Ambiguity and Insurance Decisions

By ROBIN M. HOGARTH AND HOWARD KUNREUTHER*

Imagine that you are in the insurance business and are preparing to quote premiums for two risks that can be characterized as follows:

In Situation A there is a potential loss of \$100,000 and your best estimate of this loss occurring within the period covered by the insurance is .01. Moreover, your estimate of the probability is based on the opinions of several experts all of whom agree on the .01 figure.

In Situation B there is also a potential loss of \$100,000. However, whereas your best estimate of the probability of this loss occurring within the contract period is .01, this figure is a compromise reached after considering the widely different estimates furnished by several experts.

When comparing these two scenarios, many persons deem Situation B to be inherently more risky than Situation A, such that the premium required to insure the latter would be larger than for the former. However, it is important to note that this behavior contradicts the expected utility model which economists have typically used to analyze insurance decision making (see Isaac Ehrlich and Gary Becker, 1972). The reason is that this model does not distinguish between cases where people do or do not experience uncertainty or ambiguity about their estimates. However, as demonstrated by Daniel Ellsberg (1961) and others (for example, see Selwyn Becker and Fred Brownson, 1964) in experimental settings, ambiguity or "uncertainty about one's uncertainty" does affect choice. On the other hand, if one believes that ambiguity affects behavior in markets, one needs a model that predicts how such effects occur and when they are important. Our purpose here is to explore the predictions of such a model with respect to the market for insurance.

First we sketch a psychological model of probabilistic judgment under ambiguity developed by Hillel Einhorn and Hogarth (forthcoming). This is then used to predict how both consumers (buyers) and insurance firms (sellers) are likely to react toward differing degrees of ambiguity. A brief summary of the results of experiments designed to test these predictions are presented. Finally, we discuss these results in relation to real world phenomena as well as considering possibilities for future empirical research. We particularly note the importance of developing and testing precise, falsifiable models to complement or challenge implications of the expected utility model since naturally occurring data frequently lack the power to provide stringent tests of the latter.

I. Ambiguity and Choice

A model of how people assess probabilities of events in ambiguous circumstances has recently been proposed and experimentally tested by Einhorn and Hogarth. The model is based on the following three principles.

1) People are first assumed to anchor on an initial estimate of the probability. Let p represent the anchor and note that it may be based on past experience, suggested by an analogous situation, or even the figure provided by an expert. The anchor is then adjusted by imagining or mentally simulating other values that the probability could take.

2) The greater the degree of ambiguity experienced, the more alternative values of the probability are simulated and the larger the weight given to such values in the final

*Graduate School of Business, University of Chicago, Chicago, IL 60637, and Wharton School, University of Pennsylvania, Philadelphia, PA 19104, respectively. We are grateful to Colin Camerer, Hillel Einhorn, Jack Hershey, and Paul Kleindorfer for helpful comments on an earlier version. This research is partially supported by NSF grant SES-8312123 and a contract from the Office of Naval Research.

assessment. Thus, when experts disagree on a probability estimate, people are assumed to imagine more alternative values compared to situations where the experts agree.

3) The weight given in imagination to alternative values of the probability that are greater or smaller than the anchor p depends on the individual's attitude toward ambiguity in the particular situation.

Let the adjustment to the anchor be represented by k so that the assessment of the ambiguous probability, denoted $S(p)$, is given by

$$S(p) = p + k. \tag{1}$$

To allow for the effects of ambiguity, Einhorn and Hogarth decompose k into two parts that capture forces favoring positive and negative adjustments, respectively. The positive force reflects the weight given to possible values of the probability above the anchor and is taken to be proportional to $(1-p)$; the negative force reflects the weight given to values below the anchor and is proportional to p. In both cases, the constant of proportionality is a parameter θ that represents the amount of perceived ambiguity in the situation $(0 \leq \theta \leq 1)$. In other words, the effect of possible values of the probability above the anchor are modeled by $\theta(1-p)$, of those below by θp, and k is the net effect of positive and negative adjustments from the anchor. However, to account for the fact that values above and below the anchor may be differentially weighted in imagination, θp is adjusted to the form θp^{β} where $\beta(\beta \geq 0)$ represents the person's attitude toward ambiguity in the circumstances. That is, when $\beta = 1$, equal weight is given to imaginary values above and below the anchor; when $\beta > 1$, more weight is given to larger values; and for $\beta < 1$, more weight is given to smaller values. This leads to the model

