Characteristics of Risk and the Value of a Statistical Life: Evidence from the Labor Market[*]

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Abstract

Accumulating evidence suggests that preferences for safety depend on characteristics of risk. This paper examines whether the value of statistical life (VSL) depends on risk characteristics using an expected utility model where unconditional fatality risk equals the product of unconditional risk of injury and conditional risk of death given injury. The model shows how to express the VSL in terms of the characteristics considered (frequency and severity of injury) as well as how to test the null hypothesis that these characteristics do not matter using the marginal rate of substitution between unconditional injury risk and conditional death risk. This hypothesis is not rejected using perceived risk and stated preference information from a recent national survey of workers.

Keywords: value of statistical life, injury risk, fatality risk, safety.

JEL Classification: I10, J17, J28.

Is the value of a statistical life (VSL) the same for all types of mortality risks or does the VSL depend on risk characteristics? Standard economic models of willingness to pay (WTP) for safety frequently are constructed as if only the level of mortality risk matters, suggesting that the VSL is independent of risk characteristics. Additionally, policy makers sometimes treat estimates of the VSL obtained in one setting (i.e., workplace safety) as if they can be automatically transferred to other settings (i.e., transportation, food, and drinking water safety). This simple perspective, however, may require modification because people's preferences for saving lives appear to depend on aspects of the hazard considered (Slovic, Fischhoff, and Lichtenstein 1985; Mendeloff and Kaplan 1989; Viscusi 1992; Sunstein 1997). For example, Subramanian and Cropper (2000) find that survey respondents care about both psychological risk characteristics such as whether the risk is voluntary, controllable, serious or personal as well as characteristics of public programs to reduce risk. Jones-Lee, Hammerton, and Philips (1985), Savage (1993), and Tolley, Kenkel, and Fabian (1994) present evidence that WTP is greater for lowering risk of cancer deaths than for lowering risk of motor vehicle deaths. Carlsson *et al.* (2004) report that people are willing to pay more for greater transportation safety when traveling by air than when traveling by taxi. Hammitt and Liu (2004) find that the value of risk reduction depends on the affected organ, environmental pathway, and the payment mechanism.

This paper responds to this mounting observational evidence by accounting for selected risk characteristics in a standard expected utility framework and showing how the model can be applied to test whether risk characteristics "matter" in estimating the VSL. The model envisions three health states, healthy, injured, and dead, and is formulated using the example of job related accident risks in which the unconditional risk of accidental death, r, is the product of the unconditional risk of injury, p, and the conditional risk of death given injury, q (i.e., $r=pq$).[1] Risk characteristics such as "frequency of occurrence" (p) and "severity" (q) are related to those considered in the previously cited studies. The model demonstrates that testing whether these risk characteristics matter in calculating the VSL is equivalent to testing whether the willingness to pay for a change in p or q is equal to the willingness to pay for the corresponding change in r. A necessary condition for this equality to hold is that the marginal rate of substitution between q and p must be equal to q/p. This condition turns out to be satisfied if injuries are seen as minor; in other words, utility in the healthy state is the same as utility in the injured state.

The hypothesis that the marginal rate of substitution between q and p is equal to q/p is tested using perceived risk and stated preference information collected in a recent national survey about risk of workplace injury and death. Both parametric and nonparametric tests presented in Section 4 do not reject this hypothesis. This outcome suggests that in the data analyzed, workplace injuries are seen as minor so that WTP for a reduction in r (the VSL) can be computed without knowing the underlying values of p and q, i.e., without information about the risk characteristics considered. A practical implication of this result is that in labor market studies of wages and job risks, it is unnecessary to include measures of both risk of injury and risk of death, as in Viscusi (1981) and Kniesner and Leeth (1991). The effects of both the risk of injury and the unconditional risk of death given injury are fully accounted for by including the measure of unconditional risk of death. More generally, results presented here suggest that risk characteristics need to be taken into account when estimating the VSL in situations where people may differentiate the injury (or illness) state from both the healthy state and the death state (e.g., car crashes and cancer) and are less important to consider in situations where accidents tend to result either in minor injuries or certain death (e.g., workplace accidents (see below) and plane crashes).

1. Model

This section presents a simple extension of the standard von Neumann-Morgenstern expected utility model with state dependent utility functions. This type of model lies behind most empirical estimates of the value of a statistical life (VSL). The extension shows how to calculate the VSL when a worker faces risks of nonfatal as well as fatal injury. Because the framework is familiar, discussion is kept to a minimum and focuses only on aspects directly related to empirical work presented in Section 4.

A worker perceives the probability of injury at work to be p and perceives the conditional probability of death given that injury to be q. Perceived probabilities, which may or may not be related to the corresponding "actual" probabilities, are determined according to

$$\begin{aligned} p &= p_0 + f(x) \\ q &= q_0 + g(x). \end{aligned} \tag{1}$$

In equation (1), p_0 and q_0 are experimental design parameters (described more fully in Section 3) representing (hypothetical) treatments that reduce risk, x denotes a vector of personal characteristics and variables reflecting past experiences with risky situations and f and g are continuous functions.[2] The worker perceives different values of p and q for different jobs and different workers may perceive different values of p and q for the same job.

If healthy, the worker supplies one unit of labor to the labor market and earns a wage of w. Utility in the healthy state is $U(I)$, where $I = w + A$ and A denotes non-labor income. If injured, the worker may earn a lower wage than in the healthy state or may receive worker's compensation or other benefits that affect non-labor income, but these differences are subsumed into the injured state utility function $V(I)$. Utility also may be derived from a bequest and utility at death is given by $D(I)$. The uninjured state is preferred to the death state ($U(I) > D(I)$) and is at least as preferred as the injured state ($U(I) \geq V(I)$). For minor injuries, $U(I)$ and $V(I)$ may be nearly equal while for severe injuries viewed as "fates worse than death," $D(I)$ may exceed $V(I)$. The marginal utility of income is positive in all states. The worker is assumed to survive unless a fatal workplace injury occurs. Expected utility is given by

$$EU = (1-p)U(I) + p(1-q)V(I) + pqD(I). \tag{2}$$

This approach has at least broad similarities to models previously applied in the literature on environmental risks to health. In their model of health consequences of exposure to hazardous wastes, Smith and Desvousges (1986, 1987) split the unconditional risk of death from exposure into the probability of exposure and the conditional probability of premature death given exposure. Eeckhoudt and Hammitt (2001) examine how a specific risk to an individual's health should be valued when the individual faces independent life-threatening background risks. Both of these models, however, envision only two health states (alive and dead) and thus do not explicitly treat morbidity risk.

