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# Are Individuals Bayesian Decision Makers?

*By* W. KIP VISCUSI*

There has been increasing interest in whether normative models of individual choice under uncertainty accord with actual behavior. These concerns have been much greater than in other economic contexts because of the particularly severe demands such decisions place on the rationality of the decision maker. The limitations of these decisions have widespread consequences, as they provide the rationale for many governmental efforts to regulate the risks people face. Here I explore the issues raised by a Bayesian decision framework, focusing particularly on my analyses of worker and consumer behavior.

## I. Risk Perceptions

Ideally, individuals should fully understand the risks they face before making decisions with probabilistic outcomes. In most instances, extensive experimental evidence is not available, so that individuals must rely on their subjective probabilistic judgments. Such assessments will clearly not always be accurate and may be systematically biased as well. Precise analysis of the nature and extent of such biases is impeded by the paucity of data on individuals' probability assessments and the actual risks that they face.

My analysis (1979) of worker risk perceptions focused on survey data for which I linked an objective risk index (the BLS injury rate for the worker's industry) and a measure of the worker's subjective risk perceptions—a dummy variable for whether or not the worker's job exposed him or her to dangerous or unhealthy conditions. The expected positive correlation was observed, but such evidence can only be suggestive because the workers did not scale the risks in probabilistic terms.

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To refine this evidence, in my article with Charles O'Connor (1984) we presented over 300 chemical workers a linear scale that they would use to rate the hazards of their jobs. This scale was constructed in a manner that made it possible for us to compare workers' responses to objective measures of the chemical industry risk. In particular, each rating could be converted into an equivalent level for the BLS injury and illness rate. Overall, workers' subjective risk assessments were above the reported injury and illness rate for the chemical industry, which one would expect since health risks are notoriously underreported. What was particularly noteworthy is that once the long-term chemical hazards were excluded from consideration (for a subsample that was told that they would be working with sodium bicarbonate instead of their present chemicals), the subjective risk perceptions were identically equal to the published accident rates. Although one would be hard-pressed to claim that such a fortuitous result implies that all job risk perceptions are unbiased, there does appear to be a strong correspondence between actual and perceived risks for a major class of risks that people face.

When asked to rate their job risks using a linear scale or when asked about whether or not their jobs pose a hazard, most respondents give plausible risk-perception assessments. These assessments are much more accurate than the responses in studies that frame the risk perception issue in relative terms (for example, whether or not the respondent believes he or she is an above-average risk driver), where systematic optimism has been observed. Some observed biases in past studies may be due to the manner in which the risk-perception question is framed, rather than any underlying shortcoming in individual behavior.

It is well known, however, that individuals have particular difficulty in thinking about low probability events. An especially influential study is that of Sarah Lichtenstein et al.

(1978), who explored fatality risks, ranging from tornadoes to strokes and homicides. The pattern they observed was that individuals overassessed small risks of death and underassessed large risks.

Although these biases in risk perception are widely cited as evidence of irrationality, in my forthcoming article I show that such a pattern is exactly what one would expect from a Bayesian learning process. Let $p_i^*$ be the probability of death from accident category $i$, $s_i$ be the actual risk from category $i$, and $p$ be the prior risk assessment before knowing the category to which the accident belongs. If individuals behave rationally and their probability assessments are characterized by a *beta* distribution, one can show that

$$(1) \qquad p_i^* = (p + \psi_i s_i)/(1 + \psi_i),$$

where $\psi_i$ is the relative informational content associated with category $i$ compared with the individual's prior. More specifically, $\psi_i$ represents the equivalent number of Bernoulli trials that the individual acts as if he (or she) has drawn for category $i$ accidents divided by the number of trials he acts as if he has observed when forming his prior $p$.

Individuals' risk perceptions should be a weighted average of the true risk and their prior, where the weight depends on how much information they have about category $i$. The value of the prior risk assessment $p$ was not ascertained in the survey so I used two different proxies for this risk in separate equations. The first was an Akerlof "lemons" model measure—the average of all of the risks in the sample. The second proxy used was the reference point that each respondent was given in the survey before assessing the risks (either motor vehicle deaths or electrocutions).

The subsequent empirical estimates were consistent with the linear relationship specified in equation (1). For small risks, individuals revised their prior beliefs downward, but not fully, leading to overestimation of the risk. Similarly, for large risks the prior is revised partially in the upward direction, leading to an underassessment of the risk. It is particularly noteworthy that the relative weight $\psi_i$ placed on the true risk level was not significantly correlated with the degree of risk so that there was no bias in the manner in which probabilistic beliefs are revised in the direction of the true risk.

