THE QUANTITY-ADJUSTED VALUE OF LIFE

MICHAEL J. MOORE and W. KIP VISCUSI*

The traditional compensating differential analysis is extended to reflect the effects on wages of the duration of life at risk and of insurance benefits to the surviving spouse and dependents. The implicit discount rate that workers use in making their life-cycle employment decisions is also estimated. The revealed discount rate ranges from 10 to 12 percent, and the implicit value per year of life is $175,000. There is also evidence of significant wage reductions resulting from higher workers' compensation benefits for fatal and nonfatal injuries, suggesting an important trade-off between ex ante and ex post compensation for risk.

I. INTRODUCTION

In the past decade, labor economists have devoted substantial effort to analyzing Adam Smith's proposition in *The Wealth of Nations* that workers will demand compensating differentials for health and safety risks and for other unattractive job characteristics.[1] Although this theoretical proposition is not controversial, attempts to estimate these differentials have yielded mixed results, with various measures of the riskiness of the job yielding the strongest findings.

Two simplifying assumptions are typically made in the empirical death-risk and injury-risk studies. First, the measure of risk used—the probability of a fatal or nonfatal accident—abstracts altogether from life-cycle issues such as variation across individuals in the potential losses resulting from death or injury.[2] Some losses, such as immediate pain and suffering and medical expenses, are likely to be similar across individuals for similar accidents. In the case of nonfatal accidents, it is probably not too great a simplification to assume that these losses are similar for different persons, since the duration of a given injury type is not highly variable. There may be greater differences, however, in the financial losses and the associated reduction in utility that result from

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1. The result that compensating differentials must exist to lead workers to accept hazardous jobs is shown for a wide variety of contexts in Viscusi [1979]. Also see Adam Smith [1776], Thaler and Rosen [1976], Smith [1976, 1979], and Viscusi [1983, 1986], among others, for contributions to this literature.

2. Theoretical analyses of life-cycle job risk models have appeared in the literature. See, for example, Conley [1976], Viscusi [1979], and Arthur [1981].

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a permanent change in health status, particularly with respect to the extreme loss of welfare that results from death.

In the case of fatalities, a young person loses a much greater amount of lifetime utility than does an older person, a source of variation in risk that has not been reflected in past empirical studies of the value of life. In this paper, this variation is incorporated by weighting the standard death risk measure by the remaining life of each sample member. More specifically, the information used includes expected lifetimes, the worker's current age, a discount rate that is computed as part of the estimation process, and measures of death risk. This information makes it possible to calculate the worker's expected remaining life at risk, reflecting the fact that the worker's principal concern is not simply the probability of a fatal accident, but the discounted duration of life and the associated lifetime utility at risk on the job. This discounted duration of life at risk is referred to below as the quantity-adjusted death risk and is used in calculating the quantity-adjusted value of life. The quantity-adjusted value of life differs from conventional estimates of the value of life in that the trade-off is not between wages and death risk probabilities, but between wages and death risks that have been weighted by the discounted number of potential years of life lost.

Obtaining a quantity-adjusted measure of the value of life also has potentially important policy implications. Analysts have long noted that the appropriate value of life for policy analysis cannot be divorced from the duration of life involved since lives are extended, not permanently saved.[3] The task of actually developing a measure of the value of life that incorporates changes in expected lifetime utility has never been undertaken, however, in large part because there was no sound empirical basis for doing so. The results reported here will take into account quite explicitly the influence of the duration of life.

A related issue arises in obtaining these quantity-adjusted measures. That is, what discount rate do people use in valuing their future utilities? Estimates of discount rates have appeared elsewhere in the literature, as in the studies by Fuchs [1982], Hausman [1979], Lang and Rudd [1986], and Weiss [1972], but none of these studies addressed the job risk problem. The closest of these studies to the health risk issues considered here is that of Fuchs. His analysis obtained rates of time preference from survey questions relating to financial opportunities at different dates, which he then related to health concerns such as cigarette smoking.

Estimated discount rates that diverge substantially from the financial market rates faced by workers are of interest in their own right to the extent that these diversions provide evidence pertaining to irrationality in the valuation of future health losses. It has long been suggested that people are myopic in

3. Zeckhauser and Shepard [1976] provide an extensive policy discussion of their concept of quality-adjusted life years. Arthur [1981], Shepard and Zeckhauser [1984], Rosen [1988], and Cropper and Sussman [1986] have developed elaborate life-cycle models. Arthur and Rosen explicitly treat the quantity of life effects that are the principal focus here.

their risk-taking decisions. This issue is addressed quite explicitly in this paper by comparing estimated discount rates to financial market interest rates for the period. These estimated rates are also of interest in that they suggest the appropriate rate of time preference to use in discounting future effects of health and safety policy.