The worker maximizes expected utility by choosing from among jobs offering different combinations of w, p and q along a market opportunities locus, $w = w(p,q)$. This locus is formed from matches between workers and jobs by equating workers' marginal willingness to pay for perceived risk reductions with firms' marginal cost of reducing perceived job risk. At unchanged x, the constant expected utility risk-dollar tradeoff is

$$dI = \left[\frac{U(I) - V(I) + q(V(I) - D(I))}{\Delta}\right] dp_0 + \left[\frac{p(V(I) - D(I))}{\Delta}\right] dq_0, \tag{3}$$

where $\Delta = (1-p)U'(I) + p(1-q)V'(I) + pqD'(I) > 0$ denotes the expected marginal utility of income. Alternatively, the equation (3) may be written as

$$\beta_p dp_0 + \beta_q dq_0, \tag{4}$$

where β_p and β_q are both functions of p, q and I. β_q can be interpreted as marginal WTP to be injured, rather than dead and β_p can be interpreted as marginal WTP to healthy, rather than injured. If total and marginal utility are highest in the healthy state and lowest when in the death state, then β_p and β_q are both positive and increasing functions of p and q, holding money income constant. If in addition the worker is financially risk-averse in the sense that $(\partial\Delta / \partial I) / \Delta \le 0,$ then both marginal valuations also are increasing in income. However, if the death state is preferred to the injured state, $\beta_q < 0$ and comparative static effects of p, q and I may be reversed. In section 4, it will be of interest to use the available data on workplace safety to determine whether $\beta_q > 0$.

The worker's valuation of a marginal change in the unconditional risk of death can be found by rewriting the expected utility function as

$$EU = (1-s)(1-r)U(I) + s(1-r)V(I) + rD(I), \tag{5}$$

where $r = pq$ denotes the unconditional risk of death and $s = (p-r)/(1-r)$ denotes the conditional probability of an injury, given that it is not fatal. Thus, the VSL equals the expected utility of survival less the utility at death, weighted by the expected marginal utility of income:

$$\partial I / \partial r = [(1-s)U(I) + sV(I) - D(I)] / \Delta. \tag{6}$$

The numerator of the willingness to pay to reduce unconditional mortality risk is smaller than $U(I) - D(I)$ because a surviving worker still faces the risk of nonfatal injury. The VSL also may be computed from valuations of p and q by using equations (4) through (6) to obtain

$$\partial I / \partial r = \left(\frac{1}{1-r}\right)\left[(1-p)\beta_p + (1-q)\beta_q / p\right]. \tag{7}$$

Equation (7), which demonstrates that marginal willingness to pay to reduce unconditional death risk is a weighted average of the willingness to pay to reduce unconditional injury risk and willingness to pay to reduce conditional death risk, is of interest from four perspectives. First, if $q = 1$ and $0 < p < 1$, the model envisions only two health states (healthy and dead) and the VSL can be expressed as the familiar monetized difference between utility if healthy and utility if dead, $\partial I / \partial r = \beta_p = \beta_p / q = [U(I) - D(I)] / [(1-p)U'(I) - pD'(I)] > 0$. In this situation (e.g., an airplane crash), willingness to pay for a change in p_0 is equal to the willingness to pay for the corresponding change in r_0 because $dp_0 = dr_0$.

Second, suppose $0 < p < 1$ and $0 < q < 1$. In this situation, if $\beta_p / \beta_q = q / p$, (i.e., the marginal rate of substitution between the two risks equals the ratio of risks), the VSL can be found from $dI = [U(I) - D(I)] / [(1-p)U'(I) - pD'(I)]dr_0 = (\beta_p / q)dr_0 = (\beta_q / p)dr_0$. Again, the willingness to pay for a change in p_0 or q_0 is equal to the corresponding change in r_0, but in this case, the simplification arises because the worker is indifferent between the healthy and injured states $(U(I) = V(I))$ (see equation (3)). Section 4 tests whether $\beta_p / \beta_q = q / p$, using labor market data. If the equality does not hold, then the components of dr_0 must be separately accounted for in computing the VSL as shown in equation (7). In this case, two hazards with the same initial value of r, but different combinations of p and q, will have different VSL values.

Third, effects of changes in p or q on the VSL may be determined by differentiating equation (7). Assuming that total and marginal utility are highest when healthy and lowest upon death, a money-income constant increase in q increases the VSL (the "dead anyway" effect, Pratt and Zeckhauser 1996), but the effect of an increase in p is ambiguous due to what might be termed the “injured anyway” effect: the higher is p, the more likely the surviving worker will be injured rather than healthy. The resulting lower marginal utility of income would boost the VSL while the lower total utility would reduce it, leaving the overall effect of a change in p uncertain. In consequence, changes in p and q that are offsetting in the sense of holding r constant have an ambiguous effect on the VSL. This implies that the sign and magnitude of the difference in VSL values between two hazards sharing a common r but having different combinations of p and q cannot be determined *a priori*. However, in the case of minor injuries where total and marginal utility are identical in the injured and healthy states, the VSL is increasing in p unaffected by offsetting changes (i.e., $dr = 0$) in p and q.

Fourth, hedonic wage studies that control for risks of injury and death generally treat these risks as if they vary independently (Viscusi 1981, Kneisner and Leeth 1991). Although these studies typically do not present an expected utility model that incorporates both risks, the model presented above reveals that a reduction in r implies an increase in s (risk of nonfatal injury), unless p falls, and thus treats both types of risks in a consistent framework. Additionally, if $\beta_p / \beta_q = q / p$, then only the level of unconditional death risk should be included as an explanatory variable in the estimated wage equation; also including the level of unconditional injury risk provides no new information. On the other hand, if this equality does not hold, then measures of both p and q would need to be included as explanatory variables to estimate VSL.

2. Data

This section describes the data and experimental design used to test whether $\beta_p / \beta_q = q / p$. Data were obtained from a survey conducted in September-October 2002 by

Knowledge Networks, Inc. Knowledge Networks' core resource is a representative panel of U.S. households that can be queried over the Internet. Panel members are given inducements such as free Internet access in return for agreeing to complete short surveys on a regular basis. Surveys are administered through WebTV©, a technology that involves attaching a device resembling a cable box to a television. Panel members use remote-control devices or keyboards to complete surveys using the television as a monitor. Alberini *et al.* (2004) previously have administered valuation surveys through Knowledge Networks.

Respondents in this study were drawn from Knowledge Networks panelists aged 18-65 years, who work in one of the following occupations: (1) Craft and Repair, (2) Laborer, (3) Machine Operator or Assembler, and (4) Transportation and Materials Moving.[4] These occupations were selected to draw a sample of workers likely to face non-negligible risks of injury and death on the job. The survey initially was transmitted to 974 persons; 745 persons returned it for a response rate of 76.5%. The sample was then reduced to 700 respondents by excluding 30 persons who were not paid employees, nine who failed to answer one-third or more of the questions, and six who did not answer the question concerning valuation of reduced risk.[5] Knowledge Networks furnished demographic characteristics (e.g., household income) for all respondents, so this information did not need to be collected in the survey.

