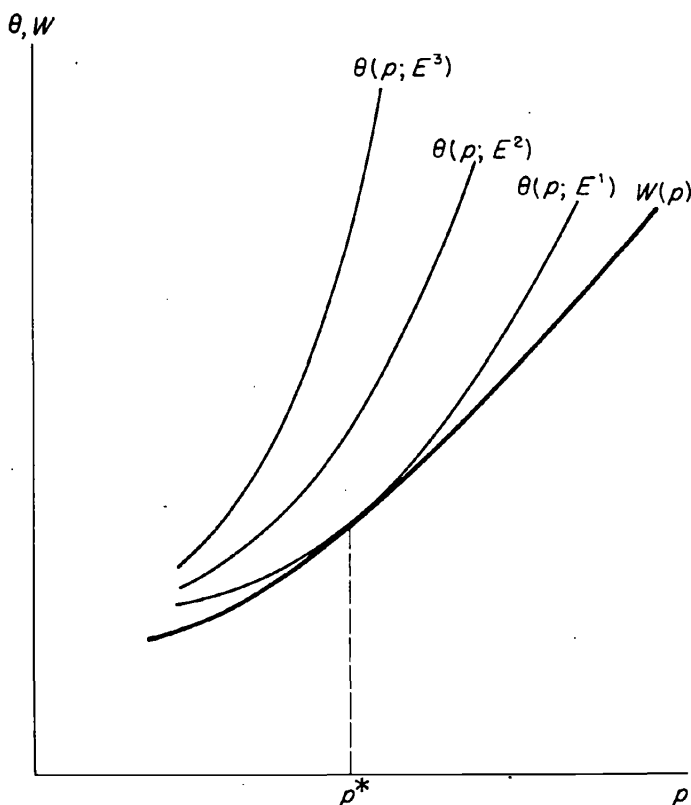


FIGURE 1

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), (iia) and (iib). 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 (iib). However, marginal valuation of risk is increasing in expected utility (iia) 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.

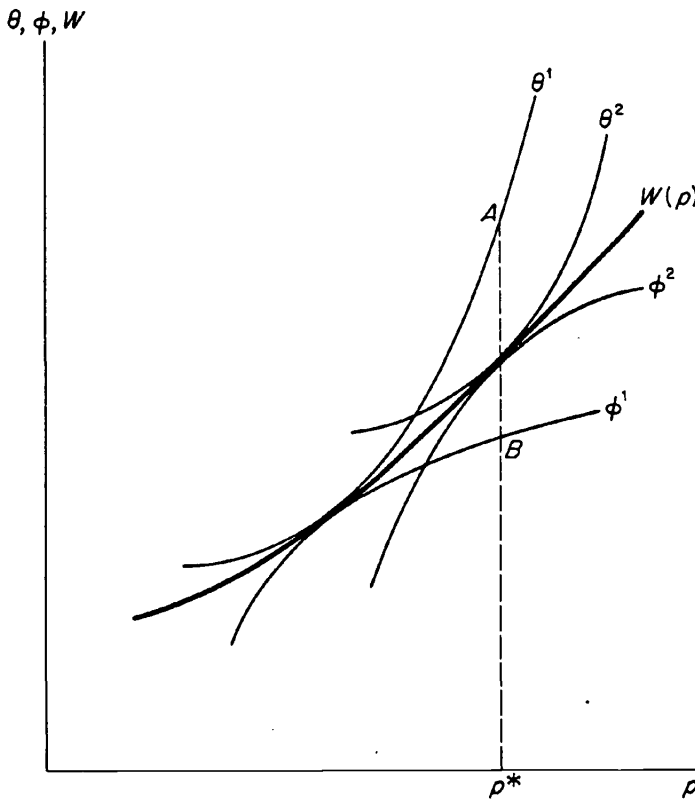
EQUALIZING DIFFERENCES AND SUPPLY PRICES