A second simplification that until recently has been applied universally in wage-risk studies is the omission of expected ex post compensation for accidents in the form of accident insurance benefits available to workers.[4] Practically every state now provides workers' compensation insurance, so that approximately 90 percent of the work force is covered by some form of accident insurance. From a conceptual standpoint, increases in ex post compensation for accidents should reduce ex ante compensation and should, if possible, be incorporated explicitly in any analysis of the relationship between wages and job risks. Ex post compensation is taken into account by including in the estimating equation a death benefit variable that reflects the worker's marital status, spouse's remainaing life, number of dependents, and characteristics of the state workers' compensation system covering each worker. These benefits are also discounted at a rate that is calculated in the process of estimation.

In section II, the data used in the analysis, from the 1977 University of Michigan Quality of Employment Survey, are described. These survey data are coupled with risk and insurance variables that are collected from external sources and matched to workers in the sample. In section III, estimates of compensating differential equations are presented; they include both the quantity-adjusted risks to life and the present value of death benefits to the surviving spouse as regressors. Estimates are also reported that condition the industry risk measures on individual assessments of working conditions, thus controlling partially for the measurement error that has impeded many previous attempts to match industry data to workers in micro data sets.

In all of the cases considered, there is strong support of the hypothesized rationality of employment decisions. Workers receive wage premiums for exposure to risk that reflect the remaining lifetime at risk. They trade ex post for ex ante compensation for exposure to risks, and they discount future utilities and the utilities of their heirs at rates consistent with observed explicit interest rates.

II. DESCRIPTION OF THE SAMPLE AND THE VARIABLES

The empirical analysis utilizes the 1977 Quality of Employment Survey. This survey, which pertains to workers' employment experience in 1976, represents the third in a series of such surveys beginning with the 1969–70 Survey of Working Conditions and the 1972–73 Quality of Employment Survey. The 1977 data set shares with its predecessors a detailed set of job characteristic questions, making it possible to disentangle premiums for job risks from other

4. The following studies include measures of workers' compensation benefits for nonfatal injuries: Arnould and Nichols [1983], Viscusi and Moore [1987a, 1987b], Moore and Viscusi [forthcoming], Butler [1983], and Dorsey and Walzer [1983].

job attributes correlated with riskiness. Past studies of these data sets in a similar vein include Duncan's [1976] and Viscusi's [1979] analyses of the Survey of Working Conditions and Viscusi and Moore's [1987b] paper on nonfatal risks using the 1977 Quality of Employment Survey.

The 1977 data offer two major advantages over their predecessors. First, the survey ascertains the worker's hourly wage so that one need not use annual earnings as the dependent variable. Second, the timing of the survey makes it possible to match more reliable industry risk measures to workers in the sample. Mandatory industry reporting of injuries to the U.S. Bureau of Labor Statistics did not begin until the 1970s, with the first publicly released figures issued in 1972. Because of confusion over reporting requirements, early reports on nonfatal injuries are unreliable. The survey year 1976 thus permits sufficient time for these reporting practices for nonfatal risks to become stabilized, and it offers several years of retrospective data on death risks.

In many compensating differential studies it is necessary to restrict the sample to male or blue collar workers to estimate wage premiums successfully. Such restrictions were not required for the 1977 Quality of Employment Survey because the detailed job characteristic questions made it possible to disentangle the role of job risks in influencing workers' wages. The sample was restricted to nonfarm household heads who were not self-employed and who worked more than twenty hours per week. Workers in industries for which the Bureau of Labor Statistics does not gather death statistics were also excluded. Thus, for example, government employees were not included in the sample.

Table I defines the key variables, and Table II summarizes many of the principal characteristics of the sample of 317 workers. The sample has an average age of thirty-eight, 6 percent black workers, and 8 percent female workers. About one-fifth of the workers have not completed high school, one-fourth have some college education, less than one-fifth have a college degree plus additional training, and the remaining two-fifths have a high school diploma. The average firm size for workers is 783 employees. Almost two-thirds of the workers hold blue-collar jobs, and 39 percent are union members.

The dependent variable in the analysis is the worker's after-tax hourly wage rate. Since workers' compensation benefits are included in the equation in their after-tax form (benefits are tax exempt), for comparability the wage variable is the worker's after-tax hourly wage in 1976 dollars. These taxes include both state and Federal income taxes and are calculated using information on the worker's wage rate and family structure.[5] We assume that each worker took the standard deduction. This tax adjustment of wages, which appears to be the first such correction in the literature on compensating differentials for job hazards, is clearly preferable theoretically and had an influence on some of the tests of statistical significance of the coefficients.

Three job risk variables are used in the analysis. The first and most important is the worker's death risk. The approach used matches the workers in the

5. Tax rates for 1976 are from Commerce Clearing House, Inc. [1977a, 1977b].

sample to a death risk variable based on death risk statistics for the worker's two-digit industry.[6] Since death risks involve a low probability of death (on the order of 5/100,000 per worker in this sample), even at this level of aggregation death risks may vary substantially across years, particularly if there is a major catastrophe that results in multiple deaths. To eliminate the distorting influence of such random fluctuations, we use as our death risk measure the average probability of death over the 1973–76 period. Unlike the nonfatal accident statistics, death rate data were not subject to the classification problems that were present in the early 1970s under the new reporting requirements. Use of shorter term average measures yielded little change in our results.

