5 ECONOMIC THEORIES OF DECISION MAKING UNDER UNCERTAINTY: IMPLICATIONS FOR POLICY ANALYSIS

W. Kip Viscusi

1. Introduction

If decisions under uncertainty were completely straight-forward, many of the government programs now in existence would not be necessary. Regulation of many job risks and product hazards would be superfluous, as market processes would create adequate incentives for safety. Programs to provide information about risks to product purchasers and the public at large also would be unnecessary because individuals would already have sufficient information to make rational decisions. The expansive scope of the tort liability system could also be reduced because the presumption that accident victims engaged in uninformed behavior would lose force. A world in which markets provided full information about risks, and people used this information effectively, would demand much less from public policy. This chapter explores ways in which impediments to rationality arise and how their shortcomings provide an impetus for several types of policy intervention.

The actual performance of the economy, unfortunately, often falls far short of our ideal. Individuals display tendencies to overestimate some risks and to underestimate others. Market responses to risk range from
inadequate to wildly alarmist. The same people who fail to buckle their seatbelts may express great alarm over the threats posed by secondhand smoke or by two grapes found in Philadelphia with traces of cyanide even though these latter threats involve less severe risks.

These difficulties have not gone unnoticed by academic researchers. A flourishing cottage industry now generates an increasing variety of anomalies and inconsistencies in choices under uncertainty. The two main messages of this literature are that people err and that in many cases the pattern of these errors is quite systematic. This chapter explores some of the most salient findings in this literature and attempts to identify the common themes that have emerged.1

From the standpoint of public policy, examination of these issues is relevant for several reasons. First, assessing the pattern of errors in individual choice is important to highlight the context in which government intervention is warranted. Second, if the character of the market failure can be identified, particular kinds of policies might be implemented. For example, if the problem is one of incomplete information, the obvious remedy is to provide appropriate hazard warnings to the affected group. Finally, examining the limitations of rational behavior also indicates potential weak links in the implementation of government policies. If individual responses are not rational, even with the aid of such efforts as well-designed informational programs, more directive kinds of policy intervention should be considered.

The chapter will first analyze individual decisions to purchase insurance against losses caused by natural disasters and will then turn to overall assessment of patterns of risk perception. After considering several of the main behavioral anomalies identified in the literature, two models of choice to address these anomalies will be presented. The chapter will conclude by indicating the potential role of public provision of information to remedy inadequacies in the knowledge individuals have about the risks they face.

2. Responses to Natural Disaster Insurance:
A Second Look

An influential early study of the rationality of choices under uncertainty was that of Howard Kunreuther (1976), who examined the patterns of purchases of earthquake and flood insurance. Because these lines of insurance are heavily subsidized by the U.S. government, Kunreuther expected widespread purchase by individuals at risk, but his predictions based on standard insurance economics were not borne out. Moreover, his detailed analysis of the risk perceptions of potential purchasers as well as their actual purchases provided a fruitful case study for examining how individuals respond to risk and whether they take advantage of subsidized insurance.

The principal conclusion reached by Kunreuther (p. 250) was quite strong: "The expected utility model, as traditionally used by economists, provides relatively little insight into the individual choice process regarding the purchase of insurance." This section will examine some of the specific evidence developed by Kunreuther and, in particular, indicate the extent to which full rationality appears not to hold.

In assessing these results the historical context in which Kunreuther worked must be noted. At that time, economists did not question the assumption of individual rationality. Because the literature dealing with deficiencies in choice-making under uncertainty was still in its infancy, a researcher would be expected to place great weight on any flaws found in the rational choice model. Yet, in the more than a decade since Kunreuther's article appeared, a substantial literature has attacked the expected utility model as failing to capture the way in which decisions actually are made, as opposed to the way in which they should be made. Thus a retrospective examination of Kunreuther's results would permit a search for the systematic and rational aspects of the behavior that are reflected in his results as opposed to dwelling on the shortcomings of the expected utility framework.

A useful starting point is to examine the individual knowledge of the insurance terms that were offered. Table 5-1 summarizes the extent to which the insured and uninsured population groups understand the terms of insurance.

<table>
<thead>
<tr>
<th>The Percent of Respondents Who Do Not Know Terms</th>
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<tbody>
<tr>
<td>Insured</td>
</tr>
<tr>
<td>Cost of insurance: Flood</td>
</tr>
<tr>
<td>Earthquake</td>
</tr>
<tr>
<td>Deductible: Flood</td>
</tr>
<tr>
<td>Earthquake</td>
</tr>
</tbody>
</table>

Source: Adapted from Kunreuther (1976: 234).
Examination of table 5-1 clearly indicates that the full-information assumption often implicit in economic analysis does not hold. The large majority of uninsured do not know the terms of insurance; even among the insured, many do not know important details such as size of the deductible. These gaps in knowledge occurred despite the fact that survey respondents were those in the household most responsible for insurance purchases.

There are also a number of positive features of the responses. Differential knowledge of the insured and uninsured follow the expected patterns. First, in every case people who purchased the insurance have a better understanding of the premiums and the deductibles than those who did not. Second, the cost of insurance is easier to remember than the deductible. As expected, almost all people who purchased flood or earthquake insurance remember its premium, even though they may not remember all of the details. Third, the fact that people do not know all of the details regarding the insurance is not necessarily a sign of irrationality. What is important is that people are being offered subsidized insurance. In effect, the government has recommended it, and if individuals take this information as a signal, they may need to know all of the details concerning what makes the purchase attractive. The uninsured likewise are not necessarily irrational for not knowing the terms of the insurance since they may not have heard of its availability. Such a lack of knowledge may be more an indication of ineffective marketing of the insurance than of any failure of individual irrationality.

