April 9, 1999

HOW DO JUDGES THINK ABOUT RISK?

W. KIP VISCUSI

Cogan Professor of Law and Economics and Director of the Program on Empirical Legal Studies, Harvard Law School, Cambridge, MA 02138, phone: 617-496-0019, fax: 617-495-3010, email: kip@law.harvard.edu. *This research was undertaken as part of the author's participation in the law and economics courses offered by the University of Kansas Law and Organizational Economics Center. The research was also supported in part by the Harvard Olin Center for Law, Economics, and Business, the Sheldon Seevak Fund, and a grant to the author by the Exxon Corporation. Jahn Hakes and seminar participants at Harvard Law School and the University of Chicago Law School provided helpful comments.*

Abstract

A sample of almost 100 judges exhibited well-known patterns of biases in risk beliefs and reasonable implicit values of life. These biases and personal preferences largely do not affect attitudes toward judicial risk decisions, though there are some exceptions, such as ambiguity aversion, misinterpretation of negligence rules, and retrospective risk assessments in accident cases, which is a form of hindsight bias. Although judges avoided many pitfalls exhibited by jurors and the population at large, they nevertheless exhibited systematic errors, particularly for small probability-large loss events. These findings highlighted the importance of judicial review and the input of expert risk analysts to assist judicial decisions in complex risk cases.

Key words: risk perceptions, hindsight bias, punitive damages, value of life, irrationality.

JEL classification: D-80, J-17

A wide body of research indicates that decisions involving risk and uncertainty are sufficiently complex that people do not always behave as would be predicted in a full information and rational economic decision world. Risk beliefs are often biased in systematic ways, and subsequent decisions may be flawed as well. Not all of these problems lead to risk levels that are too high compared to an efficiency reference point. Most well-established biases generate excessive and alarmist responses to risk.

These problems in individual behavior create difficulties for the responses of social institutions to risk. In a democratic society, governmental action is responsive to citizen preferences. If these preferences are flawed because of errors in risk perception or erroneous decisions, then the pressures on governmental action may serve to institutionalize individual irrationalities. In addition, because government officials are also human, they too may exhibit the same types of biases and errors that characterize individual behavior. Substantial evidence indicates that the governmental operation of hazardous waste cleanup efforts, pharmaceutical regulation, risk assessment practices, and a wide variety of other aspects of government risk regulation embody the same types of irrationality that have been identified in the literature dealing with irrationality of choice under uncertainty.[1] The result has been a diversion of resources to address inconsequential risks and comparative neglect of the more fundamental risks we face.

One might well raise a similar kind of concern with respect to judges. Since judges are individuals, they may be prone to the same types of irrationalities as are other people. To what extent do these various forms of irrationality carry over to how they think about risk decisions? Judges play a critical role in terms of how society responds to risk through the judicial system. If we wish to make our social institutions more effective in controlling risk sensibly, we need to understand whether these decisions are flawed and, if so, in what way.

Judges are not a random draw from the population and may not reflect all the usual patterns of error. They should be less prone to the kinds of biases and risk decision errors exhibited by the populace more generally. In addition to being better educated than the average individual, judges are also experienced observers of risky decisions. After having handled a large series of cases involving accidents and hearing the testimony presented by both sides, judges should be much better able to put risk decisions in perspective. Judges are also able to observe the outcome in these cases and whether the decisions are overturned on appeal. Since the appeals process provides a check on judicial errors, observation of this feedback mechanism should enhance judges' ability to make sounder risk decisions over time.

This paper will examine the responses by a sample of 95 state judges to a written survey about risk decisions. Although reliance on the results of a questionnaire may not capture the particular biases that are most influential in actual judicial decisions, it does provide a structured framework for exploring a wider range of issues than can be examined using case data. The judges in the sample were participants in the law and economics programs offered by the University of Kansas Law and Organizational Economics Center. The judges were sent these written surveys before the program began and returned the surveys before participating in the program, where the survey formed the basis for class discussion. The response rate was close to 100 percent. The sample consisted of program participants in two different sessions, both of which took place in 1997. Although the meetings were in Copper Mountain, Colorado, and Sanibel, Florida, participants in the program were from state courts throughout the country. The participants included many judges from state courts of appeals, state superior courts, and state supreme courts. The experience base of the sample consequently is likely to be greater than that of the average state court judge.

The two main reference points for analyzing how individual risk attitudes affect risk decisions more broadly pertain to judges' risk perceptions and personal risk tradeoffs. Section 1 analyzes the mortality risk beliefs of judges and compares these responses to the well-established pattern of biased mortality risk perceptions that has been found in the literature. A new element of this analysis is that I construct estimates on an individual basis of the person's risk perception function, making it possible to analyze whether the pattern of individual risk beliefs affects attitudes toward risky decisions more generally. The second issue pertaining to personal risk preferences is the individual's risk tradeoff in terms of the value of life, which is the subject of Section 2. A key question to be examined is whether biases in risk perceptions and the individual's personal willingness to bear risk affect the judge's attitude toward prospective judicial decisions involving accidents and other risky outcomes.

Using these aspects of individual risk beliefs and preferences, we then turn to three different areas of judicial decisionmaking. This portion of the article examines potential errors in judicial decisionmaking as well as the influence of judges' risk beliefs and personal risk preferences on these judgments. Section 3 analyzes the process of handling judicial tradeoffs in accident cases. In particular, to what extent do the judges apply economic principles for negligence correctly? Because courts operate after the fact rather than before an accident has occurred, a central concern is the role of hindsight bias, which is the subject of Section 4. Judges perform much better than mock jurors in this class of concerns. Another source of anomalies is that risks are often not known with precision. There may be substantial ambiguity pertaining to the degree of hazard. Do the same kinds of biases associated with risk ambiguity and individual behavior as reflected in the classic Ellsberg paradox also pertain to how judges view risky situations? After examining this issue in Section 5, Section 6 concludes the paper.

A recurring theme in these results is that judges exhibit a variety of biases, some of which have been documented for human behavior more generally. Many of the departures from fully rational decision making have direct implications for judicial decisions, such as the failure to interpret negligence rules correctly. The influence of hindsight bias on the retrospective assessment of an accident situation is also directly pertinent, but most judges were not prone to hindsight bias. Other biases, heuristics, and personal attitudes may have an indirect effect on how judges make risk-related decisions. Biases in risk beliefs and the judge's personal willingness to bear risk are two such personal differences. The analysis below will explore the extent to which these influences have a broader effect on how judges view legal doctrines, such as the application of negligence rules. The reassuring result is that in many instances judges' personal biases and beliefs do not have a broader contaminating effect.

Judges, nevertheless, are prone to a variety of systematic errors. Their interpretation of legal rules and accident situations often falls short of the usual law and economics efficiency reference points. These shortcomings highlight the importance of judicial review as well as the input of objective risk analysis that can assist the courts in thinking about risk in a systematic and unbiased manner.

1. Mortality Risk Perceptions

One of the most well-established results in the literature on risk is that people systematically overestimate small mortality risks and systematically underestimate large mortality risks. However, hidden hazards in situations of ignorance may not be perceived at all.[2]

In the case of identified risks, there is a well documented, systematic relationship between people's perception of the risk and the actual value of the risk. This relationship varies depending on the size of the risk. Lichtenstein et al. (1978) found that people systematically erred in their risk perceptions in this manner, and Morgan (1983) replicated this result.[3] These studies involved convenience samples of students and other groups, whereas this study will use a large group of state judges. The observed pattern of biases in risk beliefs found in such studies also plays a central role as an assumption in Kahneman and Tversky's (1979) prospect theory model and as a principal prediction in Viscusi's (1989) prospective reference theory model. These models do, however, incorporate recognition of a variety of other biases, heuristics, and characterizations of preferences that lead to departures from the standard expected utility model.

Although people may not estimate risks correctly, this pattern of biases may not necessarily imply irrationality. Much of the literature has treated the risk perception bias finding at face value as indicating a form of irrationality or quasi-rationality, but there are other interpretations of this effect that are quite consistent with rational behavior consistent with Bayesian expected utility maximization. Viscusi (1985) shows that the patterns in the Lichtenstein et al. data follow the pattern predicted using a rational Bayesian risk belief model. Suppose, for example, that people start with the same prior risk beliefs for all classes of accidents. They can, however, acquire partial information about the risks involved through their own experience, the media, hazard warnings, and other mechanisms. A rational learning process will move their beliefs partially in the direction of the true probability, but their perceptions will not reach it because of the lack of full information. As a result, we would expect to observe the well-known pattern in which small risks tended to be overestimated and larger risks underestimated. Such an effect will occur to the extent that people learn but do not move completely in the direction of the true risk from their prior risk beliefs, which do not fully distinguish different degrees of riskiness by cause of death.

