Decision Processes for Low Probability Events: Policy Implications

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Abstract
This survey describes the impact of judgements and choices about low probability, high consequence events on the policymaking process. Empirical evidence indicates that normative models of choice, such as expected utility theory, are inadequate descriptions of individual choices. The ambiguity of low probabilities also affects decisions in ways that are not normative. Further, people exhibit biases in judgments about risks and probabilities. These findings have stimulated development of new theories, such as prospect theory and generalized utility theories incorporating attributes such as regret. The authors survey many of these empirical results and explore their implications for policy. They consider the role of information, economic incentives, compensation, and regulation in inducing socially desirable effects through the reframing of outcomes. They suggest that surveys and experiments can help analysts better understand the decision process for low probability events and design more effective public policies.

Editor's Note: The following article raises important issues concerning how analysts should take account of low probability risks. It is being published with scientific-referencing, rather than JPAM's more aesthetically pleasing format, to take full advantage of its usefulness as a review of the relevant literature.

INTRODUCTION
Technological advances and scientific progress continue to create and uncover low probability, high consequence risks. How do people make judgments and choices concerning these risks? We describe here normative theories of how such choices should be made, mainly expected utility theory, and then we present evidence of how actual judgments and choices often violate normative theories. Then, in the face of this evidence, we suggest the factors
policymakers should consider in dealing with problems involving low probability risks.

Low probability risks are especially controversial because experts often disagree about the chances and potential consequences associated with specific events (Mandl and Lathrop, 1982). Even when experts agree, public perceptions are often unrealistic, in part because people lack direct experience with the risks. For example, motorists perceive their chances of suffering a severe accident as very low, even though the data show that cars are one of the leading causes of death in the U.S., (over 47,000 deaths in 1986). The public perceives other technological hazards, such as a nuclear power plant accident, to be much more likely than do experts. Thus, the nature of risk affects how people perceive them (Slovic, 1987). Furthermore, standard economic analysis usually assumes people have clear, stable preferences over various risks, when preferences are often labile, and inconsistent (Tversky, Sattath, and Slovic, 1988).

Although we adopt here primarily an economic perspective, psychological research informs, and policy concerns motivate our discussion. Economists instinctively ask whether misunderstanding of probabilities and switching of preferences by individuals (violations of the assumptions that underlie normative theory) necessarily imply that market outcomes are suboptimal. The presumption is often that incentives, past experience, and competitive forces in markets may correct or nullify the violations (Hogarth and Reder, 1986). Our reading of the evidence suggests that market outcomes often are suboptimal. Therefore, our primary focus here is with problems in which the invisible hand of the market is replaced by the visible hand of the policymaker; we ask what policymakers should do when people do not appear to behave according to economic rationality.

Functions of Policy Making

One of the functions of government is to improve the allocation of goods when markets are not operating efficiently or equitably. Welfare economics provides guidelines for diagnosing situations where private activity leads to inefficiency. The classic "market failures"—public goods, externalities, natural monopoly, and information asymmetry—can lead to allocative inefficiency even when people effectively use all available information. Our concern here is with the less well-explored possibility that people do not always effectively use information to estimate the probabilities of risky events. Nevertheless, we focus our attention on misperceptions that involve externalities. In particular, we distinguish private risks, which affect only the persons making decisions, with social risks, which affect others beyond those actually making the decisions. Consider the following examples involving private and social risks.

Seat Belts

Wearing a seat belt reduces the private risk of injury in a car accident. Survey data from before 1985 indicate that only between 10% and 20% of motorists wore seat belts voluntarily, even though it was widely known that seat belts save lives (Williams and Lund, 1986). Although it seems that many people are not acting optimally, it may not be appropriate to require the use
of seat belts if we assume that people are well-informed and the risks they incur are private. It appears, however, that many people do not wear seat belts because they believe accidents will not happen to them, even though they recognize that accidents are common—their personal probability estimates have an optimistic bias (Weinstein, 1980).

Others admit a self-control problem: They are too lazy to spend the time to buckle up, or too macho to wear a motorcycle helmet, but they would vote for laws forcing them to wear either one (Schelling, 1983). The regulations and laws we have can therefore be justified on the grounds that people misperceive risks to themselves or demand external behavioral control.

Cigarettes

Cigarette smoking is a risk that was thought to be private and was relatively unregulated (though heavily taxed) until recent evidence suggested that inhaling cigarette smoke from others was dangerous too. Smoking is therefore a social risk: Smokers impose a negative externality on nonsmokers. The externality has been regulated by a variety of recent laws creating separate smoking sections in restaurants or banning smoking entirely in many public facilities (including airline flights under two hours and all flights in California).

Technology Risks

Technological facilities, like nuclear power plants and underground storage facilities for radioactive waste, benefit society, but concentrate risk in the communities in which they are located. Although scientists and experts note that the risks of such facilities are very low, people who live in potential host communities are strongly opposed to them. Their fears are caused by dimensions of risk that are not captured by simple statistical measures, like the unknowability and uncontrollability of the hazard and its catastrophic potential (Fischhoff, Watson, and Hope 1984; Slovic, 1987). Compensation for host communities and regulations are obvious policy tools for locating facilities, but reluctance to make tradeoffs between risk and money make the use of these tools controversial (National Academy of Engineering, 1986).

These three examples illustrate that effective policies must consider psychological factors as well as economic considerations. The low probability high consequence events that are the subject of this article are often misperceived by individuals (automobile accidents), create externalities to others (smoking), and are not easily amenable to market-like solutions such as compensation for risk (location of noxious facilities). Having said this, we also feel that normative models of choice such as expected utility theory provide a natural starting point for addressing these issues.

NORMATIVE THEORY: EXPECTED UTILITY AND MULTI-ATTRIBUTE UTILITY

Assumptions of the Normative Model

Expected utility theory provides the standard model for analyzing policies involving risk. A utility function represents preferences among objects by assigning higher numbers to more preferred objects. The theorems in utility
theory specify the axioms that preferences must satisfy to ensure that utility scales have certain numerical properties. For instance, three simple axioms ensure that the numerical utility associated with a risk can be represented by its expected utility (that is, the sum or integral of the utilities of its possible outcomes weighted by their probabilities).

More formally, if \( x \) is a possible consequence and \( f(x) \) represents a continuous probability distribution over all possible consequences, then the expected utility of the risk \( f(x) \) is

\[
U(f) = \int U(x)f(x)dx
\]  

(An analogous expression, a summation rather than an integral, holds for discrete probability distributions.) Once the utilities of the underlying outcomes in \( x \) are elicited, expected utility theory (EU) enables one to derive a numerical measure of preference for any risk that is a combination of these outcomes.

In policy applications, the outcomes in \( x \) often have several different attributes \((x_1, x_2, \ldots, x_n)\), like economic costs and benefits, number of injuries and fatalities, noise level, pollution level, or employment impact. The large literature on multiattribute utility theory (MAUT) shows the conditions under which one can decompose a utility function \( U(x) \) into separable utility functions for each attribute \( x_i \) (Keeney and Raiffa, 1976). Decomposition typically facilitates the task of estimating an individual’s overall utility function because a person is only required to state preferences for one attribute at a time.