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 $W(\rho)$ line. It is apparent that $W(\rho)$ is the lower envelope of a family of acceptance wage functions depending on the joint distribution of y , U and ψ across workers. $W(\rho)$ is observed, while the functions θ^i are not. However, evaluate the derivative of the equalizing wage difference function at some value of ρ , say ρ^* . Then, from the equilibrium conditions, $W'(\rho^*) = \partial\theta^i(\rho^*, E^*)/\partial\rho$ for workers finding ρ^* optimal, and $W'(\rho^*)$ identifies the marginal acceptance wage for such workers. Therefore, $W'(\rho^*)$ identifies $\partial\theta^i/\partial\rho$. $W'(\rho^*)$ estimates how much money is necessary to induce a person into accepting a small incremental risk. Alternatively, it esti-

mates 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 $0 \leq p < \bar{p}$, $g_p \geq 0$ 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

$$\Pi = g(p, L) - W(p)L - G(1 - p) \quad (10)$$

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

$$\begin{aligned} g_p + G' &= W'(p)L \\ g_L &= W(p) \end{aligned} \quad (11)$$

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

$$\begin{aligned} \phi &= [g(p, L) - G(1 - p) - \Pi]/L \\ \phi &= g_L(p, L) \end{aligned} \quad (12)$$

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]

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

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

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

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 $c = (c_1, \dots, c_m)$. 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, $L = f(c_1, \dots, c_m)$ 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 $x = h(p, c_1, \dots, c_m) = h(p, c)$. 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

$$W = a_0 + a_1p + a_2(pz) + \text{random error} \quad (13)$$

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 ex-

pect 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 steve- dors	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 ($= 132 \times 50$), 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 $\times 10^6$)	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.] (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 (.0210)	.0520 (.0219)	.100 (.108)	.0410 (.102)
Risk × age	-	-	-.0019 (.0018)	-.0030 (.0019)
Risk × married	-	-	.0791 (.0380)	.0701 (.0412)
Risk × union	-	-	.0808 (.040)	.0869 (.042)
Risk × white	-	-	-.118 (.072)	-
Urban	13.80 (4.2)	15.71 (2.95)	17.0 (3.0)	17.0 (3.2)
Northeast	-3.71 (3.65)	-4.29 (3.67)	-4.27 (3.63)	-4.92 (3.83)
South	-8.86 (3.70)	-8.90 (3.74)	-10.5 (3.72)	-8.18 (3.97)
West	9.13 (4.13)	10.30 (4.18)	9.57 (4.12)	9.50 (4.37)
Age	3.89 (0.80)	3.81 (0.83)	3.83 (0.82)	3.78 (0.87)
(Age) ²	-.0479 (.0092)	-.0468 (.0097)	-.0442 (.010)	-.0415 (.011)
Education	3.40 (0.55)	3.27 (2.40)	4.13 (2.39)	4.81 (2.80)
(Education) ²	-	-.021 (.128)	-.0237 (.128)	-.042 (.148)
Manufacturing industry	-	-	-13.0 (4.3)	-14.7 (4.62)
Service industry	-	-	-9.45 (3.95)	-10.9 (4.24)
White	22.92 (4.53)	22.93 (4.50)	37.7 (9.6)	-
Family size > 2	-	-	.400 (3.57)	2.10 (3.89)
Union	25.5 (3.25)	27.16 (3.23)	15.9 (5.4)	15.39 (5.72)
Full-time	-1.63 (12.9)	-.86 (12.6)	-1.16 (12.6)	.45 (15.0)
Hours worked	1.50 (.12)	1.41 (.12)	1.47 (.123)	1.44 (.129)
Occupation 1: operative	-18.7 (9.2)	-	-13.9 (3.24)	-13.5 (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 to 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 (.000167)	.000286 (.000174)	.000943 (.000856)	.000108 (.000782)
Age × risk	-	-	-.000022 (.000014)	-.000032 (.000015)
Married × risk	-	-	.000969 (.000301)	.000907 (.000316)
Union × risk	-	-	.000823 (.000315)	.000895 (.000320)
Race × risk	-	-	-.001312 (.000572)	-
Urban	.114 (.033)	.132 (.024)	.144 (.023)	.135 (.024)
Northeast	-.00357 (.00289)	-.00573 (.0291)	-.00904 (.0288)	-.0131 (.0293)
South	-.0632 (.0293)	-.0568 (.0298)	-.0729 (.0295)	-.0459 (.0304)
West	.0857 (.0327)	.0974 (.0332)	.0933 (.0327)	.0855 (.0334)
Age	.0381 (.0063)	.0385 (.0065)	.0390 (.0065)	.0380 (.0067)
(Age) ²	-.000469 (.000073)	-.000475 (.000077)	-.000450 (.000078)	-.000419 (.000081)
Manufacturing industry	-	-	-.0790 (.0340)	-.0888 (.0353)
Service industry	-	-	-.0758 (.0314)	-.0922 (.0324)
Education	.0332 (.00436)	.0531 (.0190)	.0623 (.0189)	.0613 (.0215)
(Education) ²	-	-.00129 (.00101)	-.00147 (.00102)	-.00133 (.00113)
White	.228 (.036)	.228 (.036)	.389 (.076)	-
Family size > 2	-	-.00204 (.0274)	-.0194 (.0283)	-.00220 (.0297)
Union	.203 (.026)	.214 (.025)	.108 (.043)	.0997 (.0437)
Full-time	.275 (.103)	.303 (.101)	.284 (.100)	.340 (.115)
Hours worked	.0113 (.00096)	.0105 (.00095)	.0109 (.00098)	.0101 (.00099)
Occupation 1: operative	-.0885 (.0728)	-	-.105 (.026)	-.101 (.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 ($= .000206 \times 132 \times 50 \times 10^5$), while equation 2 implies an estimate of \$189,000 ($= .000286 \times 50 \times 132 \times 10^5$). Further, standard errors of risk coefficients are slightly larger in Table 4. Nevertheless, the estimates lie in a reasonably narrow range of about $\$200,000 \pm \$60,000$.

