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An investigation of the rationality of consumer valuations of multiple health risks

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After developing a conceptual analysis of consumer valuation of multiple risks, we explore both economic and cognitive hypotheses regarding individual risk-taking. Using a sample of over 1,500 consumers, our study ascertains risk-dollar tradeoffs for the risks associated with using an insecticide and a toilet bowl cleaner. We observe the expected positive valuation of risk reductions and find empirical support for a diminishing in the valuation of risk reduction as the extent of the risk reduction increases. We also find evidence of certainty premiums for the total elimination of one risk, but no strong evidence of additional certainty premiums for the elimination of multiple risks. Strong reference risk effects are evident, as increases in risk were valued much more greatly than were decreases.

1. Introduction

■ During the past decade, economists have devoted considerable attention to assessing the nature of individuals' risk-dollar tradeoffs, particularly in the labor market context (e.g., Thaler and Rosen, 1976; Viscusi, 1979, 1986; Smith, 1979). The basis for these analyses is Adam Smith's theory of compensating differentials for labor market risks, which generalizes quite directly to other choices, such as those involving product safety.

Because of their reliance on market data, primarily data from the labor market, past studies have been restricted to analyzing only the most fundamental aspects of economic behavior.[1] The chief relationship that has been examined is the existence of a positive tradeoff between wage rates and risk and variations in the rate of this tradeoff with factors such as wealth and union status. Studies of compensating differentials have provided perhaps the strongest empirical evidence in support of rational decisions under uncertainty.

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[1] Studies using data other than wage-risk tradeoff information have been less numerous. See, for example, Acton (1973) and Viscusi and Magat (1987).

A second line of research in psychology, and more recently in economics, has explored the rationality of individual choices under uncertainty and its implications.[2] These analyses have primarily relied on experimental evidence and some survey data to assess the reliability of individuals' formations of probabilistic perceptions and the consistency of their behavior under uncertainty. In some instances analysts have observed deviations from rational behavior.

The net impact of these research findings is unclear. The studies of market behavior are broadly consistent with rational behavior, whereas experimental evidence often is not. Testing the competing theories has been difficult since there has been little overlap in the range of economic behavior analyzed by the two sets of studies.

In this article we report the results of a survey of consumer preferences with respect to multiple risks. These data enable us to examine whether individual behavior is consistent with the major predictions of an optimizing economic framework. In addition, the structure of our survey permits us to examine whether this same behavior is consistent with features of cognitive processes that are not generally explored in standard economic models.

The structure of the study permits us not only to examine simultaneously these two general classes of concerns, but to extend them. In terms of predicted economic behavior, we go beyond examining issues such as the existence of positive risk-dollar tradeoffs to consider influences such as the dependence of the rate of tradeoff on the extent of risk reduction. Similarly, we extend the forms of potential irrationality to address some special concerns arising with multiple risks that have not yet been examined in the literature.

Section 2 develops the theoretical underpinnings of our analysis. We analyze the determinants of the risk-dollar tradeoff when there are multiple risks and briefly discuss two possibly influential cognitive factors—certainty premiums and reference risk effects—that we examine empirically. In Section 3 we discuss the nature of our sample and the structure of the survey instrument. Section 4 reports mean effects of different risk changes on consumers' product valuations. As we observe in Section 5, our results provide some support for a more diverse set of predictions of a model of rational economic choice than have heretofore been examined. In addition, they reveal substantial departures from the model's predictions that are consistent with other "nonrational" features of cognitive processes.

2. The theory of consumer choice involving multiple risks

■ Before considering some of the cognitive factors that influence consumer valuations of risk avoidance, we develop a formal economic model of utility-maximizing behavior that serves both as a point of reference for our empirical study and as a contrast to the cognitive considerations.

□ **Economic framework.** Consider consumers who maximize their expected utility when making choices among potentially hazardous products, where their preferences can be characterized by von Neumann-Morgenstern utility functions indexed by different health states. Whereas the standard compensating differential literature focuses on individual selling prices for increases in risk, our focus is on buying prices for reductions in risk. For sufficiently small changes in risk, the results for buying and selling prices reflect the same rate of tradeoff.

The theoretical analysis below considers two different health risks, although the results generalize directly to any finite number of risks. For simplicity, we model consumer decisions in terms of purchase of a single product, where the influence of other purchases has been subsumed into the relation between income and utility. The basic issues are how much the

[2] Contributions to this literature include Arrow (1982), Hogarth and Kunreuther (1985), Kahneman and Tversky (1979, 1982), Lichtenstein *et al.* (1978), Thaler (1980), and Viscusi (1985b). Kahneman, Slovic, and Tversky (1982) and Tversky and Kahneman (1981) review much of this work.

consumer should be willing to pay for a safer product and what the determinants of this amount are.

The consumer has an income Y, of which he spends C on a particular risky product. This product poses a chance p_1 of injury 1's occurring alone and p_2 of injury 2's occurring alone. Since we assume that the two risks are independent, they both occur with probability $p_1 p_2$, and $(1 - p_1)(1 - p_2)$ is the probability of no injury. For the three injury states and the healthy state the consumer has a state-dependent utility function defined on his income net of the purchase price of the risky good, which we denote by x.[3]

The restrictions on individual preferences are quite minor. The consumer would rather be healthy than not.

