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The Value of Saving a Life: Evidence from the Labor Market *

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INTRODUCTION

LIVELY controversy has centered in recent years on the methodology for evaluating life-saving on government projects and in public policy. It is now well understood that valuation should be carried out in terms of a proper set of compensating variations, on a par with benefit measures used in other areas of project evaluation. To put it plainly, the value of a life is the amount members of society are willing to pay to save one. It is clear that most previously devised measures relate in a very imperfect way, if at all, to the conceptually appropriate measure.[1] However, in view of recent and prospective legislation on product and industrial safety standards, some new estimates are sorely needed.

This paper presents a range of rather conservative estimates for one important component of life value: the demand price for a person's own safety. Estimates are obtained by answering the question, "How much will a person pay to reduce the probability of his own death by a 'small' amount?" Another component of life value is the amount other people (family and friends) are willing to pay to save the life

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[1] See Schelling (1968), Usher (1972) and especially Mishan (1971) and the references therein.

of a particular individual. This second component is ignored. As a matter of course, a new conceptual framework for analyzing this problem is offered. We believe our model will be valuable for other investigations in this and related areas.

The usual methodology of preference revelation from observed behavior in demand theory is the most natural way of approaching the problem. Two types of behavior are relevant in this connection. First, individuals voluntarily undertake many risks of death and injury that are not inherent in their everyday situation, and which could be avoided through expenditure of their own resources.[2] Suppose a person is observed taking a known incremental risk that could be removed by spending one dollar. Then the implicit value of avoiding the additional risk must be something less than one dollar or else it would not have been observed. For example, many people would not purchase automobile seat belts if they were not mandatory. Further, when installation was required, many individuals did not use them, or at least that was so prior to the tied installation of ignition locks and warning buzzers. Some people make a point of crossing streets in the middle of the block rather than at corners, most do not completely fireproof their homes, and so forth. While these and other examples provide scattered evidence on death and injury risk evaluation, it appears doubtful whether they can be systematized enough to yield very convincing evidence on the matter. The second kind of behavior is observed in the labor market in conjunction with risky jobs. Analysis of those data is pursued here.

Our method follows up Adam Smith's ancient suggestion that individuals must be induced to take risky jobs through a set of compensating differences in wage rates. Here the evidence is highly systematic and the data are good. Different work situations exhibit vastly different work-related probabilities of death and injury. Moreover, lots of data are available on wages in these jobs, on the personal characteristics of people who work at them, and on the industrial and technical characteristics of firms who offer them. Further, parties who voluntarily face such risks daily and as a major part of their lives, or production processes, have a special interest in obtaining reliable and objective information about the nature of the risks involved. This is especially true of very risky jobs. Finally, we have uncovered a new source of genuine actuarial data on death rates in risky occupations that is superior to other existing data sources and that until now has not been used for estimation.

[2] Such an approach is suggested by Bailey (1968) and Fromm (1968).

Smith's theory has been familiar to economists for almost two hundred years and, in fact, forms the basis for the best recent inquiries into the economics of safety.[3] Yet very little effort has gone into empirical implementation of the idea. Some people have been hostile to it, asserting—without proof—that forces producing observed wage variation are so varied and complex as to preclude isolating the effect of risk. As will be demonstrated below, Smith's logic suggests that the labor market can be viewed as providing a mechanism for implicit trading in risk (and in other aspects of on-the-job consumption) with the degree of risk (and other job attributes) varying from one job to another. It certainly is not clear why price determination in such markets should be more complex than in any other markets where tied sales occur, such as the housing market. Indeed, the hedonic reconstruction of demand theory suggests that tied sales and package deals of product "characteristics" are the rule and not the exception in virtually all market exchange. Moreover, estimates presented below belie the assertion that partial effects of job risk on wage rates cannot be observed.

Given that risk-wage differentials can be estimated, How are the estimates to be interpreted, and How do they relate to the demand price for safety? Existence of a systematic, observable relationship between job risk and wage rates means that it is possible to impute a set of implicit marginal prices for various levels of risk. Like other prices, the imputations result from intersections of demand and supply functions. In the present case, there are supplies of people willing to work at risky jobs and demands for people to fill them. Alternatively, workers can be viewed as demanding on-the-job safety and firms can be regarded as supplying it.

Difficulties of interpretation arise from two sources. Individuals have different attitudes toward risk bearing and/or different physical capacities to cope with risky situations. In addition, it is not necessarily true that observed risks are completely and technologically fixed in various occupations and production processes. For example, changing TV tower light bulbs on top of the World Trade Building in New York is inherently more risky than changing light bulbs inside the offices of that building. However, it is conceivable to think of ways in which the first job could be made safer, though at some real cost. Whether, in general, firms find it in their interest to make safety-enhancing expenditures, and in what amounts, depends on weighing the costs of providing additional safety to workers against prospective

[3] For example, see Calabresi (1972).

returns. Costs are incurred from installing and maintaining safety devices and returns come in the form of lower wage payments and a smaller wage bill. How can it be known whether observed risk-wage relationships reflect mainly marginal costs of producing safety—the supply of job safety—rather than the demand for it?

This question raises fundamental and familiar issues of identification. Its resolution in terms of job attributes (or in terms of goods attributes in the hedonic view of demand, for that matter) requires a framework of analysis slightly altered from the usual one. The identification problem is resolved on a conceptual level in the following sections, where the nature of equilibrium in the implicit market for job risk is examined in some detail.[4] We show how the observations relate to underlying distributions of worker attitudes toward risk and to the structure of safety technology and particular production processes. The extent to which inferences about the demand for safety can be unscrambled from wage and risk observations quite naturally follows from this exercise. Data, estimates and interpretation of the results are presented subsequently.

THE MARKET FOR JOB SAFETY

As noted above, the theory of equalizing differences suggests labor market transactions can be treated as tied sales. Workers sell their labor, but at the same time purchase nonmonetary and psychic aspects of their jobs. Firms purchase labor, but also sell nonmonetary aspects of work. Thus, firms are joint producers: some output is sold on products markets and other output is sold to workers in conjunction with labor-service rentals. For purposes of exposition, we concentrate on one nonmonetary aspect of jobs, namely the risks of injury and death to which they give rise. The model can easily be extended to several attributes such as free lunches, good labor relations, prospects for on-the-job learning and the like, but the resulting complexity would detract from the main point.

For purposes of analyzing demand for job safety, it is sufficient to consider a market for productively and personally homogeneous workers. Assume worker attitudes toward death and injury risk are independent of their exogenously acquired skills. Workers in this market all have the same skill and personal characteristics, though tastes for job risk bearing generally differ among them. Workers are productively homogeneous, and the only distinguishing characteristic of jobs is the amount of death and injury risk associated with

[4] In fact, the model is an empirical application of a general model suggested by Rosen (1974).

each of them.[5] Jobs exhibiting the same risks are identical, and, by assumption, the personal identity of particular employers and employees is irrelevant to the problem. Job risk itself is a multidimensional concept and requires, at least, a distinction between deaths and injury probabilities, on one hand, and various levels of injury severity, on the other. Again, in line with our aim at simplification, represent job risk by a univariate index p. Further, let p denote the probability of a "standard accident." Then, each job is perfectly described by a particular value of p on the unit interval.

Equilibrium in the job market is characterized by a *function* $W(p)$, yielding the wage rate associated with each value of p. In fact $W(p)$ is a functional generalization of Smith's equalizing differences concept. Given an equilibrium function $W(p)$, each worker chooses an optimal value of p by comparing psychic costs of increased risk with monetary returns in the form of higher wages. This assumes, of course, that workers are risk averse and $W(p)$ is increasing in p. Operationally, optimal choice is achieved through each worker applying for a job offering the desired degree of risk (p). Firms decide what risks their jobs contain by comparing costs of providing additional safety with returns in the form of lower wage payments, and are constrained by their basic underlying technologies. $W(p)$ is an equilibrium function when the number of workers applying for jobs at each value of risk equals the number of jobs offered at each risk. Therefore, $W(p)$ serves as an equilibrating device for matching or marrying off workers and firms, the same role that prices play in standard markets.

Analysis of optimal choices of workers and firms gives an intuitive picture of the mechanism generating the observations on risk and prices (the function $W(p)$). Both decisions are considred in turn. We have sometimes found it convenient to think in terms of supply of workers to risky jobs and firms' demands for job risk, rather than the obverse concepts of workers' demand for job safety and firms' supply of it: safety is the negative of risk.

[5] The reader should note that analysis of worker job choice is confined to people with identical personal characteristics. The point is tricky and will be considered again below. For now, the following example will have to do. Suppose clumsy and careless persons have large negative externalities in risky settings involving groups of workers. Then a set of equalizing differences must arise on worker characteristics (one of which is "carelessness") that are not independent of risk. Costs of employing a careless worker exceed the costs of employing a careful one, and the latter must be paid less than the former. Employers attempt to internalize these externalities by choosing employees with the optimal packages of personal characteristics. It is as if there are separate risk markets for workers with each bundle of personal characteristics, and the present analysis of worker choice is confined to only one of those markets.

AN EXAMPLE

A good starting point for our analysis is the essay by Walter Oi (1973). Some fundamental aspects of the problem and our basic methodology are well illustrated by proving a variant of Oi's main result in very simple fashion and going on from there.