The main focus of this paper is on the quantity of life adjustment of the standard death risk measure. Information on the worker's age, race, sex, and remaining life data from life expectancy tables are used to calculate the remaining life of worker i, R_i.[7] Discounted remaining life years are then

$$\text{Discounted Remaining Life}_i = (1/r)[1 - \exp(-rR_i)],$$

where r is the worker's rate of time preference. Weighting the discounted remaining life by the probability of a fatality yields the expected discounted life years lost variable,

$$\text{Expected Life Years Lost}_i = \text{Death Risk}_i \times \text{Discounted Remaining Life}_i.$$

The variable representing expected life years lost is inserted as a regressor in a compensating differential equation to estimate the impact of changes in expected remaining lifetime on wages. Since this particular risk variable is a nonlinear function of the discount rate parameter, it is necessary to estimate the model using nonlinear regression techniques.

It is useful to interpret the effect of expected life years lost on wages in the context of Arthur's [1981] theoretical paper on the value of extensions to life. In a general equilibrium intertemporal consumption-loans model, Arthur shows that the welfare gains associated with a reduction in age-specific risks consist of three forces affecting consumption—the increase due to lengthened life, and the increased productivity that is due to both increased work years and increased births over the extended life span. These gains are offset to an unknown degree by the fact that the increased consumption during later years must be financed by someone's decreased consumption. This last term is shown by Arthur to depend upon the consumption elasticity of utility, a parameter that has been estimated elsewhere by Viscusi and Moore [1987a] and by Rosen [1988]. If this elasticity has a value close to zero, financing considerations can effectively be ignored, since extended life affects utility independently of the changes in consumption that it entails. In Viscusi and Moore [1987a] this

6. This level of detail in terms of industry aggregation is greater than is available from published sources. Death risk measures were obtained by copying death statistics manually from the death statistic files at the Bureau of Labor Statistics office in Washington.

7. Life expectancies are taken from U.S. Department of Health and Human Services [1980].

TABLE I
Variable Definitions

Variable	Definition
Age	Age in years.
Race	Race dummy variable (d.v.): 1 if worker is black, 0 otherwise.
Sex	Sex d.v.: 1 if worker is female, 0 otherwise.
Poor health status	Severity of health limitation d.v.: 1 if limiting physical or nervous condition has created either sizable or great problems in working on or in getting jobs, 0 otherwise.
Less than high school education	Education d.v.: 1 if worker did not finish high school, 0 otherwise.
High school education	Education d.v.: 1 if worker finished high school, 0 otherwise.
Some college education	Education d.v.: 1 if worker has some college education, 0 otherwise.
College degree	Education d.v.: 1 if worker has at least a college degree, 0 otherwise.
Experience	Experience variable: years worked for pay since age 16.
Firm size	Firm size: midpoints assigned to intervals.
Blue-collar occupation	Collar color d.v.: 1 if the worker is in a blue collar occupation, 0 otherwise.
Union status	Union status d.v.: 1 if worker belongs to a union or employee's association, 0 otherwise.
Wage	Computed hourly after-tax wage measure.
Fast work pace	Work pace d.v.: 1 if job requires worker to work very fast a lot, 0 otherwise.
Job security	Job security d.v.: 1 if it is very true that the worker's job security is good, 0 otherwise.
Supervisory status	Supervisory status d.v.: 1 if worker supervises anyone as part of his job, 0 otherwise.
Overtime work requirements	Overtime work d.v.: 1 if worker works overtime often, 0 otherwise.
Availability of training	Training program d.v.: 1 if employer makes available a training program to improve worker skills, 0 otherwise.
Fatal accident rate	BLS industry hazard variable: average annual fatality rate by 2-digit SIC code, averaged over 1973–76 period.
Lost workday accident rate	BLS industry hazard variable: annual incidence rate of lost workday cases by 3-digit SIC code.
Hazard perceptions	Hazardous working conditions d.v.: 1 if worker cited at least one dangerous or unhealthy working condition, 0 otherwise.
Replacement rate	Workers' compensation replacement rate: benefit level/wage.
r	Discount rate.
Residence in an urban area	Urban area d.v.: 1 if worker lives in a major SMSA, 0 otherwise.
Marginal tax rate	Marginal federal and state income tax rate.

TABLE I
Continued

Variable	Definition
R	Expected remaining life of worker, based on reported age, race, and sex. Remaining life reported in Census life tables.
S	Spouse's expected remaining life.
Residence in the northeast region	Northeast region d.v.: 1 if worker lives in northeastern United States, 0 otherwise.
Residence in the southern region	Southeastern region d.v.: 1 if worker lives in southeastern U.S., 0 otherwise.
Residence in the north central region	North Central region d.v.: 1 if worker lives in north central U.S., 0 otherwise.
Residence in the western region	Western region d.v.: 1 if worker lives in western U.S., 0 otherwise.

parameter is estimated to be less than .10, while in Rosen [1988] it equals approximately .25, suggesting that the financing considerations associated with life extension are not of major consequence.

