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The Value of Risks to Life and Health

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1. *Introduction*

HEALTH AND SAFETY RISKS comprise one aspect of our lives that we would all like to eliminate. Even if we set out to provide a risk-free existence, however, our efforts would be constrained by our economic resources. If the entire American GNP were devoted to preventing fatal accidents, we would be able to spend an average of only $55 million per fatality. There are also other demands on these resources, ranging from food to recreation, which will reduce the funds available for risk reduction.

One possible approach is to set the risk reduction priorities based on the magnitude of the hazard. Table 1 lists a series of risks involving market processes and individual decisions that have been the focus of economic analyses to be considered below. The vigilance that individuals and society should devote to reducing these risks is not, however, governed solely by their size. Risks thought to be amenable to technological improvements, such as motor vehicle safety, have attracted the greatest attention. Risks beyond our control have merited comparatively modest risk reduction efforts.

Scientists estimate that we face an annual fatality risk from asteroid impact—the "doomsday rock"—of 1/6,000 (*New York Times*, June 18, 1991, p. B5). Yet, few would argue that we should abandon efforts to reduce smaller risks, such as those posed by jobs and home accidents, and reallocate these funds to fending off asteroids.[1] The key issue is the risk reduction that is achievable for any given expenditure and the value society places on this risk reduction.

The government faces a variety of opportunities to reduce risk.[2] Airplane cabin fire protection costs $200,000 per life saved; automobile side door protection standards save lives at $1.3 million each; Occupational Safety and Health Administration (OSHA) asbestos regula-

[1] Some scientists have begun speculating on the feasibility of such risk reductions. For example, some have suggested the use of nuclear weapons to alter the path of an asteroid. Thus far, it appears that less flamboyant policies, such as improved guardrails on highways, would be more cost-effective.

[2] For a review of the federal guidelines on the valuation of health risks, see the U.S. Office of Management and Budget (1988, 1990).

TABLE 1

Source of Risk	Annual Fatality Risk
Cigarette smoking (per smoker)	1/150
Cancer	1/300
Motor Vehicle Accident	1/5,000
Asteroid (doomsday rock)	1/6,000
Work Accident (per worker)	1/10,000
Home Accident	1/11,000
Poisoning	1/37,000
Fire	1/50,000
Aviation Accident (passenger deaths/ total population)	1/250,000

Source: National Safety Council (1990); and further calculations by Viscusi (1992a, 1992b): the smoking risk estimates are averaged over the entire smoking population. The average smoker consumes 1.5 packs per day.

tions save lives at $89.3 million each; Environmental Protection Agency (EPA) asbestos regulations save lives at $104.2 million each; and a proposed OSHA formaldehyde standard cost $72 billion per life saved (John Morrall 1986).[3] Which of these different policies should be pursued, and which provide benefits that are not commensurate with their costs?

In a democratic society, the appropriate starting point for analyzing these tradeoffs is the value individuals bearing the risk place on the improved safety.[4] Over the past two decades, there has developed a substantial literature on the value of these risk-money tradeoffs. The greatest emphasis has been on the tradeoff involving mortality risks and wages. These labor market studies have addressed the implicit values of life of workers in many countries, including the United States, the United Kingdom, Australia, Canada, and Japan. Straightforward extensions of these models have included a measure of nonfatal risks faced by the worker, enabling analysts to impute an implicit value per statistical injury in the workplace. Economists have also analyzed the price-risk tradeoff for a variety of consumer products. In situations in which no market data are available, such as some environmental risks, one can use surveys to derive a market value if a market for the good existed. This paper explores these different approaches to establishing appropriate economic values for risks to life and health.

2. *Estimating the Value of Life Using Labor Market Data*

The dominant approach to obtaining estimates of the risk-dollar tradeoff uses labor market data on worker wages for risky jobs to infer attitudes toward risk. The theory underlying this analysis extends back to Adam Smith (1776), who observed that risky or otherwise unpleasant jobs will command a compensating wage differential.

Basic Elements of the Hedonic Wage Methodology

The main empirical approach to assessing risk tradeoffs in the labor market has utilized a methodology known as "hedonic" (i.e., quality-adjusted) wage equation.[5] Controlling for other aspects

[3] These estimates reported by Morrall (1986) are for new government regulations. For example, the 1986 OSHA asbestos standard that cost $89.3 million per life was more stringent than the 1972 OSHA standard, which cost $7.4 million per life.

[4] This principle is the same as in other benefit valuation contexts. The primary matter of interest is society's willingness to pay for the benefits generated by the policy. Thomas Schelling (1968) first presented the willingness-to-pay approach in the lifesaving context.

[5] A forerunner of this line of work is the research on hedonic price indexes by Zvi Griliches (1971). Sherwin Rosen (1986) provides a survey of this approach focusing on nonpecuniary job attributes in general, where health and safety risks represent a special case. See also Richard Thaler and Rosen (1976), Robert Smith (1979), and Viscusi (1979). Schelling (1968) first outlined the proper use of value of life estimates.

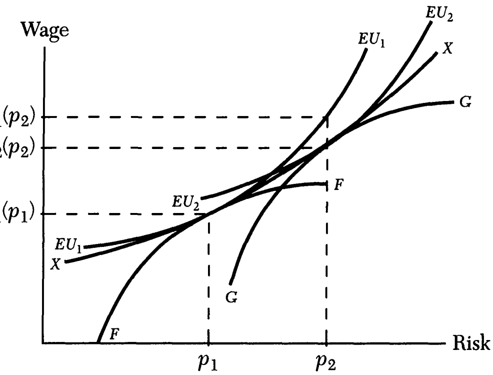

Figure 1. Market Process for Determining Compensating Differentials

of the job, what is the wage premium workers receive for risk? These premiums are the result of the interaction of labor demand by firms and labor supply decisions by workers.

Providing greater workplace safety is costly to the firm. To maintain the same level of profits along some isoprofit curve, the firm must pay a lower wage rate to offset the cost of providing a safer work environment. The firm's wage offer curve consequently will be an increasing function of the risk. The offer curves for two different firms appear in Figure 1 as *FF* and *GG*. For any given risk level, workers will prefer the market offer curve with the highest wage level.

The characteristics of the supply side of the market are defined by several mild restrictions on preferences. Consider a formulation using a von Neumann-Morgenstern expected utility model with state-dependent utilities. Suppose that $U(w)$ denotes the utility of being healthy and $V(w)$ denotes the utility of being injured. Post-injury workers' compensation benefits are usually a function of w, where the exact relationship is subsumed into the functional form for $V(w)$.[6] The only critical assumptions required for workers to demand compensating differentials for risk are that one would rather be healthy than not $[U(w) > V(w)]$ and the marginal utility of income is positive $[U'(w),\ V'(w) > 0]$. It is not necessary to assume that individuals are risk-averse $[U'',\ V'' < 0]$ in their attitude toward financial gambles.[7]

Workers will select the available wage-risk combination from the schedule *WW* that yields the maximum expected utility. For worker 1 in Figure 1 the optimal job risk is at the point where the worker's constant expected utility locus EU_1 is tangent to *FF*, and for worker 2 it is where EU_2 is tangent to *GG*.

The slope of the EU_1 and EU_2 curves can be readily verified. Wage-risk combinations that maintain a worker's constant expected utility level consist of the points that satisfy

$$Z = (1 - p)U(w) + pV(w).$$

The wage-risk tradeoff along this curve is given by

$$\frac{dw}{dp} = -\frac{Z_p}{Z_w} = \frac{U(w) - V(w)}{(1 - p)U'(w) + pV'(w)} > 0,$$

or the required wage rate increases with the risk level.

The points (p_1,w_1) and (p_2,w_2) in Figure 1 represent the points of tangency of the two constant expected utility loci with the market wage opportunities. These are the points that are observable using labor market data. In effect, economists only observe particular wage-risk choices of different workers at points of tangency with the market opportunities curve.

The econometric task is to estimate the locus of these wage-risk tradeoffs for the

[6] If there is no dependence of benefits on w, $V'(w) = 0$. So long as $U'(w) > 0$, the results below will hold.

[7] Risk neutrality $(U'',\ V'' = 0)$ always leads to the results below. If individuals are risk lovers, the second-order conditions may not be met. See Viscusi (1979).

entire market. In effect, the hedonic wage studies fit a curve XX through points such as these and estimate the market locus of wage-risk tradeoffs.

The observed (p_i,w_i) reflect the influence of both supply and demand on the market equilibrium for the entire set of workers.[8] The estimated rate of tradeoff $\partial w/\partial p$ equals the slope of constant expected utility loci that are tangent to XX, thus providing a local measure of the wage-risk tradeoff for marginal changes in risk. For any given worker located along XX, the estimated slope simultaneously reflects the marginal willingness to accept risk and the marginal willingness to pay for greater safety. The points on XX also represent the points of tangency of firms' offer curves with workers' constant expected utility loci. The slope for the firm reflects both the marginal cost of greater safety and the marginal cost reductions from an incremental increase in risk. The slope at any point $\partial w_i/\partial p_i$ consequently represents the marginal supply price as well as the marginal demand price of risk for both the worker and firm located at that point. Econometric models that estimate a linear XX assume that the observed tradeoff rates are the same at all levels of risk.

The shape of the estimated locus of tradeoffs depends on the mix of firms and workers. The situation illustrated in Figure 1 consists of heterogeneous workers and firms. If all workers were homogeneous and, for example, had a constant expected utility locus EU_1, then the observed market combination (p_i,w_i) would consist of a series of points along EU_1 that were tangent to different firms' offer curves. The resulting estimates of XX would then approximate EU_1, and the local tradeoff rate would characterize every worker's wage-risk tradeoff at that particular risk level. Similarly, consider the case of homogeneous firms, where all firms have offer curves FF. If there are heterogeneous workers, the market tradeoff curve XX would approximate the firm's offer curve, and its slope would approximate the marginal cost of altering job risks at that risk level.

With heterogeneous workers and heterogeneous firms, as in Figure 1, XX does not provide estimates of either the offer curves or constant expected utility loci. Rather, XX reflects only a set of tangencies between different firms' offer curves and different workers' constant expected utility loci. The value of $\partial w_i/\partial p_i$ at any given point (p_i,w_i) is the local tradeoff that is pertinent to the particular worker and firm located at that risk level. The estimated tradeoff rate at different levels of risk reflects other job-worker matches.

The estimated local tradeoffs may be a misleading index of the wage differentials required to maintain a worker's constant expected utility in the presence of a major change in risk because workers' risk preferences may differ. Worker 2 is willing to accept risk p_2 for $w_2(p_2)$. However, worker 1 will require a higher amount of wage compensation $w_1(p_2)$ along EU_1 to face the risk level p_2 than worker 2 requires on EU_2. If the estimated wage-risk tradeoff curve XX for the market were linear, then the estimated rate of tradeoff would be the same for all workers whose indifference curves are tangent to XX. However, even for a linear locus of tangencies XX, for changes of more than a marginal amount from the current risk level, the worker's wage-risk tradeoff will not be the same because the pertinent tradeoff value must be measured along a constant expected utility locus, not the estimated market tradeoff curve.

[8] Inframarginal workers earn an economic rent. The wage-risk tradeoff of the marginal worker is instrumental in establishing the wage rate the firm must pay and consequently the value of the risk reduction.