Again, suppose all job risk involves standard injuries and can be represented by work time lost and, consequently, by earnings lost. Deaths and "pain and suffering" due to injuries are ignored for the time being. Adopting this simplification, injuries can be measured in monetary equivalents: a proportion of the wage permanently lost, say, kW, where k is an exogenously determined constant and $0 < k < 1$. Workers choose jobs offering injury probability p, basing decisions on maximization of expected utility. Let $U(Y)$ represent some worker's utility function, where Y is the prospect of certain income. Assume risk aversion: $U' > 0$ and $U'' < 0$. Assume a perfect insurance market: the cost of insurance equals its actuarial value, with no additional load factor, and workers choosing jobs offering injury probability p can purchase insurance at price $p/(1-p)$ per dollar coverage. Both workers and insurance companies know the true probabilities and there is no moral hazard. Let I denote the amount of insurance purchased. Expected utility is given by

$$E = (1-p)U[W(p) - \frac{p}{1-p} I] + pU[(1-k)W(p) + I] \qquad (1)$$

where $W - [p/(1-p)]I$ is net income if an accident does not occur, and $W(1-k) + I$ is income if it does. The worker chooses p and I to maximize E.

Consider optimal amounts of insurance coverage first, conditional on an arbitrary value of p. Differentiate E with respect to I, set the result equal to zero and simplify to obtain

$$U'(W - \frac{p}{1-p} I) = U'[W(1-k) + I] \qquad (2)$$

or equalization of marginal utility in both states of the world. In that losses are converted into monetary equivalents and U is strictly increasing in its argument, condition (2) can be realized only if incomes in both states of the world are equated. That is, (2) implies $I = (1-p)kW$. Substituting this result into equation 1 and simplifying gives

$$E = U[(I - pk)W(p)] \qquad (3)$$

The problem has been converted to optimal choice of p, conditional on prior optimization of insurance coverage.

Define an *acceptance wage* θ as the payment necessary to make the worker indifferent to jobs offering alternative risks, again conditioned on purchasing optimal insurance coverage for each risk. The acceptance wage is defined for a constant expected utility index E, and with recourse to (3) implicitly is defined by

$$E = U[\theta(p, E; k)(1 - pk)] \tag{4}$$

Invert equation (4)

$$\theta(p, E; k) = U^{-1}(E)/(1 - pk) \equiv f(E)/(1 - pk) \tag{5}$$

Equation 5 defines a family of indifference curves in the earnings/risk (θ,p) plane such that the compensated (utility held constant) acceptance wage is increasing in risk at an increasing rate: The marginal rate of substitution between job risk and money is positive and increasing. Differentiating the log of (5) with respect to p shows that the relative marginal acceptance wage, $\frac{1}{\theta}\frac{\partial\theta}{\partial p} = k/(1 - pk)$, depends only on risk, and k is independent of E. In other words, relative marginal acceptance wages are the same for all workers, independently of workers' degrees of risk aversion. This is due to the presence of perfect insurance so that full coverage is rational.

The fact that the function $\frac{1}{\theta}\frac{\partial\theta}{\partial p}$ is equal for all workers yields some arbitrage restrictions on observable wage/risk relationships in the market. Arbitrage mandates the restriction $W'(p)/W(p) = \frac{1}{\theta(p,E)} \cdot \frac{\partial\theta(p,E)}{\partial p}$ for every possible value of p. For proof, assume to the contrary that at some value of p, say p^*, $W'(p^*)/W(p^*) > \frac{1}{\theta(p^*,E)} \cdot \frac{\partial\theta(p^*,E)}{\partial p}$. Then, everybody currently working at a job with risk p^* could improve themselves by applying for jobs involving slightly higher risk. Additional wages on higher-risk jobs exceed relative marginal valuations of them and expected utility must rise from taking slightly larger risks. Jobs such as p^* are unfilled, and relative wages have to change in an obvious way to induce people to apply for them. Exactly the opposite logic applies when the inequality goes in the other direction. In that case, it is also not rational for anyone to apply for any job offering risk p^*. Jobs offering smaller risks yield larger expected utility and $W'(p^*)/W(p^*)$ must increase if p^* type jobs are to be filled. Therefore $W'(p)/W(p) = \frac{1}{\theta}\frac{\partial\theta}{\partial p}$ must hold for all p, and the observed market wage-risk function must satisfy $W'(p)/W(p) = k/(1 - pk)$. This market equilibrium condition can be integrated to yield

$$W(p) = C/(1 - pk) \tag{6}$$

In (6), C is a constant of integration, determined by the side condition that total quantity of labor supplied to the market equals total demand for it. Only if market observations lie along an approximately semi-log function such as (6) can the labor market be in equilibrium in this simple example.

The problem considered above reveals the basic essentials of Smith's theory. In this case, wage differentials are exactly equalizing everywhere, at both the margin and on the average, and wage differences only reflect actuarial differences in risk between jobs. To see this, note that expected earning is $(1 - p)W(p) + p(1 - k)W(p)$, which, from (6), equals C: Expected earning is constant across all jobs, independent of job risk and the distribution of risk aversion in the labor force. Following the general "free lunch theorem," such a distinct and strong result comes from strong assumptions. Perfect insurance implies all risk-averse workers act as expected income maximizers and induces them to act alike, independently of their degree of risk aversion. The result would not have been true had we allowed for pain and suffering, imperfect insurance (nonzero load and hence incomplete coverage), or interpersonal differences in physical capacities to cope with job risk.[6] Equalizing wage-risk relationships depends on the demand for workers, as well as on the supply of them, in those cases, as will be spelled out below.

It is important to note differences between compensation and earnings before turning to a more general formulation of the problem. The

[6] Suppose realized risks in a given situation differ from person to person for exogenous reasons and that personal characteristics (e.g., sense of balance) involve no externalities. Also, in line with footnote 5, assume equalizing difference functions for job risk $W(p)$ and personal characteristics are independent of each other in the relevant sense. Differences in real risks can be handled in the example by specifying a distribution on k across workers. Then the arbitrage-everywhere argument breaks down because all workers cannot be indifferent to all jobs. Even in the presence of perfect insurance, relative marginal acceptance wages depend on k and are not equal for everyone. Obviously those individuals for whom k is small apply for the riskier jobs.

two are related by an identity: Compensation ≡ earnings + fringe benefits. Fringe benefits were ignored above. Had they been included (employers "pay" insurance premiums), no systematic relationship between earnings and risk would have occurred. However, the relationship between compensation and risk would have been described by (6). Insurance fringes act like a tax that is completely "backward shifted" and nominal earnings fall by the amount of the benefit. Workers always pay these costs, whether or not they nominally do so. Therefore, since earnings before fringe benefits and insurance premiums stand in a fixed relationship to each other (the insurance premium is pkW), differences in compensation serve to equalize the market, not differences in net earnings. For example, workmen's compensation is a force making for uniformity in net wage rates across jobs with alternative risks, so long as benefit schedules reflect true monetary (and psychic) losses and the amount of insurance is no more than workers would buy voluntarily. Henceforth the words wage and compensation will be used interchangeably.

SUPPLY PRICE OF JOB RISK

Now the assumptions of perfect insurance and the absence of pain and suffering are relaxed. Only two states of the world were distinguished in the example above, accident-no accident. Taking account of alternative levels of injury severity requires introducing N possible states. For example, N might be 4, a value of 1 indexing no accident, 2 indexing "minor" accidents, 3 "nonminor," nondeath accidents, and 4 indexing death. Demarcation between states 2 and 3 or any other boundaries along the injury-severity continuum are achieved through the use of dummy variable splits on an index such as work days lost. For instance days lost greater than zero but less than some number D_1 correspond to state 2, days lost between D_1 and D_2 correspond to state 3, and so forth. Finer distinctions (and more states) can be made by combining work-days-lost severity indexes and the physical nature of accidents, such as loss of limb, impairment of hearing, and so on.

Conceptually, pain and suffering are represented by different-state utility functions depending on the states themselves. For example, suppose losses for states n through $n + m$ can be converted into monetary equivalents. Then the n through $n + m$ state utility functions are of the same functional form as utility associated with the no-accident state. All other states have utility functions specific to themselves measured in such a way as to be conformable with expected utility axioms.[7]

In general, each possible job is described by an $N - 1$ component vector of probabilities $(p_2, p_3, \ldots, p_N)$ with p_i indexing the probability of state i. [The no-accident probability is ignored because it can be inferred from all the other probabilities: $p_1 = 1 - \prod_{j=2}^{N} p_j$, assuming independence.] In other words, each job is perfectly described by a bundle of different accident probabilities, with the package varying from one job to another. Jobs are associated with a multivariate function, $W(p_2, \ldots, p_N)$, giving the market wage for alternative bundles of job risk. Workers maximize expected utility over all states subject to the equalizing difference function $W(p_2, \ldots, p_N)$. Each worker chooses an optimal p-vector and applies for the job offering those probabilities.