The purchase of insurance is a standard illustration in economic analysis of the use of expected utility theory. Suppose a person has wealth \( W \) and faces a \( p \) chance of an economic loss \( L \), or can buy full-coverage insurance for a price \( I \). Without insurance, expected utility is \( pU(W - L) + (1 - p)U(W) \); with insurance, expected utility is \( U(W - I) \). Insurance is preferred if \( U(W - I) > pU(W - L) + (1 - p)U(W) \).

The price \( I^* \) at which \( U(W - I^*) = pU(W - L) + (1 - p)U(W) \) is the “certainty-equivalent” of the risk, the certain loss that is equivalent in terms of utility to bearing the risk. The actuarial cost of the insurance policy is its expected value, \( pL \). If the certainty-equivalent \( I^* \) is greater than \( pL \), a person is called “risk-averse” — the person would rather buy insurance at an actuarially fair premium than bear the risk (and would pay more than the fair premium if necessary). If \( I^* < pL \) the person is risk-prefering; if \( I^* = pL \) the person is risk-neutral. Risk-aversion is equivalent to concavity of the utility function \( U(\cdot) \), as if dollars have declining marginal utility.

**Biases in Probability Judgment**

The EU model is simple and easy to use in theoretical applications. It has been shown to be an adequate description of individual choices in many ways, however (Schoemaker, 1982; Machina, 1987). Many descriptive violations arise because people use heuristic rules to estimate probabilities — rules that yield systematic errors.

**Conjunction Fallacy.** For instance, people often judge event probabilities by their plausibility. Adding details to the descriptions of events make them appear to be more likely because such details add plausibility (Tversky and
Kahneman, 1983). In fact, details make the specific outcome less likely because it is now a conjunction of a set of events A and B, and \( P(A \text{ and } B) \leq P(A) \). For example, the event “a civilian airliner refuses to identify itself and is shot down by a U.S. warship” seems unlikely. The same event with the added detail “and local boats happened to film the episode” seems more likely, because it evokes the previously ignored hypothesis that the locals arranged the destruction to win international sympathy. Scenarios rich in detail often have a plausibility that outweighs their likelihood, leading policymakers and the public to worry too much about unlikely conspiracies or elaborate chains of events that cause accidents.

**Optimism.** Another example is the optimistic “it can’t happen to me” attitude of drivers about their chances of having an accident. In a survey, Ola Svenson (1981) found that almost 90% of drivers felt they were better than the median driver. People often form such biased perceptions because data that are easily retrievable or psychologically “available” (Tversky and Kahneman, 1973) weigh more heavily than they should. Optimistic drivers often justify their optimism by saying, “It hasn’t happened to me.”

Optimistic bias might be cured by reminding people in a vivid way that only half of them can be better than the median. Upon arriving at a difficult college or graduate school, students are sometimes reminded of the dropout rate in a public assembly. If the dropout rate is 1/3, students are told to “look at the people to your left and right; one of the three of you will drop out.” Of course, the statement is not literally true, but it is statistically true, and riveting. (We know of no specific studies of the effectiveness of this kind of debiasing method, but Camerer (1987) reported that feedback about relative performance reduced optimistic bias substantially.)

**Availability.** Discrepancies between availability and frequency cause many judgment errors besides optimism. A study of causes of death found that judgment biases could be linked to biases in media reporting (Combs and Slovic, 1974). People perceive the likelihood of deaths from highly reported disasters such as fires and homicide to be higher than those of events such as diabetes and breast cancer. But the two diseases together actually take twice as many lives as the two more dramatic events.

A bias in favor of available data implies a bias against data that are hard to imagine (Slovic, Fischhoff, and Lichtenstein, 1978). In a study of fault tree judgments, for example, auto mechanics were given a variety of fault trees showing causes of a car failing to start, including a “miscellaneous” branch. Mechanics attached very little probability to the miscellaneous branch, even when an important cause of failure (e.g., the “electrical system”) was omitted. (Other mechanics had given a large probability to such an event when it was explicitly included as a branch of the fault tree.)

A similar bias occurs when people are asked to specify confidence intervals for estimates of numerical quantities, such as the increase in deaths from raising speed limits. Intervals are typically much too narrow; 90% intervals contain the true value only about half the time. In constructing an interval, people seem to anchor on a single estimate and adjust it upward then downward, by too little.

The attachment to point estimates is familiar in policymaking. Debates often revolve around “mythical numbers” created by multiplying guesses together—heroin addiction costs New York City $1 billion a year, govern-
ment deregulation would save $100 billion, etc. (Singer, 1971; Reuter, 1988). These are point estimates with their confidence intervals forgotten or foregone.

Introducing confidence intervals into the policymaking process to deal with uncertainty may be pointless in many situations unless the policy analyst eliminates the point estimate itself. A specific number has a vividness and simplicity which make it an inevitable focus of public debate.

Availability biases, like the tendency to underestimate the probability of miscellaneous fault-tree outcomes or narrow confidence intervals, can be partly cured by asking people to record possible outcomes they had not considered initially (Fischhoff, 1982). Availability biases can be exploited by making risks more salient to induce people to adopt protective measures. Highly personal messages emphasizing the high risk of not buckling up increased seat belt use by employees at Johnson and Johnson (Weinstein, Grubb, and Vautier, 1986). A study by Kip Viscusi, Wesley Magat, and Joel Huber (1987a) showed that mentioning the potential hazards associated with specific products (e.g., cleaning agents) led people to take precautionary actions (e.g., wear rubber gloves, store in a childproof location). The labels themselves indicated the types of actions that could be taken ("Keep out of reach of children"), which surely helped the process. Some individuals overreacted to the hazard by taking more precautionary actions than deemed desirable while others underreacted.

Ignoring Low Probability Risks. Many policy problems arose when people ignore risks with low probabilities. For instance, in experiments and field surveys, individuals seem to buy insurance only when the probability of risk is above a threshold (Slovic et al. 1977; Kunreuther et al. 1978), even when insurance is heavily subsidized.

If probabilities were aggregated over time or groups of people to make them seem larger, people might protect themselves more often. The chance of a fatality on an average driver is extremely low (about .00000025), well below the threshold many people set before paying attention to a risk. But over a lifetime of driving, the probability of a fatality is .01 (Schwalm and Slovic, 1982). In one study 39% of respondents who were given lifetime probability figures said they would use seat belts, compared to 10% of those who were provided with the single-trip probability.6

Viscusi, Magat, and Huber (1987b) described the risk from a bleach as 50 gas poisonings for every 2,000,000 homes, rather than as the equivalent probability \( p = .000025 \) (which equals 50/2,000,000). They then indicated that a new bleach would yield a 50% decrease in gas poisonings, rather than stating that the new probability was \( p = .00012 \). Consumers were willing to pay more for the new bleach when the benefit was stated as a percentage reduction in poisonings than when it was stated in terms of the reduction of the probability of poisoning.

There are many ways other than probability to express risk, like annual fatality rates per 100,000 persons at risk (Crouch and Wilson, 1982) or the amount of an activity that increases a person's chance of death by 1 in 1,000,000 in a year (Wilson, 1979). The impact of providing data in these various forms has not been examined.7 Furthermore, some argue (Slovic, 1986) that the degree of uncertainty associated with these risk estimates, which is often quite large, should be explained. Otherwise, people may distrust the entire analysis.
GENERALIZATIONS OF EXPECTED UTILITY

Biases in probability judgment are violations of almost every theory of choice, including EU. Many other violations of EU, like the paradoxes due to Allais, 1953 (often called the “common ratio” and “common consequence” effects, Machina 1987), are violations of the “independence axiom,” which underlies EU. The independence axiom assumes that a choice between two risks should be independent of any common outcome that occurs with the same probability in the two risks. This axiom implies that utilities and probabilities of outcomes are evaluated separately and then multiplied together, as in Eq. (1).

