and pervasive in this population of underwriters. Since these are line managers who determine what prices the insurer will actually charge, this survey suggests that these effects are likely to occur in the marketplace.

Our results on risk aversion are consistent with studies by MacCrimmon and Wehrung (1986). They also asked a sample of managers to make risky decisions similar to the choices often made in their jobs. MacCrimmon and Wehrung found that executives tended to be strongly risk averse for situations that entailed the possibility of major losses, the situation faced by underwriters in this study.

Our results on ambiguity aversion are consistent with many laboratory studies that indicate that people prefer nonambiguous bets to ambiguous ones and surveys in which consumers behave in an ambiguity-averse way (see e.g., the review

by Camerer and Weber, 1992). They are also consistent with the results of our previous study of actuaries. If both actuaries and underwriters adjust prices upward for ambiguity and uncertainty, as suggested by these studies, then risk for which there is limited historical data may be offered at premiums greatly exceeding the insurer's best estimate of EV.

4. Understanding Insurers' Risk and Ambiguity Aversion.

The patterns of risk aversion by underwriters are consistent with expected-utility predictions rather than with expected-profit maximization. Ambiguity aversion patterns, however, suggest that underwriters are influenced by factors that are not explicitly considered by expected-utility models since these models predict that underwriters should have charged the same premium for a single risk whether the probability was or was not ambiguous. Recent empirical studies suggest several explanations for the observed behavior.

Assessment by Others. Curley, Yates and Abrams (1986) found that an important reason individuals exhibit aversion to ambiguity is that they are assessed by others after they have made a decision. Perhaps they anticipate it will be difficult to convince others that they have made a good decision when the information available cannot be documented precisely. This suggests that managers are more likely to be ambiguity averse if organizations institutionalize accountability (cf. Tetlock, 1985) and/or if formal procedures require justifying choices if large losses occur (Staw 1980).

Reference Points. March and Shapira (1992) have summarized a growing literature which suggests that managers often rely on reference points when making decisions with respect to risk. The manager chooses a reference point (e.g., minimum surplus level) and refuses to accept a risk if the probability of falling below the reference point is too high. In an earlier study of managerial risk taking, March and Shapira (1987) found that when the probability of loss is poorly specified or ambiguous, managers are likely to place particular importance on such reference points.

Describing actuaries' premium-setting strategies, Lemaire (1986) reports that many use a premium based on EV as a reference point under the assumption that probability and loss levels are known. They then increase the premium to reflect uncertainty or ambiguity. Similarly, in observing the practice of underwriting in the U.K., Phillips and Wisniewski (1983) observed a multi-stage process requiring many judgmental inputs. Risks are first classified into "base rate" groups. Adjustments to the base rate are then made judgmentally, depending on characteristics of the risk in order to assess the "pure" rate. In turn, the pure rate is adjusted to reflect current market conditions.

A special set of reference points in the insurance industry are the stability and insolvency constraints (Stone 1973a; 1973b). Using these reference points as decision criteria amounts to focusing on "safety first" rather than maximizing expected profits. Stability constraints reflect a firm's concern with specific financial ratios. As mentioned earlier, insurers may treat their premium/surplus ratio (R) as a stability constraint, since it is used by insurance commissioners as an early indication of insurer insolvency.

In the insurance industry, an insolvency constraint exists if a decision maker

treats some probability, p^*, as the maximum acceptable likelihood that aggregate losses exceed the firm's surplus. If such a constraint is not satisfied for a proposed premium and given number of policies, companies can either raise premiums and/or reduce the coverage in force. The latter option can be achieved by reducing the upper limits on policies and/or by insuring fewer risks in that class.

Berger and Kunreuther (1991) have shown that as a particular risk becomes more ambiguous an insurer will be reluctant to take it on as part of their portfolio unless the premium is increased relative to the expected loss. They demonstrate that the lack of interest by private insurers in providing protection against ambiguous risks is consistent with a safety-first model and would be difficult to explain using an expected-utility approach.

Competitive Behavior. Market, competitive, or strategic forces may also affect the behavior of underwriters when there is ambiguous information about the risks. Mumpower (1991) points out that underwriters may want to set higher premiums for ambiguous risks than for nonambiguous ones in order to avoid the winner's curse. If they are uncertain about experts' estimates of the probability of a claim, they would rather price their coverage higher than would be implied by p^* to avoid winning the business and experiencing an expected loss. The costs of collecting information on low-probability ambiguous risks may be an additional factor raising premiums.

Context. Although expected-profit maximization and expected-utility criteria predict that insurers should be indifferent between losses so long as they have the same p and L, there is theoretical and empirical evidence suggesting that the context or nature

of a risk makes a difference in how individuals respond to ambiguous information.