Overall, the evidence suggests that individuals may have reasonably accurate perceptions of risks that have a fundamental impact on their welfare. Risk perceptions for other more remote hazards are less precise, and the observed biases are exactly what one would expect from a rational, Bayesian learning process. The inadequacies in risk perception also do not appear to be clearcut in either direction. The overestimation of small risks and underestimation of large risks represents a more complex type of market failure than is reflected in the usual economic models incorporating biases in risk perception, which typically assume that risks are underestimated.

## II. The Role of Learning

The cornerstone of the Bayesian approach is the learning process by which individuals update their risk perceptions. This learning process was implicitly involved in the formation of the risk perceptions discussed above. In my 1979 study, I analyzed the consistency of workers' risk perceptions with the possibility of on-the-job learning using cross-sectional data. Workers who had experienced a job injury or viewed other working conditions as being unpleasant were more likely to view their jobs as being dangerous, controlling for the industry risk level and related factors. One cannot be confident based on this evidence that workers do in fact learn, since the results may simply reflect the correlation of high initial risk assessments with risky job attributes.

To explore the evolution of workers' risk judgments, O'Connor and I undertook an experiment with chemical workers at four plants. Each worker was shown a label for a chemical (either sodium bicarbonate, chloroacetophenone, asbestos, or TNT) and was told that this chemical would replace the chemicals on his present job. Workers' risk perceptions responded in the expected man-

ner, falling for sodium bicarbonate and rising for the other three chemicals. Since the true job-specific risks posed by these substances and the worker's other job risks is not fully understood, the most that could be concluded is that the prior probability assessments were revised in the correct direction.

Based on the worker responses, it was possible to estimate the key parameters in equation (1) that are associated with the label's impact—the risk $s_i$ implied by the label and its relative informational content $\psi_i$. Except for sodium bicarbonate, the implied risks $s_i$ did not differ greatly. There was, however, a substantial difference in the relative informational content $\psi_i$ of the hazard warnings. The unfamiliar chemical chloroacetophenone had a $\psi_i$ value of 1.3, implying an informational content just above that of the worker's prior, whereas TNT had a dominant $\psi_i$ value of 31.4.

These results suggest that people can process risk information in the expected direction, but that it is the informational content of the message, not simply the associated risk level, that is instrumental. The ineffectiveness of informational campaigns to promote seatbelt use and to discourage cigarette smoking are not unexpected, since the new information contained in such ads is not great. These efforts might be viewed more accurately as being policies of exhortation rather than information.

While available evidence suggests that individual learning about risks can often play an important economic role, this learning process may not be ideal. The critical reviews by Amos Tversky and Daniel Kahneman (1974), Kenneth Arrow (1982), and Baruch Fischhoff and Ruth Beyth-Marom (1983) have identified a number of systematic shortcomings. Individuals tend to exaggerate the completeness of hypothesis sets, ignore the base-rate frequency of outcomes, and more generally fail to fully understand the laws of probability. Individuals may behave in the general spirit of Bayesian decision makers in the learning process, but this behavior does not conform identically with an optimal learning process. The degree to which the various shortcomings identified in laboratory experiments affect market behavior involving risks has not yet been ascertained.

### III. Risk Perceptions and Individual Behavior

A number of studies have linked higher wages to job risks, consistent with Adam Smith's theory of compensating differentials. This is the most basic test of rational decisions involving uncertainty, and the supporting evidence is strong and quite diverse. Compensating differentials have been estimated for a large number of data sets using a variety of risk measures. It is particularly noteworthy that the observed premiums are roughly similar whether the risk variable is an objective hazard measure (for example, the industry death rate), or a measure of subjective risk perceptions (see my 1979 study and my article with O'Connor). Since it is the subjective perceptions that are instrumental from an economic standpoint, these results suggest that the fundamental behavioral assumption of the theory is satisfied.

Although the risk level is the only feature of the job risk that is of consequence in a single-period model, in a multiperiod model in which there is the possibility of terminating the job either through a job change or one's death, I have shown that the precision of the risk judgments is an addition concern. The underlying rationale is that in this class of two-armed bandit models, loose prior beliefs are preferred because they offer the potential for greater gains from experimentation with the uncertain job. As predicted, chemical labels associated with higher $\psi_i$ values lead to higher worker reservation wages, as do labels with higher $s_i$ values. Both the risk level and its precision affect a lottery's attractiveness if one is incurring a sequence of such lotteries that may be terminated conditional on an unfavorable outcome.