Assumption 1. For all x, $U^0(x) > U^1(x)$, $U^0(x) > U^2(x)$, and $U^0(x) > U^3(x)$, where the superscripts index the health states (0 = healthy, 1 = only injury 1, 2 = only injury 2, and 3 = both injuries).

We assume that utility with both injuries can be no higher than utility with either injury by itself.

Assumption 2. For all x, $U^1(x) \geq U^3(x)$ and $U^2(x) \geq U^3(x)$.

In addition, for any given level of consumption, the marginal utility of consumption is positive and greater when the consumer is healthy than not healthy.

Assumption 3. For all x, $U^0_x > U^1_x > 0$, $U^0_x > U^2_x > 0$, and $U^0_x > U^3_x > 0$.

Finally, there is diminishing marginal utility of consumption.

Assumption 4. U^0_{xx}, U^1_{xx}, U^2_{xx}, and $U^3_{xx} < 0$.

Thus, adverse health impacts lower the individual's welfare and his marginal utility of consumption, which is an effect quite different from equating injuries to monetary losses.[4]

The two injuries are not necessarily ordered in terms of their severity. Moreover, an injury may affect both the level of utility and one's marginal utility in a complex fashion so that, for example, injury 1 may result in a lower level of utility than injury 2, but the marginal utility at one's current consumption level may be greater for injury 1.

Suppose that the consumer can reduce each of the risks through some additional expenditure for a safer product. Let the risk reduction be α for p_1 and β for p_2. The willingness to pay for this reduction is V, which is the maximum premium the consumer would spend to leave him just indifferent between the original version of the product at price C and the safer version at price $C + V$. To make the notation below more compact, define $A \equiv Y - C$ and $B \equiv Y - C - V$.

The consumer's willingness to pay V for a safer product satisfies

$$
\begin{aligned}
&(1 - p_1)(1 - p_2)U^0(A) + p_1(1 - p_2)U^1(A) + p_2(1 - p_1)U^2(A) + p_1 p_2 U^3(A) \\
&\qquad = (1 - p_1 + \alpha)(1 - p_2 + \beta)U^0(B) + (p_1 - \alpha)(1 - p_2 + \beta)U^1(B) \\
&\qquad\qquad + (p_2 - \beta)(1 - p_1 + \alpha)U^2(B) + (p_1 - \alpha)(p_2 - \beta)U^3(B). \quad (1)
\end{aligned}
$$

As in the single-risk case, there is a positive incremental willingness to pay for greater risk reduction:

$$\partial V/\partial \alpha > 0 \qquad \text{and} \qquad \partial V/\partial \beta > 0.^{5} \quad (2)$$

[3] Viscusi (1979) employs the health-state framework. The multiattribute framework in Weinstein, Shepard, and Pliskin (1980) is a variant of the same approach.

[4] In the case of a fatality, the utility function can be viewed as the bequest function.

[5] In an appendix available from the authors we provide a more detailed exposition of these relationships for the multiple-risk situation.

This is the product market variant of Adam Smith's compensating differential result, which a large number of authors have subsequently shown to hold in a variety of contexts. In the empirical analysis we test whether this result is present for consumers' use of risky products.

The second relationship that we investigate empirically is whether there is any variation in the risk-dollar tradeoff as the extent of the risk reduction is increased.[6] In particular, will consumers' risk-dollar tradeoff be the same, higher, or lower if they are purchasing larger reductions in risk? The model implies that the tradeoff diminishes with the extent of risk reduction, or

$$\partial^2 V/\partial\alpha^2 < 0 \qquad \text{and} \qquad \partial^2 V/\partial\beta^2 < 0. \tag{3}$$

Two factors drive this result. As an individual purchases successively larger reductions in risk, he becomes poorer, and this wealth effect diminishes his willingness to pay for further reductions. In addition, larger risk reductions increase the probability of being in more desirable states.

The final issue we examine is the influence of a simultaneous reduction in both risks by equal amounts. Consider the case of infinitesimally small risk reductions γ, with $\alpha = \beta = \gamma$. The model implies that

$$\frac{\partial V}{\partial\gamma} = \left.\frac{\partial V}{\partial\alpha}\right|_{\alpha=\gamma} + \left.\frac{\partial V}{\partial\beta}\right|_{\beta=\gamma} > 0. \tag{4}$$

That is, for equal *incremental* reductions in risk, the sum of the marginal valuations for each risk equals the value the consumer places on eliminating both risks simultaneously.[7] The various consumer product risks that we consider experimentally tend to be small in terms of the associated probabilities and involve fairly minor health losses. As a first approximation, then, one would expect the sum of the marginal willingness to pay for each risk reduction to equal the willingness to pay for reducing both risks together.

□ **The role of cognitive processes.** In making decisions under uncertainty, individuals may be affected not only by the economic parameters of the problem, but also by the manner in which complex probabilistic information is processed and acted upon. In the simplest case the role of cognitive processes will simply be an intervening mechanism that has no influence on the predicted outcomes from the preceding model of rational economic behavior. At the other extreme, if individuals are unable to make reasonable judgments under uncertainty and are unresponsive to changes in risks, then none of the economic predictions may hold. Here we focus on two specific hypotheses regarding information processing—certainty premiums and reference risks.