Other explanations of the observed phenomena depend on the character of the risk. Viscusi, Hakes, and Carlin (1997) show that much of the claimed bias in risk perception is attributable to the different length of life lost from different sources of risk. Risks with a longer future lifetime that is lost receive a greater perceptional weight than risks with a smaller future lifetime at risk. Benjamin and Dougan (1997) also find that the risk perception data may be consistent with a rational expectations model in which people use the hazard rates for people in their own age group in forming their risk perceptions.[4] Thus, respondents may have been indicating assessed probabilities for risks to themselves, not the population at large.

Irrespective of the interpretation of the phenomenon and whether it involves a departure from rational behavior, the size-related risk bias is real and of potential consequence. If people overestimate the level of the risk, they will tend to value safety too greatly, as compared to the perfect information case. Markets will generate too great a level of safety. If they underestimate the level of the risk, they will value safety too little. Effective hazard warnings efforts have a potentially productive role to play in these instances. The observed patterns of risk perception biases indicate that we pay far too much attention to the small risks in our lives and far too little attention to the truly major risks that we face. Risk communication efforts, if effective, could potentially ameliorate these distortions. To the extent that liability and other risks addressed in court cases are small, they will be prone to overestimation and excessive court awards.

This phenomenon is pertinent for assessing how well judges think about risks as well. Judges are the arbiters of how the legal system treats risk in a wide variety of contexts including accidents, medical malpractice cases, and product liability cases, as well as cases involving dimly understood health risks, such as breast implants. Do judges share the same kinds of biases that are reflected in individual behavior and, more importantly, do these biases intrude upon their thinking about judicial decisions? The survey results presented here will examine the pattern of judges' perceptional biases and will then explore whether these biases intrude upon legal judgments.

Table 1 summarizes the different causes of death for which the judges' risk beliefs were elicited. That table also reports their associated risk values, where most of these causes of death overlap with categories considered in previous studies. The table lists these causes in order of their importance in terms of the number of deaths associated with the cause in 1993. The total number of deaths for the different causes ranged from two deaths from botulism to over two million deaths per year from all causes.[5]

Respondents were not given the list of deaths in order of importance and were not told the actual death rate. Rather, the judges received the following information:

> In 1990, 47,000 people died in automobile accidents. How many people died from the other causes of death listed below? Fill in your best estimate in the space.

Respondents then considered each of the causes of death listed in Table 1, but in a random order. Table 1 reports the actual death risk levels, the mean perceived deaths, and the geometric mean of perceived deaths (the measure most often used in previous studies). The responses by the judges reflect the widely observed pattern of overestimating small risks and underestimating larger risks. In particular, based on the geometric mean values in the final column of Table 1, judges overestimate all risks in the lower risk categories, from botulism to accidental firearm discharges. Thereafter, they underestimate all of the larger risk groups from accidental drowning to all causes of death, with the exception being stomach cancer, which they underestimate by a very small amount. The main difference in the patterns displayed by the mean perceived deaths as opposed to the geometric means is that for the mean values there is a much wider range of death categories for which people overestimate the risk, ranging from botulism to diabetes and including lung cancer as well.

To analyze the properties of these risk responses further, Table 2 reports estimates of equations that are variants of the following three formulations for linking perceived death risk categories j with the actual death risk categories j and, where appropriate, individual i*:*

$$\ln(PerceivedDeaths_{ij}) = \alpha + \beta_1 \ln(ActualDeaths_{ij}) + \in_{1ij} \qquad (1)$$

$$\ln(PerceivedDeaths_{ij}) = \alpha + \beta_1 \ln(ActualDeaths_{ij}) + \beta_2 [\ln(ActualDeaths_{ij})]^2 + \in_{2ij}, \qquad (2)$$

$$\ln(PerceivedDeaths_{ij}) = \alpha_i + \beta_1 \ln(ActualDeaths_{ij}) + \in_{3ij}, \qquad (3)$$

and

$$\ln(PerceivedDeaths_{ij}) = \alpha_i + \beta_1 \ln(ActualDeaths_{ij}) + \beta_2 [\ln(ActualDeaths_{ij})]^2 + \in_{4ij}. \qquad (4)$$

Equation 1 is a simple linear equation linking the log of perceived deaths with the log of actual deaths, where this and all other regressions are based on the unit of observation of the individual response to each question. All individuals are pooled in the regression, leading to 1,874 observations. Equation 2 adds a quadratic term to the estimation. To account for the possibility that there are person-specific differences in risk beliefs, equations 3 and 4 include a person-specific intercept term in the counterparts to equations 1 and 2. Thus, these latter two equations are fixed effects models in which person-specific differences in the level of risk beliefs are reflected in an intercept. Finally, I also estimate, but do not report here, a separate equation for each individual judge given by

$$\ln(PerceivedDeaths_{ij}) = \alpha_i + \beta_{1i} \ln(ActualDeaths_{ij}) + \in_{2ij}. \qquad (5)$$

The estimates of equation 5 give rise to an intercept term and a slope coefficient that is specific to each individual in the sample based on the responses to the risk. I will designate these values by $\hat{\alpha}_i$ and $\hat{\beta}_i$. These parameter values will play a critical role in a subsequent analysis, as they will serve as measures of the individual's own patterns of risk perception biases. The range of the $\hat{\alpha}_i$ values was from –0.19 to 8.26. Since the variables are in logs, the intercept terms are in a plausible range, indicating an assessed risk value if the true risk is zero ranging from 0.83 to 3,866 deaths per year. The range for the $\hat{\beta}_i$ values was from 0.22 to 0.84. The slope coefficients indicate a partial responsiveness of perceived to actual risks, ranging from 22-84 percent, i.e., a 100 percent increase in the actual risk boosts risk beliefs by 22 to 84 percent.

Table 2 summarizes the regression equation estimates of equations 1 to 4. All reported standard errors are robust standard errors that take into account the clustering of multiple mortality risk estimates per individual. In a linear specification there is a positive intercept term, which reflects the overestimation of small risks. Even very small risks will have associated a perceived risk value in excess of the actual risk level. The slope coefficient of 0.59 in both the ordinary least squares and the fixed effects estimates indicate that respondents are responsive to risk levels, but less than proportionally. The quadratic term estimates in equations 2 and 4 are both positive, indicating that the relationship between the log of perceived deaths and the log of actual deaths becomes increasingly close to the 45 degree line as one moves to the larger risk categories.

Figure 1 presents the estimates based on equation 2 in Table 2. As is indicated, the judges overassess the small risks, such as botulism and fireworks accidents, and underestimate the larger risks of death, such as stroke and heart disease. It is noteworthy that the extent of the overestimation of the small risks is much greater than the extent of the underestimation for large risks. People tend to have much less information and a smaller sample size on which to base estimates for the very small risks that they face, making these judgments much more imprecise than the risk assessments for the more consequential hazards. Thus, this figure indicates that the nature of the size-related bias in risk beliefs is more than simply a situation of overestimating small risks and underestimating large risks. There is also evidence that the absolute value of the gap between risk beliefs and the true risk levels narrows as one moves to the very high-risk categories. For the truly significant risks, the judges do quite well in terms of the accuracy of the risk assessments.

Overall, however, judges did exhibit the general character of biases found in other studies. In the subsequent analysis I will use the judge-specific estimates of $\hat{\alpha}_i$ and $\hat{\beta}_i$ as measures of the character of the judges risk beliefs. Do, for example, judges with high values of $\hat{\alpha}_i$, indicating substantial overestimation of small risks, behave differently in their treatment of accident cases than judges who are less prone to overestimating small risks? Similarly, is the extent of the relationship between perceived and actual mortality risks in terms of the slope of this function $\hat{\beta}_i$ influential in driving judges' views on risk issues more generally? Thus, the broader question for which these estimates will serve as the main building block is whether person-specific biases in risk beliefs contaminate other aspects of judicial behavior.