General Specification Issues

The basic approach in the literature is to specify a wage equation which characterizes the line XX in Figure 1, or

$$w_i = \alpha + \sum_{m=1}^{M} \psi_m x_{im} + \gamma_0 p_i + \gamma_1 q_i + \gamma_2 q_i WC_i + u_i, \quad (1)$$

where w_i is worker i's wage rate (or its natural logarithm), α is a constant term, the x_{im} are different personal characteristic and job characteristic variables for worker i ($m = 1$ to M), p_i is the fatality risk of worker i's job, q_i is the job's nonfatal risk, WC_i reflects the workers' compensation benefits that are payable for worker i's job injury, u_i is a random error term reflecting unmeasured factors that influence the wage rate, and the remaining terms are coefficients to be estimated.[9] The x_{im} values play a key role in that different worker characteristics, such as education, will affect the firm's offer curve, the market opportunity locus, and worker preferences.[10] Figure 1 pertains to a group of workers who have identical productivity, but different preferences. Some researchers have interacted various x_{im} variables with the risk variables to capture the role of different markets for workers that differ in terms of their market opportunities.[11] Interactive terms, such as education and risk, reflect the joint influence of possible differences in worker preferences as well as differences in firms' offer curves for workers with different educational attainment. Alternative econometric approaches involving the use of structural equation systems have also been used to isolate the wage-risk tradeoff controlling for other aspects of the job and the worker.[12]

Efforts to estimate variants of equation (1) before the 1970s were largely unsuccessful because of the absence of detailed micro data sets on individual worker behavior. Large individual data sets on worker behavior generally include a more extensive set of demographic and job characteristic variables than industry data. Moreover, the values of these variables are matched to a particular worker rather than being averaged across the entire industry. If there is also available job risk data by individual (e.g., self-assessed risk data) or by occupation, one will have information on actual points (p_i, w_i) selected in individual job choices rather than an average of such points

[9] A fuller version of the model also could include annuity benefits in the event of a fatality.

[10] See Thaler and Rosen (1976), especially pp. 283–286.

[11] Although these interactions are usually to capture productivity-related influences, discrimination-based effects may also be influential as well. In any event, these interactive effects will reflect the joint influence of worker and firm variations.

[12] More recently, some economists have estimated structural equation systems. See, in particular, James Brown (1983), Shulamit Kahn and Kevin Lang (1988), Jeff Biddle and Gary Zarkin (1988), Viscusi and Michael Moore (1989), Moore and Viscusi (1990b, 1990c), and Joni Hersch and Viscusi (1990). These models, which will be discussed further below, consist of two-equation systems for which researchers have augmented equation (1) with variables such as regional variables that ideally serve to identify the market wage opportunities locus, and there is a second equation defined by the tangency of worker preferences with this market opportunities locus.

In particular, one estimates the nonlinear equation obtained after equating $\partial w/\partial p$ on both a constant expected utility locus and the market wage frontier. For this approach to be feasible, one must assume a specific functional form for the utility function. The use of regional economic variables to identify the market opportunities locus assumes that the regional differences reflect differences in economic conditions and perhaps technologies as well (e.g., logging in the Pacific Northwest, petroleum exploration in Texas and Alaska, etc.) If, however, individual preferences also vary across regions, then $\partial w/\partial p$ may also vary systematically across regions. At the current stage of development, it is not clear whether the strong estimation assumptions of structural models are satisfied to a sufficient degree to yield reliable estimates that will be robust across data sets. The emphasis here will be on traditional hedonic wage estimation because many of the econometric issues are common to the structural models as well.

across heterogeneous workers in an industry.[13]

Estimation using industry-wide data sets often encountered difficulty in distinguishing the positive wage premium for job risks. The reliance on aggregative industry data pools workers with heterogeneous preferences and firms with perhaps quite different offer curves so that the estimated tradeoffs at any particular risk level cannot be linked to any worker's preferences or any firm's offer curve. In contrast, micro data sets give information pertinent to one (p_i,w_i) point in resulting from the decisions of a single firm and worker.

One source of variation lost with aggregation is that due to differences in lifetime wealth. A negative relation between wealth and risk arises for two reasons. First, differences in worker preferences will influence this relationship because job safety is a normal economic good.[14] More affluent workers will select a lower risk level from any given wage offer schedule. The wage w_i that a worker requires to accept any given risk p_i will increase with wealth, and the wage-risk tradeoff $\partial w/\partial p$ will also increase with wealth. Employees also will have more incentive to protect their more highly skilled employees because they have a greater investment in their training.

Overall, as John Stuart Mill observed, the best jobs in society will tend to be the highest paid. However, this does not imply that there are no compensating differentials for any particular position, only that there is a broader societal wealth effect at work that will make it difficult to disentangle the wage-risk tradeoff that is present. Use of individual level data that includes measures of worker education, experience, and other productivity-related variables isolates the additional compensation workers of a given productivity will receive for jobs posing greater risk. It cannot be determined, however, whether observed differences in risk tradeoff rates reflect heterogeneity in firms' offer curves for workers with different characteristics.

The Wage Variable

It is instructive to consider each of the components of equation (1) in turn. The dependent variable is the worker's hourly wage rate. In practice, researchers have often been forced to use other income measures, such as the worker's annual income or a constructed wage value using information on weeks and average hours worked. What is particularly relevant to the worker is not the gross wage but rather the aftertax wage from a particular job. For most labor market studies this distinction is not of great consequence because the main effect of taxes is not too dissimilar from scaling up the wage rate by a factor of proportionality if workers' income levels and tax rates do not differ substantially. However, if the equation also includes a workers' compensation variable, as in the case of equation (1), then the workers' compensation benefits and the wage rate should be expressed in comparable aftertax terms so as to measure the wage effects of workers' compensation correctly.

Job Risk Measures

For most purposes, the most important of the explanatory variables is the fatality risk variable p that is the basis for estimating the worker's fatality risk-money tradeoff. The ideal risk measure would

[13] Note that a firm's offer curve *FF* in Figure 1 for one class of workers may differ than its offer curve for a different group of workers.

[14] See Thaler and Rosen (1976), Michael Jones-Lee (1976), Viscusi (1979), and Viscusi and William Evans (1990). Researchers have attempted to capture the role of wealth through interactive risk x wealth variables, where wealth has been measured directly and captured through various proxies for lifetime wealth, such as education.

reflect subjective assessment of the fatality risk of the job by both the worker and the firm. In practice, researchers have a less perfect measure. Most studies have used information from available national data sets that typically provide information on several thousand workers and their jobs. These data sets include detailed information pertaining to the worker's demographic characteristics (age, race, sex, years of schooling, health status, marital status, etc.), nature of employment (wage rate, hours worked, industry, occupation, union status, years of experience, etc.), and place of residence. The University of Michigan Survey of Working Conditions and Quality of Employment Survey also included information on the worker's job attributes, as perceived by the worker. Among these variables is whether the worker believes he faces hazards on his particular job. Usually, researchers have matched objective measures of the industry or occupation risk to the worker based on his job classification.

The degree of refinement of these risk variables varies. The pre-1971 Bureau of Labor Statistics (BLS) death risk data are published for three-digit Standard Industrial Classification (SIC) codes. Manufacturing and nonmanufacturing industries are both represented.[15] After 1971, the BLS published death risk data for one-digit SIC codes so that the available data became more aggregative. Unpublished death risk data by two-digit SIC code are also available from the agency. The National Institute of Occupational Safety and Health (NIOSH) death risk data are available by one-digit SIC industry codes for each of the states. The Society of Actuaries fatality data are based on occupational fatality risks rather than industry risks, and 37 occupations are represented in these data. The performance of these different measures differs, as will be explored below.

A fundamental issue is how systematic biases in individual risk perception affect the market processes that give rise to the compensating wage differential estimates.[16] A sizable literature in psychology and economics has documented biases in individual assessments of risk. Individuals tend to overestimate low probability events, such as the chance of being struck by lightning, and to underestimate risks of high probability events, such as the chance of dying from heart disease (see Baruch Fischhoff et al. 1981).

Because these biases are systematic, we know a great deal about their consequences. In particular, the relationship between perceived risks and actual risks is similar to that displayed in Figure 2. The perceived probability line *CD* lies above the actual probability level for

[15] Government employees are not, however, included in the BLS or NIOSH data.

[16] Labor market estimates focus on the wage that workers require to accept risks, whereas policy evaluations are based on willingness to pay for risk reduction. For sufficiently small risk changes, willingness-to-pay and willingness-to-accept values should be equal. One experimental study—Viscusi, Wesley, Magat, and Joel Huber (1987)—found substantial differences in these valuations for risk changes on the order of 5/10,000. When presented with risk changes in a survey context, individuals may require a large financial inducement to accept an increase in risk from their accustomed risk level that greatly exceeds their willingness to pay for incremental reductions in risk even though those tradeoff rates should be identical.

The source of this influence appears to be a perception bias on the part of survey respondents in which they overreact to newly identified risks. The survey results in Viscusi and Charles O'Connor (1984) and Shelby Gerking, Menno deHaan, and William Schulze (1988) suggest that these effects may not be as great for job safety contexts, perhaps in part because workers' familiarity with job risks make them less alarmed by information regarding a minor increase in risk. Explicit estimates that do this in the case of worker injury risks are provided in Viscusi and Evans (1990). Indeed, this effect is borne out in the behavior of society at large in terms of the frequent overreaction to small, but highly publicized risks. If, however, the risk changes are of more than a modest incremental amount, then the curvature of the constant expected utility locus shown in Figure 2 will also affect the tradeoff rate.

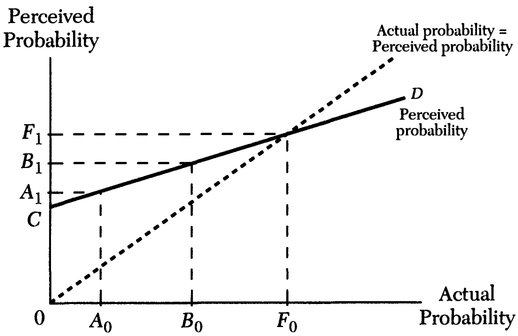

Figure 2. Relation Between Actual and Perceived Probabilities

small risks and under this amount for large risks. The role of risk perceptions is to decrease the risk change that individuals associate with any incremental change in the risk. Thus, in the case of a job that poses some specific incremental risk A_0B_0 to the worker in Figure 2, the worker will perceive this incremental increase to be a lower amount A_1B_1 and will consequently demand less compensation than he otherwise would.[17] In terms of the estimated compensating differential, workers will demand less compensation per unit of actual risk that they face because the risk increase is greater than they believe it to be. The value of $\partial w/p$ will be smaller at any given value of p (see Viscusi 1990), thus influencing the market equilibrium locus that is estimated. The net effect on the estimated value of XX depends on how these changes in the EU_i interact with the available offer curves. In addition, random measurement error in the risk variable would tend to bias the estimated tradeoffs downward, but systematic measurement error could lead to a bias in either direction.[18]

To isolate the wage premium for risk, the wage equation should include other attributes of the worker's job. Jobs that are risky tend to be unpleasant in other respects. One such variable is the other component of job risk—the nonfatal risk q indicated in equation (1). Inclusion of this variable is sometimes difficult either because of the correlation between the death risk variable and the nonfatal risk measures or because the differences in the data sources and the reference populations for which these data have been gathered may make it difficult to include both variables simultaneously. As a result, few studies in the literature include both risk measures. The exclusion of the nonfatal injury variable may lead to an upward bias in the estimated coefficient for the fatality risks if the death risk variable's coefficient captures the omitted influence of the premiums for nonfatal risks, which should be positively correlated with fatality risks.[19] In addition, a bias may result if the probability of injury is positive but the death risk is zero.