We shall not attempt to present a completely general treatment of the problem. Discussion is specialized to two states for purposes of illustration. State 1 represents no-accident; and state 2, accidents resulting in death. Workers either survive their jobs or they don't, certainly two mutually exclusive events! Each job is associated with a number p, now indexing the probability of death. The market reveals an equalizing difference function $W(p)$ giving compensation as a function of death risk. $W'(p)$ is positive, and other restrictions will be put on it later. Insurance is available at market price $\lambda p/(1-p)$ per dollar of coverage, with $\lambda \geq 1$. The load factor is $(\lambda - 1)$.

Assume a concave utility function $U(Y)$ for the life state as before, choosing the origin so that $U(0) = 0$. The utility (bequest) function for the death state is $\psi(Y)$, also concave with $\psi(0) = 0$. For obvious reasons, U and ψ are restricted to obey the inequality $U(Y) > \psi(Y)$ for all common values of Y. The worker chooses p and I to maximize

$$E = (1-p)U\left[W(p) + y - \frac{\lambda p}{1-p} I\right] + p\psi(y + I) \tag{7}$$

where y is nonlabor income. $W + y - [\lambda p/(1-p)]I$ is income if the worker lives and $y + I$ is beneficiaries' income if he dies. Assuming E is strictly concave in p and I, necessary and sufficient conditions for a maximum are

$$E_I = -p(\lambda U' - \psi') = 0$$

$$E_p = -U + \psi + (1-p)U'[W' - \lambda I/(1-p)^2] = 0 \tag{8}$$

[7] See Hirshleifer (1965).

Equations (8) jointly determine optimal values of p and I. Notice that it is no longer true that marginal utilities in both states are equal. Even if they were (i.e., if $\lambda = 1$), equality would not imply equal incomes in both states, because U' and ψ' are not identical functions. Hence the arbitrage argument used in the example above no longer applies because people with alternative utility functions behave differently.

Conditions (8) are not very informative in and of themselves unless functional forms are specified for U and ψ. In the absence of that, a very general picture of equilibrium is obtained by going the route described in the section above. Again define an acceptance wage θ as the amount of money the worker would willingly accept to work on jobs of different risks at a constant utility index, conditioned on optimal purchase of insurance. Then $\theta(p, E; y, \lambda)$ is defined implicitly by solving for θ and I in terms of E, y and λ from

$$E = (1 - p)U[\theta + y - \frac{\lambda p}{1 - p} I] + p\psi(y + 1)$$

$$0 = \lambda U'\{\theta + y - [\lambda p/(1 - p)]I\} - \psi'(y + I) \qquad (9)$$

The following properties of θ can be derived from the implicit function theorem[8]

$$\theta_p > 0,\ \theta_{pp} > 0 \qquad \text{(i)}$$

The marginal acceptance wage is positive and increasing in risk. θ_p is the expected-utility compensated supply price to risky jobs and is rising because of risk aversion, imperfect insurance, and pain and suffering (U is not the same as ψ). Property (i) is crucial to what follows.[9]

$$\theta_E > 0,\ \theta_y < -1 \qquad \text{(ii)}$$

The acceptance wage is increasing in expected utility and decreasing in nonlabor income at any given risk. Moreover, an additional dollar of nonlabor income lowers the acceptance wage (utility held constant) by more than a dollar. The reason for the latter is that additional dollars of nonlabor income increase utility in both states, thereby reducing

[8] These results can easily be checked by the reader. Take care always to treat θ *and* I as dependent variables and p, E, y, and λ as independent variables in the differentiation.

[9] It is conceivable that no insurance is purchased if strict concavity in (7) is not assumed. Suppose marginal utility of bequests rapidly approach zero after some dollar value. A husband might want to leave his wife with at least \$100,000 if he dies, but bequest dollars in excess of 100,000 do not yield much additional utility. It may be rational for him not to purchase insurance if his nonlabor wealth is in the neighborhood of \$100,000. Even in such cases, the fundamental convexity property of indifference curves in Figure 1 still applies.

optimal amounts of insurance and payments of insurance premiums in the life state.

$$\theta_{pE} > 0,\ \theta_{py} < 0,\ \theta_{p\lambda} > 0 \qquad \text{(iii)}$$

The marginal acceptance wage increases at higher levels of welfare: the better off a person is, the larger the monetary inducement necessary to coax him into a higher risk job. On the other hand, marginal acceptance wages decrease as nonlabor income rises (utility "held constant") for reasons stated under property (ii). Finally, increasing λ renders risk bearing more expensive and increases its reservation price.

Risk/earnings indifference curves $\theta(p;\ E,\ y)$ for a worker with some fixed amount of nonlabor income are shown in Figure 1. Labels E_1, $E_2, \ldots$, are in ascending order of expected utility, from property (ii). Convexity follows from property (i). Notice that the slopes of the indifference curves rise along a vertical line, a result of property (iii).

The heavy line labeled $W(p)$ represents risk/earnings opportunities or the market equalizing-difference wage function.[10] As usual, optimum choice of p (represented by p^* in the figure) occurs where the budget line and an adjoining indifference curve have a common tangent. Clearly, the curvature of $\theta(p)$ and $W(p)$ must stand in a proper relationship to each other if the solution is to be unique and interior, as is true in the assumption of strict concavity of (7).

Three empirically meaningful propositions emerge from properties (i)–(iii) and the equilibrium condition in Figure 1.[11]

Proposition I: Job safety is a normal good.

This statement needs careful interpretation and qualification. Consider the following parameterization of the budget: $W(p) = A + BV(p)$, where $V(p)$ is an increasing function of p and A and B are parameters. The statement holds true for changes in A. For example, let A increase. The budget line rises parallel to its initial position and expected utility also rises. But property (iiia) implies marginal acceptance wages rise too. Hence risk falls and the worker chooses a safer job.[12] Changes in A are analogous to pure income effects in demand

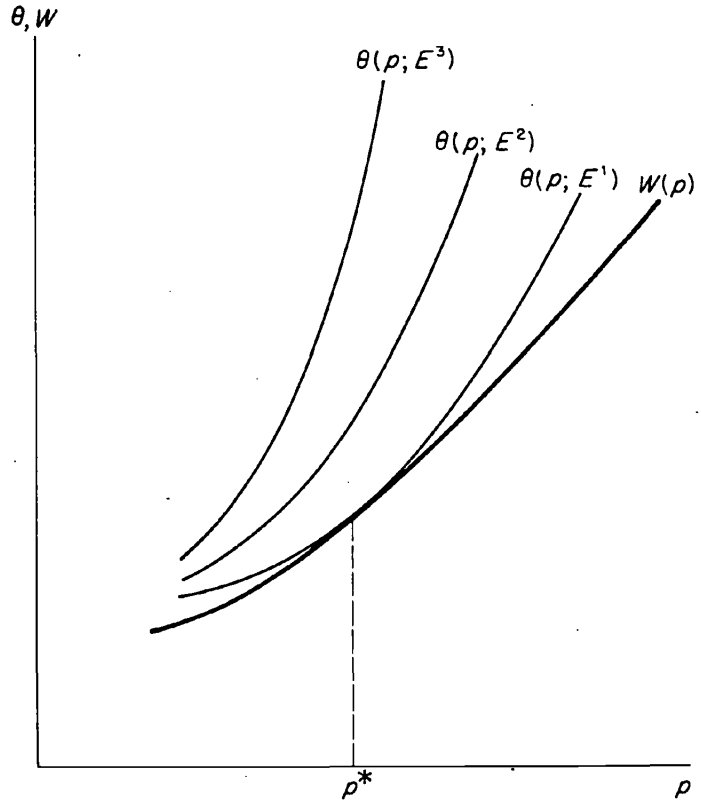
[10] As shown by example in the preceding section, there is no reason for $W(p)$ to be linear in p. The budget constraint can be distinctly nonlinear.

[11] These statements are easy to prove analytically. Differentiate equations (8) and exploit second-order conditions for a maximum, as usual.

[12] Some casual evidence is relevant here. Secularly increasing job safety in the U.S. has been accompanied by a trend of rising real wages. No doubt improvements in safety technology have decreased the price of safety as well.

FIGURE 1

Worker Equilibrium



theory. The statement does not hold for changes in B. An increase in B results in a negative income effect (on risk), but a positive substitution effect (on risk) in that increasing marginal earnings on riskier jobs makes risk bearing more attractive. The net outcome is unpredictable without further specification.

Proposition II: Job safety is positively related to the price of insurance.

This is an immediate consequence of (iiic). Decreasing the insurance load factor makes risk bearing cheaper, everywhere decreasing marginal rates of substitution between money and risk. More risk necessarily is purchased.

Proposition III: Job safety is not necessarily normal with respect to property income.

This nonintuitive result can be motivated in part as follows: Increasing nonlabor income provides a kind of self-insurance against the death state, since nonlabor income (willed to one's heirs) is not at risk in the labor market. This reduces needs for market insurance and makes risk bearing less expensive, a kind of substitution effect. However, increasing y also increases expected utility and has the effect of increasing the marginal acceptance wage for any incremental risk, a kind of income effect. The two effects work against each other. Mechanically, the result comes from properties (iib), (iiia) and (iiib). An additional dollar of nonlabor income shifts the entire indifference map downward by more than a dollar (iib) and also reduces marginal rates of substitution for given expected utility measures (iiib). However, marginal valuation of risk is increasing in expected utility (iiia) and marginal rates of substitution still increase along any vertical line in Figure 1. The first effect is a force making for increased risk, while the second works in the opposite direction. Curiously, it can be shown analytically that risk is necessarily inferior in nonlabor income when the insurance load is zero (i.e., $\lambda = 1$). Evidently, when the price of insurance exceeds its actuarial value there is a possibility for the kind of substitution effect described above to dominate the real income effect, tantamount to a type of risk preference.