2. The Value of Life

A critical variable that may affect judges' assessment of risk situations is their own attitude toward risks to life and health. The most commonly used measure of the individual's implicit value of life is the person's risk-money tradeoff for mortality risks. This amount is not the level of compensation required to make one indifferent to certain death. No amount of money may suffice. Rather, it is the risk-money tradeoff rate that is pertinent when facing small risks of death, or the value of a statistical life. In the usual context in which one is purchasing a product that must be made safer or instituting a government regulation to foster safety, the measure I advocate is society's willingness to pay for the reduction in risk. This value provides the basis for determining what the reference point should be in terms of the level of society's investment in greater safety. This measure is now used throughout the U.S. Federal government to value risks to life and health. Although the usual reference point for assessing the implicit value of life is the wage-risk tradeoff reflected in workers' job choices, a number of other studies have also examined the tradeoff reflected in stated willingness to pay questions.[6] For environmental losses and for many refined health effects, such as cancer, it is necessary to utilize survey methods rather than direct estimation techniques based on labor market information. This section reports on the survey value-of-life estimates as reflected in the judges' responses to a risk question.

In particular, the judges answered the following question framed in terms of their willingness to pay for a reduction in mortality risk:

> Suppose that participating in this course poses a one-time only risk of death of 1/10,000. Thus, if there were 10,000 judges in this course, there would be one expected death in your group. This risk is the average annual mortality risk faced on the job by the typical U. S. blue-collar worker. Which dollar range best reflects the amount you are willing to pay to eliminate this risk you have taken?

Judges then considered six-dollar ranges from zero to fifty dollars to a high range of above $1,000, where the survey also included a final category of "infinite-all present and future resources." Calculating the implicit value of life from these responses is straightforward and indicates what is actually meant by the value of life terminology. Suppose, for example, that a judge responded that an amount between $200 and $500 would be appropriate for reducing the mortality risk by 1/10,000. Let us take the midpoint of this range, or $350 dollars, as the pertinent value for the respondent. Suppose that there were 10,000 judges with similar responses. Then overall there would be one expected death to this group. It would be possible to raise 10,000x$350, or $3.5 million in order to prevent this one statistical death. This amount is the value of life, which is simply the amount people are willing to pay per statistical death averted. Similarly, one can view the value of life in terms of the willingness to pay per unit risk, which is simply $350 divided by 1/10,000, which equals $3.5 million.

Following this approach, Table 3 indicates the distribution of the value-of-life estimates for the judges in the sample. The mean value of life for the respondents, excluding the three judges who indicated an infinite value, was $3.6 million. The median response was substantially less.

Overall, these responses seem to be somewhat low, but by no means outside of the range of estimated value-of-life statistics. Most estimates based on labor market data indicate an implicit value of life on the order of $3 million to $7 million for workers in average risk jobs and an implicit value of life in the vicinity of $1 million for workers in higher risk jobs. Thus, the general order of magnitude of the responses seems appropriate. A reason why it is likely that these judges' responses may tend to be a bit low is that hypothetical survey risks will not be as compelling as an actual risk of death. To the extent that the respondents discount the probability of death and treat it as smaller than is stated in the survey, which is certainly appropriate given their relatively safe lifestyles, then one would tend to get lower willingness to pay answers and consequently lower estimates of the implicit value of life based on survey responses.

Table 4 reports on regression results in which the judges' value-of-life estimates are analyzed with respect to the pertinent parameters of the risk perception function for the individual judge. The first set of results is an ordinary least squares regression in which the implicit value of life for the judge is regressed against the constant term, the intercept of the perception equation $\hat{\alpha}_i$, and the slope of the risk perception equation for that particular judge $\hat{\beta}_i$. Neither of the risk perception coefficients is statistically significant, indicating that any biases in mortality risk beliefs apparently do not affect how the judges process the stated risk information and then determine their implicit value of life. This is a favorable result since it indicates that the perception of probabilities stated in the survey is not distorted by their more general perceptional biases.

The second set of estimates is a probit analysis of the probability that the respondent indicated an infinite value of life. In this case as well neither of the risk perception variables is statistically significant.[7]

What these findings suggest is that any biases in risk beliefs that the judges might have do not also affect their expressed implicit values of life when faced with a tradeoff between money and a stated risk level. This result does not imply that in situations involving risks to life that judges will not misperceive the risk and, in effect, reflect this bias in risk beliefs in subsequent decisions. However, it does suggest that the valuation component of the analysis will not be contaminated by any apparent biases in risk perceptions. In the subsequent analysis of a variety of risk decisions, we will use two sets of judge-specific parameters to assess how individual judge characteristics affect attitudes towards risk decisions. The first set of parameters pertains to the first two risk perception parameters $\hat{\alpha}_i$ and $\hat{\beta}_i$, and the second class of influences will be those pertaining to risk attitudes, which will be captured using the estimate of the implicit value of life for that judge.

3. Judicial Tradeoffs—Negligence Rules

The standard economic prescription for determining an efficient level of safety is whether the benefits of the safety improvement exceed the cost. For continuous changes in safety, the question is whether safety levels have been increased until the marginal benefits just equal the marginal costs. These same kinds of principles form the foundation for law and economics interpretation of negligence rules as well.[8]

Judges considered one of three survey questions designed to test the degree to which they would apply the principles embodied in this standard negligence test. The cost of the safety improvement in every instance was $2,000. In addition, the expected benefits of the safety improvement, which equal the reduction in the risk probability multiplied by the size of the loss, equal $1,500 in every instance. Thus, applying the negligence rule as cast in law and economics terms would suggest that the safety measure is not efficient and that the firm should not be held liable for the repair.

The three experimental manipulations varied the probability of the accident and the size of the loss but held constant the expected value of the loss that would be prevented by undertaking the $2,000 repair. In the first instance, judges considered a property damage loss of $15,000 coupled with a risk probability of 1/10 that would be eliminated through the safety repair. The expected loss is consequently $1,500, which is less than the repair cost. The second variant increased the size of the property damage by a factor of 100 to $1.5 million, reducing the probability of loss by a factor of 100 to equal 1/1,000, leaving the expected loss unchanged at $1,500. The third variant increased the size of the loss to $1.5 billion, which included the value of personal injury losses, and accompanied it with a probability of the loss of 1/1,000,000. Thus, this change scaled losses up by a factor of 1,000 and scaled the probability down by a factor of

1,000, leaving the expected loss unchanged. For the personal injury question, the lives lost were valued at $5 million/life and respondents were told that this amount would reflect the full social value of the loss. In every instance, the survey indicated that the company had sufficient resources to pay the damages. [9]

An example of one of these questions (the intermediate case) is the following:

> You are CEO of Rocky Mountain Airline. The cargo door on the plane does not operate properly. Fixing it costs $2,000. If it is not fixed, there is absolutely no safety risk. Very reliable engineering estimates indicate that there is only a 1/1,000 chance over the expected life of the plane that there will be a total loss to your company of $1.5 million due to property damage caused by this problem. Thus, there is a 999/1,000 chance that there will be no damage whatsoever. Your company has no insurance but does have sufficient resources to pay these damages. [10]

Respondents were then asked to circle whether or not the firm should undertake the repair and second, if the repair is not undertaken and there was $1.5 million in property damages, to indicate whether punitive damages should be awarded.

How one views the scenario depends in part on the test being applied. The CEO of the company should presumably be concerned with profit maximization. The safety measures described involved financial effects that would all be internalized by the firm. Since safety improvements fail a benefit-cost test, they would not enhance firm profitability. Judges responding as CEOs might, however, impute a loss in the value of the company's reputation in the event of an accident involving personal injury, making them more likely to advocate safety improvements in this instance.

Application of legal rules should not be affected by broadly based reputational effects. If a safety measure does not pass a benefit-cost test, the company should not be found negligent for failing to adopt it. Punitive damages pertain to situations of reckless behavior. To be reckless, not only must the foregone safety measure pass a benefit-cost test, but presumably there should be a wide spread between benefits and costs, a repeated failure by the company to adopt safe practices, or other considerations that make the company truly reckless and not simply negligent.

In none of the three scenarios is there any basis for awarding punitive damages. Indeed, by construction the company will never be negligent for failing to adopt the safety improvement.

Table 5 summarizes the responses to the two questions for each of the risk scenarios. In the case of the low property damage amount, 68% of the judges would not undertake the repair, which is consistent with economic efficiency principles. Almost 1/3 of the sample would undertake the repair even though the cost of the repair was below the expected benefits.