Violations of the independence axiom have led people to develop more general theories in which independence is replaced by a weaker axiom (Weber and Camerer, 1987) which allows interactions between probabilities and outcomes. One source of interactions is the influence of desirability of outcomes on perceptions of their likelihood. People may overestimate the chances of winning a lottery because of the excitement of winning and underestimate the chances of having their houses destroyed by an earthquake because of its horror. In economic terms, people act as if they prefer certain beliefs, perhaps those which resolve cognitive dissonance (Akerlof and Dickens, 1982). They may also selectively choose information that confirms those beliefs.

In “weighted utility theory,” the utility of a risk is its expected utility weighted by a function that depends on the outcome $x$ (Chew, 1983):

$$w(f) = \frac{\int u(x)w(x)f(x)dx}{\int w(x)f(x)dx}$$  \hspace{1cm} (2)

The weighting function $w(x)$ reflects the way in which a probability $f(x)$ is distorted by the outcome $x$, because certain outcomes are more salient or vivid, or because of wishful thinking (better outcomes are thought to be more likely) and pessimism. A higher weight $w(x)$ was attached to them.

In “expected utility with rank-dependent probabilities” (Quiggin, 1982; Chew, 1985; Yaari, 1987), the cumulative distribution $F(x)$ is transformed by an increasing function $g(.)$ before the expectation is taken.\footnote{Thus, the value of a gamble is $r(f)$,}

$$r(f) = \int u(x)d(g(F(x)))$$  \hspace{1cm} (3)

The function $g(.)$ reflects risk-aversion in a novel way. Suppose $g(.)$ is concave, which implies $g(p) > p$ (because we require also that $g(0) = 0$ and $g(1) = 1$). By ordering outcomes from worst to best, the lowest probabilities in the cumulative distribution, $F(x)$, are attached to the worst (lowest-ranked) outcomes. If $g(p)$ is concave the lowest probabilities are overweighted; probabilities attached to the highest outcomes are underweighted. A concave $g(.)$ therefore reflects a kind of risk-aversion or pessimism, because the worst outcomes are overweighted, much as the utility function reflects risk-aversion in expected utility theory (Yaari, 1987). This theory resembles Lopes’s (1984) idea that people judge risks like they judge inequality of distributions of income in society.

Weighted utility and expected utility with rank-dependent probabilities are two ways of representing the psychological interdependence of probabil-
ties and outcomes formally. In weighted utility, dependence is expressed by weighting probabilities by a function of outcomes, \( w(x) \). In rank-dependent expected utility, dependence is expressed by weighting probabilities of function that depends on the relative magnitude of outcomes.

Machina (1982) offers a third way to express dependence when he formalized the following hypothesis: People act as if they use more risk-averse utility functions when they are evaluating better risks. Dekel (1986) and Becker and Sarin (1987) present related models, allowing the utility functions people use to vary with the risks they are considering.

All these theories are so new that their implications for economic theory and policy analysis have yet to be worked out. A simple implication is that a person may not have one utility function, which complicates analysis. Preliminary evidence suggests the theories can explain some descriptive violations of EU (including the Allais paradoxes), but not all of them.\(^9\)

An important open question is the implication of these theories (assuming they characterize individual behavior correctly) for the performance of a market. For example, suppose a weighted utility model is a good description of individual behavior and individuals place a low weight on bad outcomes. Can one utilize market mechanisms for protective activities (e.g., selling insurance, providing automatic seat belts) and encourage people to take action? If one doesn’t resort to voluntary activity, what actions should one take? These questions have not been addressed by either economic theorists or policy analysts in evaluating choices involving low probability, high consequence events.

**PROSPECT THEORY**

Many violations of EU can be accounted for by prospect theory (Kahneman and Tversky, 1979), which is not a mathematical generalization of EU. Prospect theory differs from EU in four basic ways: First, people are assumed to value gains and losses from a reference point (rather than valuing net wealth as in EU; see also Markowitz, 1952); Second, a loss and a gain of the same magnitude leave people worse off and people are risk-averse toward gains and risk-seeking toward losses; Third, people are assumed to "edit" risks by making them simpler and hence easier to understand; Fourth, people are assumed to weight probabilities nonlinearly, either overweighting very low probabilities or ignoring them. Other probabilities are assumed to be underweighted. (While the conditions under which low probabilities are overweighted or ignored are not spelled out in the theory, probabilities are presumably overweighted if the outcome is salient (e.g., accident from a nuclear power plant) and dismissed if they feel the event cannot happen to them (e.g., automobile accident)).

Inconsistent decisions can be explained by the choice of reference point and the asymmetry between gains and losses. Consider a disease that is expected to take 600 lives. When hypothetical treatment programs are framed in terms of lives saved people typically prefer a Program A that saves 200 lives to a riskier Program B that saves 600 lives with a 1.3 probability (and saves no lives with probability 2/3). Yet, when the same programs are framed in terms of potential lives lost, people usually prefer Program B
which causes 600 deaths with probability 2/3 and no deaths with probability 1/3, to Program A which causes 400 deaths with certainty.

Mental Accounting

The study of reference points and the framing they induce is called "mental accounting" (Thaler, 1985). Whereas financial accounting is a set of categories and rules for recording cash flows that help managers run organizations, mental accounting is a set of rules people use to choose reference points and categories for comparing various gains and losses. The rules of mental accounting may violate the rules of financial accounting and economic decision making. A $3000 income tax refund and a $3000 salary bonus are identical in financial accounting terms, but people seem to put them in different mental accounts, earmarked for different purposes. They may treat the $3000 income tax refund as a windfall and spend it on luxuries they would not buy with the salary bonus.

Economists say money is "fungible:" all dollars are the same. Gaining $500 from a stock price rise should be treated the same way as a $500 honorarium, tax refund, or wedding present. But people violate fungibility by treating dollars differently, depending on how they got them. Policy examples are easy to find. When corporations introduce pension plans, the amount of discretionary personal saving should be roughly offset by the increased saving created by the pension plan. But personal saving does not seem to be offset (Munnell, 1976), which suggests that discretionary and pension saving are recorded in separate mental accounts.

Reframing

Buying insurance, wearing a seat belt, or adopting health prevention measures are viewed as especially burdensome because their benefits are often distant and are stored in separate mental accounts from their costs. People tend to view insurance as an investment, rather than as protection against a loss, so that it is difficult for them to comprehend the expression that "the best return on my insurance policy is no return (i.e., no damage) at all" (Kunreuther et al., 1978). Integrating mental accounts by associating costs more directly with benefits may encourage protection.