The survey centered on eliciting perceived risks of injury from an accident at work and perceived risks of death given that such an injury occurs. Viscusi (2004) argues that workers' subjective perceptions represent ideal risk measures, although they have seldom been available in labor market studies (Gegax, Gerking and Schulze (1991) is an exception). The elicitation procedure began by stating that according to government statistics, about 17 of every 1000 are injured each year and miss at least one day of work.[6] To reinforce this idea, respondents were shown a grid of 1000 squares arrayed in 50 rows and 20 columns with 17 squares colored red. Grid squares were used to convey this information because this approach appears to be more understandable than other risk communication devices (Corso, Hammitt, and Graham 2001). A box beneath the grid reported the number of squares that were filled in (17) and a text message tied the meaning of these graphics back to the previously presented "government statistics." The next screen stated that the respondent's own risk of getting injured and missing at least a day of work is probably not the same as the average person's risk because some people have relatively safe jobs, while other people have more dangerous jobs. Respondents also were told that an important reason for the survey was to find out what they thought about injury risks on their own jobs.

Perceptions of injury risks then were elicited in two steps aimed at encouraging respondents to collect their thoughts before providing an estimate. First, respondents were asked to consider the possibility of various accidents on their own jobs (e.g., motor vehicle mishap, industrial equipment mishap, a fall, electrocution, fire, poisoning, explosion, etc.) and were asked to rate the likelihood of each by choosing the most appropriate phrase from among the following: (1) could never happen to me at work, (2) could happen to me at work, (3) has happened to me at work, (4) has happened to me at work and caused me to miss work. Then, respondents were asked: (1) whether, in their lifetime, they ever had missed work because of a work-related injury, (2) whether they thought they had missed more or less work because of such injuries than other people doing similar jobs, and (3) whether they thought they are more or less prone to injury than other people they know.

Second, respondents were shown a grid like the one presented earlier and were asked to fill in the number of squares corresponding to the chances in 1000 that they would be injured and miss at least one day of work within the next 12 months. This task was divided into two parts. (1) After reminding respondents of the average worker's injury risk, respondents were asked whether they thought their own risk was higher, lower, or about the same as the average. They also were told that if they thought their own risk was higher (lower) than the average worker's risk, they should color in more (less) than 17 of the grid squares. (2) Respondents were then asked to choose the number of grid squares (from 0 to 1000) that best represents the extent of injury risk they face on their own jobs. After doing so, they were asked whether they were satisfied with their answer and were given as many opportunities as desired to revise it before moving on. Table 1, column 2 shows the distribution of perceived unconditional injury risk. Mean perceived unconditional injury risk (about 52/1000) exceeds the previously presented average worker's risk (17/1000) by a factor of about three (recall that workers in risky jobs are over-represented in the sample), although the median perceived risk (12/1000) is lower. Also, 72 respondents said that they faced no risk of an injury at work, 43 respondents said that their own risk is equal to the average worker's risk, 54 respondents said that their risk was at least 1/10, and some risk estimates appear to have been rounded-off because they pile up at values such at 5, 10, 15, 20,…,100 chances in 1000.

The next section of the survey asked respondents to first imagine that they will be injured in a job-related accident during the following year and to think about the likelihood that the accident would be fatal. They were told that according to government statistics, approximately 4 such injuries out of every 1000 results in death and were shown another 1000-square grid with 4 squares colored red.[7] After considering whether their own risk of death given injury was higher or lower than the average worker's, respondents chose the number of grid squares that best represents the risk they face on their own job. Table 1, column 3 presents the frequency distribution of estimates obtained. Similar to the outcome for injury risk, the mean of perceived conditional death risk estimates exceeded the average worker's risk (about 20/1000 vs. 4/1000), while the median perceived risk is lower (2/1000). Also, 622 respondents (89%) said that they faced less than a 10/1000 chance that a work related injury would turn out to be fatal (including 154 respondents who said this would not occur), and 4 respondents indicated that this risk is at least 500/1000.

Considering the two perceived risks together, the null hypothesis that the means of injury risk and conditional death risk are equal is rejected at less than one percent significance in a matched samples difference between means test, and the estimated Pearson correlation coefficient is 0.3. This suggests that workers are able to distinguish between the two risks.[8] The implied unconditional risk of death, computed as the product of the risk of injury and the conditional risk of death given injury, has a sample mean of 4.66/1000. Also, Table 1 also presents the ratio of sample means of perceived conditional death risk and unconditional injury risk ($\overline{q} / \overline{p}$) of about 0.4. This ratio provides a benchmark value of q / p to be used when testing the hypothesis $\beta_p / \beta_q = q / p$.

The final section of the survey asked respondents to value changes in injury risk or conditional risk of death given injury. This section of the survey was introduced by stating that employees frequently spend their own money on clothing and equipment to make their jobs safer. Numerous examples were provided (e.g., protective eyewear, coveralls, tools, special shoes and boots, flame retardant clothing, gloves, and devices for respiratory and hearing protection) and care was taken to point out that some safety equipment items were designed to reduce the chance of injury, others were designed to reduce the chance of death given injury, and still others were designed to do both. Respondents then were told to think about a new piece of equipment to make their job safer. A detailed description of the equipment was not provided because a specific item might not be useful on all types of jobs.[9] Respondents were told, however, that the equipment: (1) would not be provided by their employer, (2) would wear out after one year of use, and (3) would reduce risk of either injury or conditional death risk as described below.

Respondents were randomly assigned to treatment groups that differed according to the function and effectiveness of the hypothetical safety equipment.[10] Approximately half of the sample (364 respondents) was told that the equipment would reduce risk of injury on the job but would have no effect on the severity of injury should one occurr. The remainder of the sample (336 respondents) was told that the equipment would not change the risk of an injury, but would lower the risk of death should an injury occur. Among those assigned the injury risk treatment, 180 respondents were told that the equipment would reduce injury risk by 1/1000. Responses from those who said they perceive no risk (20 respondents) were interpreted to mean that injury is possible, but less likely than 1/1000. Remaining sample members in this treatment group (184 respondents) were told that use of the equipment either would lower injury risk by 5/1000 or would reduce the risk to zero depending on whether the level of perceived injury risk initially faced exceeded 5/1000.

Additionally, of the 336 respondents given the conditional death risk treatment, 172 were told that this risk would be lower by 1/1000. Responses from the 38 workers in this group who stated they perceive no death risk given injury were assumed to mean that this risk is less than 1/1000. The 164 remaining respondents were told that use of the safety equipment either would reduce this risk by 3/1000 or make the risk equal to zero depending on whether the level of perceived risk initially faced exceeded 3/000.