□ **Certainty premiums.** Certainty premiums exist if, for any given risk change, individuals place an added value on the complete elimination of risk. In our empirical analysis we provide not only the first quasi market test of certainty premiums, but also the first investigation of certainty premiums in a multiple-risk context.

Certainty premiums may arise for three reasons. First, completely eliminating all the risk from a product reduces both the anxiety associated with uncertainty and any decision-

[6] This issue arises in the labor market context as well. See Viscusi (1979) for a theoretical analysis of this issue.

[7] In an appendix available from the authors, we show that for *nonincremental* risk reductions, in general the sum of the willingness to pay for reducing risks 1 and 2 separately may exceed, equal, or fall below the willingness to pay for reducing both risks simultaneously. In the one special case of equal probabilities of each injury ($p_1 = p_2$), equal utilities when either injury occurs ($U^1 = U^2$), and utility differences across states satisfying ($U^1 - U^3$) $\geq$ ($U^0 - U^1$), we prove that the risk values are subadditive, that is, $\partial V/\partial\alpha + \partial V/\partial\beta > \partial^2 V/\partial\alpha\partial\beta$. But if either the disutilities of the two injuries differ ($U^1 \neq U^2$) or the probabilities of the two injuries differ ($p_1 \neq p_2$), then both subadditivity and superadditivity are possible.

making costs associated with thinking about a probabilistic outcome.[8] Anxiety effects for uncertainties resolved over time are quite consistent with rational behavior.

Second, the value of a risk reduction that eliminates all residual risk is greater to the extent that individuals overassess small probabilities. If they overestimate the initial risk but accurately assess the terminal risk (because all risk is eliminated), they overestimate the magnitude of the risk reduction. Thus, in this case consumers attach a higher value to the risk reduction than they would if they had correctly assessed the initial risk.[9]

The prospect theory developed by Kahneman and Tversky (1979) provides a third reason that consumers may overvalue risk reductions that completely eliminate risk. According to their theory, individuals place decision weights on probabilities. Because these decision weights exceed the probability values for low probabilities but equal zero for zero-probability events, consumers would tend to overvalue risk reductions that eliminate all risk from products.

□ **Reference risks.** Reference risks arise because the value of any given risk reduction may depend on the level of risk usually borne by the consumer in using the product. In particular, we consider the importance of departures from the reference point of the initial level of the risk before the consumer was asked to consider possible risk changes. Is the consumer's risk-dollar tradeoff sensitive to whether the change in the risk raises or lowers his risk from the preexperimental risk level? Our hypothesis is that individuals exaggerate the magnitude of any increases in risk from levels to which they have become accustomed. Thus, if a product poses a risk of 15/10,000 and this risk is increased to 16/10,000, the implied risk-dollar tradeoff will be much greater than if consumers were asked to purchase a risk reduction from 16/10,000 to 15/10,000. Even for very small changes in risk for which buying and selling prices for risk should be identical, the compensation required to accept an increase in risk will be much greater if there is a reference risk effect.

Several authors have theorized about the role of reference points in analyses of cognitive processes in the risk area. Kahneman and Tversky (1979) and Tversky and Kahneman (1981), for example, incorporate reference effects into their prospect theory of decisions under uncertainty. In their case, however, the reference points pertain to payoffs. Consequently, individual utility is based on the utility implied by the effect of a lottery on the change in the individual's income. Our reference points are the probabilities of the outcomes rather than the payoffs, and the mechanism of reference risk effects is the perception of the probability rather than the utility of the payoff.[10]

3. The sample and experimental design

■ Ideally, one would like to obtain market data that are sufficiently rich to explore the hypotheses raised above. Unfortunately, market data that permit investigation of multiple

[8] For a discussion of the impact of anxiety on the theory of compensating differentials, see Viscusi (1979, chap. 4).

[9] In their study of individuals' assessment of risks of fatality Lichtenstein *et al.* (1978) found that individuals tended to overassess low probability risks of death. They viewed this phenomenon as evidence of a systematic bias in behavior, and it has often been cited as an example of individual irrationality. The analysis presented in Viscusi (1985a) using the same data set suggests that this phenomenon is quite consistent with rational Bayesian behavior. The overassessment of small risks and the underassessment of large risks is exactly what one would expect if individuals revised their probabilistic beliefs toward the true probabilities, but did not do so completely because they lacked full information about the risks. What is most important is that there is no risk-related bias in the degree of learning about the true probabilities.

[10] Bell's (1982) theory of decision regret provides another possible explanation for why individuals act as if an increase in a risk above a natural reference point, such as the risk associated with an existing product, is larger than the actual value of the risk increase. Under this theory consumers associate regret with the risk increase but not the risk decrease. Thus, they must be paid more to accept the risk increase than they would pay to acquire the risk decrease.

risks that take on different values are not available. The alternative approach we adopted was to construct a hypothetical market situation in which we questioned individuals about economic decisions involving health risks.

Specifically, we explored differences in consumer valuations for changes in two risks from two products, a toilet bowl cleaner and an insecticide. Each product is technically designated a pesticide and is among the leading product categories for pesticide injuries. By replicating our experiments on four different risk-product pairs, we are able to generalize more confidently our findings about the properties of consumer risk valuations, as well as to check the consistency of the valuations of more serious injuries relative to the valuations of less serious ones.