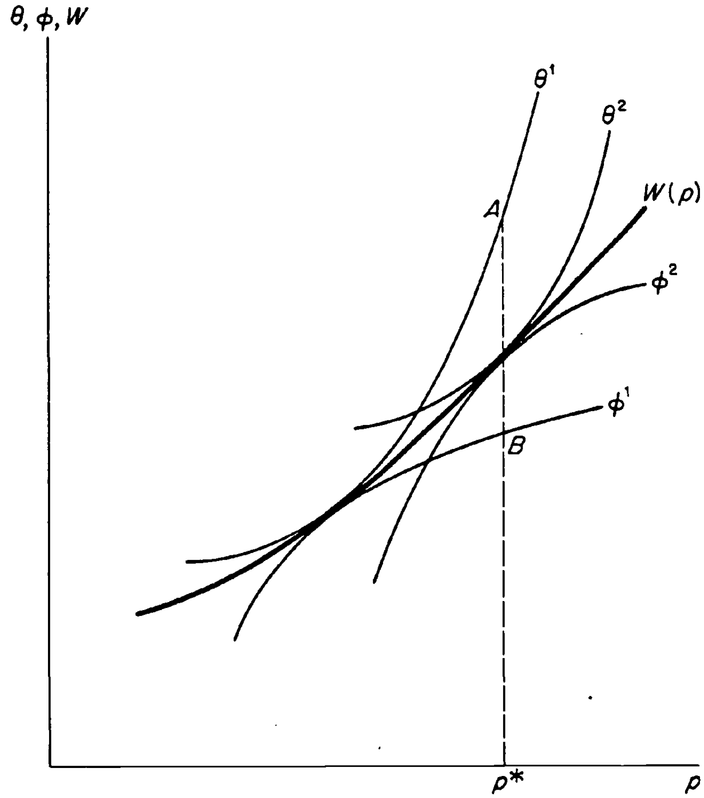
EQUALIZING DIFFERENCES AND SUPPLY PRICES

The discussion above shows that worker choice is characterized by two equilibrium conditions: $W(p) = \theta(p, E)$ and $W'(p) = \partial\theta/\partial p$, two equations in two unknowns, p and E. Workers differ in their attitudes toward risk, bequest motives, and nonlabor income. Consequently there is a distribution of acceptance wage functions in the market. Those with less risk aversion have smaller marginal acceptance wages (i.e., smaller values of $\partial\theta/\partial p$) and lower reservation prices to risky jobs. The opposite might be true of people with many dependents or with high degrees of risk aversion in the accident state. Whatever the source of interpersonal differences, workers with lower marginal acceptance wages work on riskier jobs.

A picture of market equilibrium on the supply side of the market is shown in Figure 2. Ignore the curves labeled ϕ^j for the moment. $W(p)$ is the equalizing difference function as in Figure 1. Two workers are shown in Figure 2, one with acceptance wage θ^1 and the other with θ^2. $(\partial\theta^1/\partial p) > (\partial\theta^2/\partial p)$ and worker 2 is employed on a riskier job, since

FIGURE 2

Market Equilibrium



safety is not as valuable to him. The picture may be generalized. Add more workers and fill in all points on the $W(p)$ line. It is apparent that $W(p)$ is the lower envelope of a family of acceptance wage functions depending on the joint distribution of y, U and ψ across workers. $W(p)$ is observed, while the functions θ^i are not. However, evaluate the derivative of the equalizing wage difference function at some value of p, say p^*. Then, from the equilibrium conditions, $W'(p^*) = \partial\theta^i(p^*, E^*)/\partial p$ for workers finding p^* optimal, and $W'(p^*)$ identifies the marginal acceptance wage for such workers. Therefore, $W'(p^*)$ identifies $\partial\theta^i/\partial p$. $W'(p^*)$ estimates how much money is necessary to induce a person into accepting a small incremental risk. Alternatively, it estimates how much the person will pay to reduce risk by a small amount, exactly the number we seek.

The empirical work reported below uses data from very risky jobs, on the average perhaps as much as five times more risky than most jobs in the U.S. economy. It must be true that individuals working on such jobs have lower reservation supply prices and consequently smaller demand prices for safety than the average worker. The point is illustrated in Figure 2. Evaluating W' at p^* provides the correct estimate for person 2, but is an underestimate for person 1. The price the latter is willing to pay for safety at p^* is given by the slope of his acceptance wage function evaluated at p^*, the slope of θ^1 at the point marked A in Figure 2. It follows from the fact that compensated supply functions to risky jobs are rising (i.e., acceptance wage functions are convex) that $\partial\theta^1(p^*, E^*)/\partial p$ exceeds $W'(p^*)$. Most people in the labor force do not work on risky jobs. Therefore, use of data on very risky jobs understates average demand prices for safety at the observed risk levels in our sample. This justifies our initial assertion that the estimates below are conservative and probably biased downward when extrapolated to the population as a whole.

DEMAND PRICE FOR JOB RISK

It was demonstrated above that $W'(p)$ identifies supply price of risk at the relevant margin. That conclusion was reached independently of demand considerations. We now consider a very simple model of demand prices and firm decisions in order to complete the model. It will hardly be shocking to discover that $W'(p)$ also identifies demand price for risk at some margin.

Accidents are an unpleasant, though in part avoidable, by-product of production. This fact of life (or of death!) can be represented analytically by a joint production function $F(x, p, L) = 0$ for some firm, where x is marketable output, p is the accident rate, and L is labor input. Inputs other than labor are ignored. p can be a vector of state accident probabilities as mentioned above. However, to simplify, collapse it into a univariate index denoting the probability of death. Invert F and assume the following properties for $x = g(p, L)$: (i) $g_L > 0$ and $g_{LL} < 0$. Labor has positive and diminishing marginal product. (ii) $g_{Lp} < 0$. Safety increases the marginal product of labor. (iii) $g_p > 0$ for $0 \leq p < \bar{p}$, $g_p \gtrless 0$ for $p \geq \bar{p}$, where $\bar{p}$ is some "large," technically determined constant, and $g_{pp} < 0$. The assumptions on

g_p are best explained by noting that they imply that the transformation locus between output (x) and safety ($1-p$) is negatively inclined, except possibly at very low levels of safety. Accidents are "productive," at least up to a certain point, and can be avoided only by changing the organization of production within the firm away from marketable output and toward accident prevention. The assumption on g_{pp} means the transformation function is concave.

The production function $g(p, L)$ has been written so that safety is, in effect, produced internally by the firm. Safety devices (such as guard rails and hard hats) can also be purchased and installed externally. Let $G(1-p)$ represent the cost of externally provided safety (converted to an annual flow), with G' and $G'' > 0$. The latter means installation activities are subject to increasing costs, though that is not strictly necessary to what follows.

The firm maximizes profit Π with respect to L and p

$$\Pi = g(p, L) - W(p)L - G(1-p) \tag{10}$$

where the price of x has been normalized at unity. Again $W(p)$ represents the competitive wage that must be paid for alternative levels of risk. Necessary conditions for a maximum are

$$g_p + G' = W'(p)L$$
$$g_L = W(p) \tag{11}$$

Labor is hired up to the point where its wage and marginal product are equal. Marginal costs of risk are the additional market wage payments necessary to attract workers to riskier jobs. Marginal benefits come in the form of additional market output and cost savings from installing fewer safety devices. Second-order conditions require certain curvature restrictions on $W(p)$ as will be shown.

Symmetrically with the treatment above, define an *offer* function ϕ as the amount the firm willingly pays the optimal number of workers at alternative levels of risk and constant profit. With recourse to the definition of profit and the marginal condition on labor, $\phi(p, \Pi)$ is defined implicitly by

$$\phi = [g(p, L) - G(1-p) - \Pi]/L$$
$$\phi = g_L(p, L) \tag{12}$$

Clearly $\partial\phi/\partial p$ is the compensated demand price for risk. Differentiating (12) [again, always treat ϕ and L as dependent variables, and Π and p as independent variables]

$$\partial\phi/\partial\Pi = -1/L$$

$$\partial\phi/\partial p = (g_p + G')/L$$

$$\frac{\partial^2\phi}{\partial p^2} = [(g_{pp} - G'')g_{LL} - (\phi_p - g_{Lp})^2]/Lg_{LL} \lesseqgtr 0$$

The marginal demand price for risk is positive. However, even the common assumption of concavity of the production function does not guarantee that the compensated demand schedule is negatively inclined: $\partial^2\phi/\partial p^2$ can be positive.