Risk changes assigned were illustrated using the grid previously marked by the respondent. The risk reduction was shown by changing the color of the appropriate number of squares from red to green, so that the size of the risk change was indicated by the number of green squares while the risk that the respondent would still face was indicated by the number of squares that remained red. After receiving reminders about the size of the risk reduction, the one-year useful life of the safety equipment, and the budget constraint, respondents were asked whether they would purchase the equipment at one of five randomly assigned prices ($50, $100, $250, $400 and $750 for reduced risk of injury and $100, $250, $400, $750, and $1000 for reduced risk of death given injury). Those answering affirmatively were asked whether they would buy the equipment at a higher price while those answering negatively were asked if they would buy it at a lower price. Respondents were unaware that a follow-up bid would be presented at the time of the first purchase decision.

3. Empirical results

Empirical analysis begins by comparing fractions of respondents across each of the 20 treatments that stated they would pay the first bid amount presented to purchase the safety good (see Table 2).[11] Responses to the follow-up bids are considered later in this section. Comparisons of these fractions only are suggestive because they include respondents who were assigned a risk change that exceeded the level of risk initially perceived. Assuming independence between treatment cells, standard errors of differences between fractions are roughly equal to 0.12; thus, fractions differing by 0.24 or more are significantly different from zero at the 5% level. In consequence, for given cost values in both the injury risk and conditional death risk treatment groups, null hypotheses of no difference between proportions of "yes" responses between cells are never rejected at 5%. For given risk changes, however, null hypotheses of no difference between proportions of “yes” responses for the highest and lowest cost values are rejected in three of four cases (the exception is the case of conditional death risk reduction by 1/1000).[12]

Table 2 also provides the information needed to compute Turnbull estimates (see Haab and McConnell 2002, pp. 72-78) of lower-bound mean WTP to reduce risk of injury or risk of death given injury. These estimates of β_p and β_q make no use of covariates, are not based on an assumption about the distribution of underlying WTP values, and are asymptotically normally distributed. Turnbull estimates also assume that WTP values are confined to the positive domain and that everyone in a given treatment cell has the same value of WTP. These estimates, shown in Table 3, are used to test the null hypothesis that $\beta_p / \beta_q = q / p$ and thus whether $U(I) = V(I)$.

Table 3 shows that lower-bound mean WTP for each of the four risk reduction treatments is significantly different from zero at conventional levels and is larger for reductions in conditional mortality risk than for reductions in risk of injury. However, assuming independent samples, a difference between means test shows that the estimated lower-bound mean WTP for a 5/1000 injury risk reduction ($140.00) is not significantly different at the 5% level from the estimated lower-bound mean for the 1/1000 injury risk reduction ($88.75) ($z=1.21$). Also, lower-bound mean WTP for the 1/1000 conditional death risk reduction is unexpectedly larger than the corresponding value for the 3/1000 conditional death risk reduction. These outcomes pertaining to the behavior of WTP as the risk change increases suggest that respondents did not distinguish between the magnitudes of risk changes presented. However, only between-respondent comparisons are available because one risk reduction scenario was presented to each respondent.

To test the null hypothesis that $\beta_p / \beta_q = q / p$, attention is first directed to the sub-sample of respondents who received the 1/1000 reductions either in unconditional injury risk or in conditional death risk. From Table 3, the estimated ratio of β_p to β_q equals 0.235 with a standard error of 0.085 (estimated by the delta method assuming independent samples). Based on the asymptotic normality of Turnbull estimates, the 95 percent confidence interval for this ratio brackets: (1) the ratio of sample means of perceived risk measures from Table 1 (0.396), (2) the ratio of median perceived risks (2/12=0.167), (3) the median of the ratio of perceived risks computed for respondents reporting nonzero values of injury risk (0.200), and (4) the 4/17=0.240 ratio implied by risk information presented to respondents. Of course, the ratio of sample means $\overline{q} / \overline{p}$ is itself subject to sampling error. Accounting for the standard errors of both β_p / β_q and $\overline{q} / \overline{p}$ but assuming the two ratios are uncorrelated, the difference between the two ratios of 0.175 has a standard error of 0.135. Thus, at conventional levels of significance, the null hypothesis that $\beta_p / \beta_q = q / p$ is not rejected. Analysis of lower bound mean valuations of the larger risk changes also fails to reject the hypothesis that $U(I) = V(I)$.[13] These results suggest that respondents perceive utility in the healthy state to be about equal to utility in the injured state and that willingness to pay for a change in p or q is equal to the willingness to pay for the corresponding change in r. Evidently, the risk characteristics embedded in p and q do not matter for calculating the VSL.

As previously noted, the Turnbull estimates just presented do not rest on an assumed distribution of WTP values and provide only lower bounds on means of β_p and β_q. To determine whether these properties could be responsible for failing to reject the null hypothesis that $\beta_p / \beta_q = q / p$, Table 4 presents parametric estimates of equation (4) based on an assumed

Weibull distribution of WTP. These regressions pool the data from injury risk and death risk reductions and reflect responses to both the initial and follow-up questions in order to use all available information to estimate β_p and β_q. Initially, follow-up responses were excluded because of concern that their inclusion may bias estimators of WTP (Bateman et al. 2001, Burton et al. 2003, Cooper, Hanemann and Signorello 2002, DeShazo 2002). However, the hypothesis that $\beta_p / \beta_q = q / p$ was never rejected based on estimates employing only responses to the first question, a result that could have arisen because exclusion of follow-up responses reduces efficiency.[14] Estimates in Table 4 maximize the log-likelihood function for an interval estimator of double-bound, discrete choice data: $\ln L = \sum_i \log[F(WTP_i^U;\Theta,\sigma) - F(WTP_i^L;\Theta,\sigma)]$, where $F(\bullet)$ denotes the Weibull distribution with shape parameter Θ and scale parameter σ, and WTP_i^L and WTP_i^L respectively denote the lower and upper bounds on respondent *i's* WTP, computed from responses to initial and follow-up questions.

Estimates in column (1) of Table 4 are based on the sub-sample of 352 respondents exogenously assigned 1/1000 reductions in either injury or conditional death risk, using dummy variables indicating the assigned experimental treatment as the only explanatory variables; no constant term is included because the two treatment dummies sum to unity. Estimated coefficients of dummy variables are positive and significant at less than the 1% level, indicating that WTP is significantly related to reductions in both injury risk and conditional death risk. Estimates in column (2) add interaction variables constructed as products of treatment dummies and mean-centered variables corresponding to household income and initial values of perceived risks. Mean-centering implies that interaction terms are zero at the sample mean, so that coefficients of treatment dummies are interpreted as treatment effects for the average worker. As shown, the numerical magnitude of estimated treatment effects are quite close to corresponding results presented in column (1) and remain significant at the 1% level. This outcome is not unexpected because the randomly assigned experimental treatments are orthogonal to both observed and unobserved respondent and job characteristics. However, contrary to theoretical predictions in Section 2 that β_p and β_q are increasing functions of I, p and q, coefficients of three of the four interaction variables involving baseline risks are not significant at conventional levels. The positive effect of household income on WTP to reduce injury risk is significant at the 5% level under a one-tail test.