The possibility of differences due to context was originally raised by Ellsberg (1961) when he noted that the origin of ambiguity concerning probabilities lay in the nature of one's uncertainty or lack of knowledge about particular uncertain events. The study by Heath and Tversky (1991) suggests that less knowledge about a situation makes a person feel less competent and more unwilling to bet on the event in question.

Empirically, Kahn and Sarin (1988) report that in one experiment context actually caused subjects in a consumer choice experiment to switch from being ambiguity averse to being ambiguity seeking. Subjects were ambiguity seeking when choosing between two restaurants when the quality of food at one was described ambiguously (i.i. a range of probabilities given) while quality of food was described nonambiguously (i.e. a single probability given). The same subjects were ambiguity averse when choosing between two film-processing services with ambiguous vs. nonambiguous timeliness and dependability.

In the underwriter survey, ambiguity always caused prices to rise but the size of the increases varied by scenarios. The proportional Price/EV increase when Ap was introduced was greatest in the underground tank case (67 percent), lower in the neutral (55 percent), and lowest in the earthquake case (23 percent). It is not clear why these differences occurred but their significance indicates the need for systematic exploration of context effects in future research.

Structure. Dionne and Doherty (1991) have pointed out that there are important differences in the ways stocks and mutuals handle residual risks. This has

implications for which organizational form might more efficiently contract for correlated and nondiversifiable risks. In mutual companies, residual risk will (in general) fall to policyholders; in stock companies, it will (in general) be spread to stockholders. Hence, stock companies may tend to charge higher prices than mutuals when they expect their portfolios to be imperfect in order to avoid damaging their position in the capital marketplace.

In particular, Doherty and Dionne expect correlated and nondiversifiable risks to be handled through mutual-like contracts rather than stock-like ones. Our survey findings suggest that stock companies offered significantly higher prices for underground tank coverage than did mutual companies. This is consistent with the Doherty and Dionne hypothesis insofar as rising court awards for pollution casualty damages are viewed as a correlated risk even though the probability of detecting a leak at one underground storage tank may be independent of another.

5. Conclusions

The presence of ambiguity aversion appears to be robust. Not only did we find it in this study in which underwriters set prices of different types of insurance policies, but we have previously found it in studies of actuaries and MBA students who were asked to price insurance products. Others have observed ambiguity aversion in many other contexts (Camerer and Weber, 1992).

In the case of insurance firms which face competition from others, the question arises as to why such behavior persists. Charging higher prices for ambiguous risks promises to yield excess profits in the long run. New firms should enter the market and offer coverage with lower premiums. This competitive pressure

should drive prices down to a level consistent with what would be predicted by an expected-utility model.

We believe that there are several reasons why this does not happen. First, insurance markets are not perfectly competitive. Insurers may have private knowledge about their clients based on past claims experience which they will not share with other firms and customers are not able to provide verified histories (Kunreuther and Pauly 1985). Furthermore, insurance clients face switching and search costs which lead them to stay with their current insurer. Insurance also is marketed on dimensions other than just price. For example, insurers attempt to differentiate their products by means of their reputations and their risk- and claims-management services. Higher prices for ambiguous risks might be justified to clients in terms of these differentiated qualities. Offering higher prices for ambiguous risks may, for example, signal more care and therefore lower probability of insolvency.

Second, it is difficult to learn from experience what the appropriate price of insurance should be for very low-probability events. By definition there is limited information since losses are few and far between. When the risks are also ambiguous learning is still more difficult. Neither insurer nor client will know what the appropriate premium should be.

At a behavioral level there is considerable empirical evidence that there is a tendency to maintain the status quo in the face of great uncertainty (Samuelson and Zeckhauser1988). Hence, the more ambiguous the risk is, the less likely an insurer will offer it on the market. They will thus get limited feedback on the nature of the risk and not learn what price they should have charged for the risk. (cf. Einhorn and Hogarth, 1978). Under these circumstances it is difficult for firms to even want to offer

policies where the risk is ambiguous unless they charged a sufficiently high price to make it worth their while. This may explain why few insurers offer environmental pollution insurance today and why insurers are reluctant to market earthquake insurance despite its profitability.

Finally, we speculate that in ambiguous circumstances insurers may not think probabilistically due to their lack of experience with risk. Actuaries, who are trained to assess risks using quantitative analysis, are most comfortable setting premiums on statistically-rich events such as life, automobile, and homeowners insurance. Underwriters tend to be less analytic in their thinking and are more comfortable than actuaries with ambiguous risks. However, they will be unlikely to use probabilities to set premiums, relying much more on qualitative information (Phillips and Wisniewski, 1983).