The attitude toward punitive damages in this low loss case shown in Panel A of Table 5 differs moderately depending on whether repairing the plane to prevent a $15,000 loss is attractive. In each case a minority of the judges believe that punitive damages would apply if the repair was not undertaken and a loss occurred, where the fraction favoring punitive damages is greater for those who chose to repair the plane. What is perhaps most striking is that three of the judges who did not believe that the plane should be repaired nevertheless would have awarded punitive damages had the plane not been repaired and a loss was suffered. For the entire group, 18% of the judges would award punitive damages, which is not in line with economic efficiency principles since not only are punitive damages not warranted but based on a negligence test the repairs should not even be undertaken.

Panel B of Table 5 indicates how the responses change if the stakes are increased by a factor of 100 and the probability of damages is reduced by a factor of 100. Judges in this instance are almost evenly divided as to whether the plane should be repaired. Respondents who did not indicate that repairing the plane was worthwhile almost unanimously opposed punitive damages, whereas for the respondents who favored repairing the plane there was an equal division between those who supported punitive damages and those who did not.

The final variation in Panel C increases the loss to $1.5 billion, which includes the value of personal injuries, where the survey indicated that this damages amount is intended to reflect the full social cost of the accident. As before, the expected loss is $1,500, but the responses differ quite starkly from those in the previous scenarios. Respondents are now unanimous that the plane should be repaired. Moreover, over two-thirds of the respondents supported punitive damages in this instance. What appears to be most consequential is that in situations involving personal injury, there is a much greater willingness to undertake repairs and impose punitive damages than in situations involving property damage even though the expected economic losses are the same in each instance. The results in Panel C for both the award of punitive damages and repairing the plane differ to a statistically significant degree from the results in Panels A and B.

Table 6 refines this analysis using probit regressions for the determinant of the probability that the respondent will indicate that the cargo door should be repaired and that punitive damages should apply. The level of damages does not have a significant effect on the cargo door repair decision. What does matter is the nonmonetary character of the loss, which was sufficiently influential that these respondents could not be included in the repair equation. There was no variation in this scenario group as all respondents in the personal injury variant favored repairing the cargo door. The implicit value of life measures and the risk perception measures are not statistically significant except for one instance. Respondents who had higher values of the perception equations slope coefficient $\hat{\beta}_i$ were less likely to undertake the cargo door repair. Increased values of $\hat{\beta}_i$ indicate that the respondents' assessed probabilities were closer to the 45 degree line and thus tended to reflect the actual risk level more accurately. Thus, accurate risk beliefs and lower biases in risk perceptions are associated with judges being more willing to act according to efficiency norms with respect to the cargo repair decision. *A priori* the role of this variable is not clear since higher values of $\hat{\beta}_i$ could indicate more alarmist responses to risk in that perceived risks respond more quickly to changes in actual risks. However, since all $\hat{\beta}_i$ values were below 1.0, in this case the variable seems to better reflect the accuracy of risk judgments.

This variable is not, however, directly influential in the punitive damages decision, as the only statistically significant variables here are the level of expected damages and whether the judge believes that repairing the cargo door was worthwhile. Thus, to the extent that the risk perception slope variable matters it is indirectly in that it increases the probability that the respondent will want to repair the cargo door, which in turn increases the probability that the respondent believes that punitive damages should apply. Overall, however, it seems that perceptional biases and the respondent's own implicit values of life do not play a central role in how they would address the negligence issue or the punitive damages issue in this instance. Attitudes toward the underlying repair decision and the size of the accident loss are the primary factors of consequence. An attractive aspect of this finding is that personal preferences and perceptional biases do not greatly affect negligence judgments. However, the size of the stakes ideally should not matter since the expected losses (i.e. probability x damage) is the same in every instance.

Although personal risk perception biases and risk valuations do not appear to be instrumental, the results are not entirely favorable with respect to the soundness of judicial decisions. In terms of the overall responses to the scenarios, judges were evenly divided between repairing and not repairing the plane even though strict application of economic negligence rules would indicate that not repairing the plane was desirable. Moreover, even though the firm was not negligent in these examples, many judges believe that punitive damages were applicable, particularly when non-monetary losses are high. Awarding punitive damages when a firm meets a negligence standard is certainly inappropriate, as it indicates a failure to reflect on the underlying benefit-cost tradeoffs, particularly when there are large nonmonetary stakes.

This result is a sobering message for companies faced with risk-cost calculations. If these companies follow the urgings of judicial scholars such as Judge Frank Easterbrook and attempt to systematically think about the risks and costs of their action,[11] then even if they make the correct economic decision it is possible that they will risk punitive damages, particularly when nonmonetary consequences are involved. In the GM truck side impact case, GM had calculated the cost of the safety improvement and concluded that these costs were not outweighed by the expected safety benefits.[12] This analysis paralleled the approach taken for the Ford Pinto. These analyses undervalued the personal injury loss by considering only the prospective court awards and not also the implicit value of life and health. However, even the calculations had been done correctly and had generated the result that the safety improvements were not worthwhile on an economic basis, then it is quite possible that the company would nevertheless have been found liable for punitive damages. The company had confronted the risk decision with explicit probabilities of risk, clear potential for adverse health effects, and a level of costs that would not have jeopardized the solvency of the company. If companies cannot rely on economic efficiency prescriptions or negligence rules for determining the level of safety after such an analysis, then there may be no safe harbor other than the zero-risk level, which is infeasible.

4. Hindsight Bias

The courts operate after the fact. In the case of accidents, courts consider situations in which accidents have already occurred as opposed to contexts in which there is a prospective risk of an accident. Given the retrospective nature of judicial proceedings, an important potential source of bias that has been identified in the literature on risk perception is that of "hindsight bias."[13] Judge Easterbrook characterized the problem as follows: "The *ex post* perspective of litigation exerts a hydraulic force that distorts judgement."[14] After an accident, the potential causes often are much more apparent than they were before the accident occurred. The role of hindsight extends beyond accidents to other domains as well as is reflected, for example, in the second-guessing of managerial decisions in major sports contests. This section will consider two different tests of the role of hindsight bias. The first test examines the explosion of the Challenger shuttle and the ability of respondents to assess the risk of disaster before and after the accident. The second test involves a railroad accident case in which the respondents must also make the appropriate risk or liability decision as well as assess the risk.[15]

<u>Challenger Shuttle Risk Assessments</u>

In the Challenger problem, respondents had to assess the risk of an accident. There were two possible scenarios--an *ex ante* scenario and an *ex post* scenario. There were three different survey formulations of the Challenger question. One group considered only the risk assessment before the accident. A second group considered the risk assessment after the accident, and a third group provided risk assessments both before and after the accident. The sample in which the risk assessment was elicited for both time periods could potentially be more prone to subjects trying to be consistent in their responses, thus fostering hindsight bias through the survey structure. However, in practice the patterns of the *ex ante* and *ex post* probabilities for the samples that considered only one of these two risk assessments were not much different than for the sample that conceivably tried to give similar answers to both the before and after questions.

The scenario before the Challenger accident was the following:

> Take yourself back, prior to the Challenger accident... You are the administrator of NASA. Congress has been reducing your budget so that it is no longer possible to continue space shuttle missions using liquid-fueled boosters. However, NASA can substitute Air Force surplus, solid-propellant engines, allowing the project to continue. Historically, NASA has considered solid-propellant boosters too dangerous for manned flight because they cannot be shut down after ignition whereas liquid-fueled engines can. But with experience gained over years of manned space flight, and refined safety procedures currently in place, NASA engineers now estimate a fatal accident rate per launch with solid-propellant engines of 1/100,000. The Air Force engineers at Cape Kennedy who have experience launching solid-propellant missiles estimate a fatal accident rate of 1/35.
>
> In your judgment as the NASA Administrator before the Challenger accident, what is the probability of a fatal accident? Choose the range you believe to be the best estimate of the fatal accident risk per launch before the accident.

Respondents then considered six different intervals in which the risk could fall. The *ex post* scenario was analogous except that it concluded by noting the following.

> The Challenger accident was attributed to failure of the O-ring seals in the solid-propellant engines. That problem was fixed. Indicate which you believe to be the best estimate of the fatal accident risk per launch after the Challenger accident and design fix.

In the case of the subjects who considered only one of the two Challenger scenarios, the thirty-two subjects making the risk assessment *ex post* assessed the risk of another catastrophe as 0.0158, and the twenty-seven judges who considered the risk *ex ante* had a mean risk assessment of 0.0125. Although the *ex post* risk assessment is somewhat higher, the differences are not statistically significant (t=0.70).