One could then raise the secondary issue of whether the consumer search process to learn about such insurance is fully rational. With the substantial stakes involved in disaster insurance, consumers have some financial incentive to acquire information about such coverage.

It should also be noted that the fact that not all people choose to purchase subsidized insurance is not necessarily irrational since individual risks differ, thus affecting the relative value of insurance. Furthermore, the prospect of government aid after natural disasters provides for at least some insurance without any prior purchase, and we would want to know what these expectations were before pronouncing behavior irrational.

One can obtain a more refined perspective on the expectations of the different population groups by examining the damage expected from a severe flood of earthquake (see table 5-2). Perhaps the main anomaly in this table is that 9 percent of those who purchased flood insurance, and 2 percent of those who purchased earthquake insurance, expected zero damage. Notwithstanding the careful questionnaire that was administered, it may be that some individuals did not properly understand the survey, perhaps confusing the probability of severe damage with the absolute level of the damage. Another possibility that was borne out in the interviews by Kunreuther and co-workers (1976) is that even when there was no assessed risk, consumers valued the peace of mind that insurance provided.

More specifically, Kunreuther and his colleagues examined whether insurance would be attractive from an expected value standpoint by examining the contingency price ratio, which gives the relative odds that the adverse event will occur. Many consumers who purchased insurance even though they understood that it had a low perceived expected payoff did so because they indicated that having insurance provided reassurance. This beneficial effect is similar to influences such as anxiety and regret that have played an important role in the subsequent literature. In particular, insurance is a multiattribute commodity that provides a diverse set of consumer benefits not readily captured by the standard expected utility model.

A principal inference from table 5-2 is that the overall relationship between insurance purchases and damage perceptions is quite plausible. In terms of distribution of the expected claims for both flood insurance and earthquake insurance, the groups with the highest expected damage claims are generally more likely to purchase insurance. The best statistics for assessing the rationality of these patterns are the ratios of the insured to the uninsured purchasers for any particular damage claim group shown in the third and sixth columns of table 5-2. The fraction of each damage claim category purchasing insurance steadily rises as one moves to the higher claims groups.

<table>
<thead>
<tr>
<th>Damage Claims ($)</th>
<th>Flood</th>
<th>Earthquake</th>
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<tbody>
<tr>
<td></td>
<td>Insured</td>
<td>Uninsured</td>
</tr>
<tr>
<td>0</td>
<td>9</td>
<td>29</td>
</tr>
<tr>
<td>≤10,000</td>
<td>22</td>
<td>26</td>
</tr>
<tr>
<td>10,001–30,000</td>
<td>37</td>
<td>24</td>
</tr>
<tr>
<td>&gt;30,000</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td>Don't know</td>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>

Note: In addition to data drawn on data in Kunreuther (1976: 234), this table includes statistics on the "Insured/Uninsured" calculated by the author.
Kunreuther also explores detailed measures of the rationality of insurance purchases, using information on individual decisions and risk perceptions. Once again, some of the patterns are plausible. For example, the assessed probability of a severe flood or earthquake is higher for those who purchase insurance than for those who do not.

Nevertheless, the results do not accord with fully rational insurance purchases, as Kunreuther demonstrates quite convincingly. The two key variables driving insurance purchases are the perceived seriousness of the disaster (often coupled with past experience) and discussions with friends and neighbors. These variables are consistent with a fully articulated Bayesian model of insurance decisions and with the literature on the psychology of risk perceptions. However, the standard expected utility model in the insurance literature placed little emphasis on these concerns.

3. Aspects of Risk Perceptions

The inadequacies in individual risk perceptions are now well established in the literature. In particular, individuals may not accurately assess the probabilities of the adverse events that may affect them. One identified variation concerns size of the risk. Once a risk is known, people tend to overestimate low probability events and underestimate larger risks. These regularities have been documented in detail by Fischhoff and colleagues (1981). Among the small risks that are overestimated are those of dying from botulism, tornadoes, floods, pregnancy, and smallpox vaccinations. The substantially hazardous yet under-estimated risks of dying include from diabetes, stomach cancer, stroke, heart disease, and homicides.

Combs and Slovic (1974) attribute this effect to an availability bias. The greater media coverage of some events assists consumers in recalling them. The media coverage effect is also consistent with a Bayesian learning model since it represents a potentially valuable source of information. Unfortunately, this coverage may provide inaccurate information regarding the relative magnitude of risks.

A systematic bias in risk perception assumes, of course, that individuals are aware that the risk is present at all. Hidden risks, such as the hazards from unknown carcinogens, may be neglected altogether if individuals have no awareness that a risk is present. Once they have some awareness of the risk, however, they tend to overestimate the extent of the hazard for very small risks. The implications of this result are reflected both in the actions that individuals take as well as policies that government implements. Low-probability events, such as being killed by a terrorist attack while vacationing in Europe or dying from eating Chilean fruit, often elude large responses. In contrast, individuals have been reluctant to wear seatbelts voluntarily but have been compelled to comply by mandatory seatbelt requirements in many states, which have not resulted in full compliance. Similarly, large controllable probabilities such as the risks posed by our diet often merit little attention, whereas we focus instead on minuscule hazards such as those that have been targeted by the media.