Another key risk-related variable is the workers' compensation variable indicated by qWC in equation (1). What is pertinent to the worker is the expected workers' compensation benefit.[20] Most of the early studies in the compensating differential literature did not include a workers' compensation variable, but it has been included in several recent studies discussed below. This ex post compensation variable ideally will be in terms of the expected workers' compensation benefit or some other form (e.g., expected rate of replacement of lost earn-

[17] For a more formal exploration of these issues, see Viscusi (1990).

[18] Comparison of the BLS and NIOSH data in Moore and Viscusi (1988a) suggests that the measurement error is not random in the case of the BLS data, if we use the NIOSH data as the reference point. Other biases also may be present, such as an upward bias that arises if the study omits other nonpecuniary attribute variables.

[19] Viscusi (1978a) presents estimates with and without such control variables.

[20] More formally, what the worker is truly concerned with is the insurance premium he is willing to pay for workers' compensation benefits. The expected workers' compensation value captures this for a risk-neutral worker.

ings) that takes into account the probability that the worker will actually collect the benefits. If the worker faces a job that poses zero risk, then workers' compensation benefits offer no expected welfare benefit, and consequently there will be no compensating differential.

A related issue is the role of worker uncertainty. Apart from the fact that we do not know exactly what workers' risk perceptions are, there is the additional problem that these perceptions may not be precise. Thus, workers have a subjective risk perception pertaining to the hazards posed by a job, but these perceptions may not be as tight as an objective probability.

The main consequence of this uncertainty for workers is to increase the likelihood of a worker quitting once he learns about the adverse properties of a job and revises his prior risk beliefs. This quit effect can be viewed as a generalization of the theory of compensating differentials to a situation of worker uncertainty and adaptive behavior (Viscusi 1979; Viscusi and O'Connor 1984). One measure of the magnitude of this effect is that if all industries eliminated their job risks, holding constant other aspects of the job including wages, it would reduce the manufacturing industry quit rates by one-third.[21] On a theoretical basis, the opportunity for learning and adaptive behavior should lead workers to demand less compensation per unit risk than they would if they were fully informed about the probabilities even if this information did not alter the assessed risk level (see Viscusi 1979). The reasoning behind this result is that workers in a sequential job choice situation should prefer the less precisely understood risk because they can quit if they acquire sufficiently unfavorable information about the risk, and they can remain on the job if they acquire favorable information. Employers may also respond to this quitting by raising worker wages to retain experienced workers who are aware of the risk. Empirically, the net effect is that more experienced workers on hazardous jobs receive higher compensating differentials (see Viscusi and Moore 1991).

Recognition of the Duration of Life

The standard hedonic wage equation includes the probability of death, but the amount and quality of life at risk differs.[22] For the typical healthy worker, the major difference across individuals will be in terms of the quantity of life at risk. A 20-year-old worker faces a more substantial loss from a given fatality risk than a 60-year-old worker. An offsetting influence that should also be taken into account is that there may be age-related differences in the proclivity toward risk taking, some of which may be attributable to differences in family structure. Age clearly is a factor that may potentially affect where along the market equilibrium curve XX a worker is located. If XX is nonlinear, then age may also affect the slope. Worker age may also influence the offer curves workers face as well.[23]

The simplest approach to addressing the life duration issue is to include a fatality risk variable interacted with worker age, i.e., $p \times$ worker age. This approach is used in Thaler and Rosen (1976) and

[21] Wages, of course, would also change in a competitive market. This estimate is based on the implications of quit rate regressions using data from the University of Michigan Panel of Income Dynamics, as reported in Viscusi (1979). The one-third figure (more precisely, 35% is calculated using these results in Viscusi 1983, pp. 67, 182).

[22] Richard Zeckhauser and Donald Shepard (1976) develop a quality-adjusted value-of-life concept to recognize quantity and quality differences. Economists have had more success at estimating quantity differences than quality differences.

[23] Although the earlier models with age interaction terms did not attempt to sort out both sets of influence, the structural models discussed below attempt to do this.

Viscusi (1979), with evidence of a significant negative age-risk interaction.

A refinement of this approach is to include a variable that reflects the expected years of life lost, such as $p \times$ life expectancy. This variable would capture two influences at work. First, younger workers have a longer future life at risk. Second, as we age, the expected date of death conditional upon our age is pushed out.

Although the life expectancy approach represents a refinement of simply interacting worker age with death risks, it does not recognize the role of discounting with respect to the years of life at risk. Instead of estimating the coefficient for a variable pertaining to the worker's life expectancy, one would prefer to estimate the discounted loss in life expectancy, so that the job risk variable takes the form $p(1 - e^{-rT})/r$, where r is the rate of discount and T is the remaining period of life. Assuming that the only affect of age is to influence the character of worker preferences, not firms' offer curves for risky jobs, estimation of such a model yields an estimate of the implicit value of life, the implicit value per discounted expected life year lost, and the rate of time preference that workers use in discounting years of life. Including the discounted expected loss in life expectancy in equation (1) in lieu of the job risk variable p produces an estimated rate of time preference of 10–12 percent with respect to expected life years (Moore and Viscusi 1988b). As in the case of wage-risk tradeoffs, the presence of heterogeneity of worker preferences will make this estimate a nonlinear weighted average of the individual workers' preferences.[24]

[24] Some of the more important sources of heterogeneity can be ascertained through interaction terms. For example, college-educated workers exhibit lower rates of time preference than those with less education, as one might expect.

A more elaborate alternative is to develop a model of lifetime job choice from which is derived a functional form for the worker's decision to engage in potentially hazardous work. Rosen (1988) and a series of papers by Viscusi and Moore (1989) and Moore and Viscusi (1990a, 1990b, 1990c) have explored these models. By using a structural model of the job choice process, these analyses ideally distinguish differences in worker preferences from worker characteristics that affect the market offer curve available to these workers.

Two general approaches have proven estimable.[25] One is to estimate a standard life-cycle consumption model, with the main difference being that the model recognizes that there is a probability in each period that the consumption stream may be terminated. The alternative is to construct a lifetime decision model, where the worker selects the optimal job risk from the wage offer curve, where this risk affects the probability of death in each period. One example of the latter approach is the Markov decision model in Viscusi and Moore (1989).[26] In selecting their optimal job risks, workers determine their life expectancy.[27] After assuming an explicit functional form for the

[25] Rosen's (1988) paper does not estimate the life cycle model directly, but uses the results of Thaler and Rosen (1976) in conjunction with the model to obtain estimates of the key components of interest.

[26] This variant of the model will exclude causes of death other than one's job to simplify the exposition.

[27] More specifically, let the utility of death equal to zero and assume that the worker faces a time-invariant sequence of lotteries on life and death. To recognize the dependence of the job risk data on worker i's reported industry j, p_{ij} will be used to denote the pertinent fatality risk level. Worker i selects the optimal death risk p_{ij} from the available opportunities locus $w(p_{ij})$ to maximize discounted expected lifetime utility

$$G = U(w(p_{ij}))(1 - p_{ij}) \sum_{t=1}^{\infty} [\beta(1 - p_{ij})]^{t-1},$$

where t indexes time periods and β is the discount factor (the inverse of 1 plus the interest rate).

utility function (i.e., a constant relative risk aversion utility function, $a + bw^c$), Viscusi and Moore (1989) estimate a two-equation structural system based on the local tradeoff implied by the optimization problem in which the worker selects the optimal fatality risk, and a wage equation characterizing the market opportunities locus.[28] For worker i in industry j with market opportunities affected by variables x_{im}, the market implicit price equation takes the form

$$\ln w_i = \sum_{k=1}^{4} (\phi_k R_{ik} p_{ij} + \delta_k R_{ik} p_{ij}^2) + \sum_{m=1}^{M} \psi_m x_{im} + \epsilon_i \quad (2)$$

where the R_{ik} are regional dummy variables, the first summation is over the four geographical regions, ϵ_1 is a random error term, and ϕ_k, δ_k, ψ_m are coefficients to be estimated.[29] The worker decision equation generated by this particular model is

$$\ln w_i = (1 - \beta)(1 - p_{ij}) \frac{\partial \ln w_i}{\partial p_{ij}} + \sum_{n=1}^{N} \alpha_k x_{ik} + \epsilon_2, \quad (3)$$

where β is the discount factor $1/(1 + r)$ to be estimated, ϵ_2 is a random error term, and the α_k are coefficients on the taste-shifter variables to be estimated. The value of $\partial \ln w_i / \partial p_{ij}$ is computed from the first stage market wage equation. This general estimation approach follows the procedure advocated by Kahn and Lang (1988) and Biddle and Zarkin (1988) to estimate structural hedonic systems.

In all such models, the worker selects the optimal job risk p_{ij} from among a schedule of wage-risk combinations in the workplace. From this optimization problem is derived an explicit functional form that relates the worker's rate of tradeoff $\partial w_i / \partial p_{ij}$ to various aspects of the job choice problem, including the job risk p_{ij}, the discount rate, and in models based on a finite time horizon, the worker's remaining life. Some models also include a probability of death from causes other than the job to reflect the fatality risks that a worker faces throughout his life. This nonlinear equation (3) is coupled with a second market wage equation (2) to complete the structural equation system. The estimated discount rates range from 1 to 14 percent, which are broadly consistent with financial rates of return that one might use as a reference point in assessing the rationality of intertemporal choices.

Estimation of Utility Functions

Knowledge of the shape of worker utility functions rather than a local tradeoff rate along a constant expected utility locus would provide the basis for more detailed judgments. For example, it makes possible analysis of variations in the value of life with respect to income levels and assessments of valuations of nonmarginal changes in risk. The utility function models are based on two different state-dependent utility functions. In the good health state 1, the utility function is $U(w)$, and in the ill health state, the utility function is $V(y)$, where y is the benefit paid upon death. One can make y a function

[28] Identification remains an issue. Regional dummy variables are used to identify the market wage equation based on the assumption that these variables indicate geographically distinct labor markets, but do not affect worker preferences. These regional variables include interactions with the linear and quadratic job risk variables. This identification issue is present in hedonic price models as well. See Dennis Epple (1987).

[29] This equation differs from equation (1) in that the death risk and (death risk)^2 variables are included by region. The nonpecuniary risk variable q and its interaction with workers' compensation does not appear because the NIOSH risk data pertain to fatalities only. More generally, the hedonic wage equation focuses on both supply and demand factors, whereas structural models attempt to distinguish factors reflecting tastes and opportunities using separate equations for each.

of w. In the case of fatality risks, $V(y)$ represents the worker's bequest function, which can equal zero if the worker has no beneficiaries.

Estimating utility functions involves a quite different estimation procedure than the hedonic wage equation approach, and it utilizes a different type of data as well. The concern is no longer with tracing out the locus of tangencies involving a firm's offer curve and an individual worker's constant expected utility locus. Rather, the focus is on information provided by two or more points along a particular worker's constant expected utility locus. Because natural market experiments do not provide such information, researchers have used survey evidence regarding the stated compensating differentials that the worker would require if faced with a change in job risk. This procedure leads to estimates of the state-dependent, von Neumann-Morgenstern utility functions $U(w)$ and $V(y)$ up to a positive linear transformation.