In framing the study in terms of a marketing survey directed toward potential consumers of the products, we attempted to replicate the outcomes that would occur if we could observe a market in which there were risk-dollar tradeoffs. There is ample precedent for this approach in the economics literature. Viscusi and O'Connor (1984) analyzed chemical workers' wage and quit responses to a job hazard labelling experiment using an approach similar in spirit to this consumer risk study. They found levels of risk-dollar tradeoffs and structures of wage and quit equations that were similar to those obtained by using market data. Similarly, in an earlier consumer study reported in Viscusi and Magat (1987), we found that our overall approach to eliciting the risk-dollar tradeoffs yielded results that were similar to those obtained with the conjoint analysis technique used in the marketing field (cf. Acton, 1973; Smith and Desvousges, 1987).

The reliability of using this survey approach was also corroborated by examining consumers' responses to a set of questions on precautionary behavior. The stated precautions for the labels on hypothetical products presented to consumers in our experiment closely paralleled the reported precautions for users of similar products, which we corroborated by using a telephone survey of a different group of consumers. The reliability of these studies stemmed in part from their establishing a realistic context.

While the psychology and marketing literatures contain large numbers of experimental findings that have been replicated in field studies, it is important to recognize that the primary purpose of experiments is to test causal hypotheses. For our purposes we use the approach to test the hypotheses outlined in the previous section. The consumers' responses in our experiment may accurately reflect those that would be given in actual choice situations, but our study was not designed to make population estimates of the magnitudes of consumer risk valuations.[11]

□ **Subjects.** The sample was drawn from a representative mix of consumers at a Greensboro, N.C., shopping mall and hardware store. As discussed in Viscusi and Magat (1987), this population reflected a broad cross section of the users of consumer products. The survey we report is a sequel to that discussed in Viscusi and Magat (1987) and in Viscusi, Magat, and Huber (1986). In this effort we supervised the administration of the survey and designed the questionnaire, but professional interviewers from a marketing research firm recruited the subjects and administered the survey.

The sample for analyzing the toilet bowl cleaner responses consisted of 551 respondents without children under five years old and 183 respondents with children under the age of five. For the insecticide survey the sample comprised 672 respondents without children under five and 113 respondents with children under five. The age five cutoff provided a useful basis for segmenting each sample because it is for the cohort below this that the frequency of child poisonings from both products is most prevalent.

[11] Appendix A of Magat, Payne, and Brucato (1986) discusses the use of experiments for testing theories about behavior and the common misconceptions about their interpretation.

The sample was limited to individuals who were either over age 21 or over age 20 and not students. The sample was also restricted to the user groups for these products so that the valuation questions would reflect the actual purchase decisions that they regularly make. The insecticide survey sample consisted of only those individuals who had used an outdoor insect spray for plants or lawns in the past year. Similarly, the toilet bowl cleaner sample consisted of individuals who had used toilet bowl cleaner or cleanser to clean a toilet in the past year.

□ **Procedure.** The interviewer first showed the subject a new toilet bowl cleaner or insecticide and asked him to examine it as if using it for the first time in his home, yard, or garden. Although the products were fictitious ones, their labels were professionally printed in several colors and appeared to be commercially sold brands. After giving the subject at most two minutes to read the label, the interviewer asked a series of questions about how to use the product and then asked the subject how frequently he used the general class of products and the names of specific brands he used.[12]

At this point the interviewer informed the subject that all toilet bowl cleaners (or insecticides) can cause injuries if misused. The interviewer then explained that a recent newspaper article had identified two particularly serious injuries from misuse.

For households with children, the interviewer focused on the risks of child poisoning and eyeburns from the toilet bowl cleaner and the risks of inhalation and child poisoning from the insecticide. For households without children, the child-poisoning risk was replaced by the risk of chloramine gassing for the toilet bowl cleaner and the risk of skin poisoning for the insecticide.

The interviewer then showed each subject a card describing in detail the health implications of each risk. The risk that is perhaps most unfamiliar is that of chloramine gassings. If a toilet bowl cleaner is mixed with products containing bleach, then chloramine gas forms, and can cause lung damage and other potentially serious conditions. Chloramine gassings represent the leading cause of poisonings among adults except for suicidal and other "intentional" drug overdoses.

Each consumer considered only a single product. The interviewer told the subject the current price per bottle ($10 for insecticide and $2 for toilet bowl cleaner) as well as the current risk level of 15 injuries of each type per 10,000 bottles sold. The subject was then asked his willingness to pay for a safer product according to the contingent valuation approach, a standard nonmarket methodology for eliciting estimates of willingness to pay. The survey focused on the appropriate economic matter of concern, which is the incremental willingness to pay for an incremental change in the risk. The following instructions given by the interviewer for the insecticide questionnaire for consumers without young children illustrate the procedure:

Suppose that you currently use an insect spray that costs you $10.00 per bottle and it results in 15 inhalation poisonings and 15 skin poisonings for every 10,000 bottles of insect spray that are used. (Show current insect spray card and point to numbers on the card.)

6.1 I want you to think about a new formulation of insect spray that a manufacturer might develop which is as effective as your current product but eliminates all chance of inhalation poisonings. The number of skin poisonings caused by the product remains the same. (Show last card. Point to card but cover the number of inhalation poisonings with finger.) Would you be willing to pay more than what you currently pay to reduce this risk of injury to your household?