In the case of the sample that considered both the before and after risk assessments, their risk assessments before the Challenger accident were 0.0090, and their risk assessments after the Challenger accident were 0.0100. These risk assessment values differ very little—by 0.001—with a difference that is not statistically significant (t=0.27). Finally, pooling these results with those of the judges who considered only the *ex ante* or the *ex post* risk assessment leads to an *ex ante* risk assessment value of 0.0107 and an *ex post* risk assessment value of 0.0130. This difference of 0.002 is not large and is also not statistically significant (t=0.73).

The task of a judicial system in accident cases is to consider the risk decisionmaking process using the state of the information at the time of the accident. How well can people disregard the information provided by the accident as part of this thought process? In the case of the Challenger accident, the risk assessments after the accident and the risk assessments they would have made before the accident are almost identical, with the risk assessments before the accident being lower by a statistically insignificant amount. NASA engineers before the accident put the risk at 0.00001, and Air Force engineers estimated the risk as 0.02857. In each instance the judges' risk assessment value of roughly 0.01 was of the same order of magnitude as that of the Air Force engineers and one thousand-fold greater than the risk estimated by the NASA engineers. Clearly, the benefit of hindsight has pushed judges' risk assessments much closer to the group which proved to be more accurate after the fact.

The regression analysis in Table 7 of both the *ex ante* and the *ex post* probability as a function of the risk perception and implicit value of life parameters is interesting as well. Neither set of influences affects the *ex post* probability, but the *ex ante* probability is significantly related to both parameters of the risk perception bias analysis. Subjects with a larger intercept $\hat{\alpha}_i$ who are consequently likely to overestimate mortality risks are more likely to assess a higher *ex ante* probability. In addition, subjects with higher values of the slope parameter $\hat{\beta}_i$ which indicate a steeper responsiveness of subjects' risk assessments with the value of the actual death level also indicates a positive relationship. Thus, the more general patterns of risk assessment biases with respect to mortality risk carry over in terms of their influence on the hindsight case, which is the *ex ante* probability. In contrast, the *ex post* probability is unaffected by perceptional bias patterns for mortality risk. Judging risk in hindsight is sensitive to the character of people's perceptional biases more generally, but assessing the risk *ex post* does not exhibit the same kind of sensitivity.

It is also noteworthy that the hindsight bias results differ from the findings for negligence and punitive damages judgments in terms of the influence of perceptional biases. Hindsight probability beliefs are reflective of the broader perceptional biases, with respect to risk, whereas the earlier results were not affected by perceptional factors.

Railroad Safety: *Ex Ante* and *Ex Post*

The second set of hindsight bias tests utilized a much more extensive case description. The case involved a railroad that was considering whether to make improvements in a section of track that would be related to potential property damage and economic loss. Because of updates that were scheduled to occur at a later date, the decision involved only whether a railroad structure that had led to no accidents in the past would be permitted to continue in the future. In one case the judges considered whether the railroad should be relieved of a National Transportation Safety Board (NTSB) order to modify the track and make the safety improvements, which was an *ex ante* scenario. The other group of judges considered the case after the accident had occurred so this was an *ex post* scenario, where the main decision was whether punitive damages should be awarded.

The judges who considered the risk scenario *ex ante* largely supported relief of the NTSB order, as 85.1% did not favor requiring the safety improvements. For the judges considering the *ex post* scenario, 76.6% were sympathetic with the railroad and only 23.4% agreed with punitive damages. The differences in terms of the percentage of judges who were sympathetic to the railroad was not statistically significant (t=0.84).

This behavior contrasts substantially with that observed using the same survey instruments with mock juries reported in Hastie and Viscusi's (1998) discussion of 277 jurors.

For citizen respondents, 33 percent took an anti-railroad position in the foresight case, as compared to 15 percent for the judges. However, whereas in the hindsight case 67 percent of the citizens took on anti-railroad position, only 25 percent of the judges did so. Judges' attitudes change very little across the foresight and hindsight cases, whereas there was a stark increase in jurors' anti-railroad sentiment in the hindsight case.

There is more evidence of hindsight bias in the judges' risk assessments than in their safety and judicial decisions. When asked to assess the risk of a serious accident happening before the line is closed, judges with the *ex ante* scenario assess the risk probability as 0.20, whereas judges with the *ex post* scenario assess the risk as 0.36. The *ex post* risk assessment is consequently almost twice as great as the *ex ante* risk value, where this difference is statistically significant at the 1% level (t=3.16). Judges also considered the risk on a linear grave danger scale, scaling the risk from zero to nine. Such metrics are not as meaningful as a probability scale and do not have the same quantitative significance, but it is useful to report these results both to show the robustness of the findings and to facilitate comparisons with the literature. Judges with the *ex ante* scenario rated the risk as 2.45 and judges with the *ex post* scenario rated the risk as 4.28. These differences are also significant at the 1% level (t=3.76). Judges' risk assessments seem to be more affected by hindsight bias than are their safety decisions.

Judges also differ less than jurors in how hindsight affects their risk beliefs. Judges' assessed probability of a serious accident roughly doubles from 0.20 to 0.36, as do the risk assessments of mock jurors – from 0.34 to 0.59. Although the absolute increase in probabilities is somewhat greater for judges than for the jurors – 0.16 versus 0.25 – the overall character of these results is that judges' risk beliefs are more in line with those of mock jurors than are their overall railroad liability judgements. This pattern suggests that it is how judges interpret legal rules rather than their risk beliefs that primarily accounts for the lesser effect of hindsight bias on their decisions.

A useful test for the reasonableness of the judges' responses is whether they are significantly related to benefit–cost principles, or a negligible test. For the *ex post* scenario, the survey indicated the cost of the damage as well as the repair cost. Coupling this information with the judge's own reported assessed probability of an accident makes it possible to determine whether the cost of the repairs exceed the expected benefit, as indicated by the expected accident costs. For the foresight case, the survey did not indicate the dollar cost of an accident. As a result, I will use the hindsight survey cost value in making the benefit–cost calculations for all scenarios, recognizing that different respondent assessments of the likely costs will affect their benefit–cost calculations in the foresight case.

Table 8 divides the entire sample and each of the two survey scenario groups into different benefit–cost ratio quartiles. The *ex post* scenario in which respondents knew the costs is the most informative. Somewhat strikingly, none of the respondents with a benefit cost ratio below 6.1 favored punitive damages. Only when the benefit-cost was 6.1 or greater did respondents become evenly divided between favoring and opposing punitive damages. Negligence alone does not lead judges to favor punitive damages in this instance, but rather there must be a quite substantial departure from benefit-cost norms. In the analysis of mock jurors in Hastie and Viscusi (1998), no comparable relationship was evidenced for citizen attitudes, which were more random.

The results for the *ex ante* scenario are more mixed, no doubt because these benefit-cost calculations assume a cost figure that may differ from what the respondent assessed. The overall results for the full sample do, however, reflect a rise in anti-railroad sentiment with the benefit-cost range, a result due to the strong relationship found in the *ex post* scenario.

Table 9 breaks the responses into groups of individuals who are either for or against the railroad. For the *ex post* scenario, the calculated benefit-cost ratio for the anti-railroad group is double that of the pro-railroad group, a difference which is statistically significant. However, for the *ex post* scenario in which respondents lacked the cost data to do a benefit-cost test, the estimated benefit-cost results do not differ significantly across the two groups. In this instance, the test reflects whether the perceived accident probabilities affect the railroad attitude, but the results do not control for perceived costs. The strong *ex post* scenario results suggest that when the pertinent economic factors are available that judges do think in an efficiency-oriented manner when making punitive damages judgements.

The results in Table 10 for the regression analysis of the perceived probabilities and grave danger rating indicate that whether the judge considered the *ex ante* or the *ex post* scenario is quite influential. Receiving the *ex post* version of the survey increases the judges' perceived probability of a train derailment by 0.17 and increases their perceived danger rating by 1.8, where each of these effects is just under 20% of the associated risk scale. The other results in Table 10 are less stable across the risk perception measures. The perception equation's slope coefficient $\hat{\beta}_i$ is negative in the grave danger equation, indicating that subjects who are more responsive to perceived risk levels have a lower perceived risk of danger. The perception equation's slope is not, however, statistically significant in the perceived probability of train derailment equation. Finally, the few subjects who indicated an infinite value of life assess higher risk levels, as this variable may be a measure of whether the subject understood the survey and gave measured responses or simply gravitated to extreme values.