Viscusi and Evans' (1990) procedure uses worker survey data from four chemical firms that provides information on two equivalent jobs a and b along a constant expected utility locus, such as EU in Figure 3. This curve is tangent to the market offer curve ABC. The worker reports his current wage rate w_a and his assessed job risk q_a using a linear scale comparable to the BLS injury risk metric. The worker is then given a hazard warning for a chemical and told that this chemical would replace the chemicals with which he now works.[30] The worker then assesses the risk q_b associated with the transformed job and the wage rate w_b he would require to remain on EU. The income replacement after an injury, y_a

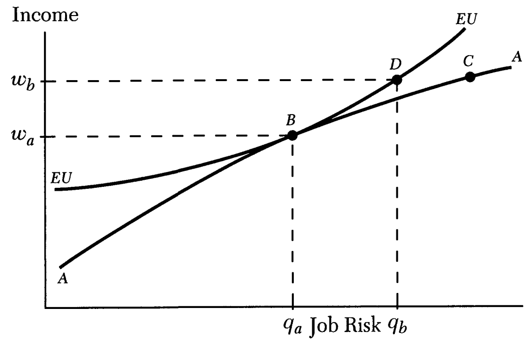

Figure 3. The Market Offer Curve and the Worker's Expected Utility Locus

and y_b, can be computed using w_a, w_b, and workers' compensation benefit formulas for the worker's state of residence. The survey addresses the components of the following equality:

$$(1 - q_a)U(w_a) + q_aV(y_a) = (1 - q_b)U(w_b) + q_bV(y_b). \quad (4)$$

All the elements of equation (4) are observable except for U and V. One must impose some structure on the utility functions to make estimations of them feasible. If we assume a specific functional form for the utility functions (e.g., logarithmic) or use a Taylor's series approximation to the general utility function, then we can solve equation (4) for the wage increase required by the worker to face the new risk, yielding an equation that can be estimated with nonlinear regression methods.[31] If we observe more than two points on a constant expected

[30] The chemicals used were TNT, asbestos, chloroacetophenone, and sodium bicarbonate. The warnings conformed with current industry practice given the properties of these chemicals. The original survey results appear in Viscusi and O'Connor (1984).

[31] Let $w_b = (1 + \delta)w_a$, where δ is the percentage wage premium for the higher risk on job b. The dependent variable in the model is δ. For the first-order Taylor's series expansion variant of the model, the parameters to be estimated are $\beta_1 = U(w_a) - V(w_a)$, $\beta_2 = U'(w_a)$, and $\beta_3 = V'(w_a)$. Thus, the estimation focuses on three parameters that characterize the nature of worker preferences. With no loss of generality one can set $\beta_2 = 1$ because von Neumann-Morgenstern utility functions are not altered by a positive linear transformation, leaving two parameters to be estimated. One can also make β_1 and β_3 functions of personal characteristics, such as education. See Viscusi and Evans (1990) for further details.

utility locus, as in Evans and Viscusi (1991), then we have an ability to estimate utility functions characterized by a larger number of parameters.

The utility function estimation procedure can explicitly recognize the role of individual heterogeneity by making the parameters of the utility function dependent on worker characteristics.[32] This ability to distinguish differences in preferences stems in part from use of data that does not confound the influence of worker and firm decisions. Only the information on multiple points (p_i, w_i) along the worker's constant expected utility locus is used. Estimates involving variation across a broad sample of worker characteristics makes possible the estimation of the dependence of the utility function parameters on personal characteristics.

3. *Review of Risk Tradeoffs in the Labor Market Literature*

Although the methodology for estimating the labor market value of life is straightforward, the empirical estimates differ substantially. Table 2 summarizes 24 principal labor market studies of the implicit value of life, where these valuation estimates are all in December 1990 dollars. These studies appear in chronological order. Robert S. Smith (1974) used industry-level data to estimate wage premiums for risk, but the other studies in Table 2 used individual worker data. The advent of large micro data sets on individual worker behavior enabled economists to isolate the role of job risks from factors such as education and experience. As Charles Brown (1980) has observed, even large micro data sets do not always resolve these estimation problems. Potentially substantial measurement error arises when the researcher creates the nonpecuniary characteristic variables by matching to the worker objective measures of job attributes, such as fatality rates, based on the worker's industry or occupation.[33]

The studies listed in Table 2 differ in a variety of respects, including the data sets as well as the wage equation specification. The initial studies in the literature consisted almost entirely of simple regressions of wage rates on risk levels, possibly interacted with worker age. Beginning with Moore and Viscusi (1988b) there was an attempt to estimate the tradeoff for discounted expected life years lost. The starkest difference among the studies consists of the structural estimation approach that is employed in differing degrees in some of the most recent studies listed in the table.[34]

The structural models focusing on the duration of life at risk assist in illuminating aspects of the lifetime job choice problem, such as workers' implicit rate of discount. However, the additional information comes at a cost. The estimation procedures often are quite complicated, and considerably greater demands are placed on the data. The risk-dollar tradeoff estimates have been less robust for these models than more straightforward estimation approaches, such as those following equation (1). As a result, I place greater emphasis upon the more conventional wage equation estimates of the risk-wage tradeoff than on the find-

[32] For the logarithmic utility function case, one might, for example, set the utility of injury equal to $\ln(w)$, and the utility of good health equal to $(\alpha + \beta_1 \text{ Education} + \beta_2 \text{ Age} + \beta_3 \text{ Sex})\ln(y)$.

[33] It should be noted that Charles Brown's (1980) effort entailed an ambitious matching of detailed information from the *Dictionary of Occupational Titles* to the workers. Another innovation is that he used panel data from the National Longitudinal Survey Young Men's sample to link wage changes to changes in job characteristics in an effort to control for omitted differences in worker ability.

[34] There were antecedents to these structural models, but not involving fatality risks. See James N. Brown (1983), Kahn and Lang (1988), and Biddle and Zarkin (1988).

ings yielded by the structural estimation models.

Although many of the studies listed in Table 2 consist primarily of replications and consistency checks on earlier results, there have been a number of important innovations in the literature. The columns in Table 2 summarize several salient dimensions of these studies. All except four of the studies rely upon large U.S. data sets, and all but two of these studies use national surveys of worker behavior.

Choice of the Job Risk Variable

Because all of these surveys include most of the demographic and job characteristic information needed to estimate the wage equation, the main distinguishing feature is the manner in which the risk variable is created. None of the sets of survey data listed includes any objective measure of the risks posed by the worker's particular job. Nor do the risk data distinguish which injuries are attributable to the job environment and which arise solely from worker actions.[35] The University of Michigan's Survey of Working Conditions and Quality Employment Survey each include a subjective risk variable, which ascertained whether the worker views the job as posing dangerous or unhealthy conditions.[36] The subjective risk perception variable p_s, which is a 0–1 dummy variable for whether the worker's job poses any health and safety risks, can be interacted with some objective measure of the risk p_0 to create a potentially more refined estimate of the risk variable ($p_s \times p_0$), as in Viscusi (1978a, 1979) and Moore and Viscusi (1988b).

Gegax, Gerking, and Schulze (1991) use a continuous measure of the worker's subjective risk of fatality derived from an interview approach analogous to the Viscusi and O'Connor (1984) study of nonfatal job injuries. However, the risk scale they presented to workers ranged from 1/4,000 to 10/4,000.[37] Because the average U.S. fatality risk of 1/10,000 lies outside the range, the risk interval used was likely to generate overestimates of the job risk. Not surprisingly, their respondents' assessed job risks were very high; their white-collar subsample assessed the annual job fatality risk as 1/2,000.[38]

The dominant approach followed in the literature is to rely upon some published measure of the risk level by occupation or industry, and then to match this risk variable to the worker in the sample using information provided by the respondent. The study by Thaler and Rosen (1976) used Society of Actuaries data pertaining to the risk associated with different occupations, as did Charles Brown (1980) and Arnould and Nichols (1983). These data pertain primarily to high risk occupations with average annual risks of death on the order of 1/1,000—roughly ten times the average for the U.S. work-

[35] Making such distinctions is difficult because workplace technologies and worker safety precautions jointly determine the risk. If all accidents were due to worker carelessness and would have arisen in all other contexts in which the worker was employed, then no wage premiums for risk would be observed.

[36] These data sets have been analyzed by Viscusi (1978a, 1979), Dillingham (1985), Leigh (1987), and Moore and Viscusi (1988b), but not all of these researchers have used the subjective risk variable. Also see the nonfatal risk study of Biddle and Zarkin (1988). None of the data sets include measures of the employer's perceptions, which are relevant to the shape of the offer curve.

[37] Respondents could select one of ten integer responses ranging from 1/4,000 to 10/4,000. The average U.S. job fatality risk is not in this range.

[38] The upward bias in risk assessments in turn will tend to produce low estimates of the value of life, as appears to be the case. The higher value-of-life estimates for changes in risk generated by the same survey instrument, as reported in Gerking, deHaan, and Schulze (1988), are also consistent with overestimation of the base job risk level.

TABLE 2

SUMMARY OF LABOR MARKET STUDIES OF THE VALUE OF LIFE

Author (Year)	Sample	Risk Variable	Mean Risk	Nonfatal Risk Incl?	Workers' Comp Incl?	Avg Income Level (1990 U.S. $)	Implicit Value of Life ($ million)	Implicit Value of Life for Air Travelers ($ million)
R. S. Smith (1974)	Industry data: Census of Manufacturers, U.S. Census, Employment and Earnings	Bureau of Labor Statistics (BLS)	NA	Yes	No	22,640	7.2	11.0
Thaler & Rosen (1976)	Survey of Economic Opportunity	Society of Actuaries	0.001	No	No	27,034	0.8	1.0
R. S. Smith (1976)	Current Population Survey (CPS), 1967, 1973	BLS	0.0001	Yes, not signif.	No	NA	4.6	NA
Viscusi (1978a, 1979)	Survey of Working Conditions, 1969–1970 (SWC)	BLS, subjective risk of job (SWC)	0.0001	Yes, signif.	No	24,834	4.1	5.7
Charles Brown (1980)	National Longitudinal Survey of Young Men 1966–71, 1973	Society of Actuaries	0.002	No	No	NA	1.5	NA
Viscusi (1981)	Panel Study of Income Dynamics, 1976	BLS	0.0001	Yes, signif.	No	17,640	6.5	12.8
Craig Olson (1981)	CPS 1978	BLS	0.0001	Yes, signif.	No	NA	5.2	NA
Alan Marin & George Psacharopoulos (1982)	U.K. Office of Population Censuses and Surveys, 1977	Occupational Mortality U.K.	0.0001	No	No	11,287	2.8	8.1
Richard Arnould & Len Nichols (1983)	U.S. Census	Society of Actuaries	0.001	No	Yes	NA	0.9	NA
Richard Butler (1983)	S.C. Workers' Compensation Data 1940–69	S.C. Workers' Compensation Claims Data	0.00005	No	Yes	NA	1.1	NA
J. Paul Leigh & Roger Folsom (1984)	Panel Study of Income Dynamics, 1974; Quality of Employment Survey (QES) 1977	BLS	0.0001	Yes	No	27,693, 28,734	9.7 10.3	11.0 11.7
V. Kerry Smith and Carol Gilbert (1984)	CPS 1978	BLS	NA	No	No	NA	0.7	NA
Alan Dillingham (1985)	QES 1977	BLS; Constructed by author	0.000008, 0.00014	No	No	20,848	2.5–5.3; 0.9	4.2–8.8; 1.5