Mental accounting suggests that people may prefer to separate a small loss into a larger loss and a small gain, because the marginal disutility of the additional loss is less than the marginal utility of the gain. (Thaler, 1985, calls this the "silver lining" effect.) For this reason, charging larger premiums, then refunding part of them if a person does not suffer a loss should be attractive. In experiments, people preferred more expensive insurance with a possible refund to regular insurance (Slovic et al., 1977). Companies have experimented with refunds but we know of no published studies on their effects.10

Nationwide Insurance estimated that an automatic seat belt costing $106 would save $19 a year, or about $130 over the life of a car (Nordhaus, 1984). More than 70% of the motorists in a survey conducted in Pennsylvania and New York said they would not purchase an automatic seat belt for $100 if their annual insurance premiums were reduced by $25 (Kunreuther and Easterling, 1988). Their reluctance could be due to high discounting of future benefits, or to mental accounting: The annual saving from reduced premiums
is small compared to the immediate expense of $100, because current expenses and future benefits are recorded in different mental accounts. The trick is to help drivers reframe the problem, thinking of the $100 as an investment in a mental savings account that yields a dividend of $25 each year. Since a reduction in premiums may be less visible than a refund, paying an annual refund of $25 for buying an automatic seat belt might encourage purchase.

One such incentive system was offered by the Mendocino County Office of Education in California, which gave a $500 deductible health insurance policy to employees. They set aside $500 to cover each employee's deductible; employees got to keep whatever remained of the $500 at the end of the year. Medical care expenses were substantially reduced during the first four years of the program. (Besides reframing costs and benefits, such a refund reduces moral hazard by inducing employees to take better care of themselves.)

Endowment Effects

Prospect theory also assumes that the pain of losses from a reference point is worse than the pleasure of equivalent gains: this property is called "loss aversion." This difference creates an "endowment effect." People demand a much larger price to sell a good than they would pay to buy it (Knetisch and Sinden, 1984). For instance, Thaler (1983) found that people would only pay $800 for an inoculation to reduce a hypothetical risk of death from .001 to zero ("willingness-to-pay"), but they would have to be paid $100,000 to be exposed to a disease resulting in a .001 chance of death ("willingness-to-accept"). (Economic theory predicts willingness to pay and accept should be about the same, except for a small income effect.) Viscusi, Magat, and Huber (1987b) found that if the risk of a product was increased by 5 injuries per 10,000, most consumers said they would not buy the product at any price (regardless of the initial level of risk).

Dramatic differences have also been observed in the willingness to accept a hazardous facility nearby and the willingness to pay to locate the same facility elsewhere. In phone surveys, Kunreuther, Desvousges and Slovic (1988) found that over 70% of respondents would not accept a facility in a geologically safe location within 100 miles of their homes, even if they were paid up to $5000 per year for the next 20 years. Yet, only 40% of the respondents said they would pay an extra $100 in annual taxes over 20 years to move a repository that would be built nearby to a more distant site.

In phone surveys, Kahneman and Knetsch asked Toronto residents several questions about willingness to accept and pay for hypothetical environment changes (Cummings, Brookshire, and Schulze, 1986, pp. 191–192). They found that people would pay about the same amount to clean up one lake as they would pay to clean up all the lakes in Canada. Apparently people have mental budgets for how much they are willing to reduce an environmental risk. Spending the budget is a symbolic act that expresses their values in a crude way; the size of the task is not important. Their budgets for reducing such risks seem to be a much smaller than budgets for reducing risks from diseases (Thaler, 1983) or potentially hazardous products (Viscusi, Magat, and Huber, 1987b).

Endowment effects imply that measures of "contingent valuation" (the value people place on activities with voluntary, contingent risk), which are
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widely used in policy analysis, are labile and unreliable. People may not know or be able to articulate their true preferences.

Yet there is a need for assessing the benefits associated with environmental goods and the contingent valuation approach is currently the only game in town. Hence it is important to understand its strengths as well as its limitations. This is particularly critical in light of President Reagan's Executive Order 12.291 requiring that federal agencies such as the Environmental Protection Agency (EPA) consider the benefits and costs of their regulations and/or actions prior to implementing them. A comprehensive assessment of the use of contingent valuations in public policy can be found in a book by Cummings, Brookshire, and Schulze (1986). By bringing together researchers who have utilized the CVM approach extensively and experts in economics and psychology to critique their studies, this study offers a set of recommendations for improving the CVM approach while recognizing its limitations for policy purposes.

Reluctance to Make Tradeoffs

Although prospect theory does not explain multiattribute choices and the tradeoffs across attributes they require, the idea of mental accounting that was developed to explain reference point shifts in prospect theory can be usefully applied to multiattribute choices. Mental accounting makes decisions simpler by segregating dollars and goods into categories. This makes tradeoffs across different kinds of mental accounts—like dollars for lives—especially difficult. Communities will spend enormous time and energy to save "identifiable lives," rescuing little Jessica McClure from a Texas well in 1987, for instance. They will then pass up equivalent social investments in roads or research that are expected to save many more "statistical lives." Spending freely to save an identifiable life is a public affirmation of how much we love life, a gesture that celebrates the idea that life is sacred at any cost.

Inability to face the tradeoff between dollars and lives leads to misguided arguments, common in public debate, that "zero risk" is the only tolerable level of risk. The desire for zero risk may have an important impact on behavior. Consider an insect spray that costs $10 per bottle and results in 15 inhalation poisonings and 15 skin poisonings for every 10,000 bottles sold. Viscusi and colleagues found that survey respondents would pay about $2 more for a spray with half the current risk, and $8 more for a spray with no risk at all. This finding supports the hypothesis that people are willing to pay an extra premium for zero risk.

Inducing people to make unhappy tradeoffs across attributes, especially lives for money, seems to be more difficult than simple reframing. The standard reminder that people make such tradeoffs all the time, in their choice of leisure, driving speed, and diet, may not help. Budgets are useful because they force an agency or firm to make difficult tradeoffs if there are many competing projects and limited funds.

EXPECTED UTILITY WITH ADDITIONAL ATTRIBUTES

Many violations of EU can be explained by including attributes other than outcomes in a generalized theory. These theories cannot usually account for framing effects as prospect theory can, but they can explain other violations.
Table 1.

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<th>States probabilities</th>
<th>A</th>
<th>B</th>
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<td>1/3</td>
<td>200</td>
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<tr>
<td>S1</td>
<td>0</td>
<td>100</td>
<td>100</td>
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<tr>
<td>States probabilities</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
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<tr>
<td>S2</td>
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Regret Theory

Consider the risks shown in Table 1. The probability distributions of risks R1 and R2 are identical: both give 200 with probability 1/3 and 0 with probability 2/3. The distributions outcomes for S1 and S2 are also identical. But many people prefer R1 over S1, but choose S2 over R2 (Loomes, 1988). In choosing one alternative over another, each state corresponds to a possible outcome and a forgone opportunity. In the example, many people fear S1 in the top choice because if state A occurs they receive 0 and regret not having chosen R1 and gotten 200; there is much less regret in choosing S2 because if state A results one gets 100 and gives up 200. If the regret associated with a 200 forgone opportunity is more than twice as large as regret associated with a 100 forgone opportunity, one can legitimately choose R1 over S1 and S2 over R2 (a preference reversal).

Regret theory (Bell, 1982; Loomes and Sugden, 1982; 1987) accounts for these reversals because preferences are represented by a function of pairs of distributions, (R1, S1). If the function is positive, R1 is preferred to S1; if it is negative, S1 is preferred, however. A person who chooses this way may violate the transitivity axiom, however. Proponents of regret theory argue that regret is a genuine sensation that arises from making a choice, so this attribute should be reflected in a theory describing or prescribing choices.