$$S(p) = p + \theta\left[(1-p) - p^{\beta}\right]. \tag{2}$$

Note that in this model θ (i.e., perceived ambiguity) determines the amount of the adjustment, whereas β in conjunction with the level of p determines its sign. Thus, when p is low, the adjustment will tend to be positive; however, as p increases, the adjustment will become negative. Moreover, the point at which the adjustment starts to become negative depends on β. That is, when $\beta = 1$, the "cross-over" point is at $p = .5$; for $\beta < 1$ this occurs when $p < .5$; and for $\beta > 1$ when $p > .5$.

Now assume that the price a consumer is prepared to pay for a given level of insurance coverage is a monotonically increasing function of $S(p)$. Furthermore, let $C(p)$ denote the premium a consumer is prepared to pay for this coverage when the probability of the loss can be precisely estimated, and $CA(p)$ that when the consumer is ambiguous. Assume further that when facing the ambiguous probability of a loss, β is not a small value (see discussion above). These assumptions imply the following predictions:

1) when p is small, the ratio $[CA(p)/C(p)]$ will be greater than one indicating "ambiguity aversion"; 2) as p increases, $[CA(p)/C(p)]$ will decrease and eventually become smaller than one thereby indicating "ambiguity seeking." Denoting the premiums that firms are prepared to charge with precise probabilities as $F(p)$, and $FA(p)$ for premiums under ambiguity, similar predictions can be made for firms—but with one exception. The exception is that one would never expect firms to charge less than expected value. Therefore, for firms, the prediction is that the ratio $[FA(p)/F(p)] > 1$ for small probabilities but that this ratio will decrease as p increases.

II. Experimental Evidence

We have collected experimental data testing the above predictions in a series of questionnaire experiments involving some 500 individuals who were participating in undergraduate, graduate and executive program courses at the University of Chicago and the Wharton School. Most of these subjects had been exposed to courses in economics and statistics and thus were relatively sophisticated concerning insurance. Since all the experiments produced similar findings, we only report here some results from two experiments (for full details, see our 1984 paper).

In the first experiment, 113 University of Chicago MBA students responded to questionnaires administered in a class on decision making. The experimental stimulus concerned the owner of a small business who was considering insuring against a potential loss of \$100,000 from claims due to a possible defective product. Subjects played the role of either the owner of the business (buyer) or the head of the department in a large insurance company (seller) who was responsible for setting premiums. Each subject responded to both the ambiguous and nonambiguous versions of the stimulus (see below) at one level of the anchor p in an experimental session during which responses were also made to questions that were not related to this study. In all, four levels of p were investigated, $p = .01$, .35, .60, and .90. In both the ambiguous and nonambiguous cases a specific probability level was provided in the stimulus (for example, .01). However, a comment was also added as to whether one could "feel confident" (nonambiguous case) or "experience considerable uncertainty" (ambiguous case) concerning the estimate. Uniformity of perceptions of ambiguity was controlled by describing the situations by the same words in both the consumer and firm versions.

Table 1 reports median prices of the minimum premiums firms were prepared to charge and the maximum premiums consumers were prepared to pay, together with the ratios of ambiguous to nonambiguous prices at each probability level. Note that in the nonambiguous condition, the median prices are close to expected value for both firms and consumers. However, there are marked differences in the ambiguous case. For firms, premiums in the ambiguous condition exceed those in the nonambiguous case at all levels except $p = .90$. Consumers, on the other hand, are only prepared to pay more in ambiguous circumstances when the probability of loss is low (i.e., $p = .01$). At $p = .35$, consumers' maximum prices are the same for both levels of ambiguity and for larger probabilities ($p = .65$, .90) they exhibit ambiguity preference in that maximum prices under ambiguity are lower than when there is no ambiguity. These results are consistent

TABLE 1—MEDIAN PRICES FOR INSURANCE[a]

Probability Levels	Ambiguous (1)	Nonambiguous (2)	Ratio Col. (1)/ Col. (2)
	Consumers' Willingness To Pay		
.01	\$1,500	\$1,000	1.50
.35	\$35,000	\$35,000	1.00
.65	\$45,000	\$65,000	.69
.90	\$60,000	\$82,500	.73
	Firms' Supply Price		
.01	\$2,500	\$1,000	2.50
.35	\$52,500	\$37,500	1.40
.65	\$70,000	\$65,000	1.08
.90	\$90,000	\$90,000	1.00

[a] Loss = \$100,000; a complete statistical analysis of these data supporting the statements made in the text is to be found in our earlier paper.

with the predictions of the Einhorn-Hogarth ambiguity model.