The pattern of bias in risk perception is not altogether inconsistent with rational behavior. Consider a simple Bayesian learning model in which we initially begin with the same risk perception for all classes of risk. As we acquire additional information about each risk, our perceptions will move closer toward the truth. Yet, because we have less than complete information, in our move toward the true probabilities we will continue to overestimate the very small risks and underestimate the very large risks. Although there are other possible explanations for the size-related bias in risk perception, this possibility is also quite plausible and is consistent with rational behavior on the part of imperfectly informed individuals. At this juncture, we do not know whether the central difficulty is that there are flaws in individual decision making or whether people simply do not have full information about the risks they face.

A second aspect of these risk perception patterns is that individuals appear to overestimate low-probability events and accurately perceive events of zero risk as truly posing no hazard whatsoever. As a result, there is a jump in individuals' risk perceptions when they move from no-risk situations to ones posing very small risks. This pattern has been documented in a variety of studies of risk perception and is reflected in the emphasis of government policies, such as the Delaney clause prohibiting the use of carcinogenic food additives even at very small risk levels.

Similarly, most government agencies attempt to eliminate all risks that are judged to be "significant." As our ability to detect risks has improved, however, the threshold for significance has steadily declined. We consequently run the risk that the stringency in the regulatory policies will be dictated by our measurement technologies rather than by the overall merits of these efforts.

Widespread media attention, often exceeding the relative importance of risks, contributes to a bias in public policy. The damage inflicted by tornadoes, floods, and earthquakes is highly touted by the media. Easterners express fear of ever having to move to San Francisco and face the perils of earthquakes, but they are far less reluctant to live in cities with higher homicide rates and greater risks of death from air pollution than posed by earthquake hazards.
An excessive emphasis on dramatic and highly publicized risks does not necessarily imply that individuals are irrational. One can envision a process whereby one forms risk perceptions by utilizing available information to update one's probabilistic judgments. The extensive coverage provided to natural disasters does not indicate the levels of risk involved, only selective body counts. If the media primarily provide evidence of highly prominent adverse outcomes, we would expect individuals processing this information to form correspondingly high risk assessments. In effect, the media are giving people the numerator of the risk but not the denominator. If information about the numerator is repeated sufficiently often, particularly if it is provided to a degree far in excess of its overall relative value, flawed risk perceptions are likely to result.

A variety of other systematic biases have been observed in the perception of risks by individuals. People tend to underestimate risks that are within their control. For example, most of us believe we are above-average drivers, and few of us regard ourselves as being average or below average. Similarly, most parents believe they are above average in the safety precautions they take for their children.

The character of the risk is also of consequence. Risks such as cancer or the chance of being killed by an explosion evoke substantial fear and dread. As a consequence, they tend to be relatively overestimated once they are called to people's attention.

The statistics in table 5–3 illustrate several of these aspects of individual risk perceptions as they affect economic decisions. Consumers participating in the study were told that the starting risks posed by different pairs of products were each 15/10,000. They were then asked to value incremental risk reductions of 5/10,000 for each of the two risks. Table 5–3 provides their valuation of each successive incremental risk reduction. The risks from household products—toilet bowl cleaner and insecticide—generally posed temporary injuries such as skin poisoning or child poisoning that respondents were told would produce nausea and stomach cramps for several days.

As people purchase successive risk reductions, their willingness to pay for risk reduction should decline. This pattern is borne out initially. At an initial risk level of 15/10,000, the willingness to pay for a risk reduction of 5/10,000 is greater than it is at 10/10,000. Once we reach a risk level of 5/10,000 and are offered the opportunity to purchase a complete elimination of the risk, however, there is a substantial jump in individual valuations. These results reflect the more general finding that people overassess low-probability events and place a premium on the elimination of risks with certainty. There is a substantial discontinuity in risk perceptions once we move from some small risk to no risk at all.

<table>
<thead>
<tr>
<th>Starting Risk (injuries/10,000 bottles)</th>
<th>Incremental Willingness to Pay (dollars/bottle)</th>
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<tbody>
<tr>
<td></td>
<td>Inhalation—Skin Poisoning</td>
</tr>
<tr>
<td></td>
<td>Inhalation—Child Poisoning</td>
</tr>
<tr>
<td></td>
<td>Gassing—Eyeburn</td>
</tr>
<tr>
<td></td>
<td>Gassing—Child Poisoning</td>
</tr>
<tr>
<td>15</td>
<td>1.04</td>
</tr>
<tr>
<td></td>
<td>1.84</td>
</tr>
<tr>
<td>10</td>
<td>.34</td>
</tr>
<tr>
<td></td>
<td>.54</td>
</tr>
<tr>
<td></td>
<td>.65</td>
</tr>
<tr>
<td>5</td>
<td>2.41</td>
</tr>
<tr>
<td></td>
<td>5.71</td>
</tr>
<tr>
<td></td>
<td>.83</td>
</tr>
<tr>
<td></td>
<td>.99</td>
</tr>
</tbody>
</table>

Source: Viscusi, Magat, and Huber (1987: 475).