Regret is created by the belief, after an event occurs, that it was more predictable before it occurred than it truly was. This mistake, called “hindsight bias” (Fischhoff, 1975), is irresistible and well-documented. Hindsight bias is more acute with low probability events (Fischhoff and Beyth, 1974), so it is especially relevant for our discussion. For instance, after tragedies, newspaper articles always point out warning signs that should have made the tragedy “obvious” and “preventable.”

Hindsight bias can be reduced the same way availability bias is reduced (Hawkins and Hastie, 1986), by asking people to record causal sequences which did not lead to the event. Curing hindsight bias might lead people to be less regretful of outcomes, which in turn makes their choices less dependent on anticipated regret.

Ambiguity

Like foregone outcomes, ambiguity (Ellsberg, 1961) or vagueness about probabilities is an attribute that is ignored in EU but which seems to affect
choices people make. Recall the insurance example. Suppose the probability of loss \( p \) is not known exactly, but instead has a distribution \( f(p) \) with expected value \( \mu \). Under EU, the expected probability \( p \) is all that matters.\(^{13}\)

Empirical evidence suggests that ambiguity does make a difference in people’s willingness to pay to avoid a risk or the required payment to take on a risk. In a series of experiments related to insurance, sophisticated subjects (including professional actuaries) indicated an aversion to ambiguity for low probability events. When subjects were asked to assume the role of the insurer, they showed an even greater aversion to ambiguity than they showed as a firm or consumer seeking insurance (Hogarth and Kunreuther, 1989). The greater ambiguity aversion of insurers helps explain the failure of private insurance markets against ambiguous risks such as environmental pollution, earthquake losses, and nuclear power plant accidents: The premium that insurers would want to charge is likely to be much higher than the potential client is willing to pay.

Formal theories that generalize EU to account for ambiguity aversion (Gilboa and Schmeidler, 1986; Bewley, 1986) suggest a person should calculate the minimum expected utility for all possible distributions of probability, and choose the alternative that maximizes that minimum expected utility. (This “minimax” rule or “pessimistic criterion” was originally proposed by Wald (1950).) Heuristic rules of this sort are often used in policymaking. For instance, interviews with managers in a chemical company revealed that managers focused on “worst case scenarios” following Bhopal in determining what preventive steps they should take for avoiding a catastrophic accident in their plants around the world (Bowman and Kunreuther, 1988).

Status Quo Bias

Ambiguity aversion is one cause of an important violation of normative theory called “status quo bias.” People often cling to the status quo when it is cheap to switch or experiment. Samuelson and Zeckhauser (1988) tell of a colleague who ordered the same lunch every day for years. One day his status quo order was unavailable so he ordered something else. Then he ordered the new lunch every day for years.

In social decisions, the status quo has a special magnetism because switching and coordinating actions may be difficult. People use QWERTY typewriter keyboards, which are less efficient than Dvorak keyboards, because it only pays to switch if enough people choose to do so and a massive switch cannot be coordinated.

Another example of a coordination problem leading to the status quo bias is illustrated by a study by Samuelson and Zeckhauser. The West German government agreed to pay for relocating a small town to another location due to a strip mining project in the area. Despite many options for redesigning the town, the citizenry opted to maintain its serpentine layout, which had evolved without any rhyme or reason over the centuries. A related phenomenon occurred after the catastrophic 1923 earthquake destroyed most of Tokyo. Despite elaborate plans on how to redesign the city if such a disaster occurred, most people pitched tents where their houses had been before, making it impossible to implement any of the redesign plans.

In individual choices, the status quo is often appealing because other options are ambiguous or require careful thought. For policymakers, there is
less responsibility associated with doing nothing than with taking any specific action (Corbin, 1980), perhaps because the cost of lost opportunities is weighed less than the cost of mistakes (Thaler, 1980). Hogarth, Michaud, and Mery (1980) describe the reluctance of a group of firms to move to two new industrial zones on the outskirts of a congested town in France despite efforts by the government to encourage financially such a change. Only after a prestigious firm decided to move did others follow. Many businesses did not take action initially because they would have regretted making the wrong decision. They also did not have any procedures for dealing with relocation decisions because they had not faced the problem before.

The tendency to maintain the status quo is particularly acute for low probability events with which decisionmakers have limited experience, such as earthquakes or nuclear power plant accidents. For events where there is a tendency to believe "it cannot happen to me," the status quo is appealing because people focus on the immediate cost of taking action (such as buying insurance) and do not see tangible benefits in the near future. For those hazards in the "it can happen to me" class, fears about regret can create a "not in my backyard" mentality and make changing the status quo difficult.

Emotional Dimensions of Risk

Judgments of riskiness are based on many dimensions other than statistical lethality. Risks that are uncontrollable or unknowable (ambiguous, perhaps) are feared even when they are statistically unlikely. A familiar example is air travel, which is uncontrollable by passengers but is much safer on a per mile basis than driving a car. The technologies perceived as most risky by individuals are those that evoke dread, such as nuclear power, and those such as chemical operations where the hazards are judged to be unobservable, unknown, delayed, or new. Experts may view these hazards as less risky than the public does because experts are worried only about statistical dimensions of risk, ignoring their emotional dimensions. When accidents do happen, the public may interpret accidents as signals that technology is not as safe as experts say (Slovic, Lichtenstein, and Fischhoff, 1984). These findings underscore a more general problem with low probability risks—because of the small sample of occurrences, experts and the public may not be able to resolve differences in beliefs.

Policy tools that reduce statistical lethality or provide insurance against risk may not be effective because of these emotional responses. People may not seek out information on specific hazards due to fear of what the knowledge will imply. Homeowners may be reluctant to test their homes for radon because they do not want to know that they and their children have long been exposed to the gas. Only after the EPA ruled that people should have their homes checked for radon has there been an interest by individuals in undertaking tests. Testing for AIDS is similar: because there is no cure for the disease, knowing that one has it causes misery and does not improve the chances of surviving (though it does help prevent the spread to others). Insurance reduces some dread but may not eliminate it; buying insurance may even remind people of their vulnerability to risks. This may be another reason why there has been such limited demand in the past by consumers for protection against hazards such as earthquakes.
Inter-temporal Risks

Many risks unfold over time. Such risks create a flow of worry over time, which Loewenstein (1988) called "dread." In standard economic analysis, a "discount rate" captures one's preference for consuming earlier rather than later. The desire to reduce dread implies people may prefer to consume bad experiences (like a trip to the dentist) earlier rather than later, in contrast to the discounting model. Pleasant experiences like vacations or dates may be deliberately postponed or planned well ahead of time so they can be "savored."

Loewenstein has found many violations of the discounting model routinely used in economic theory and in policy analysis. Many of these violations are analogous to violations of EU. For instance, Allais (1953) and Kahneman and Tversky (1979) posited a "certainty effect" in risky choice: there is a quantum drop in subjective probability from certainty to any probability less than one. A similar effect is found in choices over time: delaying choice has a substantial effect, no matter how short the delay.

People also act as if discount rates get smaller in future years. If the future-equivalent of a dollar today is $1 + r$, then according to the discounting model the future-equivalent of a dollar 30 years from now should be $1 + r$ times as large as the future-equivalent of a dollar 29 years from now; but 29 and 30 years are so far away that their future-equivalents are almost identical in the minds of most people.