Leigh (1987)	QES 1977; CPS 1977	BLS	NA	No	No	NA	10.4	NA
Moore & Viscusi (1988a)	Panel Study of Income Dynamics, 1982	BLS, NIOSH National Traumatic Occupational Fatality Survey	0.00005, 0.00008	No	Yes	19,444	2.5, 7.3	4.6, 13.4
Moore & Viscusi (1988b)	QES 1977	BLS, discounted expected life years lost; subjective risk of job (QES)	0.00006	No	Yes	24,249	7.3	10.5
John Garen (1988)	Panel Study of Income Dynamics, 1981–82	BLS	NA	Yes	No	NA	13.5	NA
Jean-Michel Cousineau, Robert Lacroix & Anne-Marie Girard (1988)	Labor, Canada Survey, 1979	Quebec Compensation Board	0.00001	No	No	NA	3.6	NA
Viscusi & Moore (1989)	Panel Study of Income Dynamics, 1982	NIOSH National Traumatic Occupational Fatality Survey, Structural Markov Model	0.0001	No	No	19,194	7.8	14.1
Moore & Viscusi (1990a)	Panel Study of Income Dynamics, 1982	NIOSH National Traumatic Occupational Fatality Survey, Structural Life Cycle Model	0.0001	No	No	19,194	16.2	29.4
Moore & Viscusi (1990b)	Panel Study of Income Dynamics, 1982	NIOSH National Traumatic Occupational Fatality Survey, Structural Integrated Life Cycle Model	0.0001	Yes	Yes	19,194	16.2	29.4
Thomas Kniesner and John Leeth (1991)	Two-digit mgf. data, Japan, 1986	Yearbook of Labor Statistics, Japan	0.00003	Yes	No	34,989	7.6	7.5
	Two-digit mfg. data, Australia, by state, 1984–1985	Industrial Accident data, Australia	0.0001	Yes	Yes	18,177	3.3	6.3
	CPS U.S., 1978	NIOSH (National Traumatic Occupational Fatality Survey)	0.0004	Yes	Yes	26,226	0.6	0.8
Henry Herzog & Alan Schlottman (1987)	U.S. Census, 1970	BLS	NA	No	No	NA	9.1	NA
Douglas Gegax, Gerking, and Schulze (1991)	Authors' mail survey, 1984	Worker's assessed fatality risk at work	0.0009	No	No	NA	1.6	NA

Note: All values are in December 1990 dollars
NA = Not available

place. To the extent that workers who select themselves into high risk jobs have a lower risk-dollar tradeoff than workers in higher risk jobs, one would expect to obtain lower value-of-life estimates in studies that use these data, as Thaler and Rosen (1976) recognize.[39] In addition, the Society of Actuaries data pertain to all incremental mortality risks associated with people in 37 different occupations, not simply the job-specific risk. Thus, this variable also reflects risks other than those on the job, which would not be compensated through the wage mechanism. Actors, for example, have a very high mortality rate.

The lower value-of-life estimates obtained using the Society of Actuaries data rather than data for workers in less risky jobs is consistent with the self-selection of individuals with low risk-dollar tradeoffs into the most hazardous pursuits. The substantial variation in the value-of-life estimates in Table 2 with the risk level, which is a consequence of the joint influence of worker and firm heterogeneity, suggests that one should exercise substantial caution in extrapolating estimates across risk ranges.

Twelve of the studies listed in Table 2 use the BLS risk data based on the risks associated with different industries. The BLS risk measure is positively correlated with workers' subjective risk assessments in the Survey of Working Conditions. Moreover, the BLS objective industry risk measure and the worker-specific subjective risk variable yield estimates of the annual risk premium that are not significantly different from one another (see Viscusi 1979a; Viscusi and O'Connor 1984; and Gerking, deHaan, and Schulze 1988).

The BLS risk measure has changed over time.[40] After the advent of the OSHA, the reporting system for all injuries changed so that BLS risk data beginning in 1972 are not comparable with the earlier data. Studies such as Robert S. Smith (1974, 1976) and Viscusi (1978a, 1979) use the pre-OSHA industrial fatality data, whereas more recent studies using BLS data have relied upon the post-OSHA data.

The main deficiency of industry-based data is that they pertain to industry-wide averages and do not distinguish among the different jobs within that industry; perceptional differences in risk are also not recognized. To promote greater pertinence of the risk measures to the jobs in the survey, some researchers have restricted the sample composition by, for example, limiting it to males or blue-collar workers, for whom the risk data are more relevant.[41] Additional limitations of the BLS data are that the reporting may not be complete, and occupational diseases are underrepresented.

The National Institute of Occupational Safety and Health sought to reduce the measurement error associated with the industry level fatality data through its National Traumatic Occupational Fatality Survey. This survey yielded new data on industrial fatality rates that have been

[39] Some initial efforts to address the role of these worker differences included the interaction of the risk variable with demographic characteristic variables.

[40] An interesting and so far unexplored issue is whether the change in the BLS reporting system altered the risk data in a manner that affected workers' risk beliefs. The most that is available is a comparison of the wage premiums generated by the different risk measures.

[41] Many studies have obtained significant estimates of wage premiums without such restrictions. However, there remains an important need both for better risk measures as well as more detailed assessments of the value of other nonpecuniary aspects of the job so that the estimates will represent premiums for risk rather that job attributes correlated with risk. The Quality of Employment Survey and Survey of Working Conditions do provide detailed nonpecuniary attribute data, but the risk variable is categorical (does the worker's job expose him to dangerous or unhealthy working conditions?) rather than continuous.

TABLE 3
FATALITY RATE DATA BY INDUSTRY

Industry	BLS Fatality Rate per 100,000 Employees	NIOSH Fatality Rate per 100,000 Employees
Mining	35.4	30.1
Construction	23.9	23.1
Agriculture, Forestry, and Fisheries	17.5	20.3
Transportation, Communication, Electricity	16.8	19.5
Manufacturing	4.2	4.2
Retail Trade	2.9	1.8
Wholesale Trade	2.9	1.1
Services	2.4	2.9
Finance, Insurance, Real Estate	1.9	1.3
Public Sector	NA	NA

Source: Bureau of Labor Statistics (1985), using data for 1982–1983 combined; and data from the National Institute for Occupational Safety and Health (1987).
NA = Not Available

used in four recent studies by Moore and myself, which are reported at the end of Table 2, and by Kniesner and Leeth (1991).

Table 3 summarizes the BLS and NIOSH fatality rates per 100,000 workers for major industry groups. The overall size of the risk is on the order of 1/10,000, with agriculture, mining, construction, and transportation representing above average risk industries. The direction of the risk differences between the BLS and NIOSH data varies by industry. Differences in sampling procedure may account for the discrepancy. The BLS data are based on a sample of industry reports to the agency, whereas the NIOSH data are based on a comprehensive census of death certificates to identify job-related fatalities. In practice, the main difference is that estimates of the wage-risk tradeoff based on NIOSH data are roughly twice as large as those of the BLS data, which is consistent with the effect of greater random measurement error with the BLS measure offsetting the influence of the underreporting of injuries with the BLS data.[42]

Nonfatal Risks and Other Job Attributes

An important dimension on which the studies in Table 2 differ is the set of other job characteristic variables included in the equation. Omission of nonpecuniary attributes of the job may bias the estimated risk coefficient. Most studies attempt to control for these influences using sets of occupational or industry dummy variables. In addition, several of these studies include a measure of the nonfatal risk associated with the job.

The studies by Viscusi (1978a, 1979) were the first to obtain an estimate of a statistically significant value of compensation for injuries as well as fatalities. These studies also included a comprehensive set of nonpecuniary job characteristics, including whether the worker was a supervisor, the speed of work, whether the worker made decisions on the job, whether the job requires the worker not make mistakes, job security, overtime work, worker training, and a dummy variable for the worker's occupation.

The chief recent addition to the wage equation has been the inclusion of a workers' compensation variable, beginning with the studies by Butler (1983) and by Arnould and Nichols (1983). In practice, inclusion of this variable has raised the estimated wage-risk tradeoff. Although most studies in the literature have used state average benefit mea-

[42] See Moore and Viscusi (1988a). Suppose that we observe q_i^* instead of measuring the actual risk of q_i, where $q_i^* = q_i + v_i$. The usual random measurement error model assumption is that v_i has zero mean and constant variance, in which case the coefficient on q_i^* will be biased downward from its true value.

sures, Viscusi and Moore (1987) and their subsequent work included an individual-specific workers' compensation variable calculated based on the state benefit formulas in conjunction with the worker's demographic characteristics. This variable was interacted with the risk on the worker's job so that it was the expected workers' compensation benefit (or more specifically, the expected rate of replacement of lost earnings), which is a more pertinent measure than the overall state benefit average.

Survey Differences in Worker Earnings Levels

As the average earnings level data in Table 2 indicate, the sample composition has varied considerably. This distinction is important because what these studies yield is an estimate of the implicit wage-risk tradeoff that is pertinent to a particular segment of the population and cannot necessarily be generalized to the population at large. The standard ex post measure of economic damages for accidents—the present value of earnings—varies proportionally with income. One would also expect some earnings variation in the wage-risk tradeoffs, which are related to the compensation required for injury prevention. In particular, if w, p, and q are defined in terms of annual earnings and annual risk, then the tradeoff $\partial w/\partial p$ is the implicit value per statistical life and $\partial w/\partial q$ is the implicit value per statistical injury. Viewed somewhat differently, the statistical value of life is the total amount of compensation n workers would require to face one expected death from their group, where n is a large number. The implicit values of life evaluated at the sample mean risk levels appear in the second-to-last column of Table 2. Using survey data that provided information on the two points along EU indicated in Figure 3, Viscusi and Evans (1990) calculated the elasticity of $\partial w/\partial q$ with respect to earnings, which was approximately 1.0. The calculations below assume that a unitary income elasticity also pertains to $\partial w/\partial p$.

To see how one might apply the value-of-life estimates to a different group, suppose that we are valuing the benefits from improved aviation safety. The average passenger on a U.S. airline has a median income level of $32,840, which is considerably higher than the income levels listed in Table 2 (see The Gallup Organization 1989). Extrapolating Thaler and Rosen's (1976) values to this income group would yield a value per life of $1.0 million.[43] Those in Viscusi (1978a, 1979) would rise to $5.7 million. The results from the U.K. by Marin and Psacharopoulos (1982) would be even higher—$8.1 million—even though their estimates for workers in the U.K. are lower than in most studies of U.S. workers. The final column in Table 2 summarizes the implied value-of-life estimates for the typical airline passenger.

The Value-of-Life Range

As the implicit value-of-life estimates in Table 2 indicate, the estimated wage-risk tradeoff varies considerably across data sets and methodologies. Some heterogeneity is expected. The value of life is not a universal constant, but reflects the wage-risk tradeoff pertinent to the preferences of the workers in a particular sample. The mix of workers in these samples is quite different. The majority of the estimates in Table 2 are in the $3 million—$7 million range.

The results that I place the greatest reliance on for the typical worker are those in Viscusi (1978a, 1979), which include the most comprehensive set of non-

[43] These calculations used the income levels and value of life estimates reported in Table 2 and scaled up the estimates proportionally with the income of airline passengers relative to the average sample member's income.

pecuniary characteristic variables, and the NIOSH data results in Moore and Viscusi (1988a). Other studies are better suited to estimating the value of life for workers in high risk jobs (Thaler and Rosen 1976) or workers in other countries.