<table>
<thead>
<tr>
<th>Injury Pair</th>
<th>Percentage for Whom Product Is Too Risky to Purchase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inhalation—skin poisoning</td>
<td>77.2</td>
</tr>
<tr>
<td>Inhalation—child poisoning</td>
<td>68.1</td>
</tr>
<tr>
<td>Eyeburns—gassing</td>
<td>61.5</td>
</tr>
<tr>
<td>Gassing—child poisoning</td>
<td>74.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mean Value ($/bottle) of Positive Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inhalation—skin poisoning</td>
</tr>
<tr>
<td>Inhalation—child poisoning</td>
</tr>
<tr>
<td>Eyeburns—gassing</td>
</tr>
<tr>
<td>Gassing—child poisoning</td>
</tr>
</tbody>
</table>

Note: This question asked subjects what price discount they would require on the new product to accept an additional risk of 1/10,000 for both injuries, starting with risks of 15 injuries per 10,000 bottles sold for both injuries. See Viscusi, Magat, and Huber (1987: 477).

Moreover, the extent of this overestimation of low-probability events may not be symmetric. From an economic standpoint, a person's willingness to pay for a sufficiently small risk reduction should have a value equivalent to his or her willingness to accept a small risk increase. For larger changes, willingness to pay amounts should be less than willingness to accept values. Individuals who gave the values for their willingness to pay for risk decreases were also asked how much of a price discount they required to be willing to accept a risk increase of 5/10,000. The universal response was that they would not purchase the product at all. As a result, the survey was reformulated, inquiring about how much of a price discount they required to accept a product that posed an extra risk of 1/10,000 of each type.

The results of this exercise are reported in table 5–4. For the overwhelming majority of consumers, the product is too risky to purchase at any price. The survey even inquired whether individuals were willing to accept a cash payment and free use of the product. As a result, these
responses fully reflect all of the options economists might develop to get people to display a finite risk-dollar trade-off. Moreover, for those who were willing to state a price discount they would accept the extent of the discount given in the final column of table 5-4 greatly exceeds their willingness to pay for a risk reduction of much greater magnitude described in table 5-3.

What these findings suggest is that individual inadequacies in risk perceptions are highly complex and have profound implications for perceptions are highly complex and have profound implications for economic behavior and risk regulation policies. Most of these results represent a substantial departure from the full information world of perfect rationality. Nevertheless, many systematic patterns to these biases highlight situations in which government intervention can be most profitable. In particular, these results suggest that political pressures for intervention may be greatest when there is an upward shift in a small risk. However, it is the large, stable probabilities of an adverse event that merit the greatest public concern.

4. Behavioral Anomalies

The literature on the rationality of choice under uncertainty is replete with examples of behavior that contradicts most models of rational decision making. The frame of reference for assessing rationality is the expected utility model. Under the expected utility framework, individuals maximize a linear weighted average of the utility of different payoffs, where these weights are the probabilities associated with the outcome. This framework has strong appeal from a normative standpoint because of the plausibility of the axioms on which it is based. Some of the implications of the risk perception patterns noted in the last section are inconsistent with the maximization of expected utility. Here I consider two additional examples that illustrate fundamental deviations in behavior from the expected utility model.

Consider a situation in which you are required to play Russian roulette. For concreteness, suppose that you are unmarried and have no children and that three bullets are left in the gun. How much would you pay for the removal of one bullet? Alternatively, consider a situation in which only one bullet is in the gun. How much would you be willing to pay for the removal of this single bullet? In general, people would be willing to pay a much greater sum for removal of the final bullet than for removal of one bullet, which would not buy them complete freedom from death.

The behavior in this example, which was developed by Richard Zeckhauser, contradicts the predictions of standard expected utility theory. The purchase of a bullet when many bullets remain in the gun should be more highly valued because the expected marginal utility of money is much less when the risk of death is substantial. The opportunity cost of buying back the bullet is very low if there is a good chance that one may die. The attractiveness of purchasing the bullet that ensures survival stems from people's tendency to overestimate low-probability events. As a consequence, the inadequacies in risk perceptions discussed earlier also emerge as an influential factor that leads to prominent contradictions in the rationality of economic behavior.

Perhaps the most well known anomaly in expected utility theory is the Allais Paradox. If people are confronted with two sets of lottery choices, they often give responses that are not mutually consistent. The particular example constructed by Allais can be summarized by two equations:

\[ U(100) > (.10) U(500) + (.90) U(100) + (.01) U(0) \]  

(1)

and

\[ (.11) U(100) + (.89) U(0) < (.10) U(500) + (.90) U(0). \]  

(2)

In the first case, shown in equation 1, the utility of the certain reward of $100 is preferred to a 0.1 chance of a $500 reward and a 0.89 chance of a $100 reward, since there is also a 0.01 chance that the person will receive nothing at all. Even though the expected payoff is much greater under the dominated option, the chance of losing all one's money leads individuals to prefer the certain payoff of $100.

If, however, we reduce each of these two prospects by a 0.89 chance of winning $100 so that the chance of no payoff is 0.89 for the formerly preferred case and 0.90 for the formerly dominated case, we generally find the reversal in preferences shown in equation 2. This reversal obtains even though we have simply subtracted an amount, 0.89 U(100), from each side of the equation. Since subtracting any positive amount from an inequality should leave the direction of the inequality unaffected, there is a clearcut contradiction.

A wide variety of models have been developed to explain inconsistencies such as the Allais Paradox. Clearly, the expected utility theory is not adequate and one must either modify our characterization of individual preferences or our assumptions regarding how probabilistic information enters individual decisions.