Whereas the above analysis is useful for testing the predictions of the ambiguity model across the range of p, it is less illuminating from a market perspective. The real issue here is whether willingness to trade on the part of firms and consumers is also affected by ambiguity. This issue was tested in a second experiment, also involving University of Chicago MBA students, who were again assigned either the roles of consumers or firms. Using the same scenario as the previous experiment, subjects were required to respond by stating whether they would trade ("Yes" or "No") at a given price. Having answered this question, subjects turned a page in their experimental booklets and were asked the same question with respect to a different price. To simulate trading conditions, the second price for consumers was lower than the first, whereas the reverse order was used for firms. Since the market for insurance typically covers situations where probabilities of losses are small, we only report here data for $p = .01$. The prices quoted were \$1,500 and \$3,000 and the results of this experiment are presented in Table 2. The results of this experiment are consistent with our earlier findings. Consumers are prepared to buy insurance at premiums well in excess of expected value for a low probability event ($p = .01$). Moreover, there

TABLE 2—PERCENTAGES OF SUBJECTS PREPARED TO TRADE AT GIVEN PRICES[a]

	Prices Offered		
	\$1,500	\$3,000	n
Consumers:			
Ambiguous	87	83[b]	23
Nonambiguous	77	50	22
Firms:			
Ambiguous	16	36	25
Nonambiguous	67[b]	87[b]	15

[a] Potential loss = \$100,000; $p = .01$.
[b] Differences between ambiguous and nonambiguous significant ($p < .01$).

is greater willingness to insure at high prices when ambiguity is present than when it is not (83 vs. 50 percent). Some firms are also willing to provide insurance for such events. In addition, as the price increases, more firms are prepared to do business in both the ambiguous and nonambiguous cases. However, there is a marked difference in willingness to insure at the stated prices between the ambiguous and nonambiguous cases, that is, 16 vs. 67 percent at \$1,500, and 36 vs. 87 percent at \$3,000.

III. Implications for Market Behavior

The effect of ambiguity can be precisely isolated in experimental situations, but this becomes far more difficult in natural settings. Insurance markets are rich contexts for studying ambiguity because insurers can always specify a maximum amount of coverage, but may be highly uncertain as to the probability that they will experience a loss of this magnitude. This effect of ambiguity combined with problems of adverse selection, moral hazard, and fear of bankruptcy may result in limited insurance markets. Consider the following two illustrations.

Less than 5 percent of California homeowners purchase earthquake coverage despite their belief that they will receive only limited aid from the federal government in the event of a large loss (Kunreuther et al., 1978). Insurance firms, on the other hand, charge high rates for coverage which may partially explain lack of consumer interest. Over the sixty-year period since coverage has been offered in California, \$269 million in total premiums have been collected and only \$9 million in losses have been experienced (Arthur Atkisson and William Petak, 1981). These figures by themselves may not be unreasonable if there is a chance that a large earthquake would create huge losses. Furthermore the spector of bankruptcy could restrict this coverage to only large firms who would then have some monopoly power. The counterargument is that damage to residential homes is relatively minor even in a severe earthquake, so that all insurance firms should have an interest in providing coverage at more reasonable rates.

Special institutional arrangements have emerged for dealing with insurance against low probability high loss events. For example, the Price Anderson Act passed in 1957 currently offers \$160 million insurance protection by the private sector to cover nuclear accidents, with the government handling potentially large losses up to a maximum of \$560 million. The industry feels that it will be extremely difficult to increase coverage of private insurers on a voluntary basis due to the ambiguity associated with the probability of a catastrophic event (Alliance of American Insurers et al., 1979). Similarly, the passage of a federal-private flood insurance program in 1968 and the provision of political risk insurance, primarily by the Overseas Private Investment Corporation, are examples of programs for handling events where the probability of a given loss is ambiguous and where private insurers have provided only limited coverage.