The offer function $\phi(p, \Pi)$ defines a family of indifference curves in money and risk, one member of which is shown in Figure 2. ϕ^1 refers to one firm and ϕ^2 refers to another firm, possibly in a different industry and in any case, with a different technology than firm 1. The diagram assumes $\partial^2\phi/\partial p^2 < 0$, which is not necessarily true. Equilibrium of each firm is characterized by tangency between the market availabilities function $W(p)$ and the lowest possible constant-profit indifference curve (profit increases as ϕ decreases at any level of risk, since $\partial\phi/\partial\Pi < 0$). W'' must exceed $\partial^2\phi/\partial p^2$ at the point of tangency for an interior maximum.

Similarly to the case of worker choice, $W'(p) = \partial\phi/\partial p$ at equilibrium, and $W(p)$ represents an upper envelope of the distribution of offer functions in the market. The family of offer functions depends on the nature of production functions in various firms and industries and on corresponding distributions of industrial safety technology. In any event $W'(p^*)$ also identifies $\partial\phi^i(p^*, \Pi^*)/\partial p$, where firm i is one that has chosen p^* optimally. Using the same logic as above, $W'(p^*)$ overestimates the average supply price of safety (again, at p^*) if p^* is a very risky job. This is easily seen in Figure 2, since the slope of $\partial\phi^1/\partial p$ at point B necessarily is smaller than the slope of $\partial\phi^2/\partial p$ evaluated at the same level of job risk.[13]

MARKET EQUILIBRIUM: SUMMARY

It will be useful to summarize results of the model so far.

(a) The observable wage-risk relation represents a double envelope

[13] Suppose L is exogenous. Then, the offer function is defined by the first equation in (12), and it is easy to show that increased values of L reduce demand price for risk ($\phi_{pL} < 0$), providing incentives to offer safer jobs. Increasing incentives toward job safety vary directly with establishment size because of larger cost savings from lower wage rates. It is well known that accident rates decline with establishment size, at least after some minimum size. Accident rates also tend to be low in very small establishments as well, so this cannot be the entire story.

function: It is the lower boundary of a set of acceptance wage functions and the upper boundary of a set of offer wage functions. Marriages between jobs and applicants at each level of risk are represented by common tangents of appropriate acceptance wage and offer wage functions.

(b) The envelope property in (a) implies that the derivatives of observed risk-wage differentials (evaluated at each level of risk) identify *marginal* supply and demand prices of workers and firms choosing those particular job risks.

(c) Supply price of risk (equivalently, demand price for safety) identified in (b) from very risky jobs underestimates the average supply price in the labor force for those risks, since people choosing risky jobs have a comparative advantage at job risk bearing. Similarly, demand price for risk (supply price of safety) identified from very risky jobs overestimates the average demand price for most firms in the economy, since firms offering risky jobs have a comparative disadvantage at producing safety.

(d) The numbers identified in (b) represent single points on compensated supply and demand functions, not the functions themselves. Use of such numbers for evaluation overestimates consumer surplus of finite increases in safety because workers' compensated demand schedules for safety are negatively inclined.

EQUILIBRIUM AND WORKER CHARACTERISTICS

A very simple demand model has been specified above, and it may be too simple. Recall the production function has been written $x = g(p, L)$, where L is labor and p is risk. But what is labor?[14] Our data contain indicators of personal productivity such as education and work experience. Suppose there are m such indicators, denoted by a vector $c = (c_1, \ldots, c_m)$. Of course, sample wages vary with worker characteristics as well as with job risk. Let $W(p, c)$ represent the market wage-risk-characteristics equalizing difference function. Writing the production function for a firm as we did implies that firms act as if there exists a single index of labor input, $L = f(c_1, \ldots, c_m)$ defined independently of job risk. If so, the production function must be separable in c and p. This is also a sufficient condition for separability of $W(p, c)$ as well. Suppose $W(p, c)$ is additive in p and c: $W(p, c) = V(p) + T(c)$. Hence, firms care only about total amounts of "skill" they employ (i.e., L) independently of how skills come packaged in

[14] The reader may be thinking, "What is risk?" The two questions are very much related. See below.

people and also independently of job risks to which their employees are subjected. In effect, it means that packages of worker characteristics can be untied. For example, firms might be indifferent between a worker with 8 years of schooling and 10 years of experience and another with 12 years of school and 3 years of experience, or between workers with other combinations of these characteristics.

The real issue under discussion here involves how many interactions to allow in the risk and characteristics wage-explaining regression. At one extreme is the possibility for a universal implicit market for risk, independent of worker personal productivities (no interactions). At the other extreme are separate implicit markets for all possible combinations of personal characteristics (complete interactions). The former case corresponds to the firm choice model sketched above. Yet there is a distinct possibility that risk affects productivity in a nonhomogeneous manner with respect to various productivity indicators. Then some interactions are required. In general, the market reveals implicit prices for both risk and worker characteristics. All prices are determined simultaneously and cannot be separated,[15] and the firm choice model sketched above must refer to a single type of worker (c held constant).

If there is no interaction in production between worker characteristics and safety, only one risk premium for each value of risk appears in the market. Furthermore, the risk-wage function is independent of any further interaction between worker characteristics and attitudes toward risk. Differences in worker characteristics (age, marital status, and so on) that result in different acceptance wage functions simply help identify which workers accept riskier jobs. On the other hand, if there are interactions in production, differential risk premiums according to personal characteristics generally appear, so long as the preferred characteristics are in sufficiently scarce supply. If these characteristics are not in short supply, only those workers with preferred attributes work on risky jobs and no differential risk premium need arise in the market. Finally, if differential risk premiums exist, $W(p)$ in Figures 1 and 2 becomes a family of curves $W(p, c)$, one for each value of c, as was noted above (see footnote 5).

[15] In part, firm decisions can be handled formally as follows. The production function is $x = h(p, c_1, \ldots, c_m) = h(p, c)$. Profit is $h(p, c) - W(p, c)$, maximized over p and c. The firm organizes production taking account of factor supplies (i.e., $W(p, c)$), designing jobs and their risks and determining a set of worker-characteristics requirements. Workers not meeting requirements are not hired by the firm. Now define a joint offer-requirements function $\zeta(p, c, \Pi)$, indicating offer prices for alternative risk-characteristics requirements at constant profit, and compare the resulting indifference surfaces in (money, p, c) space with market availabilities $W(p, c)$.

The issue is rather thorny, but an example will clarify it. Consider the regression model

$$W = a_0 + a_1 p + a_2(pz) + \text{random error} \qquad (13)$$

where W is observed wages, p is risk, z is worker age, and the a's are regression coefficients. The pure effect of age, higher order terms in p, and all other explanatory variables are impounded in the constant term a_0 for purposes of this discussion.

Age presumably affects worker's acceptance wages. Young workers risk entire lifetimes of future consumption in taking high risk jobs and have far more to lose than their older counterparts. Supply price to risky jobs should fall with age on that account. Further, a typical individual may become more or less risk averse over his lifetime, inducing shifts in acceptance wage functions over the life cycle. Job risk should be systematically related to age for both reasons. However, variations of this variety are completely captured by movements along the observed risk-wage function (taking account of possible effects of age on a_0) and there is no role here for extra marginal effects of age on risk premiums per se. Look at Figure 1. The changes under consideration are represented by systematic variations in money-risk preferences, resulting in moving points of tangency between a life-cycle shifting acceptance wage function and a fixed risk, market opportunities function. Movements along $W(p)$ should not be confused with shifts in it, and all such changes are already counted in the pure risk coefficient a_1.

Age can affect market risk premiums only insofar as it reflects unmeasured characteristics whose productivities are affected by differential risk. Exposure to risky situations makes some people far less effective agents of production than others. They not only accomplish less work of their own, but also impose extra costs on others. Both effects have to reduce wage rates of these persons if they are observed working at risky jobs. Such wage differentials serve as compensation for additional costs firms incur in employing them. For example, "nerves of steel" is a scarce factor, but steely nerves capture rents only in risky situations. Good balance is valuable to iron workers on building sites but not to desk clerks, and so forth. In the present case, young workers on the average have speedier reflexes than older ones and have faster reactions to potential accidents. But older workers have had more exposure and experience with job risk, and experience and quick reflexes probably are substitutes. Hence the effect of age on productivity in the presence of risk is uncertain, though we might expect the reflex effect to dominate, by and large, for workers past some age that varies across occupations.

Whatever the interactions between risk differentials and personal characteristics, the analysis underlying Figure 1 still applies. The marginal effect of risk on wages evaluated at the person's exogenously determined characteristics estimates supply price for risk or demand price for safety. It also estimates firms' supply price of safety to workers with those characteristics. It is certainly possible, however, that observed risk differentials vary with worker attributes.

THE DATA

Empirical implementation of the model requires information on earnings of individuals, job risks they face, and their personal and job-related characteristics. It involves augmenting standard wage equations with job-risk measures. Many cross-sectional sources of earnings data are available and we have chosen one of them, the 1967 Survey of Economic Opportunity (SEO). The SEO survey was designed to heavily represent low-income populations and our sample is restricted to an extract of the data, consisting of a random sample of 9,488 representative households in the U.S. population. Of these observations, the sample was further reduced to adult male heads of households. The SEO data provides information on personal and industrial characteristics and labor force activities of individuals. It also lists individuals' industry of employment and occupation.