Yes________ No________
(put $0 in 6.2a and go to 6.3)

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[12] Viscusi and Magat (1987) describe how variations in the information contents and format across several labels affected the recall of precautionary behavior appropriate for reducing the risks from the products.

6.2a What is the most over current costs that you would be willing to pay to avoid this risk of inhalation poisoning?

$________ more per bottle to reduce the risk of inhalation poisoning to zero.

To avoid the role of altruism, the respondents were then asked whether they assumed that fewer injuries would occur to other households if they purchased the product. If they thought other households would be affected, which most did not, they were told that this was not the case and the valuation question was repeated.

□ **Experimental design.** Each subject answered a series of six valuation questions about changes in the two primary risks associated with product usage. To simplify the task we held the starting risk constant at 15 injuries per 10,000 bottles for both of the risks faced by every subject.[13] Table 1 summarizes the risk changes presented in the six questions using the notation (c, d) to refer to a change in the first risk of c injuries per 10,000 bottles and a change in the second risk of d injuries per 10,000 bottles. For example, in the first question $(-15, 0)$ the first risk was reduced from 15 injuries per 10,000 to 0 injuries per 10,000 bottles, while the second risk was not changed from its initial level of 15 injuries per 10,000 bottles.[14]

The final column in Table 1 summarizes the relationship between each question and the hypotheses derived in Section 2. The first five questions allow us to test whether consumers are willing to pay positive amounts to decrease product risks, while the sixth question provides a test of whether they must be compensated to accept risk increases. This final question also allows us to test for the existence of reference effects caused by focusing on the base risk of 15 injuries per 10,000 bottles and then increasing rather than decreasing the risk levels. The responses to questions 4, 5, and then 3 allow us to determine whether there are diminishing valuations to additional reductions in risk. Comparing the responses to questions 3 and 5 provides a test of whether there is a certainty premium associated with reducing both risks to zero that exceeds the effect of the diminishing marginal valuation of risk reduction. Finally, questions 1, 2, and 3 test the additivity of the valuations of eliminating

TABLE 1 Design of Risk Valuation Experiment

Question Number	Change in Risk*		Hypotheses
	Risk 1(c)	Risk 2(d)	
1	−15	0	Positive valuation of risk reduction, certainty premium.
2	0	−15	Positive valuation of risk reduction, certainty premium.
3	−15	−15	Positive, but diminishing valuation of risk reduction, certainty premium.
4	−5	−5	Positive valuation of risk reduction.
5	−10	−10	Positive but diminishing value of risk reduction.
6	+1	+1	Negative valuation of risk increases, reference risk effects.

* Risk is measured in units of 1/10,000 per container of product used, with a starting risk of 15/10,000.

[13] Although it is feasible to present a given subject with different starting risks in such experiments, doing so may jeopardize the credibility of the experiment to the extent that respondents no longer believe the base value and the experimental scenario.

[14] All the questions were specifically designed to elicit willingness-to-pay values for risk reductions. Consumers may, of course, gain some consumer surplus from purchasing the product, but the questions were designed so as not to alter the size of this surplus across questions.

individual risks separately in contrast to eliminating both risks at the same time, that is, contrasting the sum of the values of (−15, 0) and (0, −15) to the value of (−15, −15).

4. Experimental results

■ **Risk reductions.** Table 2 summarizes the mean responses for the five sets of risk reduction questions. These figures reflect the additional amounts that consumers are willing to pay

TABLE 2 Risk Valuations for Reductions in Injuries

A. Subjects with No Young Children: Insecticide

Risk Change		Mean ($) Willingness to Pay (Std. Error of Mean)	
Inhalation	Skin Poisoning		
−15	0	2.05	(.13)
0	−15	1.85	(.15)
−15	−15	3.78	(.18)
−5	−5	1.04	(.09)
−10	−10	1.37	(.11)

B. Subjects with Young Children: Insecticide

Risk Change		Mean ($) Willingness to Pay (Std. Error of Mean)	
Inhalation	Child Poisoning		
−15	0	2.69	(.31)
0	−15	4.29	(.48)
−15	−15	8.09	(1.13)
−5	−5	1.84	(.35)
−10	−10	2.38	(.37)

C. Subjects with No Young Children: Toilet Bowl Cleaner

Risk Change		Mean ($) Willingness to Pay (Std. Error of Mean)	
Gassings	Eyeburns		
−15	0	.91	(.07)
0	−15	.91	(.05)
−15	−15	1.67	(.11)
−5	−5	.65	(.04)
−10	−10	.84	(.05)

D. Subjects with Young Children: Toilet Bowl Cleaner

Risk Change		Mean ($) Willingness to Pay (Std. Error of Mean)	
Gassings	Child Poisonings		
−15	0	.92	(.11)
0	−15	1.52	(.20)
−15	−15	2.22	(.22)
−5	−5	.99	(.15)
−10	−10	1.23	(.15)

for safer products. In each panel the question 3 responses for eliminating both risks produced the largest values. On average, consumers with young children indicated that they would be willing to increase their insecticide purchase price from \$10 to \$18.09 for a completely safe product, and that they would be willing to pay \$4.22 instead of \$2.00 for a toilet bowl cleaner without any risk of injury. Consumers without small children would be willing to pay an average of \$3.78 more for the completely safe insecticide and \$1.67 more for the toilet bowl cleaner that eliminated all risks of injury.