The determinants of the probability of taking a stance against the railroad (i.e., not favoring relief of the NTSB order or favoring punitive damages *ex post*) can be analyzed using probit regressions of the probability of taking an anti-railroad position reported in Table 11. Hindsight effects largely are not evident in the anti-railroad position estimates. The fact that the respondent took a survey that considered the accident *ex post* had no statistically significant effect on whether the subject took an anti-railroad position in the first three equations. The estimated coefficients for this variable are substantially smaller than their associated standard errors. Only when this variable is interacted with the assessed benefit-cost variable in equation 4 is it significant, but this influence depends on the net effect of the negative survey indicator variable and the positive interaction term.

The most influential substantive aspects of the cases have the expected effects if one believes that judges should be balancing benefits and costs when making a decision regarding the railroad. The probability of ruling against the railroad increases with the perceived probability of derailment (equation 2), the estimated benefit-cost ratio (equation 3), and, more strongly, with the benefit-cost ratio when judges had full information to make such an estimate (equation 4).

The other noteworthy result in Table 11 is that the role of perceptional biases is consistently influential. The perception slope parameter $\hat{\beta}_i$ is negative and statistically significant in every case. A higher value of the slope parameter indicates greater responsiveness of risk perceptions to the actual risk level. Respondents who are more on track in terms of their linkage of perceived risks to actual risks appear to be less likely to take an anti-railroad position. This result continues to hold even after including the judges' perceived probability of a train derailment or assessed benefit-cost ratios. Thus, perceptional biases appear to exert an influence beyond simply how they affect the assessed case-specific risks.

5. Risk Ambiguity

One of the most well-established results in the literature on the rationality of choice under uncertainty is the Ellsberg Paradox. When given an opportunity to potentially win a prize in a lottery, subjects generally prefer a precise probability of success to ambiguous probabilities with the same mean value. Similarly, results suggest that when facing a small probability of a loss that there is ambiguity aversion, as subjects prefer a precise mean probability to a more dispersed ambiguous probability with the same mean. This same type of effect could carry over to judicial contexts as well to the extent that there are more penalties on firms which undertake risk decisions in contexts of uncertainty. This phenomenon has been a continuing theme of the tort liability literature. Tort liability critics have often suggested that courts are particularly harsh on firms that make innovative decisions posing novel risks as opposed to firms choosing technologies with well-established risks.[16] This bias deters research on products such as new prescription drugs for pregnant women and new birth control devices.

Drugs with Uncertain Risk Properties

The survey presented judges with two situations involving risk ambiguity with respect to two different problems--the risk of a product and the awarding of damages. The first regulatory decision was one in which the current biases of FDA regulations favor consideration of the maximum risk rather than the mean risk. The particular example used involved a choice of a contrast agent for a CAT scan, where this example is based on the actual risk associated with such products with the main difference being that the specific probabilities are hypothetical.

You are running a pharmaceutical company and must choose only one of two variants of a drug to market as a contrast agent for CAT scans. Your company has been selling *Old Drug* for decades. *Old Drug* works well, but there is a well-established 1/100,000 chance that the patient will suffer an adverse reaction and die. Your research team has already developed *New Drug* that performs identically and will have the same price and manufacturing costs, but *New Drug* poses uncertain risks. Based on the clinical trials, the best estimate of the expected level risk is that it is 1/150,000, but the risk is not known for sure. Some scientists believe the risk from *New Drug* is zero and some believe the risk could be as high as 1/50,000. Which drug would you choose to market? You must pick one. Circle your choice below.

Overall, the old drug with the known but higher risk was the choice of 57% of the judges. Rational Bayesian decision-making suggests that the mean risk should be the guide, or all subjects should prefer the New Drug. It poses a lower risk on average. The new drug should be preferred, so that 100 percent of the respondents should prefer the new drug, but only 43 percent do. The probit analysis in Table 12 of the probability to approve the new drug indicates no statistically significant effects except for the implicit value-of-life variable. Higher valuations of one's own life, which would seem to indicate more rational responses given the appropriate level for the judge respondent group, are associated with being more likely to approve the superior new drug.

Variance of Potential Damages

Another aspect in which a risk could be ambiguous pertains to the level of damages. In some cases firms are unlucky in that the damages amount that occurs is much less than the loss that one might have suspected on average, whereas in other instances the firm may have been fortunate in incurring damages amounts less than might be expected on average. Will respondents be guided by what actually occurred, what might have occurred, or some combination of the two? From the standpoint of appropriate incentives, one should set the damages amount based on the actual loss, not on what might have been. Failing to do so is a common error in thinking about punitive damages.[17]

The scenario in which the company was fortunate given the damages lottery it created through its actions was the following:

> Acme Oil Company has been found negligent and liable for an oil well blowout that caused $10 million in property damage and no personal injury. The company in many respects was fortunate in that such blowouts have a 90% chance of $100 million in property damages and a 10% chance of minor damage of $10 million. What damages award amount would you select?

The counterpart scenario in which the company did not fare as well with respect to the damages lottery was the following:

> Acme Oil Company has been found negligent and liable for an oil well blowout that caused $10 million in property damage and no personal injury. The company in many respects was unfortunate in that such blowouts have a 90% chance of no damage and a 10% change of $10 million in damages. What damages amount would you select?

All but five of the judges answered these questions in line with law and economics principles, focusing on the actual damages amount that occurred. Even though the judges were given six damages award categories from which to choose, 92% of them correctly selected $10 million dollars as the damages amount for both cases. The regression analysis in Table 12 indicates that the value of the proposed damages award is not sensitive to the risk perception or value-of-life variables, which is not surprising since there is little variation in the recommended award amount. Judges' assessment of damages awards consequently does not seem to be affected by risk ambiguity biases and is quite consistent with what one would do if implementing sound law and economics principles.

6. Conclusion

Judges are human and may reflect the same kinds of irrationalities as other individuals. Judges did exhibit the well-established pattern of overestimating small risks and underestimating large risks, but their risk assessments for substantial risks were not substantially in error. Judges' expressed risk-dollar tradeoffs as reflected in their implicit values of life were in line with that of other population groups in terms of the general order of magnitude of the valuation.

The two key questions explored in this paper were whether these aspects of individual preferences in valuation affected attitudes in judicial contexts and whether decisions in these contexts exhibited forms of irrationality that have been identified in the literature. Judges' application of negligence rules became much more out of line with standard law and economic prescriptions once substantial nonpecuniary damages were involved. Large stakes-small probability catastrophic events seemed to pose greater problems for judicial decisionmaking than higher probability-lower loss events. The potential for such errors and the large costs of error in terms of incorrect major penalties highlight the potential benefits of judicial review for such large stakes cases.

Judges, however, are much less prone to hindsight bias than are jurors in their treatment of corporate safety decisions. Indeed, in making legal judgements there was little effect of hindsight for judges, as compared to substantial effects for mock jurors. An interesting aspect of the results is that whereas the safety decisions of the judges were not affected by the hindsight bias, there was consistent evidence that the risk assessments were sensitive to whether the judgment was being made *ex ante* or *ex post*. Unlike jurors, judges seem to be better able to put aside potential biases in risk assessments that arise with hindsight and still make sound decisions.

The scenarios involving hindsight were noteworthy in that the evidence of hindsight bias that was reflected in the results was correlated with broader patterns of judges' perceptional biases. Judges' risk beliefs and value of life measures were far less consequential with respect to interpretation of legal rules in the other scenarios examined.

Judges' performance with respect to risk ambiguity also offers two sets of messages. First, judges were remarkably sound in their setting of damages in complex situations involving uncertainty. Nevertheless, a second set of results indicated that judges did exhibit risk ambiguity aversion, which is a bias that is prevalent in risk assessment practices throughout the U. S. Federal government safety agencies. Judges favored well known, established risks to smaller but more uncertain risks for new products. The frequently cited bias of the courts against novel risks created by innovative products has a similar economic structure.

Overall, judges did exhibit many of the patterns of biases in risk judgements that have been the focus of the literature on the rationality of choice under uncertainty. For the most part, these biases do not contaminate that thinking of judges with respect to their interpretation of legal rules. Even in the case of hindsight bias, for which there was some evident influence of risk beliefs, judges performed very well overall and took a more efficiency-based approach than do mock jurors.