The standard source of data on industrial hazards is published by the Bureau of Labor Statistics (BLS) in conjunction with compliance and experience surveys under the Workmen's Compensation Act. These data give accidental death and injury rates for 4-digit SIC industry codes on an annual basis. Unfortunately, the BLS death and injury data cannot be adequately matched to individuals and is unsuitable for the purposes of this study. For example, it is possible to assign the BLS average death and injury indexes (by industry) to individuals in the SEO tape because the individual's industrial attachment is known. However, using the death and injury statistics in that manner implies introducing a huge component of measurement error for individuals, because job risks in each industry are not uniform across occupations. Hence, any estimates of the risk premium obtained in this way will probably be biased.

Luckily, another data source was discovered which does not suffer from the aggregation problems inherent in published BLS sources. The data used here come from the 1967 Occupation Study of the

Society of Actuaries. The purpose of the 1967 study was to measure *extra* risks associated with some very hazardous occupations and the study was based on a sample of insurance company records covering 3,252,262 policy years of workers' experience over the period 1955–1964. The data were tabulated on a combined industry and occupational basis, and can be matched directly to individuals on the SEO sample, using Census categories contained in the latter. The matching procedure yielded 37 occupations on about 900 individuals. The occupations and their sample actuarial risks are listed in Table 1. Of course, it would be quite rash to assert that the actuarial data overcome all matching difficulties, because Table 1 shows that the actuarial classifications are rather broad. However, they are far more narrowly defined than the BLS data. We are extremely confident that the degree of measurement error in attributing risks to SEO individuals using the actuarial data is perhaps as much as an order of magnitude smaller than would be true had we matched with BLS risk data—especially for individuals working on very risky jobs, such as most of those in Table 1. In other words, the actuarial study simply provides the best data that are available for estimating risk premiums in the labor market.[16]

The actuarial data have one other very good feature. An expected number of deaths was estimated in each occupation, based on the age distribution of persons in the sample records and standard life tables. Expected deaths were then subtracted from actual deaths and the result normalized to yield an *extra* deaths per thousand policy years statistic (those numbers are multiplied by 100 in Table 1). Hence the numbers in Table 1 are net of normal age-specific death experience and measure extra death risk associated with occupations. These statistics reflect genuine occupational hazards that may cumulate with time spent in the profession. To see how risky these jobs are, note that the mean value in Table 1 is approximately 100. In probability terms, this amounts to an extra 1 in 1,000 probability of death. The probability of death from the 1967 life table for white males 35 years of age was 2 in 1,000. Thus, though the probabilities are small in absolute terms, they are very large relative to the risks most people incur in the ordinary course of their lives.

[16] After this study was completed, we discovered a paper by R. Smith (1973), who used the BLS hazard data. At an earlier stage of our research, and before discovering the Actuaries Study, we too experimented with BLS data. Our results were very similar to Smith's. However, in view of the measurement error, we believe that Smith's very strong conclusions about the workings of the labor market are totally unwarranted and that his estimates must surely be seriously biased.

TABLE 1

Sample Occupations and Risks

Occupation	Risk [a]	Occupation	Risk [a]
Fishermen	19	Truck drivers	98
Foresters	22	Bartenders	176
Teamsters	114	Cooks	132
Lumbermen	256	Firemen	44
Mine operatives	176	Guards, watchmen, and doorkeepers	267
Metal filers, grinders and polishers	41	Marshals, constables, sheriffs and bailiffs	181
Boilermakers	230	Police and detectives	78
Cranemen and derrickmen	147	Longshoremen and stevedores	101
Factory painters	81	Actors	73
Other painters	46	Railroad conductors	203
Electricians	93	Ships' officers	156
Railroad brakemen	88	Hucksters and peddlers	76
Structural iron workers	204	Linemen and servicemen	2
Locomotive firemen	186	Road machine operators	103
Power plant operatives	6	Elevator operators	188
Sailors and deckhands	163	Laundry operatives	126
Sawyers	133	Waiters	134
Switchmen	152		
Taxicab drivers	182		

SOURCE: Society of Actuaries.
[a] Units of measure are extra deaths per 100,000 policy years. To convert to the probability of an extra death per year on each job multiply by 0.00001.

A less attractive feature of the actuarial risk data is that they only include death rates. Separate indexes for death and nondeath accidents would be preferable, but nondeath accident statistics comparable to those in Table 1 are not available. We must rest content with the knowledge that death rates and injury rates in the BLS industry data are highly correlated, and there is no reason for that not to be true in our data as well.

Several earnings measures are available from SEO data. We have experimented with all of them and settled on the weekly wage, because it probably is measured most accurately. We would prefer to use a measure of total compensation, but the value of fringe benefits are not available on the SEO tape or any other data set on individuals known to us. This omission must reduce the observed risk differential, again pointing toward conservative estimates. The extent of bias depends on the size of the load factor and the importance of pain and suffering, as well as on the precise differences between life (U) and bequest (ψ) utility functions. In any event, the average amount of life insurance provided in fringe benefits is not very large, and this source of bias must be rather small.

ESTIMATION

Our goal is to estimate the equalizing difference function $W(p, c)$. Four types of independent variables are used to control for factors determining wage rates other than job risk. These are the content of the c variables. The first set controls for regional and urban-nonurban wage differentials. The second set measures individuals' personal characteristics, including age, education, family size (or marital status), and race. The square of age and education can be included to allow for nonlinearities. The third set controls for other characteristics of the job, including unionization, dummy variables for manufacturing and service industries, and three major occupational dummy variables, one for operatives (OC1), another for service workers (OC2), and a third for laborers (OC3). Socioeconomic status (SES) was used at one stage instead of the occupational dummies as a crude measure of other nonpecuniary aspects of work. SES is an index number based on occupation, education, and income, and it might capture some other types of equalizing differences, though it was not constructed for that purpose.

Means and standard deviations of all variables are shown in Table 2. Note that the sample includes a much higher proportion of union members than obtains in the labor force generally. Sample mean earnings on an annual basis is about \$6,600 (= 132 × 50), which is a bit less than average earnings among male manufacturing workers during this period.

Regression planes have been fitted by least squares, using arithmetic values of earnings as the dependent variable; and alternatively, using the log of earnings as the dependent variable. The arithmetic results are shown in Table 3. Results using the log of earnings are reported in Table 4 and are very similar to the arithmetic results when evaluated at sample means.

The first two columns in Table 3 give alternative estimates of $W(p, c)$ on the strong assumption of no interactions. All the nonrisk variables are assumed to simply shift the wage-risk relationship, leaving its slope intact. Regression coefficients of almost all characteristics

TABLE 2

Summary Statistics

Variable	Mean	Standard Deviation
Dummy variables [a]		
Urban	.69	.46
Northeast	.28	.45
South	.29	.45
West	.17	.38
Family size exceeds 2	.76	.42
Manufacturing industry	.24	.42
Service industry	.58	.49
Worker is white	.90	.30
Worker is employed full time	.98	.10
Worker belongs to union	.45	.49
Worker is married	.92	.26
Occupation is operative	.27	.44
Occupation is service	.45	.49
Occupation is laborer	.22	.42
Continuous variables		
Age (years)	41.8	11.3
Education (years)	10.11	2.73
Weeks worked in 1966	49.4	5.4
Hours worked last week	44.9	11.6
Risk (probability $\times 10^5$)	109.8	67.6
Weekly wage (week prior to survey)	$132.65	50.80

[a] Mean is proportion in sample with designated characteristic. The number of observations is 907.

variables have the expected signs found in most other studies, and most are statistically significant. Further discussion is unwarranted here.

The theory requires the wage-risk function to be positively inclined, and that is certainly the case on the appropriate one-tailed test of significance (see equations 1 and 2 in Table 3). [It is interesting to note that the simple correlation between risk and wage (not shown) is negative in these data.] $(\text{Risk})^2$ was also entered in the regression but was not significant. We are not trying to argue here that $W(p, c)$ is linear in p, since most of the results using log W as dependent variable in Table 4 are at least as good as those in Table 3. The data simply do

TABLE 3

Regression Estimates of $W(p, c)$—Linear Form

Independent Variable	Equation 1	Equation 2	Equation 3	Equation 4
Risk	.0352	.0520	.100	.0410
	(.0210)	(.0219)	(.108)	(.102)
Risk × age	-	-	−.0019	−.0030
			(.0018)	(.0019)
Risk × married	-	-	.0791	.0701
			(.0380)	(.0412)
Risk × union	-	-	.0808	.0869
			(.040)	(.042)
Risk × white	-	-	−.118	-
			(.072)	
Urban	13.80	15.71	17.0	17.0
	(4.2)	(2.95)	(3.0)	(3.2)
Northeast	−3.71	−4.29	−4.27	−4.92
	(3.65)	(3.67)	(3.63)	(3.83)
South	−8.86	−8.90	−10.5	−8.18
	(3.70)	(3.74)	(3.72)	(3.97)
West	9.13	10.30	9.57	9.50
	(4.13)	(4.18)	(4.12)	(4.37)
Age	3.89	3.81	3.83	3.78
	(0.80)	(0.83)	(0.82)	(0.87)
$(\text{Age})^2$	−.0479	−.0468	−.0442	−.0415
	(.0092)	(.0097)	(.010)	(.011)
Education	3.40	3.27	4.13	4.81
	(0.55)	(2.40)	(2.39)	(2.80)
$(\text{Education})^2$	-	−.021	−.0237	−.042
		(.128)	(.128)	(.148)
Manufacturing industry	-	-	−13.0	−14.7
			(4.3)	(4.62)
Service industry	-	-	−9.45	−10.9
			(3.95)	(4.24)
White	22.92	22.93	37.7	-
	(4.53)	(4.50)	(9.6)	
Family size > 2	-	-	.400	2.10
			(3.57)	(3.89)
Union	25.5	27.16	15.9	15.39
	(3.25)	(3.23)	(5.4)	(5.72)
Full-time	−1.63	−.86	−1.16	.45
	(12.9)	(12.6)	(12.6)	(15.0)
Hours worked	1.50	1.41	1.47	1.44
	(.12)	(.12)	(.123)	(.129)
Occupation 1: operative	−18.7	-	−13.9	−13.5
	(9.2)		(3.24)	(3.51)