To obtain mean implicit values for avoiding an expected injury we first divided the values from questions 1 and 2 in Table 2 by the 15-injury risk reduction level, giving average values per injury avoided per 10,000 bottles, and we then multiplied by the number of bottles (10,000). Table 3 lists these implicit values, which range from \$610 to \$2,860. Since both subjects with and without children were asked to value reductions in the risk of insecticide inhalation and toilet bowl cleaner gassings, for these two injuries we calculated the weighted averages of the responses to question 1, where the weights were the fractions of subjects with and without small children.

All of the more serious insecticide injuries have higher values than the less serious toilet bowl cleaner injuries. This pattern is to be expected in view of the injury descriptions that the subjects had been given. For example, people are willing to pay almost three times as much on average to avoid the more hazardous child poisonings from insecticide than from the less hazardous toilet bowl cleaner. For both products, the child poisoning injury is valued more than either of the adult injuries. This probably reflects the severity of child poisoning injuries and a strong degree of parental altruism. In all cases the valuations are well below the estimated implicit value of \$20,000–\$30,000 for lost-workday job injuries obtained from labor market data—an expected result since reported job injuries tend to be more severe. Unfortunately, there are no more specific benchmarks that can provide a basis of comparison.

Consider each of the behavioral hypotheses presented in Section 2. First, the responses to the first five questions reflect a positive and statistically significant valuation of risk reduction, which is to be expected. Second, the economic prediction that the willingness to pay per unit of risk reduction decreases with the extent of the risk reduction is supported by the difference between the question 4 (-5, -5) and question 5 (-10, -10) responses.

This diminishing willingness to pay is reflected in the first two rows of Table 4, which provide the marginal valuations in risk reduction for different increments of five injuries of each type. The first row summarizes the (-5, -5) responses and the second row gives the incremental risk valuation for eliminating an additional five injuries of each type, that is, the difference between the (-10, -10) and (-5, -5) responses. For all four injury pairs there is a substantial and significant drop in the rate of consumers' willingness to pay, which is consistent with the economic prediction in inequality (3).

TABLE 3 **Mean Values of Statistical Injury Reduction**

Risk	Mean Values ($/injury)
Insecticide:	
Skin Poisoning	1,233
Inhalation	1,428
Child Poisoning	2,860
Toilet Bowl Cleaner:	
Gassing	912
Eyeburn	610
Child Poisoning	1,010

TABLE 4 Marginal Valuations of Reducing Both Risks by 5/10,000

	Incremental Willingness to Pay (dollars/bottle)			
Starting Risk (injuries/10,000 bottles)	Inhalation-Skin Poisoning	Inhalation-Child Poisoning	Gassing-Eyeburn	Gassing-Child Poisoning
15	1.04	1.84	.65	.99
10	.34	.54	.19	.24
5	2.41	5.71	.83	.99

An alternative perspective on this relationship is provided by an analysis of the individual responses. Columns 2–4 of panel A in Table 5 summarize the relationship between the marginal valuations of reducing both risks by 5/10,000 when the starting risk is 10/10,000 as compared with the results when the starting risk is 15/10,000. As these data indicate, for

TABLE 5 Breakdown of Individual Risk Valuation Responses

A. Comparison of Marginal Valuations of Reducing Both Risks by 5/10,000 Evaluated at Starting Risks of 15/10,000 and 10/10,000

	Percentage with Marginal Valuation at Starting Risk of 15/10,000 ______ (Than) Marginal Valuation at Starting Risk of 10/10,000		
Injury Pair	Less	Equal	More
Inhalation-Skin Poisoning	13	57	29
Inhalation-Child Poisoning	18	42	40
Gassing-Eyeburn	15	38	47
Gassing-Child Poisoning	13	30	57

B. Comparison of Marginal Valuations of Reducing Both Risks by 5/10,000 Evaluated at Starting Risks of 10/10,000 and 5/10,000

	Percentage with Marginal Valuation at Starting Risk of 10/10,000 ______ (Than) Marginal Valuation at Starting Risk of 5/10,000		
Injury Pair	Less	Equal	More
Inhalation-Skin Poisoning	65	30	6
Inhalation-Child Poisoning	75	19	6
Gassing-Eyeburn	59	31	11
Gassing-Child Poisoning	61	30	9

C. Difference between Sum of the Values of Eliminating Each Risk Individually and Value of Simultaneously Eliminating Both Risks

	Percentage with [(−15, 0) + (0, −15)] ______ (Than) (−15, −15)		
Injury Pair	Less	Equal	More
Inhalation-Skin Poisoning	33	46	21
Inhalation-Child Poisoning	35	29	35
Gassing-Eyeburn	28	37	35
Gassing-Child Poisoning	26	37	38

all four injury pairs most of the subjects valued the risk reduction from 15/10,000 to 10/10,000 at least as much as the risk reduction from 10/10,000 to 5/10,000. In all cases fewer than 20% of the subjects indicated increasing marginal valuations, with the number showing diminishing marginal valuations almost three times the number of subjects showing increasing marginal valuations. Thus, both the across subject means reported in Table 4 and the within subject comparisons reported in panel A of Table 5 are consistent with the hypothesis of diminishing marginal valuations of risk reduction.