People are impatient about the near future and myopic about the distant future. In policy settings, impatience and myopia will cause the public to prefer quick fixes (like arrests of minor drug dealers who are quickly replaced by others) and avoid long-term investments, particularly if they involve short-run costs (such as constructing a new incinerator or trash-to-steam plant). There is also a tendency to ignore long-term risks unless accompanying short-term risks are also recognized. The "greenhouse effect" only became prominent in public debate after extraordinarily hot weather and severe drought in the summer of 1988. The need to be reelected and other political pressures make it difficult for policymakers to ignore the impatience and myopia of their constituents.

PROCESS MODELS

Most of the models described in the sections above begin with intuitively appealing axioms and deduce theorems about the nature of choices. Observations of actual choices suggest people often use heuristics or rules of thumb that are difficult to capture in simple sets of axioms. Process models are lists of rules that serve as heuristics. Of course, the axiomatic models presented above may describe the outcomes of choices well "paramorphically" even though they describe the actual process of making decisions rather poorly (Einhorn, Kleinmuntz, and Kleinmuntz, 1979).

Tversky, Sattath, and Slovic (1988) have proposed a contingent weighting model of the choice process. In contingent weighting, individuals make tradeoffs between dimensions of alternatives, such as probability and utility. The weights they put on dimensions are contingent because they may vary depending on the form of their responses. For instance, when people choose between which of two technologies they consider to be more risky, the
probability dimension might be weighted more highly than when they state
the maximum insurance premium they will pay (Tversky, Slovic, and
Kahneman, in press).

Under contingent weighting, responses from probability- and certainty-
equivalence procedures may yield different results, contrary to predictions of
other theories. Indeed, evidence suggests that these procedures do yield
different results (Hershey and Schoemaker 1985; Johnson and Schkade
1989).

An extreme form of contingent weighting is lexicographic choice in which
the alternative that is best on a single important attribute is chosen. For
instance, a consumer may buy the cheapest product or a venture capitalist
may invest in a firm with the largest potential growth rate.

People often use simple rules like lexicographic ones when the number of
attributes and alternatives in a problem are large (Payne, 1976; Montgomery,
1977; Svenson, 1979). A rule in which the most important attribute deter-
mines the final choice is nonoptimal but is simpler than expected utility
maximization. Johnson and Payne (1985) estimated the tradeoff between
optimality and effort of different heuristics using simulations. Simulations
suggest that in some environments simple rules are surprisingly close to
optimal and require much less effort.

Many decisions about low probability risks appear to follow contingent
weighting. In some cases, people feel the probability of an accident is the
critical dimension. If the probability is below a threshold level they take no
action to prevent the risk. Threshold rules have been used by the Nuclear
Regulatory Commission and by chemical companies in designing safety
procedures (Fischhoff, 1983; Bowman and Kunreuther, 1988), by insurance
firms in setting premiums (Stone, 1973), and by Africans in deciding on
acceptable water quality (White, Bradley, and White, 1972). People and firms
often follow “safety-first” (Roy, 1952) principles, choosing actions that limit
the probability of bankruptcy.

In other situations, people focus on possible outcomes of an event and
compare them to a threshold, or use probability and outcome thresholds
sequentially (Weinstein, 1987a; Kunreuther et al., 1978). Concern with
disastrous outcomes made it difficult to site a Monitored Retrievable Storage
facility (Peake, 1987), a hazardous waste disposal facility (Morell and
Magorian, 1982; O’Hare, Bacon, and Sanderson, 1983), and a liquified
natural gas facilities (Kunreuther et al. 1982).

As Governor of Massachusetts, Michael Dukakis used a threshold approach
in delaying operation of the Seabrook I nuclear power plant. The New
Hampshire plant, which is two miles from the Massachusetts border, has not
developed evacuation plans that will “protect the lives of the people of
Massachusetts living within the 10-mile evacuation zone” noted Dukakis.
The governor’s statement that “the likelihood (of a major accident at
Seabrook) is irrelevant” suggests he was using an outcome threshold (Wessel,
1986).

Simple rules like thresholds or lexicographic choice are easy to explain and
justify because their simplicity makes communication easier. Policymakers
who base their choices on more complicated decision rules may have to
justify their choices in simpler terms—“we couldn’t afford it” (translation:
not enough benefit for the cost)—particularly if the public is demanding zero
risk.
Of course, the terms of public debate often become less simple as legislation and fashion introduce a new vocabulary of terminology and techniques. Cost-benefit analyses are now considered an integral part of the policy process as indicated by President Reagan’s Executive Order 12,291 discussed above. Thirty years ago it would not have been.

Shifting Attention

If people use a contingent weighting model to make choices, then perhaps policymakers should try to shift their attention among attributes. Seatbelt fines increase seatbelt use because of the law of demand, and because they create three new concerns in the decision process: the probability of being fined, the amount of the fine, and feelings about breaking the law. A concern for any of these factors shifts weight away from the underestimated probability of an accident and thus may induce people to wear seat belts.

Contextual cues seem to shift attention in dramatic ways. Hershey and Schoemaker (1980) found that subjects in an experiment were more likely to incur a loss to eliminate a low probability risk if the loss were labeled “insurance” rather than “certain loss.”

Attention to future outcomes, which are often underweighted compared to current outcomes, can be shifted by framing future outcomes as the outcomes faced by future generations—our children and grandchildren.

More detailed information about the consequences of a risk might increase the weight that outcomes are given in the decision process. Two such attempts designed to prevent building on floodplains have failed. A study by Roder (1961) revealed that floodplain maps circulated to Topeka residents, bankers, realtors, and officials had a negligible impact on their perceptions of the flood problem. In Boulder, the circulation of thousands of pamphlets showing that a 100-year flood would rise to the door of the Municipal Building failed to discourage the City Council from authorizing still further encroachments on the same floodplain (White, 1977). Campaigns stressing potential losses from not wearing seat belts have been equally ineffective. For recent evidence on the lack of interest in individuals undertaking self-protective action see Weinstein (1987b).

Better quantitative information about risks, rather than simply more qualitative information, may help too. The EPA gave four different brochures describing risks of radon gas to 2300 homeowners in New York State (Smith et al., 1987). Quantitative information reduced the gap between actual and perceived risk better than did qualitative information.

THE ROLE OF TRADITIONAL POLICY TOOLS

Given the understanding of decision processes that has emerged over the past 15 years, embodied in the descriptive theories discussed above, it is appropriate to question the role of traditional policy tools like regulations, standards, and economic incentives for dealing with low probability risks.

Of course, the use of traditional tools is intimately connected to the ideological manner of how much government should interfere with individual choice. Public policies that force people to buy insurance or wear a seat belt infringe on individual rights. On the other hand, regulations may be better
than current measures like federal relief after disasters or subsidized medical care after car accidents.

Incentives can induce individuals to protect themselves and compensation can induce communities to accept facilities. Regulations can supplement these policy tools or substitute for them if they do not work. We shall describe some evidence of the effectiveness of incentives and regulations. Most of the data come from surveys and experiments, but they are often suggestive enough to be worth considering in actual decision making.

**Economic Incentives**

Firms have considered a variety of incentives to induce people to protect themselves by wearing seat belts or quitting smoking. These incentives may work if the benefits (often, reduced insurance premiums) are perceived to be greater than the costs.