The policy implications of this research are threefold. First, recommendations that judges be given more authority over issues such as damages in complex cases appear to be well founded. Recent proposals that judges be given authority to set punitive damages would be in line with the character of these results in which judges often avoided well-established patterns of juror error, both with respect to hindsight biases and uncertain levels of damages for an accident.[18] The second policy implication is that input from experts in risk analysis would be a beneficial addition to judicial decisionmaking. Situations involving complex risks, such as those involving risk ambiguity and the need to consider the state of the information at the time of the accident, are potentially subject to distortion in terms of how people think about the probabilities. The urgings by U. S. Supreme Court Justice Stephen Breyer and others that courts avail themselves of scientific expertise could lead to the kinds of judicial reforms that could potentially alleviate these biases.[19] The final recommendation is that there are clearcut benefits to judicial review. Decisions involving complex risks pose by far the greatest challenges to rational economic decisionmaking. It is not surprising that this class of issues will also pose the greatest problems for judicial decisionmaking. Small probability-large loss events are particularly subject to error. There is a tendency to overestimate such risks, to depart from usual negligence criteria, and to fall prey to hindsight bias. In such cases, the costs of bad court decisions can be huge, as catastrophic risks tend to generate similarly enormous damages awards. Resolving these issues satisfactorily no doubt will benefit from the potential for judicial review that provides an additional perspective on such complex issues.

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Endnotes

[1] For a comprehensive perspective on these issues, *see* Viscusi (1998). A detailed analysis of these issues for hazardous waste cleanup efforts appears in Viscusi and Hamilton (forthcoming). An exposition of the underlying theory appears in Noll and Krier (1990).

[2] This possibility is examined by Kunreuther (1978).

[3] Other aspects of the risk can affect risk beliefs as well, such as newspaper coverage and the dread associated with the hazard, such as the fear of dying in an airplane crash. *See* Fischhoff et al. (1981).

[4] For a commentary on this paper and a comparison with Bayesian learning models, see Hakes and Viscusi (1997).

[5] The number of respondents to these questions ranged from 79 to 84 because of missing values for some of the survey answers. Respondents who did not answer typically skipped the entire page since it was much more time consuming than the rest of the survey.

[6] For review of this literature, *see* Viscusi (1993).

[7] Since only three respondents indicated an infinite value of life, it is not surprising that neither perception variable is statistically significant.

[8] For an exposition of these negligence rules in law and economics *see* Posner (1986) and Polinsky (1989), among others.

[9] This statement will reduce but perhaps not eliminate the possible influence of risk aversion in affecting some of the responses. Since the loss size variation primarily affects the company

not the parties injured, negligence rules should be applied in a risk-neutral fashion. Moreover, the $5 million value-of-life figure fully reflects the social loss, and no risk aversion bonus is warranted from an economic standpoint.

[10] It should also be noted that the losses associated with this risk occur over the life of the plane so that including the role of discounting would reduce the discounted expected value of the loss to an amount below $1,500.

[11] *See* his comments in Carroll v. Otis Elevator, 896 F2d (1990).

[12] The GMC truck analysis was the focus of Moseley v. General Motors, 213 Ga. App. 875, 447, S.E. 302 (Ga. Ct. App. 1994). For a review of the analogous Ford Pinto analysis *see* Viscusi (1991).

[13] For discussions of hindsight bias *see* Hastie, Schkade, and Payne (1998) and Kelman, Elliot, and Folger (1998). Also *see* Rachlinski (1998) and Jolls (1998).

[14] *Supra* note 11.

[15] This scenario was developed by Reid Hastie for a study of juror behavior.

[16] *See*, for example, Huber (1988) and Viscusi (1991).

[17] The importance of thinking about damages in terms of the actual loss rather than potential losses is articulated by Polinsky and Shavell (1998).

[18] *See* Kahneman, Schkade, and Sunstein (1998).

[19] For a fuller discussion of society's efforts to deal with risk more generally, *see* Breyer (1993).

Table 1

Actual and Perceived Risks of Death for Major Sources of Mortality

Cause of death	Actual deaths in 1993	Mean perceived deaths	Geometric mean of perceived deaths
Botulism	2	1,250.7	225.0
Fireworks accident	5	667.4	127.1
Measles	5	1,335.2	231.9
Lightning strikes	89	1,337.6	206.3
Pregnancy (birthing complications)	320	58,082.4	4,850.7
Appendicitis	500	3,080.3	589.4
Accidental electrocution	670	4,811.0	1,076.9
Hepatitis	677	8,574.8	1,789.9
Accidental firearm discharges	1,416	28,844.4	8,675.2
Accidental drowning	3,979	6,491.3	1,964.2
Fire and flames	4,175	11,973.9	3,634.7
Asthma	4,750	14,533.5	2,962.5
Accidental poisoning	5,200	13,535.3	1,909.6
Accidental falls	12,313	9,849.3	2,057.3
Stomach cancer	13,640	42,415.7	14,145.3
Homicide	24,614	48,093.4	21,634.1
Breast cancer	45,000	84,511.9	31,750.0
Diabetes	47,664	61,812.0	12,907.6
Stroke	144,088	132,480.6	44,538.7
Lung cancer	145,000	149,512.0	53,317.2
All forms of cancer	505,322	462,148.8	185,024.8
Heart disease	720,000	518,422.3	169,867.2
All causes	2,148,463	2,993,906.0	1,158,700.0

Note: The number of observations range from 79 to 84 for the different mortality risk groups.

Table 2
Regression Results for Determinants of ln(Perceived Deaths)

	Coefficient (Standard Error)			
	Ordinary Least Squares		Fixed Effects	
	1	2	3	4
Constant	3.711*** (0.220)	5.121*** (0.230)	2.160*** (0.136)	3.577*** (0.156)
ln(Actual Deaths)	0.591*** (0.016)	0.092** (0.036)	0.593*** (0.016)	0.094*** (0.036)
[ln(Actual Deaths)]^2	---	0.033*** (0.002)	---	0.033*** (0.002)
R^2	0.54	0.57	0.73	0.76

Note: The model includes 1,874 observations; all regression estimates are robust and clustered by individual.
* Significant at 90% confidence level, two-tailed test.
** Significant at 95% confidence level, two-tailed test.
*** Significant at 99% confidence level, two-tailed test.

Table 3
Distribution of Implicit Valuations of Life Elicited From State Judges

Value of life range		Number responding
0 -	$500,000	42
$500,000 -	$2,000,000	16
$2,000,000 -	$5,000,000	12
$5,000,000 -	$10,000,000	4
0ver	$10,000,000	14
Infinite		3
Mean	3,551,136	
(Standard error of mean)	($564,527)	
Median	1,250,000	

Note: Values were coded as the mid-point of each range, using $15,000,000 for the over-$10,000,000 category when calculating the mean. Responses indicating infinite value of life were omitted from the calculation of the mean and standard error of the mean. The total sample size was 91.

Table 4
Regression Estimates of the Effect of Risk Perception Biases
on the Self-Reported Value of Life

	Coefficient (Standard Error)	
	Value of Life (in $millions)	Infinite value of life = 1 Probit
Constant	9.336* (5.013)	0.293 (2.333)
Perception equation intercept $\hat{\alpha}_i$	-0.221 (0.435)	-0.215 (0.208)
Perception equation slope $\hat{\beta}_i$	-9.114 (6.105)	-2.308 (3.026)
R^2	0.04	---

The value of life model omits non-responses and responses of an infinite value of life.
* -- Significant at 90% confidence level, two-tailed test.