The existence of a strong certainty premium is apparent from the third row of Table 4. The incremental willingness to pay for a risk reduction from question 5 (−10, −10) to question 3 (−15, −15) does not decline, as predicted by the rational choice model in Section 2, but instead rises to the highest levels observed in the table. There is striking evidence of the existence of a certainty premium that more than compensates for the decline in the willingness to pay that the rational economic model predicts should occur as the extent of the risk reduction increases.

A similar pattern is borne out in the individual responses in panel B of Table 5. For all four injury pairs at most 11% of the subjects stated a marginal value for the 10/10,000 to 5/10,000 risk reduction that was greater than their value for the 5/10,000 to 0/10,000 risk reduction, and the large majority expressed a lower value for the first risk reduction than for the second. In other words, with few exceptions consumers attach a strong certainty premium to the total elimination of risk from a product that more than compensates for the effect of diminishing marginal valuations described above. The existence of this certainty premium is supported by both the mean values in Table 4 and the within subject comparisons in panel B of Table 5.

The final hypothesis tested concerns whether consumers attach a certainty premium for eliminating both risks above and beyond the sum of the certainty premiums for eliminating each risk individually. The economic model of Section 2 predicts that for a sufficiently small risk reduction, the sum of the individual risk reduction valuations should equal their valuation for eliminating both risks. For nonincremental risk reductions, however, the relation becomes ambiguous. Consideration of the certainty premiums that most consumers attach to total risk avoidance might suggest that some consumers would be willing to pay an additional certainty premium to eliminate both risks beyond what they would pay to eliminate each of them separately. Because on theoretical grounds we cannot support a hypothesis that consumers will pay more for total risk avoidance, we turn to experimental evidence to see whether the data reveal any tendencies toward either subadditivity or superadditivity of risk valuations.

Table 6 lists the mean values of the difference between the sum of the responses to questions 1 and 2 ((−15, 0) and (0, −15)) and the response to question 3 (−15, −15) for all four injury pairs. Although three of the four mean differences show positive values and thus suggest subadditivity, none of the mean differences is statistically significant at the 5% level.

TABLE 6 Tests of the Additivity of Multiple Risks

	{[(−15, 0) + (0, −15)] − (−15, −15)}*	
Injury Pair	Mean ($)	Std. Error of Mean ($)
Insecticide:		
Inhalation-Skin Poisoning	.12	.27
Inhalation-Child Poisoning	−1.11	1.27
Toilet Bowl Cleaner:		
Gassing-Eyeburn	.15	.14
Gassing-Child Poisoning	.22	.69

* Measures the difference between the sum of the values of eliminating each risk individually and the value of simultaneously eliminating both risks.

Furthermore, panel C of Table 5 shows no strong patterns for the within subject comparisons. Two of the injury pairs show more subjects with subadditivity than with superadditivity, one of the pairs shows an equal percentage, and one of the pairs has fewer subjects with subadditivity than superadditivity. Thus, there is no apparent evidence of either superadditivity or subadditivity in consumers' values for multiple risks.

□ **Risk increases.** Ascertaining consumers' responses to valuations of risk increases posed considerable practical difficulties. For risk increases on the order of (+5, +5) examined in the pretesting, almost all consumers refused to purchase the product at any price. For the very modest risk increases in question 6 of (+1, +1), up to three-fourths of all consumers said that they would refuse to buy the product at any discount below its purchase price, as is summarized in Table 7.

This dramatic response to risk increases occurred despite the attempts of the interviewers to help consumers discover their rates of tradeoff between higher risks and more disposable income. If a consumer's initial response to question 6 was that the product was too risky to purchase even with a discount large enough to reduce the net purchase price to zero, he was then asked how much he would have to be paid to use the product. The results in Table 7 reflect the willingness to accept risk valuations when we take into account whether such a follow-up question was used.

Even for the segment of consumers willing to express a finite risk-dollar tradeoff, the valuations of an injury pair are extraordinarily high. On the basis of the question 4 (−5, −5) responses, the average willingness to pay per injury pair avoided ($\times 10^{-4}$) reaches a peak of \$.368 (\$1.84/5) for the inhalation-child poisoning injury pair (see panel B of Table 2), which is a factor of almost 9 below the rate of tradeoff of \$3.19 for a risk increase of the same magnitude (see Table 7). The narrowest relative gap is for the gassing-child poisoning injury pair, for which the question 4 (−5, −5) response of \$.198 (\$.99/5) per injury pair is only a factor of 6 below the tradeoff reflected in the question 6 (+1, +1) responses. Although past interview studies of nonrisk attributes, such as Knetsch and Sinden (1984), have identified similar asymmetries between willingness-to-pay and willingness-to-accept values, the relative disparity in this case is particularly striking.

Both the large proportion of subjects unwilling to accept any finite payment to purchase and use the products and the large injury pair valuations expressed by those subjects willing to accept a payment indicate that the risk-dollar tradeoffs applicable to risk decreases are poor predictors of behavior involving risk increases. The strong reference risk effects suggest that when individuals assess the implications of increases in risk from their current level, they act as if they possess a much higher rate of tradeoff of risk for money than for decisions involving risk decreases.