One possibility may be that the utility of receiving a zero payoff is not equal to zero. Moreover, how we feel about a zero payoff could depend
on the other payoffs that we are missing. In a situation in which we are flipping a coin and have a chance to win a dollar, receiving no reward may matter little. However, if the reward had been $1 million, the zero outcome may be devastating. The potential role of regret has been formalized in a variety of theories.\(^8\)

As a practical matter, it is difficult to identify any common choice situations where the Allais Paradox is encountered. The main thrust of the various anomalies that have been provided in the literature is primarily to indicate that choices under uncertainty may be flawed in some manner. They do not suggest that the particular anomalies that have been identified are prevalent or of substantial consequence. This result is not entirely reassuring since the problems that do seem to be prevalent reflect more fundamental inadequacies in the way people process and act on risk information.

5. An Example of Alternative Models of Choice: Prospect Theory

A wide variety of models have been developed to address the problems arising from choices under uncertainty. One of the most widely discussed variants of this type is prospect theory, which was developed by psychologists Daniel Kahneman and Amos Tversky (1979). Their analysis consists both of a summary of the evidence in the psychology of risk literature as well as development of an alternative model to explain this behavior. Their analysis can be described as largely descriptive in nature. The emphasis is on developing central themes in the anomalies that have emerged and then imposing suitable amendments on the nature of choice and risk perceptions to reflect these phenomena.

The range of their discussion is quite broad. For example, they review a variety of anomalies, including the Allais Paradox discussed in the last section. The generalization that Kahneman and Tversky developed as characterizing the Allais Paradox as well as similar examples pertains to the scale of the probabilities involved. In particular, bigger payoffs look better as the difference in the odds gets smaller. For example, a 0.45 chance of winning $6000 may be viewed as being clearly inferior to a 0.9 chance of winning $3000. Yet, if we shrink these probabilities by dividing them by 450 so that we have a 0.001 chance of winning $6000 as opposed to a 0.002 chance of winning $3000, our preference is generally for the chance of winning $6000. As the probabilities become smaller they tend to look more similar, and we place greater weight on the payoffs involved. Kahneman and Tversky incorporate this property within the context of their theory, noting that it is an empirical regularity, not a prediction of their analysis.

Another phenomenon that they note is what they term the “reflection effect.” As economists have long claimed, people exhibit risk aversion with respect to potential gains. In contrast, however, when losses are at stake, individuals display risk seeking in the experimental contexts considered by psychologists. For example, people may prefer $3000 for sure to a 0.8 chance of winning $4000. Yet, they would rather face a 0.8 chance of losing $4000 than to incur a sure loss of $3000.

In the hypothetical lotteries presented to student subjects, Kahneman and Tversky found considerable boldness of this type with respect to risking losses. Although these results have been readily replicated in other experimental contexts, they do not seem to accord with actual behavior. The United States currently has a thriving insurance industry in which insurance firms offer coverage for a price that greatly exceeds the expected payoff. If individuals were truly risk seeking with respect to losses, they would not purchase insurance at all, much less the substantial quantities of actuarially unfair insurance that they now buy. Individual attitudes toward losses may be quite different when they are dealing with real stakes as opposed to paper losses in classroom experiments.

Moreover, even if the reflection effect does hold, it does not undermine theories of rational decision making. Claims that people are risk averse with respect to gains and risk loving with respect to losses suggest a preference pattern that is unusual but not necessarily different from what economists usually assume. Its only implication is that preferences are somewhat unconventional.

Another anomaly has more fundamental implications for the structure of utility functions. Kahneman and Tversky find that experimental subjects fail to integrate a bonus with the valuation of the lottery with which they are presented. For example, individuals tend to be unresponsive to having been told that they will initially be given $1000 before they confront a hypothetical lottery. That researchers should fail to find a lack of response to artificial endowments of wealth does not mean that base levels of wealth are unimportant. Rather, a more reasonable interpretation is that telling individuals in an experimental context that they are richer is not the same as actually making them richer. Wealth conveyance must take place before individuals transform their attitudes toward risk. Economists have produced an abundant literature indicating that there are substantial wealth effects in terms of attitudes toward risk bearing.\(^9\) This economic evidence is more plausible than the attempts to simulate changes in wealth in classroom experiments.

In developing their theory to explain these and other experimental
behavioral anomalies, Kahneman and Tversky incorporate a number of notions developed in the literature on the psychology of risk perception. In particular, they indicate that people sometimes edit the complex lotteries with which they are presented before evaluating them. Moreover, they note that people often have to resort to simplifications and methods of combining probabilities that may not accord with the pinpoint predictions of rationality.

Their assessments contain much truth regarding the manner in which people deal with complex choices under uncertainty. The main remaining task is to develop systematic frameworks for predicting how people will interpret complex lottery information. Psychologists know, for example, that the framework of the information presented is often of consequence. What they are less able to tell is how particular methods of framing will alter behavior. Ascertaining results is possible only after the fact. The major gap is in developing predictive models to assess what will happen before it has in fact been observed.

The essential elements of the Kahneman and Tversky theory are two-fold. First, individuals employ valuations for payoffs that differ from those in standard expected utility models. Figure 5–1 illustrates the shape of the valuation function. As indicated in the preceding discussion, individuals are hypothesized to be risk averse in the domain of gains, and risk loving in the domain of losses. The peculiar shape of the utility function is not the only novelty. Kahneman and Tversky also suggest that utility is a function of the changes in assets offered by the lottery, rather than the net asset position that will prevail after the lottery. Thus levels of wealth are not of consequence in their model. As indicated, this structure is not consistent with existing empirical evidence in actual choice-taking situations. At this stage, the utility function component of their analysis appears to be somewhat speculative. Moreover, the essential elements can probably be reconciled with standard expected utility models by simply letting utility functions have risk-averse and risk-loving regions.