Perhaps the best way to interpret these studies is that there is a value-of-life range that is potentially pertinent. The wage-risk relationship is not as robust as is, for example, the effect of education on wages.[44]

4. *The Implicit Value of Injury Based on Labor Market Studies*

Estimation Issues

As in the case of fatalities, the principal source of evidence on risk-dollar tradeoffs for nonfatal injuries is labor market data. The procedure for measuring the wage premium for nonfatal risks parallels that for fatalities.

Ideally, one would like to distinguish the compensation for fatality risks from that for nonfatal risks. In practice, estimation of significant wage premiums for both a fatal risk measure and a nonfatal risk measure has proven difficult.

Two types of problems arise. First, if there is a strong positive correlation between fatal and nonfatal risk measures for the industry, which are then matched to the individual worker, then it will be hard to disentangle the premiums associated with each of these risk measures. Second, recent studies have begun to rely upon the NIOSH fatal accident data rather than the BLS accident data. Because there is no nonfatal injury variable counterpart to the NIOSH data, whereas there was such a counterpart for the BLS data, there is no ideal pair of variables gathered by government agencies that covers both classes of accidents. Attempts to include a NIOSH fatality risk variable in equations with BLS nonfatal risk measures have thus far not led to significant estimates for both sets of coefficients, perhaps due in part to the different reporting bases and methodologies used in gathering these accident statistics. Exclusion of the fatality risk measure from a nonfatal risk equation will tend to bias the estimates of the fatality risk premium upward, whereas random measurement error that arises from matching up an industry injury risk measure to an individual based on the reported industry will tend to bias the estimated value of the injuries downward.

Estimates of Wage-Injury Risk Tradeoffs

Table 4 summarizes 17 studies that have estimated statistically significant wage premiums for job injury risk, where these are the $\partial w/\partial q$ values evaluated at the mean sample risk.[45] For 14 of these 17 studies it is possible to compute an implicit value of job injuries based on the data presented by the authors.[46]

The studies in Table 4 do not pertain to a homogeneous class of nonfatal injuries. In some cases, the injuries reflect only those accidents that led to a loss in work, whereas in other instances less se-

[44] One possible policy approach might be to calculate the discounted costs per expected life saved and then to ascertain whether this figure is reasonable given the range of plausible value of life estimates that have been obtained in the literature.

[45] Some researchers have reported that statistically significant estimates could not be obtained. For example, Moore and Viscusi (1990a) estimated significant premiums for fatalities but not for nonfatal injuries when the BLS nonfatal accident risk variable was added to a regression including the NIOSH death risk variable. The different sources for and definitions of the two risk measures create potential problems of multicollinearity.

[46] For example, one cannot estimate the implicit value of an injury for a log wage equation without knowing the average wage level in the sample. Daniel Hamermesh and John Wolfe (1990) obtain significant estimates of the wage premiums for the frequency and duration of injuries, but they do not report an estimate of the implicit value of an injury. They do find a stronger effect of injury duration than injury frequency.

TABLE 4

SUMMARY OF LABOR MARKET STUDIES OF JOB INJURIES

Author (Year)	Sample	Nonfatal Risk Variable	Mean Injury Risk	Fatality Risk Included?	Workers' Comp Included?	Average Income Level ($1990)	Implicit Value of Injury	Implicit Value of Injury for Air Traveler ($ millions)
Viscusi (1978a, 1979)	Survey of Working Conditions, 1969–1970	BLS nonfatal injury rate, 1969 (pre-OSHA)	.032	Yes	No	$24,800	$20,038–$38,560	$26,450–$50,899
Viscusi (1978b)	Survey of Working Conditions, 1969–1970	BLS nonfatal injury rate, 1969 (pre-OSHA)	.032	No	No	$24,800	$47,993–$49,322	$63,351–$65,105
Olson (1981)	Current Population Survey, 1973	BLS total lost workday accident rate, 1973	.035	Yes	No	$27,686	$18,725–$25,194	$22,283–$29,981
Viscusi (1981)	Panel Study of Income Dynamics, 1976	BLS lost workday injury rate, 1976	.032	Yes	No	$23,656	$46,200	$64,136
Butler (1983)	S.C. Workers' Compensation data, 1940–1969	S.C. workers' compensation injury days data	.061 (claims rate)	No	Yes	$12,403	$730/day or $13,140 for an 18 day injury	$1,933/day
Dorsey & Walzer (1983)	Current Population Survey, 1978	BLS nonfatal lost workday injury incidence rate, 1976	.030	Yes, in some equations	Yes	NA	Not reported, can't calculate	NA
Smith, V. K. (1983)	Current Population Survey, 1978	BLS work injury rate	.078	No	No	$25,338	$27,675	$35,869
Leigh & Folsom (1984)	Panel Study of Income Dynamics, 1974; Quality of Employment Survey, 1977	BLS nonfatal injury rate	.074, .066	Yes	No	$27,693, $28,734	$77,547–$89,403	$92,281–$106,390
Viscusi & O'Connor (1984)	Authors' chemical worker survey, 1982	Workers' assessed injury and illness rate	.10	No	No	$29,357	$13,810–$17,761	$15,467–$19,892

TABLE 4 (Continued)
SUMMARY OF LABOR MARKET STUDIES OF JOB INJURIES

Author (Year)	Sample	Nonfatal Risk Variable	Mean Injury Risk	Fatality Risk Included?	Workers' Comp Included?	Average Income Level ($1990)	Implicit Value of Injury	Implicit Value of Injury for Air Traveler ($ millions)
Viscusi & Moore (1987)	Quality of Employment Survey, 1977	BLS lost workday injury rate, BLS total injury rate	.038, .097	No	Yes	$33,928	$55,100 lost workday accident; $21,800 for nonpecuniary loss-lost workday accident; $35,400 per accident	$53,447 lost workday accident; $21,146 for nonpecuniary loss-lost workday accident; $34,338 per accident
Biddle & Zarkin (1988)	Quality of Employment Survey, 1977	BLS nonfatal lost workday injury incident rate, 1977	.037	No	No	$32,889	$131,495 (willing to accept), $121,550 (willing to pay)	$131,299 (willing to accept), $121,368 (willing to pay)
Cousineau, Lacroix & Girard (1988)	Labor Canada Survey, 1979	Quebec compensation board occupational injury rates	.069	Yes	No	NA	Not reported, can't calculate	NA
Garen (1988)	Panel Study of Income Dynamics, 1981–1982	BLS nonfatal injury rate, 1980–1981	NA	Yes	No	NA	$21,021	
Hersch & Viscusi (1990)	Authors' survey in Eugene, OR 1987	Workers' assessed injury rate using BLS lost workday incidence rate scale	.059	No	No, same state	$17,078	$56,537 (full sample); $30,781 (smokers); $92,245 (seatbelt users)	$108,551 (full sample); $59,100 (smokers); $177,110 (seatbelt users)
Viscusi & Evans (1990)	Viscusi and O'Connor chemical worker survey, 1982	Utility function estimates using assessed injury and illness rate	.10	No	No	$29,482	$18,547 (marginal risk change); $28,880 (certain injury)	$20,660 (marginal risk change); $32,169 (certain injury)
Michael French & David Kendall (1992)	Current Population Survey, 1980, railroad industry only	Federal Railroad Administration injury data	.048	No	No	$36,097	$38,159	$34,716
Kniesner & Leeth (1991)	Current Population Survey, 1978	BLS lost workday accident rate	.055	Yes	Yes	$26,268	$47,281	$57,110

vere injuries may be included. There are other differences as well, as some sets of injury data pertain to average reported industry risk levels, whereas others are subjectively assessed injury risks.

The first of the injury variables used was the BLS injury rate data gathered before the advent of the OSHA and the institution of the new reporting system (see Viscusi 1978a, 1978b, 1979). The second injury variable used is the total BLS reported accident rate. Studies using these data capture all job injuries, including those that are not severe enough to lead to the loss of a day of work (see Viscusi 1981; Olson 1981; V. K. Smith 1983; Leigh and Folsom 1984; Viscusi and Moore 1987; and Garen 1988). To capture injuries of greater severity, some studies have used only the lost workday injury component of the reported BLS nonfatal accident statistics (see Viscusi and Moore 1987; and Kniesner and Leeth 1991).

Two studies have used subjective risk perception variables based on workers' assessed risk, where the risk scale presented to the workers was patterned after the BLS objective risk measure described above. Viscusi and O'Connor's (1984) reference scale was based on the overall reported BLS injury rate, and Joni Hersch and Viscusi's (1990) scale was based on the BLS lost workday accident rate. These two studies provide the values of workers' subjective risk perceptions that are the counterparts of the two currently maintained BLS injury rate series.[47]

The two exceptions to the standard hedonic wage equation approach are those that have attempted to explore more fully the character of individuals' utility functions. Biddle and Zarkin (1988) attempted to impose greater structure on the estimation process by taking into account the constraints imposed by the tangency of individual utility functions with the market offer curve. They jointly estimate a two-equation structural system similar in spirit to that described above for Viscusi and Moore (1989). The first equation is the hedonic income locus—the envelope of the firms' isoprofit curves for the annual income offers Y for jobs of different risk. The second equation is the first-order condition that equates $\partial Y/\partial p$ for the hedonic income locus and the worker's utility function, which they assume to be a translog utility function.

The other nonfatal risk study that does not consider a standard wage equation is Viscusi and Evans (1990). They explicitly estimate individual utility functions in good and ill health following Equation (4) using survey data in which responses to a hazard warning and baseline job information make it possible to observe two points along a constant expected utility locus.

Several additional insights are provided by knowledge of the individual utility functions. First, job accidents lower the marginal utility of income.[48] Job injuries consequently alter the structure of preferences and cannot be treated as tantamount to a monetary loss. Their estimates imply that less than full insurance of income loss (i.e., 85 percent replacement rate) is optimal. Second, differences between willingness-to-accept values for risk increases and willingness-to-pay amounts for risk reductions of a magnitude of .01 are very minor—under

[47] Two other studies have used other risk data that are more specific in nature. Butler (1983) analyzed employment data for South Carolina workers using workers' compensation data for injuries that are severe enough to be filed in the workers' compensation system in South Carolina. French and Kendall (1992) relied upon Federal Railroad Administration injury rate data to derive estimates of the implicit value of job injuries.

[48] For the logarithmic utility function cases Viscusi and Evans (1990) found that $U(w) = 1.077 \log w$ and $V(y) = \log y$, where the coefficient for $\log y$ was constrained to be unity (no loss of generality).

one percent. The extent of the risk change is, however, consequential, as the implicit value per statistical injury is much greater for large increases in risk.[49] Third, the paper estimated the elasticity of the value of job injuries (measured in terms of the risk-dollar tradeoff $\partial w/\partial q$) with respect to earnings as being approximately 1.0.[50] This estimate was the basis for the extrapolation of the value of injury statistics to reflect other earnings levels in Table 2 and Table 4. Injury valuation results for individuals with income comparable to that of airline passengers appear in the final column of Table 4.

The wage-risk tradeoffs tend to be greater for more severe types of injuries. Most of the estimates based on data for all injuries regardless of severity are clustered in the $25,000–$50,000 range. The values obtained using the lost workday injury variable tend to be somewhat greater. This risk measure excludes temporary injuries that are not sufficiently severe to lead to loss of one or more days of work. The value of lost workday injuries is in the area of $50,000, or at the high end of the range for estimates for the implicit value of injuries overall. The subjectively assessed counterparts of the total injury rate in Viscusi and O'Connor (1984) and the lost workday risk in Hersch and Viscusi (1990) also are consistent with these patterns.