Estimates in column (3) of Table 4 are based on all 700 respondents, including those originally assigned 5/1000 reductions in injury risk or 3/1000 reductions in conditional death risk. As discussed previously, many of the respondents assigned to the two large risk reduction treatments did not actually value risk reductions of this magnitude. If risk reductions originally planned exceeded the perceived level of risk, respondents valued (smaller) risk changes equal to their initial perceived risk. To distinguish between the risk changes that different respondents actually considered, explanatory variables in column (3) include four treatment dummies indicating the four basic risk reduction treatments, as well as two additional dummy variables indicating whether the risk change assigned to a respondent was smaller than the risk change originally envisioned. Results presented suggest that WTP for job safety is significantly related to reductions in injury and conditional death risk, but as discussed previously in connection with the Turnbull estimates, respondents do not appear to have accounted for the magnitude of the risk reductions when reporting their WTP. Coefficients of the larger risk changes are not significantly different from those of the smaller risk changes.

Effects of I, p and q also were estimated for the larger sample by including interactions of income and initial perceived risks with each of the four treatment dummies. These results are not reported in Table 4 because effects of income and baseline risks are similar to those obtained in column (2).[15] Finally, all estimates in Table 4 were re-computed after excluding respondents who initially reported a zero level of the risk they were asked to value, with no material difference in results.

Valuations of risk reductions based on the estimates in Table 4 are reported in the right-hand columns of Table 3. The top panel of Table 3 presents estimated median and mean values of β_p and β_q, based on 1/1000 reductions in injury or conditional death risk, while the bottom panel reports corresponding information for the larger risk changes. The estimated marginal rate of substitution β_p / β_q, which is identical for median and mean values of β_p and β_q, also is presented along with a 95% confidence interval. Estimates of β_p and β_q are computed from coefficients of treatment effects in Table 4 using properties of the Weibull distribution.[16]

Results suggest that the median worker is willing to pay about $90 for a 1/1000 reduction in annual risk of workplace injury, an amount close to the previously discussed Turnbull lower-bound mean. Estimated median WTP for a 1/1000 reduction in conditional risk of death ranges from $130 to $190. Estimates of mean WTP are four to five times greater than median valuations. The estimated marginal rate of substitution between the two risks ranges from 0.48 to 0.56 and is significantly different from unity in each case, suggesting that workers value reductions in conditional death risk significantly more than reductions in injury risk.[17]

The 95% confidence intervals for β_p / β_q include the ratio of sample mean risks $\overline{q} / \overline{p}$ for each parametric specification. Likewise the difference between β_p / β_q and the ratio of mean risks is less than its standard error (computed by accounting for the variability in both ratios but assuming zero covariance between them) for each specification. Thus it would appear that for the average worker, β_p / β_q cannot be distinguished from q / p and consequently $U(I) = V(I)$ and the VSL is independent of the composition of risk changes.

Although not the main focus of this paper, results in Table 3 support estimation of the value of statistical injury and value of statistical life implied by Turnbull and parametric estimates of WTP for 1/1000 reductions in risks. Estimated values of statistical injury are computed as $1000\beta_p$ while VSL estimates are computed by substituting estimates of β_p and β_q into equation (7) with p and q set equal to sample means and r computed as the product of means of p and q.

The Turnbull lower-bound estimate of the mean value of statistical injury and the parametric (Weibull) estimates of the median are about \$90,000, while the estimated mean value of injury avoidance is about \$400,000. Viscusi and Aldy (2003), in their review of hedonic wage studies, present a value of avoiding *nonfatal* injuries in the \$20,000 to \$70,000 range. Because the measure of injury risk used here reflects the risks of fatal as well as nonfatal injuries, the value of injury avoidance would be expected to exceed estimates obtained in hedonic wage studies that use a measure of risk of nonfatal injuries only. In fact, hypothesis tests discussed above suggesting that $\beta_p / \beta_q = q / p$ would imply that the value of nonfatal workplace injuries is zero, so that β_p reflects only the value of the associated reduction in risk of death, $\beta_p = q[V(I) - D(I)] / \Delta$.[18]

Estimates of the VSL based on median Weibull values are about \$4 million, while estimates based on mean values are four to five times higher and the VSL computed from the

Turnbull lower-bound mean valuations is \$8.5 million. Viscusi and Aldy's (2003) review of labor market estimates puts the VSL in the \$4 million to \$9 million range. Blomquist (2002) reviews studies of risk-dollar tradeoffs outside the labor market and concludes that these studies point to a VSL of about \$4.5 million. Results of a recent mortality valuation survey (Alberini et al. 2004) indicate a mean VSL for older adults (age 40 years and older) of \$1.5 million to \$4.8 million. In summary, median VSL estimates implied by results obtained here are comparable to previous estimates obtained from market tradeoffs and stated preference surveys, while mean VSL estimates are higher.

4. Conclusions

This paper has examined the issue of whether selected characteristics of risk affect the magnitude of the value of a statistical life. Analysis presented is based on a simple extension of the standard von Neumann-Morgenstern expected utility model with state dependent preferences. Whereas most prior applications of this model allow for two health states (healthy and dead), the model presented here allows also for the individual to be injured (or ill). Thus, the unconditional probability of death, r, is expressed as the product of the unconditional risk of injury (or illness), p, and the conditional probability of death given injury (or illness), q. The model, then, permits the value of a statistical life to be written in terms of the risk characteristics p and q, which might be broadly interpreted as the "frequency" and "severity" that might be associated with a hazard. The central question addressed in the paper is whether the willingness to pay for a reduction in p or q is the same as the willingness to pay for the corresponding reduction in r. If so, then the underlying risk characteristics do not matter in the sense that the value of a statistical life can be computed from knowing only the change in r. If not, then the value of a statistical life only can be computed after determining the values of p and q (i.e., the risk characteristics).

The null hypothesis that the willingness to pay for a reduction in p or q is equal to the willingness to pay for the corresponding reduction in r is tested using data collected in a recent national survey of people's perceptions of workplace accident risks. This null hypothesis is not rejected using both nonparametric and parametric tests. An implication of these tests is that most workplace injuries are viewed as minor, so that utility in the healthy state is about the same as utility in the injured state. In this case, the model collapses to envision only two health states (healthy and dead), thus explaining why the risk characteristics (p and q) do not matter in computing the VSL. This outcome raises the questions of whether it is generally true that risk characteristics do not affect the VSL, whether risk characteristics would matter in the context of a different hazard, or whether different characteristics such as latency or effects on other family members including children might be more important distinguishing features of risk than frequency and severity. These questions would be of interest to examine in future research.