Incentives may not always work. As mentioned earlier, in a survey of 331 drivers, less than 30% would buy an automatic seat belt for $100 if it would reduce their annual premiums by $25 (Kunreuther and Easterling, 1988). A more effective insurance incentive is withholding claims payments for failure to take protective action. Sixty percent of the survey respondents who do not wear seat belts said they would if their payments depended on it. While withholding medical coverage might work, paying extra compensation does not seem as effective. Since 1983 Nationwide Insurance Company has paid twice as much compensation to policyholders injured in car crashes while wearing seat belts, and $10,000 to the family of policyholders killed while wearing seat belts. But these policies have not increased seat belt use: among a random sample of motorists in Connecticut, where the policy was widely advertised, only 9% of Nationwide policyholders wore seat belts, compared to 14% of the sample (Robertson, 1984).

Incentives unrelated to insurance can also be considered. At the General Motors Technical Labs employees can sign pledge cards, promising to wear seat belts for a year. The company checks compliance at the entrance to the facility. If the entire group meets a specified target, a sweepstakes is held among the pledge signers. Eighty-five percent of the employees signed pledge cards; 82% of those used their seat belts over a 12-week period (Warner and Murt, 1984).

Incentives for not smoking at work have succeeded at the Speedcole Corporation. Employees get $7 a week for not smoking. In the first month, the percentage of employees who smoked fell from 67% to 43%. The most recent measurement is 20% (Warner and Murt, 1984).

**Compensation or Benefit-Sharing for Social Risks**

In theory, compensation can induce people to take social risks that benefit others more than themselves. For example, communities could be given money if prisons or incinerators are sited nearby.

In practice, compensation has rarely been used in siting hazardous facilities because communities will only agree to host facilities if they do not create excessive health, safety or environmental risk (Roger Kasperson, 1986a). This attitude is consistent with a contingent weighting model where
risks are opposed if the probability $p$ of some risk from a hazardous facility exceeds a threshold $p^*$. Compensation has been used successfully in a few cases. The Town Council of North Andover, Massachusetts approved the siting of a regional resource recovery plant in exchange for a one dollar per ton royalty for all waste deposited there (O'Harc, Bacow and Sanderson 1983). A coal-fired plant in Wyoming was approved because the utility company established a $7.5 million trust fund to preserve a stretch of the Platte River that was the habitat of migratory birds (Lave and Romer, 1983). The Kodak Company agreed to compensate people in Rochester, New York for decreases in property values that resulted from siting an industrial facility nearby (New York Times, 1988).

A compensation agreement was negotiated by the City of Revelstoke and the British Columbia Hydro and Power Authority for building a hydroelectric dam next to the city. B.C. Hydro agreed to pay for damages caused by the dam, and gave funds to improve the city's water and sewage systems and build a recreation facility. Skaburskis (1988) presents efficiency and equity criteria used to determine a compensation package for construction of the dam. Compensation is often rejected if it is perceived as a bribe for bearing social risk. Terms like "benefit-sharing," and indirect payments that do not look like compensation may be more acceptable.

Facilities bearing social risks are difficult to locate because governments often postpone action until there is a crisis. Few hazardous waste and trash facilities have been located in recent years. Now the costs of disposing of hazardous waste and trash are skyrocketing, so there is a strong incentive to determine where a new facility should be located, rather than whether it should be sited at all.

Assuming there is a perceived need for a new facility, a competitive bidding procedure between candidate sites might prove useful. Each community could demand funding to improve amenities (a new park, or better educational or hospital facilities) for hosting the facility. The communities that do not host the facility, but benefit from the facility, could pay the host community. A bidding procedure is most palatable, however, if the status quo procedure (i.e., the proposed location of the facility if bidding is not used) is considered too expensive or unfair.

One procedure that addresses both equity and efficiency concerns is a lottery-auction mechanism (Kunreuther et al., 1987; Kunreuther and Portnary 1988). In the first stage, each of the potential host communities specifies the compensation (or benefit-sharing arrangement) that they would demand to host the facility. Call the maximum amount of compensation demanded $t^*$. A lottery is then used to determine a candidate site. At the end of this stage the winner of the lottery would be designated as the default host community and $t^*$ dollars would be earmarked for their use if the facility is hosted there.\(^{16}\)

Following the lottery, an auction would be held in which all of the candidate sites, including the lottery winner, bid an amount of compensation they would demand to host the facility. The lowest bidder hosts the facility and gets the amount of compensation it bids. The other communities pay compensation to the host community, according to some prespecified rule. If no community bids less than $t^*$, the lottery winner would be the actual site and would receive $t^*$.

This procedure acknowledges some of the psychological principles of
behavior described in previous sections. By conducting an auction after an initial round of bidding and a lottery, communities may perceive themselves as losing funds by not bidding for the facility. The initial lottery changes the reference point so compensation may be viewed as a benefit rather than a bribe. The random lottery is equitable because it is equally likely for a high income area and a low income area to be chosen. Poor communities are not forced to accept the facility at a low price.17

There are challenges in implementing such a procedure. How will the beneficiaries of the facility be taxed to pay the compensation to the host community? How does one take into account differential risks between communities? Institutional procedures which address these issues can be developed, but there must be general agreement that the status quo is unacceptable. Most importantly, studies show that communities will not consider compensation unless they are confident that a facility is safe and appropriate control procedures will be used.18 Without these guarantees, residents are likely to treat compensation as a bribe rather than as a form of benefit-sharing.

Regulations

Regulations are intended to protect our health, safety, and environment. Our interest here is the more specific role of regulation in coping with low probability, high consequence events.

Requiring Insurance. For some risks, it may be cheaper and more efficient to require certain actions than to induce people to take those actions voluntarily with incentives or information. For example, the federal government tried to promote flood insurance by subsidizing it (instead of providing disaster relief after floods). Few people bought policies; the government provided disaster relief anyway. Of course, a governmental commitment to not provide disaster relief is not credible (Rodrick and Zeckhauser, 1988), and living up to the commitment creates short-run inequity which may outweigh long-run efficiencies.

Home buyers in flood hazard areas must now buy flood insurance to get federally-insured mortgages (Petak and Atkinson, 1982). This regulation is appealing in several ways. It is easy to enforce. It shifts the costs of floods from taxpayers, who pay for disaster relief, to insurance companies who collect premiums to bear such costs. The regulation also creates demand for private insurance: Since the regulation forces many homeowners to be insured, neighboring homeowners cannot be sure of getting generous disaster relief, which induces private lenders to require insurance on all homes.

It is important that the regulation was only imposed after economic subsidies failed to convince people to buy insurance voluntarily. Homeowners did not seem to make rational choices about insurance; they often relied on personal experience and bought insurance only after a flood (when the chance of a future flood is lower). After they got disaster relief, people concluded that their initial decision to ignore insurance was wise (Kunreuther et al. 1978).

Fines. Fines are a simple way of enforcing regulations that require people to protect themselves against risks. Fines are widely used to regulate automobile safety: Speed limits reduce driving deaths; regular automobile inspections are required in most states; and 35 states have seatbelt laws (as of 1988).
Enforcement of the flood insurance mortgage requirement is automatic, but the success of most fines depends on their probability of enforcement, their size, and on attitudes about laws. Seat belt fines are rather small: Only four states have fines greater than $25 and none has a fine greater than $50. Only a third of the states allow police to stop motorists just for a seat belt violation.