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 indi-

vidual'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.

REFERENCES

- Bailey, M. J. "Comment on T. C. Schelling's Paper." In S. B. Chase, ed., *Problems in Public Expenditure*. Washington, D.C.: Brookings Institution, 1968.
- Calabresi, G. *The Costs of Accidents: A Legal and Economic Analysis*. New Haven: Yale University Press, 1970.
- Fromm, G. "Civil Aviation Expenditures." In R. Dorfman, ed., *Measuring Benefits of Government Investments*. Washington, D.C.: Brookings Institution, 1965.
- Hirshleifer, J. "Investment Decision Under Uncertainty: Choice Theoretic Approaches." *Quarterly Journal of Economics* 79 (November 1965): 509-536.
- Mishan, E. "Evaluation of Life and Limb: A Theoretical Approach." *Journal of Political Economy* 79 (July/August 1970): 687-705.
- Oi, W. "An Essay on Workmen's Compensation and Industrial Safety." In *Supplemental Studies for the National Commission on State Workmen's Compensation Laws*, Vol. I, pp. 41-106, 1973.

¹⁹ These issues are discussed in greater depth in Chapter 1 of Thaler (1974).

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- Roseñ, S. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." *Journal of Political Economy* 82 (January/February 1974): 34-55.
- Schelling, T. C. "The Life You Save May Be Your Own." In S. B. Chase, ed., *Problems in Public Expenditure*. Washington, D.C.: Brookings Institution, 1968.
- Smith, R. S. "Compensating Wage Differentials and Hazardous Work," Technical Analysis Paper No. 5, Office of Evaluation, Department of Labor, August, 1973.
- Thaler, R. "The Value of Saving a Life: A Market Estimate." Ph.D. dissertation, University of Rochester, 1974.
- Usher, D. "An Imputation to the Measure of Economic Growth for Changes in Life Expectancy." In Milton Moss, ed., *The Measurement of Economic and Social Performance*. New York: NBER, 1973.

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

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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

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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.