The remaining influences will be reflected in the wage equation if decreasing death risks increases productivity as well as utility. Otherwise, firms will not compensate workers for placing their life years, productivity, and fertility at risk, and workers will sort themselves into more risky jobs, the less important these considerations are. In principle, empirical separation of these influences is possible. In addition to the information on life years at risk, estimation of these effects would require data on both fertility and labor force participation over the life cycle. These factors could then be incorporated into the model to hold constant the fertility and productivity effects, allowing estimation of the "pure" value of extended life. Since these effects are not incorporated here, the gross estimates of the quantity adjusted value of life are overstated if expected life years lost are correlated with expected labor force participation and fertility gains effects, and if these factors increase wages.[8]

The second job risk measure included was the nonfatal lost workday accident rate for the worker's three-digit industry. This measure pertains to the incidence rate of nonfatal accidents that entail at least one lost day of work. Workers in the sample have an average annual probability of a lost workday injury of 1/20. This accident measure is a more reliable index of injuries than the total injury and illness rate, since the definition of what consitutes an accident is clearcut. Inclusion of this measure prevents the fatality risk variable from capturing the omitted influence of nonfatal risks.

The final accident measure is the worker's subjective assessment of whether

8. Of the two, it seems likely that increased participation will be compensated, while increased fertility will not. Based upon the results in Arthur, however, the participation effect is small relative to the life year effect (about 10 percent), so failure to include participation should not bias the results significantly.

TABLE II
Selected Sample Characteristics

Variable	Mean (Standard Deviation)
Age	38.09 (12.22)
Race	0.06 (0.24)
Sex	0.08 (0.27)
Less than high school education	0.22 (0.41)
Some college education	0.25 (0.44)
College degree	0.13 (0.33)
Experience	21.30 (12.49)
Firm size	783.82 (1110.54)
Blue collar occupation	0.63 (0.48)
Union status	0.39 (0.49)
Wage (after taxes)	5.49 (1.88)
Fatal accident rate (per 100,000 workers)	5.89 (8.98)
Lost workday accident rate (per 100 workers)	4.68 (2.38)
Hazard perceptions	0.85 (0.36)
Replacement rate	0.79 (0.35)
Sample size	317

the job exposes him to dangerous or unhealthy conditions. This binary variable assumes a value of one if the worker cites one or more hazards of his job. Unlike the more directive danger perception question in the Survey of Working Conditions data analyzed in Viscusi [1979], the 1977 Quality of Employment Survey does not ascertain explicitly whether a worker's' job poses any hazards but instead inquires whether he can cite specific risks. This change in wording contributed to a higher rate of danger perception than in previous surveys, as 85 percent of the sample viewed their job as exposing them to some health or safety risk.

A well-known problem with the use of industry data to measure individual level risks is that workers in the same industry face different risks in different occupations. Some of these job-specific variations can be taken into account by utilizing the question in the Quality of Employment Survey for which the worker reports his own perception of the presence or absence of hazards. That is, the industry level risk data can be conditioned by the presence of a perceived hazard, as in Viscusi [1979]. Multiplication of the binary hazard perception variable by the fatal and nonfatal industry injury rates yields a risk measure that equals zero if a worker perceives no risk on his job, and equals the industry risk level if the worker reports his job as hazardous.

The interpretation of expected life years lost is as a measure of lifetime exposure to job risk. The implication of this use of the measure is that, for given characteristics of the job and the worker, the lifetime utility at risk is greater for a younger person than for an older one. An alternative interpretation is that the quantity adjustment serves as a proxy for "tastes for risks," i.e., that younger workers have a lower aversion to risk and, therefore, choose a higher value of expected life years lost. If this were so, expected life years lost would not be a valid measure of risk, since it would be subject to the sorting problems inherent in the compensating differential model. In the case of pure taste-sorting, there would be no evidence of a risk premium for any given point on firms' offer curves. It is more likely, however, that younger workers (who typically work on more dangerous jobs) do so because they are more productive in those jobs than are older workers, and that firms are willing to compensate workers with greater exposure for their greater productivity.

Besides ex ante wage compensation for risk, workers also receive ex post compensation through the state workers' compensation programs. Higher workers' compensation levels should reduce the wage rates for workers in hazardous jobs. As shown in Viscusi and Moore [1987b], the theoretically appropriate measure of compensation for nonfatal injuries is the expected benefit amount, which equals the probability of an injury multiplied by the benefit level.

As a measure of insurance for nonfatal injuries, we use the expected earnings replacement rate, following a procedure discussed in Viscusi and Moore [1987b]. The variable involves an interaction of the probability of collecting benefits, which is given by the lost workday accident rate, and the wage replacement rate under workers' compensation. The workers' compensation replacement rate for nonfatal accidents is defined by b_i/w_i, where b_i is the benefit amount and w_i is the after-tax wage rate.