The second component of the analysis concerns how people process probabilistic information. Kahneman and Tversky hypothesize that people attach to the payoffs decision weights that are not equal to probabilities. Essentially, probabilities are transformed into decision weights by the function \( \pi(p) \). Figure 5–2 sketches the shape of the decision weight function. Kahneman and Tversky do not indicate precisely how this function behaves near zero risks, but they do suggest that risk perceptions increase sharply when one moves away from a zero probability, as a wide variety of evidence has indicated.

Moreover, their sketching of the shape of the decision weight function implies an overestimation of low probability events and an underestimation of larger risks. a finding consistent with other psychological evidence. There is, however, no formal basis offered for the functional form they selected other than to note that it is governed by empirical regularities that have been observed elsewhere.

Although the Kahneman-Tversky prospect theory is not a generally accepted alternative to expected utility theory, it does serve to synthesize many of the experimental results. Moreover, consideration of this analysis suggests how much can potentially be lost by a move from expected utility theory. The standard expected utility model of economists has the advantage that its assumptions are quite generally appealing. As a model of behavior, it has strong predictive power. Reconciling actual patterns of choice with observed behavior tends to yield theories that by their very
nature are less attractive to economists because they deviate from normatively appealing axioms. Additionally, once we begin to alter many of the essential characteristics of expected utility theory, we lose much of the power of having a theory. If a theory ultimately consists of a descriptive analysis that is able to accept any behavioral pattern ex post, after having observed it, such a theory achieves very little because it has no predictive power.

Most fundamentally, if the difficulty is that people are simply making errors but would rationally choose to follow the maxims of expected utility theory if they were appraised of the impact of their decisions, abandoning expected utility theory may be too hasty. Expected utility may remain an excellent reference point for analyzing whether behavior is rational. We can then identify departures from expected utility theory as indicating errors in the ways in which markets function. Rather than trying to justify these errors with an alternative theory of choice, we might instead choose to intervene with government policies to correct the inadequacies that are identified.

This author developed framework, termed prospective reference theory, in an attempt to retain expected utility theory while at the same time recognizing the impediments to risk perception (Viscusi, 1989). In particular, this formulation postulates that people confronted with experimental lotteries treat the information provided as partial. In particular, their perceived probability is not the same as the actual probability but is instead a weighted average of some prior probability and the information with which they are provided. For the standard classroom experiment, the assumption is that a priori people treat all lottery outcomes as being equally likely and form their posterior probability assessments as linear weighted averages of both the stated probability and the probability that would prevail if all outcomes were uniformly distributed. This approach is consistent with Bayesian learning models (following either normal or beta distributions).

This rather simple amendment to expected utility theory recognizes that people may not treat probabilistic information as being fully informative. Moreover, it incorporates the salient properties of the evidence with regard to risk perceptions, as low probabilities are overestimated, high probabilities are underestimated, and there is a jump in probabilities once we move from a zero risk situation to one in which there is a small positive risk.

Consider, for example, how one might apply the prospective reference theory approach to the Allais Paradox. For concreteness, let us consider the extreme case in which the study participant places no weight whatsoever on the stated lottery information but instead treats outcomes within a particular lottery as being equally likely. Other variants of the perceptions of stated lotteries are also possible, including a weighted average of the stated probabilities and the equal probability case. For simplicity we will confine ourselves to the extreme situation in which the stated probabilities are given zero weight, except for the certainty cases involving probabilities of 0 and 1.

In the case of equation 1, the probability of receiving a payoff of 100 remains at 1.0. However, the probability of the payoffs on the right side of the inequality in equation 1 all become 0.33 because there are three outcomes—all of which are perceived as being equally likely. In the case of equation 2, all of the lotteries involved are binary lotteries involving two possible outcomes, so that all of the associated probabilities become 0.5. Thus we are led to a reformulation of these equations given by the following expressions:

\[
U(100) > (.33) U(500) + (.33) U(100) + .33 U(0)
\]

and
(5) \[ U(100) + (.5) U(0) < (.5) U(500) + (.5) U(0) \]

Setting \( U(0) = 0 \) without loss of generality implies that these conditions become

\[ U(100) > .33 \{ U(500) + U(100) \} \]

and

\[ U(100) < U(500) \]

Since

\[ U(500) > .33 \{ U(500) + U(100) \} \]

equalities 5 and 6 not only can occur with prospective reference theory, but they necessarily must occur for behavior to be consistent. The main manipulation of the problem is simply to treat the stated probabilities as being less than fully informative.

The advantage of this theory over models of irrational behavior is that it predicts almost all of the phenomena that have been identified as anomalies in the literature. Results such as the Allais Paradox and Kahneman and Tversky’s general principle underlying such violations of the substitution axiom in expected utility theory are all generated as predictions of this model. Whereas prospect theory can be potentially reconciled with this behavior, prospective reference theory predicts ex ante that this and similar anomalies will occur. For example, it also resolves the Russian roulette paradox. As a consequence, the theory has much greater predictive power. Moreover, the situation in which people treat the lottery information as being fully informative reduces to the standard expected utility model so that the analysis need not contradict rational choice.

Consequently, it is possible to reconcile the expected utility model and the literature on the psychology of choices under uncertainty. The main deficiency in the literature is that the reference point used is that of a classical statistician rather than a Bayesian decision maker. The classroom experiments and hypothetical studies that have been conducted may not have been treated as fully informative by the participants. This behavior in and of itself can account for the anomalies that have resulted.