Notes

[1] This framework can be extended to treat other risk characteristics including latency and involvement of family members (Dickie and Gerking 2003).

[2] An alternative approach might involve adding a random shock term to equations (1) and (2) as in Shogren and Crocker (1991). In the present context, however, this extension appears to be unnecessary if x is thought of as an exhaustive enumeration of possible factors that determine how a worker perceives risk.

[3] In general the marginal rate of substitution between q and p is given by $\beta_p / \beta_q = [U(I) - V(I)] / p[V(I) - D(I)] + q / p.$ The nonlinear constant expected utility locus between q and p is negatively sloped and convex to the origin as long as the injured state is preferred to the death state. If the death state is preferred to the injured state, the locus is positively sloped and concave to the origin.

[4] Prior to drawing the sample, a pencil-and-paper version of the survey instrument was pre-tested in focus groups consisting of workers of both genders representing a broad range of occupations. De-briefing of focus group participants led to numerous changes in the design of the survey instrument to ensure that the questions posed were understandable.

[5] Self-employed persons were excluded because the survey was directed at paid employees.

[6] This figure was computed by dividing private industry lost workday cases involving days away from work (1,584,000) by total private industry employment (110,065,000) for the year 2000 (U.S. Department of Labor, Bureau of Labor Statistics 2001a).

[7] Data on workplace fatalities are collected independently from data on workplace injuries (U.S. Department of Labor, Bureau of Labor Statistics 2001a and 2001b), so the conditional risk of death given injury was approximated by: (1) reducing the number of year 2000 private industry workplace fatalities (5344) by a factor of 0.947 (=5067) to reflect the different total employment bases used for the injury and fatality data and (2) adding this value to the number of injuries reported in footnote 4 (1,584,000) to get an estimate of total fatal and nonfatal injuries (1,589,000), and (3) dividing this result into the unadjusted number of fatalities, then, gives an estimate of deaths per injury of 0.0034, which is slightly lower than the “4 in 1000” figure presented to respondents in the survey.

[8] The ability of respondents to clearly distinguish between these two types of risk was a concern from the beginning of the study, partly because few previous surveys have dealt with compound risks. In de-briefing sessions conducted after the pre-tests, participants were asked if they understood the meaning of the injury risk and conditional death risk questions. While wording changes in the questions were suggested, all of the participants understood the meaning of the risk concepts involved.

[9] Alberini *et al.* (2004) also present respondents with a safety good that is not specifically defined.

[10] Use of randomization in the experimental design implies that risk changes are exogenous treatments that are orthogonal to observed and unobserved characteristics of workers and their jobs, thus, avoiding the endogeneity problems discussed by Garen (1988), Hwang, Reed, and Hubbard (1992), and Shogren and Stamland (2002).

[11] To test whether observed differences between treatment cells reflect treatment effects, t-tests also were performed for mean differences in race, gender, income, and age between treatment cells. Among 190 (19x20/2) possible comparisons for each of these variables, significant differences are found at the 5% level in 4 cases for race, 4 cases for gender, 2 cases for household income. No significant differences in means between cells were found for age. Details are provided in the Appendix, Table A1.

[12] For given costs, chi-square tests of independence can be performed using information reported in Table 2 to test the null hypothesis that the proportion of respondents who would purchase the safety good is independent of the size of the risk change. This hypothesis is not rejected at the 10% level in any of the 10 possible tests. Four additional chi-square tests of independence were performed to test the null hypothesis that the proportion of respondents purchasing the safety good is independent of cost. This hypothesis is rejected at the 10% level for both the 1/1000 and 5/1000 injury risk reductions, but not for either the 1/1000 or 3/1000 conditional death risk reduction. Of course, this test should be interpreted cautiously because the estimated valuations are not proportional to the sizes of the risk changes. Results of chi-square tests are presented in the Appendix, Table A2.

[13] Based on the theoretical prediction that valuations of small risk changes are proportional to the size of the risk change (Hammitt and Graham 1999), the hypothesis $U(I)=V(I)$ implies $(3/5)(\beta_p^*/\beta_q^*)=q/p,$ where β_p^* denotes WTP for a 5/1000 reduction in injury risk and β_q^* denotes WTP for a 3/1000 reduction in conditional death risk. As shown in Table 3, the Turnbull estimate of $(3/5)\beta_p^*/\beta_q^*$ is 0.337 with a standard error of 0.0872. Thus, the ratio cannot be distinguished at 5% significance from any of the four benchmark values of q/p mentioned in connection with the test based on 1/1000 risk reductions.

[14] Parametric (Weibull) estimates using only responses to the first question are reported in Appendix Table A3. As in Table 4, coefficients of dummy variables indicating risk changes are positive and significant at 1%. Implied estimates of β_p/β_q are smaller than those based on Table 4 and have wider confidence intervals. Consequently, the null hypothesis $\beta_p/\beta_q=q/p$ would not be rejected using the single-bound WTP estimates. This hypothesis also would not be rejected based on probit regressions corresponding to specifications reported in Table 4; however, coefficients of risk change dummies are not uniformly positive and significant when using probit. This result appears to result from the normality assumption underlying probit that does not constrain WTP to the positive interval.

[15] Magnitudes of treatment effects at the mean are similar to those in column (3) and remain significant at one percent. Coefficients of seven of eight interaction variables involving initial perceived risks are negative but none is significant at 10%. Three of four interactions involving household income are positive and two are significant at 10%.

[16] If b_j denotes the treatment effect estimated by the coefficient of the treatment dummy indicating a 1/1000 reduction in risk j, $j = p, q$, then median marginal WTP for the risk reduction is given by $\beta_j = \exp(b_j) \cdot \Gamma(1/\Theta + 1)$, where $\Gamma(\bullet)$ denotes the gamma function. Mean marginal WTP is $\beta_j = \exp(b_j) \cdot (-\ln(0.5))^{1/\Theta}$. Thus the estimated marginal rate of substitution $\beta_p / \beta_q = \exp(b_p) / \exp(b_q)$ for both the median and mean.

[17] As discussed in connection to the Turnbull estimates, Weibull-estimated WTP for a 5/1000 reduction in injury risk is not significantly larger than WTP for a 1/1000 reduction, and WTP for a 3/1000 reduction in conditional is unexpectedly larger than WTP for a 1/1000 reduction. Nonetheless, the hypothesis $(3/5)(\beta_p^* / \beta_q^*) = q / p$ (which implies $U(I) = V(I)$ if valuations are proportional to risk changes, where β_p^* denotes WTP for a 5/1000 reduction in injury risk and β_q^* denotes WTP for a 3/1000 reduction in conditional death risk) is not rejected based on the parametric estimates. As shown in Table 3, the Weibull estimate of $(3/5)\beta_p^* / \beta_q^*$ is 0.347 with a standard error of 0.111. This cannot be distinguished from $\bar{q} / \bar{p}$ at conventional significance levels.