The benefits variable b_i is governed by complex formulas that vary by state. The measure adopted here uses the benefit amounts for permanent total disabilities, which account for the majority of all claims.[9] This measure takes into

9. Detailed actuarial measures of other benefit categories are not feasible. Viscusi and Moore [1987b] document the plausibility of this measure and its positive correlation with other benefit categories.

account state minimum and maximum benefit amounts, the relation of the benefit to the worker's wage rate, and the benefits' favorable tax status.[10] Although this variable only approximates actual expected benefits from all injury categories, it is the most detailed and pertinent workers' compensation measure included in a wage equation to date.[11] To prevent problems of endogeneity, the wage variable w_i in the denominator has been replaced by its predicted value from a first-stage regression.

The final benefit measure is the discounted expected annuity for survivors. Estimation of the wage equation using a wage replacement rate for death insurance produced results consistent with those reported below. However, since death benefits are a measure of lifetime compensation, the discounted lifetime annuity captures the nature of the benefit better than a current period replacement rate, and its effects are therefore reported below.

Based on the state death benefit formulas and the worker's wage rate, family structure, and state of residence, one can calculate the annual annuity amount, $A(b_i)$. The value of these benefits to the family of the deceased worker also depends on their duration. Using information on the spouse's age, race, and sex, and life expectancy tables, one can calculate the spouse's expected remaining lifetime S_i. The discounted value of the annuity is consequently

$$\text{Discounted Annuity}_i = (1/r)A(b_i)[1 - \exp(-rS_i)].$$

When there are no heirs, the annuity is assigned a value of zero.

For the purpose of the empirical analysis, the appropriate variable is the worker's expected annuity, where

$$\text{Expected Annuity}_i = \text{Death Risk}_i \times \text{Discounted Annuity}_i.$$

Estimates of the parameter r in the regressions using nonlinear techniques are reported below.

In principle, the discount rates applied to a worker's future utility and to the utilities of his heirs need not be equal. This restriction was tested as a preliminary step in the analysis; the hypothesis that workers weight the utilities of other family members equally could not be rejected. It should be noted, however, that estimation of two separate discount rates increases the demands placed upon the data substantially. The unconstrained estimates were therefore less precise than the single estimate reported below, and this imprecision is partially responsible for the failure to reject the restriction. In the unrestricted estimation, the worker's own discount rate has a statistically significant effect, as in the restricted estimates reported below.

Finally, each question includes a detailed set of other variables pertaining to the worker and his job. These variables include work experience (years

10. See U.S. Chamber of Commerce [1976].

11. In addition, as noted above, the expected replacement rate variable offers several additional refinements over those appearing in the literature, including recognition of their favorable tax status, the appropriateness of the interaction with the lost workday accident rate, and detailed calculation of the worker-specific benefit levels. See Viscusi and Moore [1987b] for detailed comparisons with other benefits approaches.

worked since age sixteen), and dummy variables indicating health status, speed of work, job security, whether the worker is a supervisor, overtime work requirements, training program availability, and residence in an urban area, the south, the west, or the north central United States. Of particular importance in the estimation are the job characteristic variables. These detailed job variables are not available in the larger data sets often used to estimate compensating differentials for working conditions, and in their absence industry dummy variables are necessary as a proxy for capturing differences in jobs correlated with the worker's industry. Inclusion of such industry dummy variables makes it difficult to estimate the effects of an industry-based job risk measure that is constructed using the industry information. Since the equations include several job-specific measures of job attributes, industry dummy variables are not necessary to control for industry differences in job characteristics.

III. EMPIRICAL RESULTS

The empirical analysis focuses on a series of wage equations. Both the after-tax wage and its natural logarithm are used as dependent variables to control for sensitivity of the results to this aspect of model specification. For each equation, two versions are estimated; one conditions the death risk variables by the dummy hazard perceptions variable, and one is an unconditional estimate.

The basic form of the model is given by the equation

$$\begin{aligned} \text{Wage}_i = {} & \alpha_0 + \alpha_1 \text{Expected Life Years Lost}_i + \alpha_2 \text{Expected Annuity}_i \\ & + \alpha_3 \text{Lost Workday Accident Rate}_i \\ & + \alpha_4 \text{Lost Workday Accident Rate}_i \times \text{Replacement Rate}_i \\ & + \Sigma_m \beta_m x_{im} + \epsilon_i, \end{aligned} \tag{1}$$

and its semi-logarithmic counterpart, where the x_{im} are the aforementioned variables pertaining to the worker and his job.

This equation is in the same general spirit as the conventional compensating differential equation, with four important differences. First, the dependent variable is the after-tax hourly wage rate. An after-tax measure is especially appropriate to put wages and workers' compensation benefits on a comparable basis. Further, since it is the after-tax wage that is relevant to worker decisions, use of the pre-tax wages will introduce error into the dependent measure. Second, this is the first such equation to include the discounted expected value of the annuity in the estimating equation. Third, whereas some studies have included a workers' compensation variable analogous to the expected replacement rate, no such analysis has also included a fatality risk measure in the wage equation.[12] Finally, and most importantly, the death risk measure (expected life years lost) takes into consideration the discounted duration of remaining life that is at risk on the job. Expected life years lost is the worker's

12. Arnould and Nichols [1983] include the fatality rate as the risk measure and average workers' compensation replacement rates for injuries as the benefit measure.

discounted remaining life multiplied by the death risk, or discounted expected life years lost. This adjustment of the standard death risk variable reflects the fact that what is at stake is not death per se, but loss of years of life, that the amount of life lost is of consequence, and that individuals discount the utility attached to future years of life. The discount rate used in adjusting remaining life is computed in the estimation process. The procedure does not constrain the discount rate to be nonzero, so that the possibility that workers do not discount is not ruled out a priori.