Although these results are consistent with optimal behavior in uncertain contexts with learning, not all observed risk-dollar tradeoffs imply that decisions are accurate. In a recent study of consumer attitudes toward low probability events (on the order of 1/100,000 risk annually), Wesley Magat and I (1984) ascertained consumers' valuations of different health outcomes. The results suggested

implausibly large risk-dollar tradeoffs. For example, there was an implied externality value to society at large of roughly $200,000 to prevent a hand burn from drain cleaner that would be temporary, but severe enough to require medical treatment. Individuals clearly have difficulty making decisions involving low probability events, and in this instance there is evidence of excessive valuation of the risks. These biases in turn may lead to alarmist decisions and excessive governmental regulation. In other cases the low risk may be ignored, creating biases of the opposite nature.

Once learning is introduced as an element, individuals will continually reassess the appropriateness of the risks and its rewards in relation to their other opportunities. The tendency of individuals to experiment with activities posing dimly understood risks will be fostered by the structure of the statistical decision problem. Individuals will display a predilection for risky jobs and other lottery sequences associated with loose priors since these offer the greatest gains from experimentation.

As predicted by these two-armed bandit models, there is a significant relationship between job risks and worker decisions to switch jobs once significantly adverse information is acquired. Results for five data sets reported in my 1979 study indicate that job risks raise worker quit rates, boost quit intentions and job-search activities, and shorten paths of employment at the firm, controlling for health status and a variety of other factors. Indeed, job risks may account for as much as one-third of all manufacturing quit rates.

In addition to the positive effect of the risk level on quitting, the aforementioned work on chemical labeling produced a positive influence of the relative precision $\psi_i$ of the risk information on quit behavior. This impact is also consistent with an optimal experimentation process since more precisely understood risks are less attractive because of the diminished value of the experimentation process associated with them. The overall job choice process is consistent with a model in which individuals start jobs with imperfect information, revise these beliefs in Bayesian fashion based on their on-the-job experiences, and alter their job choice if this information is sufficiently adverse.

Consumers likewise respond to risk information in an adaptive manner. In our study of consumer product labeling, Magat and I found that labels including risk warnings increased the frequency of consumer precautions by up to 33 percent, as compared with labels without warnings. These results may understate the role of learning to the extent that consumers' prior beliefs have been conditioned by past knowledge of the product. For example, even without a hazard warning, more than half of all consumers would store drain cleaner in a location to which children did not have easy access.

Overall, individuals do not possess perfect information about the risks they face, but they do have opportunities to revise these beliefs based on thier experiences. The observed behavior patterns are consistent with the principal predictions of a Bayesian learning process and subsequent adaptive behavior.

Although this behavior is broadly consistent with a Bayesian framework, these decisions do not always coincide with optimal behavior. As with other optimizing models in economics, Bayesian decision models represents an often powerful tool, but also a tool that may not accurately reflect how decisions are made. The expected utility hypothesis that is central to these models has long been questioned. In some contexts, inconsistencies in individual choices have been observed. There also appears to be asymmetric treatment of gains and losses, as well as special attention paid to certain outcomes. Moreover, in an actual market context in which one would have expected risk-averse consumers to purchase heavily subsidized flood and earthquake insurance, Howard Kunreuther et al. (1978) have shown that they failed to do so. As a result, individuals may respond in a manner that is broadly consistent with Bayesian decision theory, but the normative guidelines of that theory may not always be met.

Nevertheless, Bayesian models remain a useful optimizing framework for analyzing economic behavior. In some cases, the ex-

isting biases in behavior may be predicted by proper application of the Bayesian model. In others, there may be shortcomings in the manner in which individuals make decisions.

The implications of these inadequacies for the nature of the market failure are not always clear-cut. Risks may be ignored, leading to a supra-optimal level of risk, or they may be over-assessed, as shown in studies of small fatality risks. The nature of the market failure is likely to be more complex than is captured in standard models of imperfect information. There may be either inadequate or excessive attention to risks, depending on the particular context. Much remains to be learned about the shortcomings of individual decisions, the magnitude of these shortcomings, and their implications for market performance.

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