In short, psychologists often have used the wrong reference point to assess rationality. Rather than assuming that people are perfectly informed, a more realistic reference point for comparison would be one in which people have incomplete information but act on this information in a rational manner. Imposing this Bayesian learning structure greatly enhances the predictive power that our theories can provide.

6. Toward a Sensible Basis for Risk Policies

Perhaps the final caveat with respect to the literature on rational choice is that substantial judgment is required to assess which aberrations are important. Tversky and Kahneman (1974) frequently recount the examples of assessing the contents of two urns. In particular, the task is to identify which urn has two-thirds red balls and one-third white balls as opposed to the reverse. Under one situation, we are told that the draws from an urn led to four red balls and one white ball being selected. Under a second scenario, we have drawn twelve red balls and eight white balls. Which of the two sets of draws provides stronger confidence that the urn is two-thirds red and one-third white?

Not surprisingly, experimental subjects presented with such lotteries (when recruited for the study at a local shopping mall) give incorrect answers. What is particularly note-worthy is that a swing of only one ball in terms of the draws from the urns will lead to a reversal in the assessment of the correct response. (It is left as an exercise for the reader to determine which of the answers is correct. It should be noted that the reader has much stronger probabilistic training than the typical experimental subject.)

Determining whether people can intuit applications of the laws of probability dealing with nontransparent choice situations about which they may care very little is not the best test of the rationality of individual behavior. What needs to be identified are the situations in which actual choices diverge from full rationality. Which deviations are important, and which are not? What systematic patterns of errors can be observed? What policies suggest themselves to address these difficulties? These are the truly fundamental issues that are often ignored in the literature’s self-sustaining search for the new and often unimportant behavioral anomaly.

The inadequacies in choice also affect the degree to which providing risk information can potentially eliminate the market failure. The principal assumption necessary for information to be effective is that there must be a choice that the individual can make. In the case of risks traded in the market, such as job risks and consumer product hazards, there is an element of discretion that makes programs providing risk information meaningful. In contrast, in situations in which there is no discretion, particularly in the short run, risk information will be less effective. For example, the market response may be slow to incorporate information about broadly based environmental hazards ranging from air pollution exposures to toxic waste leakage into the water supply. Eventually such risks will influence long-run mobility patterns, but in most cases the individual response will not be sufficient to ensure an efficient distribution of risks because the risks are not being traded in the marketplace.
Informing individuals in these contexts may be important so that, for example, people can choose to relocate or to create safety incentives through tort liability. Residents in the Love Canal, New York, area exited quite quickly once learning of the toxic contaminants there. Moreover, the risk information also facilitated their legal suits. Yet such information alone does not provide incentives for generators of the risks to reduce their magnitudes. There must be either a market response or action by some other social institution.

Informational policies alone are not sufficient to address environmental risks. Even in a case of risks traded in the market, provision of risk information may not always be sufficient. The major weak link in such programs is that the same kinds of impediments to sound decision making that lead to a variety or market failures in situations of risky decisions also may limit the efficacy of risk communication efforts. If we could provide full information about the risks and be assured of a rational response, market outcomes would be ideal. Human cognition, however, limits the kinds and amounts of information that public programs can effectively convey. As a result, informational efforts, correctly, do not attempt to provide comprehensive risk information; instead, they generally indicate in a succinct way the character of the risk and the pertinent precautionary behavior.

Consider, for example, the well-known case of cigarette warnings. The purpose of the warnings is to alert consumers to classes of risks posed by cigarettes, but in no instance is there any effort to convey the particular probabilities involved. Is the risk of cancer 0.01, 1, or 0.9 over a lifetime? In situations in which we convey risk information that is not specific, there should be continuing efforts to monitor the impacts of these programs on risk perceptions. Are the risk perceptions induced by the broad wording of these warnings biased in any particular direction? If so, can we select different phraseology to convey the risk more accurately?

A striking case in point is an example that took place in California. In an effort to provide consumers with pertinent risk information, California instituted a comprehensive hazard warning program under Proposition 65. That statute requires that all producers warn consumers of potential carcinogenic risks. Any product posing a lifetime cancer risk from daily consumption of at least one chance in 100,000 must be accompanied by a pertinent warning. The specific wording of the warning is as follows: 'WARNING: This product contains a chemical known to the state of California to cause cancer.' Although the implementation of this act is not yet complete, experimental studies of the implications of this wording for consumers in other states indicate that the risk perceptions induced differ quite markedly from the trace carcinogens that are intended to be captured by this program. In particular, the average risk assessment of adult consumers seeing this warning is that the product poses a lifetime risk of 12/100, a risk assessment that dwarfs the risk threshold for labeling and greatly exceeds the risks that are believed to be associated with any of the products that will be captured by this program.¹⁰

This example suggests that, in evaluating programs intended to provide information about risks, we should not ignore the impediments to rationality that often led to a rationale for government intervention initially. There must be a continuing effort to monitor how the risk information is processed and to determine whether it is leading to sound decisions.