Survey respondents in New York said they thought enforcement was very weak. The median estimate was that 25 of 10,000 motorists not wearing seat belts would be fined (Kunreuther and Easterling, 1988). Yet the reported seat belt usage rate in New York is 64%, which is remarkably high given the very low chance of being fined. One explanation is that people obey laws out of social obligation, not because of anticipated fines. Most of the New Yorkers surveyed (76%) approved of their existing seat belt law and 63% of Pennsylvanians favored such a law. All the Pennsylvania drivers who wore their seat belts less than half the time but favored a mandatory seat belt law said they would comply if such a law were passed. This high approval of seat belt laws suggests a social norm that may create compliance independently of economic considerations.

SUGGESTIONS FOR FURTHER RESEARCH

Our policy prescriptions are mostly speculative. We do not know if they will work, but we conclude with some ideas about the types of studies needed to determine whether they will.

Laboratory experiments and surveys can provide insight into decision processes and the impact of context. The computerized process tracing technology used by Johnson and Schkade (1989) may help us understand individual decision processes. It is especially easy to study the effect of policy tools or framing manipulations in the laboratory. Of course, field studies with experienced decision makers are important to validate generalizations from laboratory experiments.

Experiments on markets and group choices are useful in determining how policies will work when aggregated across individuals. For instance, Hogarth and Kunreuther (1989) found that insurance company actuaries appear averse to ambiguity about the probability of a loss; however, ambiguity did not affect prices set in an experimental market for insurance conducted by Camerer and Kunreuther (in press). These results are far from conclusive, but they suggest that different forces may affect individual and aggregate decisions.

It is usually presumed in economics that competition and other forces make market outcomes more rational than individual choices. Camerer (1987) found, however, that the tendency to overgeneralize from a small sample of data (as people often do after unusual accidents) was not reduced by market forces. More generally, it is unclear how policy tools like incentive mechanisms and regulations affect individual behavior in a market context when there is uncertainty and information asymmetry.

Published data on the success of various policy tools must be examined carefully. There are now many states with seat belt laws, and many quasi-experiments conducted by firms and governments, which should be studied. Cross-country differences are interesting to study too, because they reflect cultural differences in compliance that may be as important as
responses to economic incentives. An interesting example is the difference between citizens in France and the U.S. in acceptance of nuclear power. In the U.S. there have been many protests against nuclear power plant construction, especially after the Three Mile Island accident; in France there have been fewer protests. Siting procedures differ: The American procedure is more adversarial, without compensation, while the French procedure is more centralized and uses compensation. (Until recently people and businesses within 15 kilometers of a French plant could apply for a reduction of up to 20% in electricity rates; see Kunreuther et al., 1982).20

In summary, we need more empirical analyses of alternative theories of choice under risk and uncertainty. Better data and improved theory should enable us to do a better job in prescribing policies for coping with low probability risks with high consequences.

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NOTES

1. We often call these violations “irrationality,” but we do not mean to imply that the normative theories are universally accepted as rational.

2. The axioms are: “Ordering,” preferences must be complete (either A > B, B > A, or A=B for all A,B); and transitive (A > B and B > C imply A > C); “continuity,” there is a probability p such that a person is indifferent between B and the risk with a chance of A and a (1-p) chance of C (written pA + (1-p)C = pB + (1-p)C if A=B, for any p and C.

3. Arrow (1972) and Ehrlich and Becker (1972) have a detailed discussion of how one can determine the optimal amount of insurance.

4. The utility function derived from ranking risks need not be the same as the “value function” which measures how much satisfaction a person gets from various riskless wealth levels (e.g., Dyer and Sarin, 1982). This distinction is important for policy. For example, widespread risk-aversion indicates people have diminishing marginal utility but it does not justify redistributing income from the rich to the poor because people may not have diminishing marginal value for dollars.

5. A fault tree shows possible causes and subcauses of an event, such as nuclear accident, on its branches.

6. Whether individuals actually would adopt seat belts when provided with this information is still unclear.

7. The emerging literature on risk communication explores ways of presenting information on probabilities and outcomes of hazards. For a selected bibliography, see Covello, Sandman, and Slovic (1988).

8. A risk with a probability distribution f(x) can also be expressed by its cumulative distribution function, F(x) = \int f(x)dx. The probabilities f(x) are the derivatives of the cumulative probability distribution F(x) (i.e., f(x) = dF(x)/dx). Instead of writing the expected utility of a risk as \int u(x)f(x)dx, we can write it equivalently as \int u(x)dF(x).
9. For instance, people often reverse preferences by choosing a gamble A over gamble B, but attaching a higher value to gamble B (Grether and Plott, 1979; Slovic and Lichtenstein, 1983). See also Camerer (1989) for other data.

10. Mutual of Omaha has sold disability coverage that refunds all the premiums at age 65 if there were no claims over the life of the policy. Mutual of Omaha earns interest on the money and creates a reverse moral hazard: people may not make claims when they are near 65 because they would have to forego the refund.

11. Schelling (1968) wrote: "Let a six-year-old girl with brown hair need thousands of dollars for an operation that will prolong her life until Christmas. The post office will be swamped with nickels and dimes to save her. But let it be reported that without a sales tax hospital facilities in Massachusetts will deteriorate and cause a barely perceptible increase in preventable death—not many will drop a tear or reach for their checkbook.

12. One can think of $S_1$ as another attribute that is considered in deciding whether to choose R1. See Bell (1982), Loomes and Sugden (1982, 1987) for a discussion of regret theory and its implications for choice under uncertainty.

13. Under EU, the risk has expected utility $\int u(W-L)p\hat{f}(p)dp + \int u(W)(1-p)f(p)dp$. Since the utilities and probabilities are separable, this expression becomes $u(W-L)\int p\hat{f}(p)dp + u(W)\int (1-p)f(p)dp$. Because $\int f(p)dp = 1$ and $\int p\hat{f}(p)dp$ is the expected probability $p^*$ (by definition), the risk has expected utility $p^*$ $u(W-L) + (1-p^*)u(W)$.

14. Homeowners may also prefer not to know because they will feel obliged to reveal these data to buyers if they sell their houses. See Smith et al. (1987, 1988) for a detailed analysis of the problems in communicating risks of radon.

15. A related stream of research concerns choices over "temporal risks" which are resolved in the future after intervening decisions are made. "Induced" preferences over temporal risks will not generally obey expected utility theory (Spence and Zeckhauser, 1972). Therefore, in policy decisions concerning temporal risks expected utility theory is often being applied incorrectly. (It is not yet clear what theory should be applied: see Kreps and Porteus. 1979; Machina, 1984)

16. Each community should be willing to participate in the lottery because if it is chosen it will be paid $p^*$, which is the maximum amount any community bid.

17. For a more detailed discussion of equity problems associated with siting noxious facilities see Kaspersen (1986b) and MacLean (1986).

18. A recent survey of national and Nevada residents' attitude toward a high-level radioactive waste facility provided confirming evidence that individuals who perceived the risk to be high would not be willing to accept it even if they were given as much as $5,000 in tax credits or rebates over a 20 year period (Kunreuther, et al., 1988).

19. For a thorough analysis of how uncertainty, information, asymmetry, and risk misperceptions may cause market failure see Weimar and Vining (1989, pp. 79-83).

20. The rate-reduction policy was rescinded several years ago when the French government decided nuclear plants were not riskier than other technologies generating power.

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