Hersch and Viscusi's (1990) study also provides estimates of differences in the implicit value of risk for different segments of the population, illustrating the influence of differences in preferences on estimated wage-risk tradeoffs. Their analysis used both a conventional wage equation as well as a two-equation structural model. Revealed differences in risk-taking behavior affect the risk premium estimates in the expected direction, as the implicit value of injury is $30,781 for smokers, $56,537 for the full sample, and $92,245 for seat belt users.

The two studies that report estimated implicit values of injury obtained using other types of data also yield similar estimates. After adjusting for income level differences, Butler's (1983) results for the typical airplane passenger imply an injury value of $34,794. The study of railroad worker injuries by French and Kendall (1991) yields an implicit value per injury of $38,200—or $34,716 for the typical airplane passenger's income level—which is very much in the range of the aforementioned studies of job injury.

5. *Other Market Evidence on Implicit Tradeoffs*

Other market transactions could be used to estimate the tradeoff value. In our consumption, transportation, and recreational activities, we take a variety of risks. If the risk component and the offsetting benefits of these activities is identified, then the money-risk tradeoff may be estimated.

The advantage of labor market studies is that we observe the workers' incomes and wages, and we have available risk measures that distinguish risk levels across individuals. The main disadvantage of the nonlabor market studies is that either the risk facing the individual or the monetary value of the attribute (e.g., travel time) is not observed so that the researcher must impute at least one

[49] For an annual accident probability change of +.01, the implicit value of injury is $13,401 (logarithmic utility) and $9,299 (Taylor's series), and for a risk increase of +.915, these values rise to $20,777 and $16,213 respectively. Valuations are in 1982 prices.

[50] If we let w represent annual earnings, z be defined as $\partial w/\partial q$, then the income elasticity of the value of injuries ν is given by $\nu = \frac{w}{z}\frac{\partial z}{\partial w}$. For logarithmic utility functions, $\nu = 1.10$, and for a second-order Taylor's series approximation to a general utility function, $\nu = .67$.

TABLE 5
SUMMARY OF VALUE OF LIFE STUDIES BASED ON TRADEOFFS OUTSIDE THE LABOR MARKET

Author (Year)	Nature of Risk, Year	Component of the Monetary Tradeoff	Average Income Level	Implicit Value of Life ($ millions)
Debapriya Ghosh, Dennis Lees, & William Seal (1975)	Highway speed-related accident risk, 1973	Value of driver time based on wage rates	NA	.07
Glenn Blomquist (1979)	Automobile death risks, 1972	Estimated disutility of seat belts	$29,840	1.2
Rachel Dardis (1980)	Fire fatality risks without smoke detectors, 1974–1979	Purchase price of smoke detectors	NA	0.6
Paul R. Portney (1981)	Mortality effects of air pollution, 1978	Property values in Allegheny Co., PA	NA–value of life for 42-year-old male	0.8
Pauline Ippolito & Richard Ippolito (1984)	Cigarette smoking risks, 1980	Estimated monetary equivalent of effect of risk information	NA	0.7
Christopher Garbacz (1989)	Fire fatality risks without smoke detectors, 1968–1985	Purchase price of smoke detector	NA	2.0
Atkinson & Halvorsen (1990)	Automobile accident risks, 1986	Prices of new automobiles	NA	4.0

Note: All values in December 1990 dollars.

component of the tradeoff. These studies consequently provide a less direct and probably less reliable measure than labor market estimates.

Nevertheless, even if the labor market estimates are more accurate reflections of the market tradeoff, the evidence from product markets is valuable as well. Obtaining estimates of the value of life and health in a variety of risk contexts should enhance our confidence in the existence of such tradeoffs. Moreover, because these different risk contexts often involve individuals with different preferences facing different magnitudes of risk than those posed by jobs, this evidence is of independent interest.

Table 5 summarizes the components of seven different studies in the literature. The tradeoffs involve the choice of highway speed, installation of smoke detectors, cigarette smoking, property values, and automobile safety. Many of these choices involve discrete safety decisions. Will the consumer purchase a smoke detector? Such studies provide a lower bound on the value of life, but will not provide information about the consumer's total willingness to pay for safety, because with such discrete decisions consumers are not pushed to the point where the marginal cost of greater safety equals its marginal valuation.

A major difference among the studies is the observability of the monetary component of the tradeoff. An example of a study that closely parallels the labor market analysis in terms of having reliable information on the monetary component of the tradeoff is that of Scott E. Atkinson and Robert Halvorsen (1990). The dependent variable in their hedonic price model is the car's purchase price, which is the analog of the wage variable. The explanatory variables consist of product market counterparts of the job characteristics (e.g., *Consumer Reports* ratings of comfort, EPA fuel efficiency ratings) and individual characteristics (e.g., age and gender of drivers). The risk variable is the occupant fatality rate for the automobile model, and the coefficient of this variable defines the price-risk tradeoff, which they estimate to be $4.0 million per life. Their study provides the most comprehensive analysis of risk-dollar tradeoffs outside the labor market.

Many of the other studies use imputed values of the monetary component of the risk tradeoff, potentially introducing another source of error. Consider, for example, Glenn Blomquist's (1979) imaginative analysis of the decision to wear a seat belt. The risk involved pertains to the reduced risk of fatality associated with the wearing of seat belts. Before the advent of state mandatory seat belt laws, only 17.2 percent of the population always used seat belts, 9.7 used the belt most of the time, 26 percent used the belts sometimes, and 46.6 percent never used seat belts.[51] The major issue in this analysis is the value attached to the time and inconvenience costs of wearing a seat belt, which are not directly observable.

The monetary component of the risk tradeoff analyzed by Blomquist (1979) is the value of time required to buckle a seat belt, which he estimates at eight seconds per use. Valued at the driver's wage rate, he estimates the annual disutility cost to be $45.[52] Blomquist's value-of-life estimate is lower than most labor market estimates, perhaps in part because of the presence of other nonpecuniary costs (e.g., discomfort) and possible driver underestimation of the risk reduction of seat belt use. For example, Arnould and Henry G. Grabowski (1981) find that these precautions are suboptimal, given the benefits and costs of seat belt use.[53] One explanation for possibly suboptimal precautionary behavior is that the perceived risk function is flatter than the actual risk perception function in Figure 2. Risk reductions from B_0 to A_0 are viewed as being a smaller amount—from B_1 to A_1. Such misperceptions will lead individuals to take a suboptimal amount of precautions. Market estimates will understate the implicit value of life that would prevail if individuals were fully rational or informed.

Capital market contexts also may provide evidence on the value of life. Ivy Broder (1990) found that industrial fatalities such as airplane crashes and hotel fires were valued by stockholders at $50 million per death. This high estimate reflects private valuations of risk by consumers of the firm's products, the total cost of tort awards, and possibly a lowered assessment of the overall quality of the firm's operations as well.

6. *Surveys and Contingent Valuations*

Market-based evidence on risk tradeoffs offers the considerable strength that it is based on the actual risk-taking decisions individuals make. Revealed preferences toward risk are a potentially

[51] These 1983 data are for persons five years old and over. See the U.S. Department of Commerce, (1986), p. 604.

[52] This approach is similar in spirit to the approach used in highway speed-travel time tradeoff analysis of Ghosh, Lees, and Seal (1975).

[53] Their analysis does not address the nonpecuniary costs of seat belts, however, and consequently is not conclusive.

useful basis for inferring the price that individuals attach to improved safety.

The above review of these estimates identified a series of potential shortcomings. Chief among these are the following. First, the tradeoff values are pertinent only in a local range.[54] Analysis of nonincremental risk changes or other fundamental policy questions, such as how the local tradeoff rate will change if the individual's base level of risk is altered, cannot be addressed. Second, there remain substantial estimation issues regarding the identification and meaning of the risk premium estimates. The usual studies of a single risk-wage tradeoff, for example, ignore the substantial heterogeneity across individuals in their attitudes toward risk. Third, there is an important class of econometric problems pertaining to whether the researcher has in fact isolated the risk-money tradeoff. In the case of labor market studies, there are other nonpecuniary aspects of the job correlated with riskiness that one must also take into account to isolate the risk tradeoff. Many of the product market studies encounter similar difficulties, with the added complication that it is often necessary to impute the monetary component of the tradeoff. Furthermore, all of these results are premised on an assumption of individual rationality. If individuals do not fully understand the risk and respond to risks in a rational manner, then the risk tradeoff that people are actually making may not be those that researchers believe they are making based on objective measures of the risk. Finally, market studies of risk are limited to a narrow range of health outcomes.

Survey methods that elicit individual willingness to pay for greater safety or compensation required to bear an increase in the risk level may avoid these problems. Figure 3 illustrates a market wage opportunities frontier *ABC* and the worker's highest constant expected utility locus *EU*, which is tangent to the market opportunities frontier. The most that can be achieved with a well designed labor market study is an evaluation of the local tradeoff at a point such as *B*. In contrast, a survey that asks an individual what wage increase is needed to bear an increase in risk level from q_a to q_b will provide information on two points *B* and *D* on a constant expected utility locus. The wage increment in this context will truly be a compensating differential that maintains the individual's utility at a constant level. Moreover, the risk increments between q_a and q_b can be designed to analyze risk changes of any magnitude.

Perhaps most important, information pertaining to two or more points along a constant expected utility locus permits the estimation of the utility functions governing behavior. With knowledge of these utility functions, all pertinent questions regarding risk valuation may be addressed, thereby greatly extending the range of issues that can be explored.

The character of the influence of health impacts on the utility function is an important matter of concern. If, for example, adverse health effects lower the marginal utility of income in the ill health state, then less than full income replacement following these losses is optimal. The entire structure of the optimal social insurance efforts consequently hinges on the character of utility functions.

Viscusi and Evans' (1990) results mentioned earlier found that the typical job injury lowered both the absolute level of utility and the marginal utility of income. Moreover, the character of this effect differed from what would have occurred if the job injury was tantamount to a monetary loss equivalent (i.e., $V(w)$

[54] It should be noted, however, that use of the two-stage structural hedonic approach with market data can address nonmarginal risk changes as well.

$= U(w - L)$, where L is some monetary loss value equivalent of the injury).

In contrast, different kinds of results are implied by using survey data on minor health effects, in particular, temporary poisonings and other injuries related to use of household chemical products. For minor health effects, the hypothesis that these health outcomes are tantamount to a monetary loss equivalent cannot be rejected (Evans and Viscusi 1991). In situations such as this where the health outcome does not affect the marginal utility of income, full insurance of losses is optimal. Moreover, assessment of the valuations of different incremental changes in the risk of loss is straightforward once we know that the health outcome is valued at some fixed monetary amount.

Three basic survey methodologies have been used to assess points such as B and D in Figure 3. All of these involve eliciting responses to a simulated market context using variants of a procedure known as "contingent valuation," which ascertains individual preferences contingent upon some hypothetical market scenario.

The first such technique is a direct contingent valuation method. A survey might ask respondents directly how much of a wage increase they would require to accept a given risk increase. A variant on this approach is to proceed in iterative fashion. Rather than seeking a response to an open-ended question, the willingness-to-pay value may be adjusted until the respondent indicates indifference.