[18] As discussed in section 2, when $\beta_p / \beta_q = q / p$ the VSL is given by $\beta_p / q = \beta_q / p$. Using Turnbull or median Weibull values of β_p and the sample mean of conditional death risk to compute β_p / q, the resulting VSL estimates are about \$4.5 million. Using median Weibull values of β_q and the sample mean of injury risk to compute β_q / p yields VSL estimates of about \$4 million, while using Turnbull values of β_q gives a VSL of \$8.6 million.

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Table 1. Annual perceived injury and conditional death risks.

Chances in 1000	Perceived Annual Injury Risk	Perceived Annual Conditional Death Risk
0	72	154
1	52	153
2	35	67
3	17	28
4	10	98
5	65	44
6	7	20
7	6	5
8	7	15
9	7	3
10	64	35
11	5	2
12	16	4
13	1	0
14	2	0
15	22	5
16	4	1
17	43	1
18	4	1
19	5	0
20	48	9
21-25	41	9
26-40	38	6
41-50	32	7
51-100	43	11
101-500	45	18
501-999	8	2
1000	1	2
N	700	700
Median	12	2
Mean	51.56	20.43
Ratio of Means ($\bar{q} / \bar{p}$)	0.396	
(Std error of ratio)	(0.0671)	

Table 2. Fraction of “Yes” responses by treatment.

A. Reductions in injury risk.

		Cost of safety equipment ($/year)					
Risk reduction		50	100	250	400	750	Total
1/1000	Proportion willing to pay bid amount	0.533	0.427	0.250	0.283	0.270	0.344
	Number in cell	30	35	32	46	37	180
5/1000	Proportion willing to pay cost	0.606	0.514	0.333	0.231	0.222	0.375
	Number in cell	33	37	39	39	36	184

B. Reductions in risk of death given injury.

		Cost of safety equipment ($/year)					
Risk reduction		100	250	400	750	1000	Total
1/1000	Proportion willing to pay cost	0.475	0.486	0.394	0.385	0.306	0.412
	Number in cell	40	37	33	26	36	172
3/1000	Proportion willing to pay cost	0.632	0.351	0.360	0.212	0.323	0.384
	Number in cell	38	37	25	33	31	164

Table 3. Willingness to pay to reduce risk.
Estimates (standard errors computed by delta method) in US dollars of year 2002.

	Nonparametric	Weibull Distribution (Based on columns of Table 4)					
	Based on 1/1000 reductions in injury or conditional death risk						
	Turnbull Lower Bound Mean	Col (1)		Col (2)		Col (3)	
Parameter		Median	Mean	Median	Mean	Median	Mean
β_p ($)[a]	88.75 (30.43)	83.01 (18.33)	415.88 (90.09)	97.33 (30.30)	461.35 (154.37)	94.17 (16.78)	362.18 (61.40)
β_q ($)[b]	377.45 (43.18)	172.3 (37.42)	863.23 (208.46)	130.07 (37.36)	820.35 (193.38)	190.56 (34.53)	732.93 (137.24)
β_p / β_q	0.235 (0.085)	0.482 (0.128)		0.562 (0.198)		0.494 (0.115)	
95% CI	0.0686, 0.402	0.232, 0.732		0.174, 0.951		0.269, 0.719	
	Based on larger reductions in injury or conditional death risk						
β_p^* ($)[c]	140.00 (29.21)	---[e]	---[e]	---[e]	---[e]	98.91 (21.12)	380.38 (82.90)
β_q^* ($)[d]	249.45 (38.32)	---[e]	---[e]	---[e]	---[e]	170.99 (43.54)	657.61 (168.85)
$(3/5)\beta_p^* / \beta_q^*$	0.337 (0.0872)	---[e]		---[e]		0.347 (0.111)	
95% CI	0.166, 0.508	---[e]		---[e]		0.130,0.564	

[a] β_p = WTP to reduce annual unconditional injury risk by 1/1000. [b] β_q = WTP to reduce annual conditional risk of death given injury by 1/1000.

[c] β_p^* = WTP to reduce annual unconditional injury risk by 5/1000. [d] β_q^* = WTP to reduce annual conditional risk of death given injury by 3/1000.

[e] Not estimated.

Table 4. Estimated willingness-to-pay function: Weibull distribution.[a]
(Standard errors in parentheses)

Variable	(1)	(2)	(3)
Injury Risk Reduction = 1/1000	5.204 (0.190)	5.348 (0.298)	5.255 (0.163)
Conditional Death Risk Reduction = 1/1000	5.934 (0.195)	5.923 (0.193)	5.960 (0.171)
(Perceived Injury Risk[b]) x (Injury Risk Reduction = 1/1000)		-0.00323 (0.00256)	
(Perceived Injury Risk[b]) x (Conditional Death Risk Reduction = 1/1000)		-0.00218 (0.00157)	
(Perceived Conditional Death Risk[b]) x (Injury Risk Reduction = 1/1000)		0.0121 (0.0168)	
(Perceived Conditional Death Risk[b]) x (Conditional Death Risk Reduction = 1/1000)		-0.00285 (0.00204)	
(Household Income[b] $1000/yr) x (Injury Risk Reduction = 1/1000)		0.0126 (0.00731)	
(Household Income[b] $1000/yr) x (Conditional Death Risk Reduction = 1/1000)		-0.00611 (0.00691)	
Injury Risk Reduction = 5/1000 Assigned			5.304 (0.205)
Conditional Death Risk Reduction = 3/1000 Assigned			5.852 (0.247)
Injury Risk Reduction = 5/1000 Assigned, But Switched to Smaller Risk Reduction			-0.550 (0.381)
Conditional Death Risk Reduction = 3/1000 Assigned, But Switched to Smaller Risk Reduction			-0.290 (0.354)
Θ (Weibull shape parameter)	0.683 (0.0294)	0.690 (0.0303)	0.718 (0.0212)
Log-likelihood	-423.421	-417.456	-829.756
N	352	352	700

[a] Maximum likelihood estimates. The latent dependent variable is WTP for the safety good in dollars.

[b] Variable mean-centered before multiplying. Sample means for columns (1) and (2) (n=352) are: injury risk, 43.76; conditional death risk, 17.93; household income, $44,936. Sample means for column (3) (n=700) are: injury risk, 51.56; conditional death risk, 20.44; household income, $46,700.