Finally, both weighted and unweighted estimates are reported; they are derived using the two-stage technique proposed by Amemiya [1977]. Heteroskedasticity, which is common in cross section data, is usually ignored in compensating differential studies. However, given the nonlinear nature of this model, controlling for heteroskedasticity is crucial, since bias in estimates of standard errors carries over to estimates of the coefficients in this case. As shown below, weighting produced important changes in some significance levels.

In constructing the weights, it was assumed that the variances of the individual error terms, ϵ_i, were approximately a linear function of the vector $\mathbf{z}$. This vector $\mathbf{z}$ included worker experience in both linear and squared forms, nonfatal and fatal risks, and annuity terms. These variables were chosen based on residual plots from unweighted estimates, and entered as regressors in an equation with e_i^2 as the dependent variable, where e_i is the nonlinear least squares residual. This procedure was iterated twice, yielding estimates of weights that have been shown by Amemiya [1977] to be asymptotically normal and consistent.

Table III reports weighted and unweighted nonlinear least squares estimates of equation (1). A nonlinear least squares technique was required to estimate the worker's implicit discount rate. The control variables (x_{im}) generally perform as expected. Education increases wages, as does residence in an urban area, and black and female workers earn significantly lower wages.[13] The race variable is not statistically significant, no doubt because there were only nineteen black workers in the sample. In the unweighted results, a year of experience increases wages by three-tenths of a percent. Poor health causes a reduction in wages of 14 percent that is in the expected direction but is not significantly different from zero.

The job-related variables perform in a manner similar to studies that used the earlier surveys—the 1970 Survey of Working Conditions and the 1973 Quality of Employment Survey.[14] Union members receive a wage premium of 14 percent, and workers in large firms have higher wages, consistent with previous research. Workers in blue-collar occupations earn, on average, 13 percent less than those in white-collar jobs. Of those job characteristic variables

13. For purposes of estimation, the categorical variables indicating a high school degree and residence in the northeast are excluded.

14. The most extensive analyses of the Survey of Working Conditions are Viscusi [1979] and Duncan [1976]. Moore [1984] utilizes the 1973 survey.

TABLE III
Ln(Wage) Equation Estimates of Unconditional Risk Model* Coefficients and Standard Errors

Independent Variable	Unweighted Estimates	Weighted Estimates
Race	−0.028	−0.085
	(0.071)	(0.073)
Sex	−0.255	−0.273
	(0.066)	(0.068)
Poor health status	−0.139	−0.124
	(0.096)	(0.100)
Less than high school education	−0.095	−0.071
	(0.046)	(0.047)
Some college education	−0.034	−0.023
	(0.043)	(0.045)
College degree	0.096	0.123
	(0.046)	(0.062)
Experience	0.003	0.002
	(0.001)	(0.002)
Firm size	5.2E − 5	4.9E − 5
	(1.7E − 5)	(1.9E − 5)
Blue-collar occupation	−0.128	−0.148
	(0.042)	(0.043)
Union status	0.141	0.145
	(0.041)	(0.042)
Fast work pace	−0.069	−0.072
	(0.045)	(0.048)
Job security	0.051	0.060
	(0.034)	(0.035)
Supervisory status	0.065	0.043
	(0.038)	(0.039)
Overtime work requirements	−0.043	−0.041
	(0.036)	(0.038)
Availability of training	0.044	0.035
	(0.037)	(0.039)
Lost workday accident rate	0.049	0.058
	(0.013)	(0.014)
Lost workday accident rate × replacement rate	−0.048	−0.055
	(0.013)	(0.013)
Expected life years lost	11.945	17.732
	(6.861)	(5.880)
Expected annuity	−1.4E − 3	−2.4E − 3
	(0.7E − 3)	(0.8E − 3)
r (discount rate)	0.096	0.122
	(0.063)	(0.043)
$\bar{R}^2$	0.387	0.390

* Each equation also included dummy variables pertaining to the worker's residence in an urban area, and the south, the west, or the north central United States.

measuring nonpecuniary attributes, only the supervisory status dummy variable has a statistically significant effect among the subsidiary working condition variables, and its sign is in the expected direction. In most other cases, the signs approach significance at the .05 level, so the variables are included to separate their effects from those of the risk variables.

The results of primary interest are the estimated effects of the injury rate variables, the insurance variables, and the estimate of r—the worker's implicit discount rate. In the unweighted estimates, each effect has the expected sign. Furthermore, all of the injury and insurance variables are statistically significant at the .05 confidence level (one-tailed test).