TABLE 3 (concluded)

Independent Variable	Equation 1	Equation 2	Equation 3	Equation 4
Occupation 2: service worker	−24.6 (9.5)	-	−18.1 (4.66)	−19.9 (5.05)
Occupation 3: laborer	−25.0 (13.4)	-	-	-
SES 1	-	4.68 (5.17)	-	-
SES 2	-	−17.17 (3.34)	-	-
SES 3	-	−20.69 (5.53)	-	-
R^2	.41	.41	.42	.39
Number of observations	907	907	907	813
Sample	All	All	All	White only

NOTE: The dependent variable is the weekly wage rate. The SES index has been converted to dummy variables. Standard errors are in parentheses.

not provide enough resolution on functional form tc make a choice. The implied t statistic on risk is larger when SES is used in place of occupation (equation 2, Table 3), though the point estimates are not very different. First, consider the point estimate 0.0352 obtained from equation 1 of Table 3. The risk variable has been scaled by 10^5 for computational purposes and the estimate 0.0352 implies that jobs with extra risks of 0.001 (a value near the sample mean) pay $3.52 per week more than jobs with no risk. This amounts to about $176 per year, and the slope of the regression on a yearly basis is $176,000 ($= .0352 \times 50 \times 10^5$). Recall that the slope of the wage-risk relation $W'(p)$ estimates the implicit supply and demand price to risky jobs. To interpret the result, think in terms of the following conceptual experiment. Suppose 1,000 men are employed on a job entailing an extra death risk of .001 per year. Then, on average, one man out of the 1,000 will die during the year. The regression indicates that each man would be willing to work for $176 per year less if the extra death probability were reduced from .001 to .0. Hence, they would together pay $176,000 to eliminate that death: the value of the life saved must be $176,000. Furthermore, it must also be true that those firms actually offering jobs involving .001 extra death probabilities must have to spend more than $176,000 to reduce the death probability to zero, be-

TABLE 4

Regression Estimates of $W(p, c)$ – Semilog Linear Form

Independent Variable	Equation 1	Equation 2	Equation 3	Equation 4
Risk	.000206	.000286	.000943	.000108
	(.000167)	(.000174)	(.000856)	(.000782)
Age × risk	–	–	–.000022	–.000032
			(.000014)	(.000015)
Married × risk	–	–	.000969	.000907
			(.000301)	(.000316)
Union × risk	–	–	.000823	.000895
			(.000315)	(.000320)
Race × risk	–	–	–.001312	–
			(.000572)	
Urban	.114	.132	.144	.135
	(.033)	(.024)	(.023)	(.024)
Northeast	–.00357	–.00573	–.00904	–.0131
	(.00289)	(.0291)	(.0288)	(.0293)
South	–.0632	–.0568	–.0729	–.0459
	(.0293)	(.0298)	(.0295)	(.0304)
West	.0857	.0974	.0933	.0855
	(.0327)	(.0332)	(.0327)	(.0334)
Age	.0381	.0385	.0390	.0380
	(.0063)	(.0065)	(.0065)	(.0067)
$(\text{Age})^2$	–.000469	–.000475	–.000450	–.000419
	(.000073)	(.000077)	(.000078)	(.000081)
Manufacturing industry	–	–	–.0790	–.0888
			(.0340)	(.0353)
Service industry	–	–	–.0758	–.0922
			(.0314)	(.0324)
Education	.0332	.0531	.0623	.0613
	(.00436)	(.0190)	(.0189)	(.0215)
$(\text{Education})^2$	–	–.00129	–.00147	–.00133
		(.00101)	(.00102)	(.00113)
White	.228	.228	.389	–
	(.036)	(.036)	(.076)	
Family size > 2	–	–.00204	–.0194	–.00220
		(.0274)	(.0283)	(.0297)
Union	.203	.214	.108	.0997
	(.026)	(.025)	(.043)	(.0437)
Full-time	.275	.303	.284	.340
	(.103)	(.101)	(.100)	(.115)
Hours worked	.0113	.0105	.0109	.0101
	(.00096)	(.00095)	(.00098)	(.00099)
Occupation 1: operative	–.0885	–	–.105	–.101
	(.0728)		(.026)	(.027)

TABLE 4 (concluded)

Independent Variable	Equation 1	Equation 2	Equation 3	Equation 4
Occupation 2: service worker	−.126 (.075)	-	−.110 (.037)	−.124 (.039)
Occupation 3: laborer	−.218 (.106)	-	-	-
SES 1	-	.0152 (.0411)	-	-
SES 2	-	−.128 (.026)	-	-
SES 3	-	−.194 (.042)	-	-
R^2	.47	.46	.48	.43
Number of observations	907	907	907	813

NOTE: The dependent variable is the log of the weekly wage rate. The SES index has been converted to dummy variables. Standard errors are in parentheses.

cause there is a clear-cut gain from risk reduction if costs were less than that amount.

Use of SES dummies instead of occupational dummies increases the point estimate of the risk variable to .0520, with virtually no change in its standard error. Going through the same argument as above implies a value of life of $260,000. Though the t statistic is larger in equation 2 than in equation 1 of Table 3, we are not prepared to accept equation 2 as a necessarily better specification because of some reservations on the meaning of the SES variable. Corresponding estimates in Table 4 evaluated at the sample mean wage range somewhat smaller than those in Table 3. Equation 1 of Table 4 implies a point estimate of $136,000 (= .000206 × 132 × 50 × 10^5), while equation 2 implies an estimate of $189,000 (= .000286 × 50 × 132 × 10^5). Further, standard errors of risk coefficients are slightly larger in Table 4. Nevertheless, the estimates lie in a reasonably narrow range of about $200,000 ± $60,000.

Equation 3 in Tables 3 and 4 shows the results of limited interactions between risk and some of the other characteristics. Limitations on sample size forced a simple cross-product specification, rather than separate regressions on corresponding data cells. Risk is crossed with age, union membership, marital status and race in equation 3. As explained earlier, cross-product terms do not reflect differences in individual's utility functions. Instead, they represent differences in the locus of opportunities available to them, due to differential ability to work in risky situations.

A. Age

To reiterate our example above, age is likely to cut two ways on risky jobs. Young workers lack caution and experience, but have superior reflexes and recuperative ability. Our hypothesis was that physical deterioration of skills would eventually dominate and the results seem to be consistent with it. The age-risk cross-product term is negative though not significant, and firms offer older workers smaller risk premiums than younger workers. Evidently younger workers are more productive in risky situations. However, the estimate may also reflect measurement error.[17]

B. Marital Status

There is also some evidence that marital status affects risk premiums. Of course, we expect married workers to have a higher supply price to risky jobs than nonmarried workers, because they have more dependents. Again, this should induce married workers to apply for less risky jobs, other things being equal, and not change the observed risk premium. The fact that marital status increases the risk premium must mean that when married workers do in fact take risky jobs they are more productive at working on them. Exactly how such differential productivity arises is difficult to say, though we conjecture that married workers might on the average be more careful and cautious than the nonmarried.

C. Unionism

Unionism also increases the risk premium. Here the market is restricted, and unions might collect their rents through higher risk premiums rather than by other means. It is possible that lack of free entry into these markets renders the typical union member more risk averse than would be true in free markets, forcing firms to pay higher risk premiums in order to entice unwilling union members to work on

[17] There is a possibility that the negative regression coefficient reflects measurement error. Older workers may be heavily weighted in the low risk end of each occupation and our risk measures may overstate the real risks they face. If $W(p)$ is truly increasing, earnings are lower for older workers appearing to work on riskier jobs in our data than they really do. We know age-specific extra-risk data must be available on the work sheets of the actuarial study because the published statistics have been age adjusted in the manner described above. Unfortunately, we were unable to obtain the raw data.

the riskier jobs. Again, we cannot rule out the hypothesis that unionism and its resulting "industrial discipline" make workers more productive on risky jobs.