The potential efficacy of informational efforts that take the form of hazard warnings is illustrated by the results in table 5-5. This study pertained to the different precautions induced by a variety of warning labels for bleach. The table’s columns provide information for four alternative labels, the first a Clorox label that has been purged of all warning information. The second label is the Clorox label currently on the market, and the third the label for Bright bleach, a brand of bleach marketed by the Kroger Company. The final label is a test label that has been redesigned based on cognitive principles for the effective design of hazard warnings.¹¹

What these results indicate is that properly designed warnings can have an incremental effect. The main risk from bleach is that it will be mixed with a product such as ammonia and form chloramine gas, which is the

<table>
<thead>
<tr>
<th>Precaution</th>
<th>No Warning (n = 51)</th>
<th>Clorox (n = 59)</th>
<th>Bright (n = 42)</th>
<th>Test (n = 44)</th>
<th>Maximum Incremental Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Do not mix with toilet bowl cleaner (if toilet is badly stained)</td>
<td>16</td>
<td>23</td>
<td>36</td>
<td>40</td>
<td>24</td>
</tr>
<tr>
<td>2. Do not add to ammonia-based cleaners (for particularly dirty jobs)</td>
<td>69</td>
<td>68</td>
<td>69</td>
<td>84</td>
<td>16</td>
</tr>
<tr>
<td>3. Store in child-proof location</td>
<td>43</td>
<td>63</td>
<td>50</td>
<td>76</td>
<td>33</td>
</tr>
</tbody>
</table>

leading source of poisoning among adults. The hazard warning would increase precautions to avoid such mixing by 16 percent to 24 percent. Similarly, the hazard warning would induce greater placement of the product in a child-proof location in 33 percent of the instances. Moreover, for families with young children vulnerable to poisoning, the efficacy is almost 100 percent.

These results suggest that warnings can influence behavior in the intended manner. Having an impact, however, does not always indicate efficacy. In the usual instance, hazard warnings are adopted in situations where precautions are usually desirable, but that may not always be the case. Consumers, for example, may differ in the disutility they attach to wearing rubber gloves, and some individuals may therefore rationally choose not to follow this precaution when using household cleaners. Such a decision may be quite plausible based on the benefits and costs to the particular individual. What is important is that the warning alerts the consumer to the potential benefits of taking the precaution so that the individual can make an informed decision.

In many important cases, however, we do not permit such consumer sovereignty to reign. There are some precautions that we choose to make more mandatory, thus overriding individual preferences. One notable example is motorcycle helmets. Yet, many cyclists choose not to wear these helmets and several Hollywood movie stars, such as Sylvester Stallone, have visibly proclaimed that wearing helmets is not in keeping with the appropriate image that motorcyclists wish to convey. If only the motorcyclist were at risk, society might wish to condone such deliberate self-destruction. However, motorcyclists also impose substantial risks on others, notably through the accident costs imposed on automobile drivers involved in collisions with motorcyclists. In particular, if the auto driver is at fault, the cost of hitting a motorcyclist is considerably higher when cyclists do not wear helmets and thereby sustain severe injuries. Many states consequently make wearing helmets mandatory, largely in an effort to protect the well-being of nonmotorcyclists.

It may also be the case that some requirements are needed to protect the well-being of the participants themselves. Hockey helmets were long viewed with disfavor by professional hockey players who, much like the motorcyclists, believe that wearing such protective equipment would threaten their rugged image. Yet, once wearing a helmet was mandatory, complaints of this type were fewer, perhaps because players no longer risked being singled out for the apparent weakness of relying on protective equipment.

7. Conclusion

Analyses of choices under uncertainty have been a particularly active topic in the economics literature during the past decade. Perhaps the main theme of this work is that these choices are flawed in a number of ways. Individuals often do not process information well, and the decisions that result often are in substantial error.

One potential pitfall in addressing this literature is that analysts frequently attempt to summarize its implications by simply noting that people are often irrational. Such an observation is correct as far as it goes, but it does not convey the rich detail of the results found in the literature. What is most noteworthy is not that people are irrational, but rather that they have displayed systematic patterns of irrationality. Some mistakes indicate a failure to recognize properly the implications of the risk to one's well-being, whereas in other cases errors arise when people overreact to the risks they face. Thus a belief that there is an inadequacy in the way that individuals respond to risk does not necessarily mean that more governmental intervention is needed. Indeed, the situation may be that the level of risk individuals are choosing to bear is below the efficient amount. Although one would be hard-pressed to argue that government should encourage additional risk taking in these instances, at the very least government should not be engaged in efforts to further discourage such behavior by providing risk information that inflates risk perceptions that may already be too high. Rather, the objective of public policy should be to promote informed decisions and efficient bearing of risks.

The challenge for public policy is that we often need to know a great deal about the particular context before we know which action is appropriate. Thus we need to assess the extent to which people err in their risk assessments and in their subsequent behavior. Moreover, if we were going to pursue a government policy, such as a hazard warning program, we should ascertain the ways in which it will influence risk perceptions and behavior. Gaps in rationality consequently complicate the role of the policy-maker in much the same manner as they create difficulties for the individual decision maker.

Acknowledgment

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Notes

1. For alternative reviews of these issues, see Camerer and Kunreuther (1989), Fishchhoff et al. (1981), Fishburn (1988), and Machina (1987). More generally, an entire journal, the Journal of Risk and Uncertainty, is devoted to these issues. The potential for learning is particularly great when there are opportunities for search and experience. See Vining and Weimer (1988).
4. See, for example, Svenson (1981).
5. See Viscusi and Magat (1987).
7. See, for example, the survey by Machina (1987).
9. See, for example, the discussion of risk taking by Arrow (1971).
11. See, especially, chapter 2 of Viscusi and Magat (1987) for a review of these principles.

References


ECONOMIC THEORIES OF DECISION MAKING UNDER UNCERTAINTY