These research findings point out the need for further exploration of the reasons for the large reference risk effects. In particular, further experimental research should address the question of whether the high implied tradeoffs are caused by misperceptions of the magnitude of the risk increase being valued. It may be that consumers do not perceive risk

TABLE 7 **Responses to Risk Increase (+1, +1) Valuation Questions***

Injury Pair	Percentage for Whom Product Is Too Risky to Purchase	Mean Value (\$/bottle) of Positive Responses
Inhalation-Skin Poisoning	77.2	2.86
Inhalation-Child Poisoning	68.1	3.19
Eyeburns-Gassing	61.5	5.52
Gassing-Child Poisoning	74.3	1.28

* This question asked subjects what price discount they would require on the new product to accept an additional risk of 1/10,000 for both injuries, starting with risks of 15 injuries per 10,000 bottles sold for both injuries.

increases and risk decreases of comparable magnitudes as changing their probabilities of injury by an equal amount.

5. Conclusions

■ These results have several implications for the nature of consumer choice under uncertainty. First, they bear out many of the most salient predictions of economic theory. Not only do individuals display a positive valuation of risk reduction, as expected, but the valuation per unit of risk reduction declines with the extent of the risk reduced, provided that risk elimination is not achieved. This diminishing risk-dollar tradeoff accords with the predictions of a model of rational risk-taking behavior.

Second, the nature of individuals' processing of risk information is of considerable consequence and perhaps even of dominant concern. For risk reductions that lead to elimination of risk, consumers are willing to pay extremely large premiums. But there does not appear to be any additional premium offered for certain elimination of multiple risks above and beyond the sum of the premiums for eliminating each risk separately. The existence of large certainty premiums for individual risks, rather than for both risks combined, suggests that the anxiety and decisionmaking costs posed by the presence of any uncertainty are not instrumental. Rather, the driving force appears to be factors pertinent to the particular risk, such as the overestimation of low probabilities.

Risk reference points were found to be a second class of influential cognitive effects. Consumers in our sample exhibited what appears to be an excessive reaction to increases in the risk of a product from its current level. Since this overreaction is consistent with frequently observed responses to newly discovered hazards, on the part of both individuals and regulatory agencies, this finding may be a fundamental aspect of behavior toward risks.

Overall, our results provide some evidence in support of the more refined predictions of a rational model of risk bearing developed in Section 2, although alternative models are also consistent with these findings. There are, however, substantial departures from the model's predictions that appear attributable to the influence of cognitive factors lying outside economists' traditional sets of concerns.

Appendix

■ **Changes in a single risk.** The determination of the effect of changes in one risk alone is relatively straightforward. Let the consumer's expected marginal utility D be defined by

$$D = [(1 - p_1 + \alpha)(1 - p_2 + \beta)U_x^0(B) + (p_1 - \alpha)(1 - p_2 + \beta)U_x^1(B) + (p_2 - \beta)(1 - p_1 + \alpha)U_x^2(B) + (p_1 - \alpha)(p_2 - \beta)U_x^3(B)]. \quad \text{(A1)}$$

Differentiation of equation (A1) yields two basic results:

$$\frac{\partial V}{\partial \alpha} = \frac{(1 - p_2 + \beta)[U^0(B) - U^1(B)] + (p_2 - \beta)[U^2(B) - U^3(B)]}{D} > 0 \quad \text{(A2)}$$

$$\frac{\partial V}{\partial \beta} = \frac{(1 - p_1 + \alpha)[U^0(B) - U^2(B)] + (p_1 - \alpha)(U^1(B) - U^3(B))}{D} > 0. \quad \text{(A3)}$$

Thus, the marginal willingness to pay for a reduction in injury risk 1 is the weighted sum of the difference in the utility between the healthy state and injury state one and the difference in the utility of the other injury state two and the state with both injuries, divided by the expected marginal utility across all states.

The effect of variation in the extent of risk reduction, α, on the rate of tradeoff—$\partial V/\partial \alpha$—is given by

$$\frac{\partial^2 V}{\partial \alpha^2} = -(1/D^3)\{2[(1 - p_2 - \beta)(U_x^1(B) - U_x^0(B)) + (p_2 - \beta)(U_x^3(B) - U_x^2(B))] \times [-(1 - p_2 + \beta)(U^0(B) - U^1(B) - (p_2 - \beta)(U^2(B) - U^3(B))]D - [(1 - p_1 + \alpha)(1 - p_2 + \beta)U_{xx}^0(B) + (p_1 - \alpha)(1 - p_2 + \beta)U_{xx}^1(B) + (p_2 - \beta)(1 - p_1 + \alpha)U_{xx}^2(B) + (p_1 - \alpha)(p_2 - \beta)U_{xx}^3(B)]\} < 0, \quad \text{(A4)}$$

and $\partial^2 V/\partial \beta^2$ is similar.

For the reductions of both risks, α and β, by an equal increment γ,

$$\frac{\partial V}{\partial \gamma} = \frac{\begin{array}{l}[(1 - p_2 + \gamma)(U^0(B) - U^1(B)) + (p_2 - \gamma)(U^2(B) - U^3(B)) \\ \quad + (1 - p_1 + \gamma)(U^0(B) - U^2(B)) + (P_1 - \gamma)(U^1(B) - U^3(B))]\end{array}}{D(\gamma)} > 0, \tag{A5}$$

where $D(\gamma)$ is the value of D in the equation (A1) above with both α and β replaced by γ.

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