The importance of weighting is seen by comparing estimates of the discount rate. In the unweighted regressions, the estimated real discount rate of 9.6 percent is not statistically significant at the 5 percent level, with a t-ratio of 1.52. The two-stage weighting, however, causes an increase in significance for many variables, including the accident and insurance variables. Most pertinent here is that it also causes an increase in the estimated discount rate to 12.2 percent and a decrease in the standard error to .043, rendering the estimate significant at the .01 level. Based on this estimate, one can reject both extreme alternative hypotheses that workers exhibit a zero discount rate or an infinite discount rate when making their job choices.

To compare the estimate of the discount rate to observed explicit rates for the year 1976, it is necessary to convert it to a nominal rate. Using the increase in the GNP deflator of 6 percent in 1976 as a measure of the expected rate of inflation yields a nominal discount rate of 18 percent for the weighted regressions. This discount rate is above the 9 percent nominal rate for new home mortgages in 1976 but equal to the 18 percent rate of interest charged in most states by credit card companies.[15] Our estimated rate of time preference is thus consistent with a hypothesis of rationality of workers' intertemporal trade-offs.

This estimate is also among the most reasonable estimates of implicit discount rates in the literature. The estimated rate of time preference for life years is in a more plausible range than consumers' implicit rates of discount for appliance energy efficiency, which Hausman [1979] found to be around 20 percent or more and Gately [1980] found to be between 45 and 300 percent. Similarly, Fuchs [1982] generated survey data on consumers' rates of time preference that implied a mean implicit rate of time preference of 30 percent. During the recent low inflation period, corporate executives have also been found to use nominal rates of discount on the order of 15 percent or more,[16] so that the estimated nominal rates of 18 percent for this equation should not be viewed as unreasonably large.

15. The home mortgage interest rate is the Federal Home Loan Bank Board rate on new-home mortgage yields, from U.S. Council of Economic Advisers [1980, 278].

16. The results from a poll by Lawrence Summers suggest that the rate of interest companies use to discount investments is on the order of 15 percent or more for a majority of firms. See *Washington Post*, National Weekly Edition, July 16, 1986, 22.

Similar estimates are obtained with other specifications as well. Table IV summarizes the key parameters in a weighted estimation of the unconditional equations in which the job risk variables appear in their conventional form. In addition, Table 4 includes conditional equations in which the risk variable represents the interaction of the objective risk measure and the subjective hazard perception dummy variable. Workers will not demand wage premiums for jobs that they do not perceive as dangerous, and the subjective risk perception variable is incorporated in the risk measure to capture this effect. It is important to note that the conditional estimates eliminate some of the measurement error involved in the matching of average industry risks to workers. As expected, coefficients on the conditional estimates are uniformly larger than their unconditional counterparts for the death risk variables. However, the opposite holds for the injury risk coefficients.

Although the worker's subjective risk perception is the theoretically appropriate variable, the hazard perception variable may not represent the ideal adjustment for these subjective factors. The wording of the hazard perception question, which requires that the worker cite specific hazards, may not elicit perceptions of very small risks. In particular, how large must the risk be before it passes the worker's threshold for categorization as dangerous or unhealthy? Since the conditional risk measure is not necessarily more meaningful than the unconditional, both sets of findings are presented to explore the robustness of the results. The estimates reported in Table IV for the conditional and unconditional measures are very similar.

The rates of discount individuals use to discount years of life are significantly different from zero at the 5 percent level in all cases and range in magnitude from 10 to 12 percent. One can thus reject the hypothesis that workers have a zero rate of time preference. Similarly, one can reject the other extreme hypothesis that workers are myopic and, in effect, have infinite rates of discount. The 95 percent confidence interval for rates of discount is restricted to generally plausible values.

The findings in Table IV also offer striking support for the theoretical predictions regarding risks and the compensation mix. Both risk measures are consistently positive and statistically significant at the 5 percent level. The implicit values per additional expected year of life are in the $170,000–$200,000 range, which is remarkably consistent across the four equations given the wide range of life values reported previously in the literature. If the discounted number of life years is used as the denominator in this calculation, the average value of a year of life rises to almost $725,000.

These values represent the average willingness to pay for an additional year of life in present value terms. More important for policy purposes is the marginal value of a life year. If a worker expects to live thirty-five more years, then a one-year life extension is worth only $11,000 now. However, an older worker who expects to live only five years will value an additional year of life at approximately $400,000.

The value of life extension also depends on the discount rate. If the real

TABLE IV
Summary of Selected Statistics for Wage Equations with Discounted Expected Life Years Lost* Coefficients and Standard Errors

Independent Variable	Unconditional Risk Measure: Wage	Unconditional Risk Measure: ln(Wage)	Conditional Risk Measure: Wage	Conditional Risk Measure: ln(Wage)
Expected life years lost	7.8E + 1	1.8E + 1	1.0E + 2	1.9E + 1
	(3.7E + 1)	(0.6E + 1)	(0.5E + 2)	(0.5E + 1)
Expected annuity	−8.6E − 3	−2.4E − 3	−1.3E − 2	−2.5E − 3
	(4.2E − 3)	(0.8E − 3)	(0.7E − 2)	(0.8E − 4)
Lost workday accident rate	0.235	0.058	0.184	0.047
	(0.071)	(0.014)	(0.071)	(0.014)
Lost workday accident rate × replacement rate	−0.255	−0.055	−0.247	−0.053
	(0.075)	(0.013)	(0.080)	(0.014)
Discount rate (r)	0.096	0.122	0.122	0.122
	(0.052)	(0.043)	(0.056)	(0.034)
Implicit value of life** (1986 dollars)	$6.8E + 6	$6.2E + 6	$6.0E + 6	$6.2E + 6
Implicit value per life year***	$194,285	$177,143	$171,429	$177,143