Table A1. Means of race, gender, household income, and age by treatment cell.[a]

Treatment	Number of Observations	Percent White[b]	Percent Male	Household Income[d]	Years of Age
Injury 1/1000					
Bid=50	30	0.633 (0.09)	0.667 (0.09)	$43,083 (4,341)	40.767 (2.25)
Bid=100	35	0.600 (0.08)	0.857 (0.06)	$47,035 (3,904)	41.229 (2.02)
Bid=250	32	0.781 (0.07)	0.875 (0.06)	$53,125 (4,532)	38.594 (1.79)
Bid=400	46	0.782 (0.06)	0.826 (0.06)	$41,059 (3,363)	39.343 (2.04)
Bid=750	37	0.837 (0.06)	0.865 (0.06)	$46,013 (4,996)	38.027 (1.95)
Injury 5/1000					
Bid=50	33	0.697 (0.08)	0.848 (0.06)	$47,075 (3,994)	42.364 (2.10)
Bid=100	37	0.784 (0.08)	0.838 (0.06)	$43,108 (3,795)	39.297 (2.22)
Bid=250	39	0.744 (0.07)	0.744 (0.07)	$53,942 (3,900)	44.667 (1.54)
Bid=400	39	0.821 (0.06)	0.795 (0.06)	$48,910 (5,427)	40.000 (1.77)
Bid=750	36	0.750 (0.07)	0.806 (0.07)	$46,840 (4,029)	40.917 (1.83)

Table A1. (Cont) Means of race, gender, household income, and age by treatment cell.[a]

Treatment	Number of Observations	Percent White[b]	Percent Male	Household Income[d]	Years of Age
Death 1/1000					
Bid=100	40	0.800 (0.06)	0.900 (0.05)	$44,625 (4,718)	38.800 (2.04)
Bid=250	37	0.865 (0.06)	0.838 (0.06)	$43,581 (4,913)	40.027 (2.07)
Bid=400	33	0.757 (0.07)	0.939 (0.04)	$43,787 (4,536)	41.939 (2.06)
Bid=750	26	0.692 (0.09)	0.923 (0.05)	$42,019 (4,749)	40.538 (1.84)
Bid=1000	36	0.805 (0.07)	0.778 (0.07)	$45,902 (3,936)	41.194 (2.00)
Death 3/1000					
Bid=100	38	0.842 (0.06)	0.789 (0.07)	$42,335 (3,316)	39.289 (1.70)
Bid=250	37	0.892 (0.05)	0.919 (0.04)	$47,500 (4,340)	40.405 (1.88)
Bid=400	25	0.720 (0.09)	0.840 (0.07)	$55,850 (5,846)	39.120 (2.19)
Bid=750	33	0.727 (0.08)	0.818 (0.07)	$51,060 (5,344)	40.394 (2.04)
Bid=1000	31	0.677 (0.08)	0.806 (0.07)	$50,967 (6,267)	41.742 (1.95)

[a] Standard errors in parentheses

[b] Difference between means tests performed assuming independence between cells show significant differences at the 5% level in the following cases: (1) Percent White (Injury 1/1000, Bid=$50 vs. Death 3/1000, Bid=$250, Injury 1/1000, Bid=$100 vs. Death 1/1000, Bid=$250, Injury 1/1000 vs. Death 3/1000, Bid=$100, Injury 1/1000, Bid=$100 vs. Death 3/1000, Bid=$250), (2) Percent Male (Injury 1/1000, Bid=$50 vs. Death 1/1000, Bid=$100, Injury 1/1000, Bid=$50 vs. Death 1/1000, Bid=$400, Injury 1/1000, Bid=$50 vs. Death 1/1000, Bid=$750, Injury 1/1000, Bid=$50 vs. Death 3/1000, Bid=$250), (3) Household Income (Injury 1/1000, Bid=$400 vs. Death 3/1000, Bid=$400 and Injury 1/1000, Bid=$400 vs. Injury 5/1000, Bid=$250), (4) Age (no significant differences).

Table A2. Chi-square test statistics based on information in Table 2.

H_0: Proportion buying safety good is independent of cost (χ_4^2).	
Risk change	Test statistic
$dp = 1/1000$	8.78
$dp = 5/1000$	9.45
$dq = 1/1000$	3.31
$dq = 3/1000$	3.19

H_0: Proportion buying safety good is independent of size of risk change (χ_1^2).		
	Risk change	
Cost Level	Injury Risk	Conditional Death Risk
$ 50	.056	---[a]
100	1.80	.30
250	.309	.52
400	.0040	.50
750	.019	.073
1000	---[a]	.0025

[a] Not included in experimental design.

Table A3. Estimated willingness-to-pay function: Weibull distribution (single bound).[a]
(Standard errors in parentheses)

Variable	(1)	(2)	(3)
Injury Risk Reduction = 1/1000	5.143 (0.421)	5.463 (0.663)	5.254 (0.291)
Conditional Death Risk Reduction = 1/1000	6.381 (0.450)	6.329 (0.440)	6.266 (0.306)
(Perceived Injury Risk[b]) x (Injury Risk Reduction = 1/1000)		-0.0113 (0.00643)	
(Perceived Injury Risk[b]) x (Conditional Death Risk Reduction = 1/1000)		0.0334 (0.0446)	
(Perceived Conditional Death Risk[b]) x (Injury Risk Reduction = 1/1000)		-0.00307 (0.00393)	
(Perceived Conditional Death Risk[b]) x (Conditional Death Risk Reduction = 1/1000)		-0.00272 (0.00401)	
(Household Income[b] $1000/yr) x (Injury Risk Reduction = 1/1000)		0.0260 (0.0190)	
(Household Income[b] $1000/yr) x (Conditional Death Risk Reduction = 1/1000)		-0.0168 (0.0168)	
Injury Risk Reduction = 5/1000 Assigned			5.304 (0.205)
Conditional Death Risk Reduction = 3/1000 Assigned			5.852 (0.247)
Injury Risk Reduction = 5/1000 Assigned, But Switched to Smaller Risk Reduction			-0.550 (0.381)
Conditional Death Risk Reduction = 3/1000 Assigned, But Switched to Smaller Risk Reduction			-0.290 (0.354)
Θ (Weibull shape parameter)	0.492 (0.0810)	0.496 (0.0828)	0.581 (0.0498)
Log-likelihood	-227.787	-221.691	-445.401
N	352	352	700

[a] Maximum likelihood estimates. The latent dependent variable is WTP for the safety good in dollars.

[b] Variable mean-centered before multiplying. Sample means for columns (1) and (2) (n=352) are: injury risk, 43.76; conditional death risk, 17.93; household income, $44,936. Sample means for column (3) (n=700) are: injury risk, 51.56; conditional death risk, 20.44; household income, $46,700.