A second technique involves presenting subjects with pairwise comparisons. In the job risk case, for example, Job 1 might consist of a wage-risk combination of (p_1,w_1), and Job 2 might consist of a wage-risk package of (p_2,w_2). Subjects could indicate their preference between these two jobs, and the packages could be manipulated until indifference is achieved.

The third approach is to offer lotteries and to elicit preferences with respect to a reference lottery. For example, Viscusi, Magat, and Huber (1991) analyze the value of chronic bronchitis by ascertaining the equilibrating probability, s, that establishes indifference between bronchitis and a lottery on life and death, where

$$U(\text{Chronic Bronchitis}) = sU(\text{Life}) + (1 - s)V(\text{Death}).$$

Choice of the particular survey method depends in large part on which will elicit the most reliable statement of preferences, and thus far no consensus has developed.

One of the main advantages of survey-type approaches is that the analysis need not be constrained by the availability of market data. Consider, for example, the range of health outcomes addressed in Tables 6 and 7. The value-of-life estimates in Table 6 are perhaps the most homogeneous because they all pertain to different classes of accidental deaths or acute outcomes such as heart attacks. The morbidity effects in Table 7 are much more diverse, ranging from coughing spells and hand burns to nerve disease and cancer. A principal benefit of survey methodologies is that they provide insight into classes of outcomes that cannot be addressed with available market data. One such benefit category is altruistic benefits, which by their very nature will not be reflected in market risk-taking decisions (see Viscusi, Magat, and Anne Forrest 1988).

A major concern with survey valuations of health risks is that the responses will be reliable only to the extent that individuals understand the tasks to which they are responding. A matter of particular concern is the processing of risk information presented in survey context.

TABLE 6
SUMMARY OF VALUE OF LIFE ESTIMATES BASED ON SURVEY EVIDENCE

Author (Year)	Nature of Risk	Survey Methodology	Average Income Level	Implicit Value of Life ($ millions)
Jan Acton (1973)	Improved ambulance service, post-heart attack lives	Willingness to pay question, door-to-door small (36) Boston Sample	NA	.1
Jones-Lee (1976)	Airline safety and locational life expectanty risks	Mail survey willingness to accept increased risk, small (30) U.K. sample, 1975	NA	15.6
Gerking, deHaan, & Schulze (1988)	Job fatality risk	Willingness to pay, willingness to accept change in job risk in mail survey, 1984	NA	3.4 willingness to pay, 8.8 willingness to accept
Jones-Lee (1989)	Motor vehicle accidents	Willingness to pay for risk reduction, U.K. survey, 1982	NA	3.8
Viscusi, Magat, & Huber (1991)	Automobile accident risks	Interactive computer program with pairwise auto risk-living cost tradeoffs until indifference achieved, 1987	43,771	2.7 (median) 9.7 (mean) (1987)
Ted Miller & Jagadish Guria (1991)	Traffic safety	Series of contingent valuation questions, New Zealand Survey, 1989–1990	NA	1.2

Note: All values in December 1990 U.S. dollars.

Consider two different valuation studies of the same health outcome using surveys involving different risk levels. The first of the studies reported in Table 7, by Viscusi, Magat, and Huber (1987), focuses on individuals' valuations of the risks from bleach and drain opener, chloramine gassings, child poisonings, and hand burns, among others. These morbidity effects are by no means catastrophic, but the estimated values the respondents attach to them are in excess of $1 million in three cases.

Viscusi, Magat, and Huber (1987) dealt with a similar class of injuries but addressed a much more comprehensible risk level—on the order of 15/10,000 annually. The value of the morbidity effects such as skin poisonings and chloramine gassing is in a more reasonable range, as the health effects assessed in this study range in value from $700 to $3,500.

The discrepancy in the studies can be traced to the difficulties posed by the small risks in the first study. Individuals who are willing to pay one dollar to reduce the risk of bleach gassing by 1/1,000,000, will exhibit an implicit value

TABLE 7
SUMMARY OF VALUATIONS OF NONFATAL HEALTH RISKS

Author (Year)	Survey Methodology	Average Income Level	Nature of Risk	Value of Health Outcome
Mark Berger et al. (1987)	Contingent valuation interviews with 119 respondents, 1984–1985	NA	Certain outcome of one day of various illnesses	\$98 (coughing spells), \$35 (stuffed-up sinuses), \$57 (throat congestion), \$63 (itching eyes), \$183 (heavy drowsiness), \$140 (headaches), \$62 (nausea)
Viscusi & Magat (1987)	Paired comparison and contingent valuation interactive computer survey at mall, hardware store, 1984	\$39,768	Bleach: chloramine gassings, child poisonings; drain opener: hand burns, child poisonings	\$1.78 million (bleach gassing), \$0.65 million (bleach poisoning), \$1.60 million (drain opener hand burns), \$1.06 million (drain opener & child poisoning)
Viscusi, Magat, & Huber (1987)	Contingent valuation computer survey at mall, hardware stores, 1986	\$42,700	Morbidity risks of pesticide and toilet bowl cleaner, valuations for 15/10,000 risk decrease to zero	Insecticide \$1,504 (skin poisoning), \$1,742 (inhalation), \$3,489 (child poisoning), toilet bowl cleaner \$1,113 (gassing), \$744 (eye burn), \$1,232 (child poisoning)
Viscusi, Magat, & Forrest (1988)	Contingent valuation computer survey at mall, hardware stores, 1986	\$44,554	Insecticide inhalation-skin poisoning, inhalation-child poisoning	Inhalation-skin poisoning \$2,538 (private), \$9,662 (NC altruism), \$3,745 (U.S. altruism); Inhalation-child poisoning \$4,709 (private), \$17,592 (NC altruism), \$5,197 (U.S. altruism)
Evans & Viscusi	Contingent valuation computer survey at mall, hardware stores, 1986	\$32,700	Morbidity risks of pesticides and toilet bowl cleaner; utility function estimates of risk values. *T* values pertain to marginal risk-dollar tradeoffs, and *L* values pertain to monetary loss equivalents.	Insecticide: \$761 (*T*), \$755 (*L*) (skin poisoning); \$1,047 (*T*), \$1,036 (*L*) (inhalation-no kids); \$2,575 (*T*) (inhalation-children) \$1,748; \$3,207 (*T*), \$2,877 (*L*) (child poisoning); toilet bowl cleaner \$633 (*T*), \$628 (*L*) eye burn; \$598 (*T*), \$593 (*L*) gassing (no kids); \$717 (*T*), \$709 (*L*) gassing (children); \$1,146 (*T*), \$1,126 (*L*) child poisoning

TABLE 7 (*Continued*)

Author (Year)	Survey Methodology	Average Income Level	Nature of Risk	Value of Health Outcome
Magat, Viscusi, & Huber (1991)	Risk-risk computer survey at mall, 1990	$35,700	Environmental risk of nonfatal nerve disease, fatal lymphoma, nonfatal lymphoma	$1.6 million (nerve disease), $2.6 million (nonfatal lymphoma), $4.1 million (fatal lymphoma)
Viscusi, Magat, & Huber (1991)	Risk-risk and risk-dollar computer survey at mall, 1988	$41,000	Environmental risk of severe chronic bronchitis morbidity risk	.32 fatality risk or $904,000 risk-risk; $516,000 risk-dollar
Alan Krupnick & Maureen Cropper (1992)	Viscusi-Magat-Huber (1991) survey for sample with chronic lung disease, 1989	$39,744	Environmental risk of severe chronic bronchitis morbidity risk	$496,800–$691,200 (median)

for the injury of $1 million, but this response may not reflect the underlying risk-dollar tradeoff so much as it does the inability of individuals to deal with extremely low probability events. As the risk levels in Table 1 indicate, the usual range of experience with risk is with hazards of much greater frequency. The evidence in the psychology and economics literature sketched in Figure 2 indicates there is a tendency to overestimate the magnitude of very low probability events, particularly those called to one's attention. Survey methodologies may elicit individual valuations as perceived by the respondent, but one must ensure that what is being perceived is accurate. Errors in risk perceptions may be a particularly salient difficulty.

A final concern with respect to survey valuations is whether the respondents are giving honest and thoughtful answers to the survey questions. In practice, truthful revelation of preferences has proven to be less of a problem than has the elicitation of meaningful responses because of a failure to understand the survey task. Strategic misrepresentation can also be addressed by using a survey mechanism that is designed to elicit a truthful expression of preferences, such as hypothetical voting on a political referendum.

7. *Policy Implications*

Although the value-of-life literature is now roughly two decades old, the essential approach became well established in the 1970s. The appropriate measure of the value of life from the standpoint of government policy is society's willingness to pay for the risk reduction, which is the same benefit formulation in all policy evaluation contexts.

Economists have had the greatest success in assessing the risk-money tradeoff using labor market data. Although the tradeoff estimates vary considerably depending on the population exposed to the risk, the nature of the risk, individuals' income level, and similar factors, most of the reasonable estimates of the value of life are clustered in the $3 million–$7 million range. Moreover, these estimates are for the population of exposed workers, who generally have lower incomes than the individuals being protected by broadly based risk regulations. Recognition of the positive elasticity of the value of life with respect to worker earnings will lead to the use of different values of life depending on the population being protected. Taste differences may also enter, as smokers and workers in very hazardous jobs, for example, place lower values on health risks.

The 1980s marked the first decade in which use of estimates of the value of life based on risk tradeoffs became widespread throughout the Federal government. Previously, agencies assessed only the lost present value of the earnings of the deceased, leading to dramatic underestimation of the benefit value. In large part through the efforts of the U.S. Office of Management and Budget, agencies such as OSHA and EPA began incorporating value-of-life estimates in their benefit evaluations.[55] Policy makers' recognition of the nonpecuniary aspects of life is an important advance.

Given the range of uncertainty of the value-of-life estimates, perhaps the most reasonable use of these values in policy contexts is to provide a broad index of the overall desirability of a policy. In practice, value-of-life debates seldom focus on whether the appropriate value of life should be $3 million or $4 million—narrow differences that cannot be distinguished based on the accuracy of current estimates and the potential limitations of individual behavior underlying these estimates. However, the estimates do provide guidance as to whether risk reduction efforts that cost $50,000 per life saved or $50 million per life saved are warranted. The threshold for the Office of Management and Budget to be successful in rejecting proposed risk regulations has been in excess of $100 million (see Viscusi 1992a). It is in addressing the most extreme policy errors that the estimates will be most useful, as opposed to pinpointing the value of life that should guide policy decisions.

A needed major change is to establish an appropriate schedule of values of life that is pertinent for the differing populations at risk. The quantity of life at risk often varies quite widely, as do individual attitudes toward these risks. Policies that protect groups who incur risks voluntarily should be treated quite differently from policies that protect populations who bear risks involuntarily or who have a very high aversion to incurring health risks. Differences also arise on a temporal dimension. Valuation of health risks to future generations is assuming greater policy importance, but these values will not be the same as for those currently alive.

Broad gaps in our knowledge remain, particularly with regard to risks other than accidental fatalities. How, for example, should we value genetic risks and increased life extension for AIDS victims, as compared with other health outcomes? The class of health outcomes of policy interest is much broader than acute fatal injuries and lost workday accidents, which have been the main targets of analysis. Survey evidence on attitudes toward risk can potentially expand the range of health outcomes that we can value, but there is a continuing need to assess the validity of these benefit measures.

[55] Indeed, the U.S. Office of Management and Budget (1990, pp. 661–63) has developed explicit guidelines on the use of implicit values of life and health.

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