* Each equation also included the variables pertaining to the worker's race, sex, experience, union status, blue-collar occupation, firm size, health status, education, speed of work, job security, supervisory status, overtime work, training, and residence in an urban area, the south, the west, or the north central United States.

** Calculated as the product $\partial w/\partial p \times 2000$ hours $\times$ 1.891, where 1.891 is the price inflator and p is the probability of a fatal accident.

*** Calculated as the implicit value of life/remaining life.

rate of time preference is lower, additional life years increase in value. The worker described above with thirty-five years of life remaining who values an extra year at $11,000 when the discount rate is 12 percent will value his marginal year of life at over $125,000 if the discount rate is 5 percent. Likewise, the older worker with five years of life remaining will pay $570,000 for an additional year when his discount rate is 5 percent.

As the figures at the bottom of Table IV indicate, the value of life estimates on the order of $6.0 million (1986 prices) are similar to those obtained in many traditional estimates, but larger in magnitude than estimates for high risk samples such as Thaler and Rosen [1976]. Thaler and Rosen calculate the implicit value of life at about $600,000 in 1986 prices using occupational risk data. Viscusi [1981], on the other hand, generates value of life estimates of $5.3 million, again in 1986 prices, using industry risk data. It should be noted also that the annual death risk level for the sample used here of 5/100,000 is below the 1/1000 value in Thaler and Rosen [1976] and the 1/10,000 value in Viscusi [1979]. The discounted value of life estimates are larger than the average value of life for these two studies. Given the self-selection of workers with lower values of life into higher risk jobs, these results are quite consistent with the literature.

Similar calculations of the willingness to pay to avoid a nonfatal injury indicate that individuals value this element of job safety at between $15,000 and $30,000 per accident. Although not as stable as the value of life estimates, these values are also consistent with those found elsewhere in the literature that have controlled for the role of accident insurance and with those of Viscusi [1979], whose estimated values in current dollars range from fourteen to twenty-five thousand dollars. Since the value of the nonfatal accident wage replacement rate is .80, these values represent the implicit costs of pain and suffering and the uninsured wage losses.

The annuity and workers' compensation variables have the expected signs and in every instance they pass a test for statistical significance at the 5 percent (one-tailed) level. An additional dollar of weekly workers' compensation benefits for disabilities leads to a weekly wage reduction of 18 cents. As shown in Viscusi and Moore [1987b], this is higher than the optimal rate of trade-off between wages and benefits (−6.00 cents) that would exist if there were perfect insurance markets. Likewise, the rate of trade-off between wages and the discounted annuity, which equals −0.80 cents in these estimates, is much larger than the ideal rate of −0.06 cents. Abstracting from the problems of moral hazard, which may be considerable, these estimated rates of trade-off imply that benefit levels were too low in 1976. Estimates from a more recent data set reported in Moore and Viscusi [forthcoming] indicate that the dramatic increase in benefit levels since 1976 has lowered the rate of trade-off so that benefit levels are no longer suboptimal. The principal implication of these results is that there is an important trade-off between ex ante wage compensation and ex post insurance compensation for job risks.

IV. CONCLUSION

Consideration of the implications of fatality risks for workers' future lifetimes enables one to assess the roles of the duration of life lost and workers' implicit rates of time preference with respect to future life years. The most notable result was that workers discount future life years at real rates of 9.6–12 percent. Since these values converted to nominal rates are bounded from below by the prevailing home mortgage interest rate and bounded from above by credit card interest rates, there is little evidence of intertemporal irrationality.

Consideration of the duration of life lost also makes it possible to consider the value of each year of life lost. This value, which averaged more than $170,000 in 1986 prices, was associated with an implicit value of one's future life of about $6.0 million. The valuation level greatly exceeds workers' annual earnings, which is not necessarily inconsistent since it represents the rate of risk-dollar trade-off for very small risks, not the amount that workers would pay for certain life extension. Compared with other studies this estimated value of life is toward the higher end of the spectrum, but it is generally consistent with past estimates for workers with jobs of similar riskiness.

The ex post compensation for fatalities and nonfatal injuries played a more prominent role in this study than in previous analyses in the literature. Both forms of ex post compensation led to a reduction in ex ante compensation through wage reductions. Rewards for exposure to job risk thus involve two components of compensation: ex ante wage compensation and ex post insurance compensation.

In all of the aspects of this analysis, recognition of the role of the temporal dimension of job risks bolsters the support for an economic model of rational job choice. Although temporal misallocations may exist, the magnitude of any departure from rationality appears small.

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