Table 5
Relation of Judges' Opinions on Repairing Airplane Defect to Whether Punitive Damages Should Apply if an Accident Occurs

Panel A: Property Damage Low: $15,000

	Repair Plane	Don't Repair Plane	Total
Punitives apply	5 (11.4%)	3(6.8%)	8 (18.2%)
Punitives don't apply	9 (20.4%)	27 (61.4%)	36 (81.8%)
Total	14 (31.8%)	30 (68.2%)	44 (100 %)

Panel B: Property Damage High: $1.5 million

	Repair Plane	Don't Repair Plane	Total
Punitives apply	7 (24.2%)	1(3.4%)	8 (27.6%)
Punitives don't apply	7 (24.2%)	14 (48.2%)	21 (72.4%)
Total	14 (48.4%)	15 (51.6%)	29 (100 %)

Panel C: Personal Injury High: $1.5 billion

	Repair Plane	Don't Repair Plane	Total
Punitives apply	11 (68.8%)	0 (0%)	11 (68.8%)
Punitives don't apply	5 (31.2%)	0 (0%)	5 (31.2%)
Total	16 (100 %)	0 (0%)	16 (100 %)

Panel D: Overall Results

	Repair Plane	Don't Repair Plane	Total
Punitives apply	23 (25.8%)	4(4.5%)	27 (30.3%)
Punitives don't apply	21 (23.6%)	41 (46.1%)	62 (69.7%)
Total	44 (49.4%)	45 (50.6%)	89 (100 %)

t-statistics for comparisons of scenario responses:

Decision to repair airplane:
Scenario A vs. Scenario B: 1.427
Scenario B vs. Scenario C: 4.034***
Scenario A vs. Scenario C: 5.760***

Decision to award punitive damages:
Scenario A vs. Scenario B: 0.943
Scenario B vs. Scenario C: 2.854***
Scenario A vs. Scenario C: 4.178***

Note: *** -- Significant at 99% confidence level, two-tailed test.

Table 6
Probit Regressions of Judges' Opinions on Repairing Airplane Defect and Whether Punitive Damages Should Apply if an Accident Occurs

	Coefficient (standard error)			
	Repair cargo door = 1	Repair cargo door = 1	Punitives apply = 1	Punitives apply = 1
Intercept	2.453 (1.644)	2.004 (1.731)	-0.119 (1.608)	-0.548 (1.694)
Expected damages if accident occurs	0.299 (0.228)	0.355 (0.236)	0.0005* (0.0003)	0.0006* (0.0003)
Perception equation intercept $\hat{\alpha}_i$	-0.079 (0.137)	-0.035 (0.145)	-0.039 (0.137)	0.008 (0.144)
Perception equation slope $\hat{\beta}_i$	-4.500** (2.035)	-4.128** (2.093)	-1.715 (1.920)	-1.366 (1.972)
Implicit value-of-life		0.003 (0.035)		0.004 (0.034)
Infinite value-of-life indicator		-0.289 (0.824)		0.533 (0.870)
Repair cargo door indicator		---	0.982** (0.387)	0.904** (0.395)

The observations from the scenario describing human fatalities were omitted from the repair cargo door equations.

* significant at 90% confidence level, two-tailed test.
** significant at 95% confidence level, two-tailed test.

Table 7

Hindsight Bias: Ex Ante and Ex Post Perceived Risks of *Challenger* Explosion

	Coefficient (Standard Error)	
	Ex ante probability	Ex post probability
Constant	-0.072** (0.027)	0.019 (0.041)
Perception equation intercept $\hat{\alpha}_i$	0.006** (0.002)	-0.001 (0.003)
Perception equation slope $\hat{\beta}_i$	0.105*** (0.032)	0.003 (0.050)
Implicit value-of-life	-0.0003 (0.0006)	-0.0002 (0.0007)
Infinite value-of-life indicator	0.030* (0.015)	---
R^2	0.43	0.02

* Significant at the 90% confidence level, two-tailed test.
** Significant at the 95% confidence level, two-tailed test.
*** Significant at the 99% confidence level, two-tailed test.

Table 8

Correlation of Implicit Net Benefits and Benefit-Cost Ratios (B/C) with Probability of Ruling Against Railroad

Ex Post scenario only (47 observations)

B/C Percentile Range	Net Benefit	B/C	Probability of Ruling Against Railroad
00-24	-1.1-0.1	0.52-1.04	0.00
25-50	0.1-6.1	1.04-3.65	0.00
51-74	6.1-9.7	3.65-5.22	0.50
75-100	9.7-18.1	5.22-8.87	0.53

Ex Ante scenario only (47 observations)

B/C Percentile Range	Net Benefit	B/C	Probability of Ruling Against Railroad
00-24	-2.3-0.1	0.00-1.04	0.10
25-50	0.1-0.1	1.04-1.04	0.13
51-74	0.1-2.5	1.04-2.09	0.30
75-100	2.5-20.5	2.09-9.91	0.09

Entire sample (94 observations)

B/C Percentile Range	Net Benefit	B/C	Probability of Ruling Against Railroad
00-24	-2.3-0.1	0.00-1.04	0.07
25-50	0.1-2.5	1.04-2.09	0.12
51-74	2.5-7.9	2.09-4.43	0.13
75-100	7.9-20.5	4.43-9.92	0.44

Table 9

Correlation of Railroad Verdict with Implicit Net Benefits and Benefit-Cost Ratios (B/C)

Ex Post scenario:

Ruling	Mean Net Benefit	Mean B/C Ratio
For Railroad	4.17	2.81
Against Railroad	12.97	6.64

t-statistic (for vs. against railroad): 6.39, significant at 99% confidence level for B/C comparison

Ex Ante scenario:

Ruling	Mean Net Benefit	Mean B/C Ratio
For Railroad	2.65	2.15
Against Railroad	1.99	1.86

t-statistic (for vs. against railroad): 0.40 for B/C comparison

Entire sample:

Ruling	Mean Net Benefit	Mean B/C Ratio
For Railroad	3.37	2.46
Against Railroad	8.70	4.78

t-statistic (for vs. against railroad): 3.20, significant at 99% confidence level for B/C comparison

Table 10
Hindsight Bias: Regression Analysis of Ex Ante and Ex Post Perceived Probabilities of Train Derailment

	Coefficient (Standard Error)	
	Perceived probability of train derailment (x100)	Perceived existence of grave danger
Constant	11.288 (23.606)	5.842** (2.392)
Ex post survey version indicator	17.195*** (5.056)	1.758*** (0.512)
Perception equation intercept $\hat{\alpha}_i$	2.326 (1.988)	-0.136 (0.201)
Perception equation slope $\hat{\beta}_i$	-2.559 (28.099)	-4.684* (2.847)
Implicit value-of-life (inmillions)	-0.230 (0.529)	-0.060 (0.054)
Infinite value-of-life indicator	30.188** (13.238)	3.502** (1.341)
R^2	0.21	0.26

* Significant at the 90% confidence level, two-tailed test
** Significant at the 95% confidence level, two-tailed test
*** Significant at the 99% confidence level, two-tailed test

Table 11
Hindsight Bias: Probit Regression of Probability of Ruling against Railroad

	Coefficient (Asymptotic Standard Error)			
	1	2	3	4
Constant	2.074 (1.669)	2.477 (1.817)	2.477 (1.817)	2.503 (1.941)
Ex post survey indicator	0.249 (0.359)	-0.215 (0.427)	-0.215 (0.427)	-2.153* (1.148)
Perception equation intercept $\hat{\alpha}_i$	-0.124 (0.135)	-0.214 (0.150)	-0.214 (0.150)	-0.230 (0.163)
Perception equation slope $\hat{\beta}_i$	-4.706** (2.072)	-5.579** (2.312)	-5.579** (2.312)	-4.883** (2.459)
Implicit value of life	-0.005 (0.037)	-0.004 (0.038)	-0.004 (0.038)	0.017 (0.038)
Infinite value-of-life indicator	1.400 (0.827)	0.976 (0.841)	0.976 (0.841)	1.239 (0.939)
Perceived probability of train derailment		0.020** (0.008)		
Benefit/cost ratio			0.194** (0.079)	0.022 (0.127)
Ex post scenario x benefit/cost ratio				0.471** (0.226)

* Significant at the 90% confidence level, two-tailed test.
** Significant at the 95% confidence level, two-tailed test.

Table 12

Novelty and Uncertainty: Decision to Approve New Drug and Damages for Oil Well Blowout

	Coefficient (Standard Error)	
	Approve new drug = 1 Probit	Damages award after oil well blowout
Constant	-1.426 (1.390)	15.895** (7.403)
Perception equation intercept $\hat{\alpha}_i$	0.107 (0.117)	-0.257 (0.626)
Perception equation slope $\hat{\beta}_i$	1.039 (1.666)	-5.698 (8.825)
Implicit value of life	0.054* (0.031)	0.012 (0.151)
Infinite value-of-life indicator	0.056 (0.779)	-1.895 (4.093)
R^2	---	0.01

* Significant at the 90% confidence level, two-tailed test.

** Significant at the 95% confidence level, two-tailed test.

Figure 1
Comparison of Judges Perceived and Actual Mortality Risks