Reinsurers face more ambiguous risks than primary insurers since they cover the extreme tail of the probability distribution (i.e. very low probability catastrophic losses). In discussions with reinsurers they have indicated that the concept of probability is not part of their thinking. Rather, they set premiums by utilizing simple rules and heuristics revolving around the potential losses they may suffer (Meszaros et. al, 1991).

If actuaries, underwriters, and reinsurers each appear to make their premium decisions in different ways when they are provided with the same information, then this suggests that each group is utilizing different arguments to justify their actions. When do people reason by using probabilities and outcomes in determining what actions to take? Under what situations do they focus on other factors in their final actions? By gaining more insight into the type of reasoning by individuals

and groups when faced with ambiguous risks we may increase our understanding as to why behavior differs from predictions made by normative models of choice. Our hope is that this eventually will lead to prescriptive guidelines for pricing insurance when probabilities are ambiguous and losses are uncertain.

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Table 1

Classification of Risks by

Uncertainty and Ambiguity Conditions

		LOSS	
		Known	Uncertain
PROBABILITY	Well-specified	p,L	p,UL
	Ambiguous	Ap,L	Ap,UL

Table 2

Price/EV AND Log(Price/EV)
for all Scenarios and Ambiguity/Uncertainty Conditions

	P,L	Ap,L	p,UL	Ap,UL
NEUTRAL (n=159)				
Price/EV (geometric mean)	1.63	2.53	2.18	3.39
Log(Price/EV)	0.49	0.93	0.78	1.22
t-statistic		10.47*	8.12*	11.97*
EARTHQUAKE (n=74)				
Price/EV (geometric mean)	1.62	1.99	2.13	2.82
Log(Price/EV)	0.48	0.69	0.75	1.04
t-statistic		2.74*	3.97*	7.04*
UNDERGROUND TANK (n=84)				
Price/EV (geometric mean)	2.39	3.99	3.76	5.57
Log(Price/EV)	0.87	1.38	1.32	1.72
t-statistic		7.53*	7.08*	8.59*

* Difference from Log(Price/EV) in p,L condition (matched-sample t-test for differences) significant at $p<.001$.

Table 3

Experimental Effects: ANOVA Model Results
Dependent Variable: Log (Price/EV)

	NEUTRAL		EARTHQUAKE		UNDERGROUND TANK	
	F-score	Effective Direction.	F-score	Effective Direction	F-score	Effective Direction
Variables						
L	.06		15.48***	1m>10m	6.16*	1m>10m
p	.59		.62		3.36	
Structure	.91		.68		4.87**	Stocks>Mutual
Subject	52.58***		45.56***		42.73***	
UL	10.34***	UL>L	20.22***	UL>L	9.08**	UL>L
Ap	35.18***	Ap>p	11.02***	Ap>p	10.37**	Ap>p

* significant at p<.05
** significant at p<.01
*** significant at p<.001

Appendix A

Neutral Scenario

p = .005 L = $1 million

AI1

Your insurance company has been asked to underwrite four different risks. You are given some information on which to base an annual premium. No other information is available and no new information will become available before setting the premium.

For each of the four risks, assume that the policy limit is $2 million. That is, the maximum your company will pay out is $2 million for the year coverage is offered.

1. For risk one you learn that:

Estimates of possible insured loss: All experts agree that if a loss occurs it will equal $1 million.
Estimates of annual probability of loss: All experts agree on 5 in 1000.

Question: What is the minimum premium you would charge to accept this risk?_____

Comments:_____

2. For risk two you learn that:

Estimates of possible insured loss: All experts agree that if a loss occurs it will equal $1 million.
Estimates of annual probability of loss: 5 in 1000, however, there is wide disagreement on this figure and a high degree of uncertainty among the experts.

Question: What is the minimum premium you would charge to accept this risk?_____

Comments:_____

3. For risk three you learn that:

Estimates of possible insured loss: Experts' best estimate is that if a loss occurs it will equal $1 million. However, estimates range from negligible to $2 million.
Estimates of annual probability of loss: All experts agree on 5 in 1000.

Question: What is the minimum premium you would charge to accept this risk?_____

Comments:_____

4. For risk four you learn that:

Estimates of possible insured loss: Experts' best estimate is that if a loss occurs it will equal $1 million. However, estimates range from negligible to $2 million.
Estimates of annual probability of loss: 5 in 1000, however, there is wide disagreement on this figure and a high degree of uncertainty among the experts.

Question: What is the minimum premium you would charge to accept this risk?_____

Comments:_____