Our principal reason for focusing on ambiguity is that it affects the way human judgment and choice deviates systematically from the rational models underlying much of economic analysis when both consumers (buyers) and firms (sellers) have the same information. However, instead of simply documenting another instance where the expected utility model fails to predict behavior (see Paul Schoemaker, 1982), we have specifically tested the implications of a model that does account for the effects of ambiguity. Note also that our model is similar *in spirit* to analyses of insurance markets that are based on the expected utility model. That is, starting from some propositions about human choice behavior at the individual level, we proceed to make and test predictions at the aggregate market level. Moreover, we handle real phenomena that the expected utility model essentially assumes not to exist.

The impact of ambiguity on insurance markets seems to be particularly important for low probability events where there are limited opportunities for learning over time. For some events (for example, fire, life), consumers may have limited opportunities to learn while insurers have a wealth of experience from their claims files. Both parties may be uncertain as to the probabilities of other events (for example, earthquakes, chemical plant accidents etc.) due to limited past experiences and imperfect causal models. There is a need for future research to determine the extent of the ambiguity surrounding probabilities of different events consumers and insurers face, the impact this has on the premium structure and the extent of the market.

There is also a need for more theoretical and experimental work regarding the effects of "uncertainty about uncertainty" on behavior. Market-based experiments in the spirit of Charles Plott (1982) and Vernon Smith (1982) can further extend the questionnaire approach of this study to settings that mimic market conditions more accurately.

Finally, we recognize that ambiguity is but one of a number of phenomena such as regret (David Bell, 1982) and the context or "framing" of decisions (Amos Tversky and Daniel Kahneman, 1981) that can have important impacts on behavior. Nonetheless, we are impressed by the fact that ambiguity is a significant aspect of much economic activity and believe that the topic merits greater attention than has been the case to date.

REFERENCES

Atkisson, Arthur and Petak, William, *Earthquake Insurance: A Public Policy Analysis*, Report prepared for the Federal Insurance Administration, Federal Emergency Management Agency, Washington, 1981.

Becker, Selwyn W. and Brownson, Fred O., "What Price Ambiguity? Or the Role of Ambiguity in Decision Making," *Journal of Political Economy*, February 1964, *72*, 62–73.

Bell, David E., "Regret in Decision Making under Uncertainty," *Operations Research*, 1982, *30*, 961–81.

Ehrlich, Isaac and Becker, Gary, "Market Insurance, Self-Insurance and Self-Protection," *Journal of Political Economy*, July-August 1972, *80*, 623–48.

Einhorn, Hillel J. and Hogarth, Robin M., "Ambiguity and Uncertainty in Probabilistic Inference," *Psychological Review*, forthcoming.

Ellsberg, Daniel, "Risk, Ambiguity, and the Savage Axioms," *Quarterly Journal of Economics*, November 1961, *75*, 643–69.

Hogarth, Robin and Kunreuther, Howard, "Risk Ambiguity and Insurance," Center for Risk and Decision Processes WP 84-10-05, Wharton School, University of Pennsylvania, 1984.

Kunreuther et al., Howard, *Disaster Insurance Protection: Public Policy Lessons*. New York: Wiley & Sons, 1978.

Plott, Charles, "Industrial Organization Theory and Experimental Economics," *Journal of Economic Literature*, December 1982, *20*, 1485–527.

Schoemaker, Paul, "The Expected Utility Model: Its Variants, Purposes, Evidence and Limitations," *Journal of Economic Literature*, June 1982, *20*, 529–63.

Smith, Vernon L., "Microeconomic Systems as an Experimental Science," *American Economic Review*, December 1982, *72*, 923–55.

Tversky, Amos and Kahneman, Daniel, "The Framing of Decisions and the Psychology of Choice," *Science*, 1981, *211*, 453–58.

Alliance of American Insurers (American Insurance Association, National Association of Independent Insurers, Mutual Atomic Energy Reinsurance Pool, and American Nuclear Insurers), *Nuclear Power, Safety and Insurance: Issues of the 1980s—The Insurance Industry's Viewpoint*, 1979.