D. Race

The relationship between race and risk premiums is very complex. The white-risk cross-product term is negative (and not significant at conventional levels), but the results are not easy to interpret. For one thing, we know from other studies that nonwhites tend to be loaded in the low wage end of occupational job classifications. Notice again that the occupations in Table 1 may be too broadly defined for detecting racial differences. If nonwhites tend to be highly represented in the riskier subcategories of each classification, our risk index is measured erroneously for them. This in itself would tend to produce the result found in Tables 3 and 4 and cross-terms would reflect measurement error in the data. The coefficient suggests that nonwhites receive higher risk premiums than whites, but it may simply be the case that they work at even more risky jobs than our data say they do (again, assuming $W'(p) > 0$). Alternative hypotheses are also available. (1) Nonwhites may be better workers in risky situations than whites. For example, we know that a large fraction of structural iron workers are nonwhite, and it is said that these individuals have an unusual sense of balance compared to most people in the population. (2) There may be less discrimination against nonwhites in risky jobs than in less risky ones.

To get around possible measurement errors, we reran the regression excluding nonwhites from the sample. The result is shown by equation 4 in Table 3, and previous conclusions regarding other variables are hardly affected.[18]

CONCLUSION

We have estimated marginal valuations of safety for a select group of individuals in 1967. All qualifications surrounding our estimates have

[18] Computation of the marginal risk premium under the cross-product specification must be made at specific values of the interactive variables (age, race, and so on) because $W'(p)$ is then a function of those variables. A little experimentation with equations (3) and (4) of Tables 3 and 4 shows that the imputations vary a great deal, depending on the point in the sample at which they are made. Indeed, some of these imputations are actually negative (e.g., older white nonunion, nonmarried individuals), which may indicate an undesirable restriction of the functional form or measurement error and not necessarily a model defect. We have not imposed any nonnegative restrictions on the estimates. Further, the possibilities of measurement error extensively pointed out at several points in the text preclude too much massaging of the data. Hence, we regard the cross-product results as suggestive only.

been given in the text and there is no need to repeat them here.[19] Certainly this study indicates feasibility of the method, the usual caveats about data quality notwithstanding. Are the estimates reasonable? We are unaware of similar studies with which to compare our results. However an example suggested by Bailey (1968) may be informative in this regard, and also illustrates how the estimates can be used.

The National Safety Council estimates that highway deaths would be reduced by about 10,000 per year if all automobile users wore lap safety belts. Assuming that the estimate is correct, seat belts reduce the probability of dying in an automobile accident from about 25 per hundred thousand (25×10^{-5}) per year to about 20 per hundred thousand per year (20×10^{-5}). Using the risk coefficient in equation 1 of Table 3 we estimate that the *average person in our sample* would be willing to pay *at least* $8.80 per year (in 1967 dollars) for a seat belt for himself. The cost of seat belts includes not only the purchase price and installation costs, but also costs associated with use, including bother and time spent buckling and unbuckling, so that it is easily within the realm of possibility that decisions not to purchase seat belts prior to the law were rational. We can make some more back-of-the-envelope calculations. How much would the time and bother costs (of individuals in our sample) have to be to justify not using seat belts even after they are mandatory? The sample mean hourly wage was about $3.50. Using that as an estimate of the value of time, time spent buckling and unbuckling would have to be about 2.5 hours per year to cost as much as $8.80. Assuming 500 trips per year, this amounts to about 18 seconds per trip in time-equivalent costs of using seat belts, a much smaller number than Bailey assumed. We leave it to the reader to experiment with other possibilities.

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Comments on "The Value of Saving a Life: Evidence from the Labor Market"

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IN their everyday conversations and discussions, people are often reluctant to espouse the view that a monetary value can or should be placed on life. Yet, as Thaler and Rosen point out, in the normal course of their working and leisure activities, people are constantly making choices involving risks and rewards. Through these choices, they are implicitly placing some valuation on life or on the risk of death. In addition, public policy decisions very often involve choices concerning public expenditure of funds or the cost of applying regulations compared to their impact on the risk of accident, injury, or death.

In making public policy choices, it would be extremely useful to have information on the value society places on risk reduction in terms of the choices of its members, even though determining how much *ought* to be spent may remain elusive. The conceptual framework developed by Thaler and Rosen in this paper is extremely valuable in gaining insight into what might be meant by questions like: How much are people willing to pay (or forgo) to reduce the risk of serious injury or death? How does what they are willing to pay relate to the resource costs of restructuring jobs or altering equipment to reduce these risks? What interpretation can be placed on data and analyses dealing with alternative risk/reward situations? In addition, the propositions that emerge from the analysis are of considerable interest on their own right, since they are not all easily derived through intuition.

The empirical section presents estimates of the implicit price that is paid through wage differentials in the job market for variation in exposure to risk of death. The results are of particular interest because they were generated by using a set of data providing risk measures for quite detailed occupational categories, and the data provide relatively clean measures of net risk. The conceptual framework developed in the paper enables the authors to make careful distinctions between the price concept for which they were able to obtain estimates and concepts involving demand curves for safety or cost curves for risk reduction.

The price estimates obtained, while difficult to judge in terms of plausibility, are not so high or so low that they can be easily dismissed as irrelevant for application in a real-world policy-problem situation. The experiments with interaction terms are also extremely interesting, but unfortunately the data cannot provide sufficient resolution to explore them in any great detail. These relations are also likely to be extraordinarily complex because it is easily conceivable that there are differences in the direction of the effects between occupations. For example, age may reduce the price of risk bearing in some instances, while in other instances, increased age may be more than compensated for by work experience. The interpretation of these interaction effects is quite subtle, and the conceptual framework developed in the paper is valuable for distinguishing between movements along the wage risk function and differences in its slope represented by these interaction effects. As indicated in the paper, these interactions must reflect differences in productivity, market power, discrimination, and the like.

The higher risk premium estimated for unionism, however, suggests the possibility that better occupational risk information could play a role. It seems likely that unions are better equipped to assemble good information on risk and utilize it more effectively in bargaining than might be the case for nonunion workers. If poor information on differences in risk between occupations leads to a relatively greater emphasis placed by workers on wage premiums when they make their wage/risk choices, differences in the quality of risk information could influence the observed wage/risk tradeoff. If workers make their wage risk decisions as if they were applying a Bayesian decision framework, with more emphasis placed on the risk side of the bargain as the quality of information on real risk improves, a bias would be introduced into the estimated price of risk that operates in the opposite direction of the bias from analyzing occupations at the riskier end of the occupational spectrum. The role of information is not addressed in the paper, but a glance at the occupational risk data makes it hard to avoid the feeling that information quality may be important. For example, I would not have thought that it is more risky to be an elevator operator than a marshal, constable, sheriff, or bailiff, or that risk of death is nearly twice as high for waiters as it is for police and detectives! It is worth noting, however, that although it would be plausible to assume that nonwhites might have poorer information on risk than whites, the evidence suggests that nonwhites obtain higher risk premiums than whites.

The estimates developed in the paper are based on data drawn from the "demand for safety" side of the conceptual framework. It would be interesting to know how private firms treat the analysis of the supply side in making decisions on altering job content, working conditions, or equipment in order to devote optimal resources to provision of safety. If engineering studies of such alternatives were available, they could provide information from an independent source on the implicit price attributed by firms to variations in risks. It would also be interesting to explore decisions by the military concerning death risks to see if the implicit price of risk is significantly higher in what must be an occupation with significantly higher risk than those considered in this paper.

The qualifications on the meaning and interpretation of the estimate of the increase in wage premiums accompanying higher risk are so carefully spelled out in the paper that cautious analysts might be reluctant to place much reliance on the estimate for policy purposes. For small policy changes, however, the conceptual basis of the estimate is probably adequate for policy purposes. Most policy changes that might be analyzed using estimates of this sort in an effort to quantify their impact and desirability are likely to be small compared to the entire package of risk-reward choices that confronts the average person. Of course, policies that influence risk in a person's working environment may have the largest single impact on the typical person's overall risk portfolio, since such a large fraction of most peoples' lives is spent at work. The significance of work in the typical person's life makes the case for approaching the question of the price people are willing to pay for reduction in risk through analysis of wage-risk relations in the marketplace very persuasive.

Comments on "The Value of Saving a Life: Evidence from the Labor Market"

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THALER and Rosen wish to find a measure of the risk an individual incurs by working in a given hazardous occupation rather than in the average occupation. They wish to associate this risk with the additional wage that is required to induce an individual to accept the hazardous occupation, in order to calculate individuals' valuations of safety. However, as we might infer from some of the surprises in their list of hazardous occupations, the data on risk that they use measure something else: the extra risk to an insurance company of insuring those who are in a particular occupation. That insurance company risk includes both the true occupational risk and something we might call personal-characteristics risk—the risk that arises from the fact that people who go into bartending, for example, may have habits or characteristics aside from a lesser aversion for risk, which Thaler and Rosen mention, that would produce high mortality rates no matter what occupation they entered. Since these personal characteristics are attached to the individuals, rather than to the occupations they enter, the associated mortality risks will not be compensated for by higher wages. The only case in which the personal-characteristics risk might enter the wage rate for an occupation is that of interaction between the effects of the two types of risks (a person who leans toward heavy drinking may lean further in that direction if he becomes a bartender). Thus, the independent variable for risk in the Thaler-Rosen equations is not entirely the risk measure they want, and it is not clear whether the irrelevant personal-characteristics part of the insurance risk is systematically related to the relevant part. One might guess that the presence of this personal-characteristics element in the risk measure produces a downward bias in the estimate of the price of occupational risk, additional to the bias from self-selection of less risk-averse workers.