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Utility-Based Measures of Health

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I.   INTRODUCTION

A large body of empirical work in economics seeks to determine how individuals value risks to life and limb (Viscusi, 1992). Most of this work has estimated premiums for job risks based on hedonic models of wage determination. Although there has been considerable debate in the literature regarding estimation of such models and selection of an appropriate implicit value of a statistical life based on these estimates, the scope of this debate is inherently limited. Market estimates can only provide information on the average rate of tradeoff of income for risks. These tradeoffs are also pertinent only to marginal changes in risk. Important policy questions, such as the benefits of non-marginal changes in risks or the benefits of risk reductions in heterogeneous populations, cannot be adequately explored with results from market settings.

The increased availability of survey data has brought these and many other questions regarding individual valuation of health risks within the range of answerable inquiries. In a standard survey setting, consumers are faced with a series of hypothetical choices, for which subjects give a probability or an income value that makes them indifferent between the lotteries. An essential feature of experimental data is that surveys can be constructed to provide information on multiple points on a constant expected utility locus rather than a single point, as with market data. The points along the same locus will allow us to estimate the underlying structure of utility when utility depends on health. The key advantage of using such estimates is that it greatly broadens the scope of economic inquiry beyond the simple marginal income-risk tradeoff one finds in the hedonic wage literature.

In this paper, we will explore the implications of some recent advances in the estimation of state-dependent utility functions for evaluation of health outcomes. First, we briefly review the theoretical literature that indicates how ill health should affect utility. Second, we outline how, with standard survey data, one can utilize survey data to produce utility function parameter estimates. Finally, we illustrate the types of policy questions which can be answered with utility-based measures of health.

1

II.   MODELING THE UTILITY OF ILL HEALTH

Viewed in its most general form, one can treat health status as simply a component of an individual's utility function, where utility U is a function of income Y and a health state H_i. If there are n possible states of the world, each with an associated probability of occurrence P_i, and income is assumed to be a function of health status, then expected utility is defined to be

$$(1) \qquad EU = \sum_{i=1}^{n} P_i \, U \, (Y_i, H_i).$$

To explore the economic consequences of changing health status, ideally one would like to obtain a continuous measure of health. Typically, we do not have sufficient information to construct such a measure. More likely, researchers have information on discrete events, such as the probability that a certain type of injury will occur. Frequently, health status is subsumed into the analysis by indexing the utility function by the state of nature. This choice of modeling forms the basis for analyses of state-dependent utility. The state-dependent form of utility has been used extensively for risks to health, as in the work of Zeckhauser, Phelps, Arrow, Cook and Graham, and Spence.

To incorporate the dependence of utility on the health state, let state 1 be defined as perfect health with utility U(Y). In the remaining (n-1) state of nature, the individual suffers some ill health. Let $V_i(Y_i)$ be utility in each poor health state i. With state-dependent utility, expected utility is now defined as

$$(2) \qquad EU = P_1 \, U(Y) + \sum_{i=2}^{n} P_i \, V_i(Y_i).$$

Economists generally postulate the natural assumption that $U(Y) > V_i(Y)$. Assuming good health is preferable to ill health simply recognizes that health is a valued economic good. A more troublesome issue is how ill health affects the marginal utility of income.

2

The theoretical literature typically assumes that for catastrophic events, ill health lowers the marginal utility of income, where for some fixed level of income Y in each state, $U'(Y) > V_i'(Y)$. In the extreme case of death, this assumption is clearly the case. However, for more minor injuries, ill health may be tantamount to a drop in income, i.e., for each poor health state i, the utility effects of poor health are equivalent to a drop in income of L_i dollars. In this instance, utility in the unhealthy state is defined as $V_i(Y) = U(Y - L_i)$, where L_i is defined as a "monetary loss equivalent". In this instance, poor health lowers utility but increases the marginal utility of income.

Determining how ill health affects the marginal utility of income is of paramount importance in answering a number of policy questions. For example, if ill health lowers (raises) the marginal utility of income, less (more) than full insurance is optimal. The optimal level of disability insurance and court awards for injuries consequently hinge on this issue.

III.   ESTIMATING STATE-DEPENDENT UTILITY FUNCTIONS

The dominant focus of the empirical literature on risk–dollar tradeoffs has been on estimation of wage premiums for job risks using hedonic models of wage determination. In the simplest hedonic wage models of workplace risk, jobs are assumed to vary along two dimensions: wages and risks. The wages a worker receives and the risk he faces are based on the tangency of the worker's expected utility locus with the market wage offer curve. The tangency of these two curves is depicted in Figure 1. Hedonic wage studies of compensating differentials for job risks involve estimation of an average rate of tradeoff for the equilibrium set of expected utility–wage offer tangencies. The information contained in market data for any particular worker is simply point A of Figure 1. Without any additional information, one cannot make any inferences about the shape of the individual's utility function other than the slope of the expected utility locus at point A. For policy analysis the most one can do is determine the average value of a marginal change in risk for a population similar to this group of workers.

Survey data provide a unique opportunity to estimate the state–dependent utility functions and the entire expected utility locus because the researcher observes multiple points along the same locus. In a typical setting, a "reference job" is introduced, where expected utility is a function of an original level of income Y, utility in the healthy state U(Y), utility in the unhealthy state V(Y), and the original risk of injury P. Next, the risk of injury is changed to some level Q, where in this case, we assume Q>P. Given the increased risk, the respondents are then asked how much additional income is required to compensate them for the increased risk of injury. The amount the consumer must be paid, K, is a value that equates expected utility across the two formulations of the job, where

$$EU_1 = EU_2$$

(3)   or

$$(1-P)\ U(Y) + P\ V(P) = (1-Q)\ U(Y+K) + Q\ V(Y+K).$$

The new information generated through the survey is depicted as point B in Figure 1 along the original expected utility locus. As has been demonstrated in Viscusi and Evans, and Evans and Viscusi (1991), parameter estimates of state–dependent utility functions can be derived once we assume an explicit functional form of utility. The estimation procedure is as follows.

Let β be a vector of utility function parameters to be estimated. The parameters in β are obviously a function of the assumed shape of utility. The response variable K is assumed to be the dependent variable since its value is conditioned on all others. Given a simple form of utility (as in Viscusi and Evans), or utilizing a series of Taylor's series expansions (as in Evans and Viscusi, 1991), the response variable K can be shown to be a nonlinear function of Y, P, Q, and β. An error term (ϵ) with zero mean and finite variance is then added to each equation and the model to be estimated is of the form

(4) $K = f(Y, P, Q, \beta) + \epsilon.$

4

Equation (4) can be estimated through nonlinear-least squares, or in a limited number of instances, equation (4) reduces to a simple linear model.

We have estimated several variants of equation (4), for both major and minor injuries. In these models, we have varied not only the types of injuries, but also the assumed functional form of utility.

a)   Evidence from Workplace Survey - Viscusi and Evans

Using survey data from Viscusi and O'Connor, we estimate the impact on the marginal utility of income from an on-the-job injury severe enough to cause at least one lost workday. That survey collected information from chemical workers in 4 different plants pertaining to their income, individual and job characteristics, and the risks of injury they face on the job. The reference job was therefore their present employment situation. Next, workers were given a warning label for one of the following chemicals that would replace the chemicals with which they currently worked: TNT, asbestos, chloroacetophenome (an agent that causes tearing), or sodium bicarbonate. Based on their reading of the warning label, workers were asked to assess their individual risk of injury if they had to work with the new chemical. In all instances where a worker was faced with an increased risk, the survey ascertained how much their wage must increase in order to make them indifferent between the new and old formulations of their job.

Using an unrestricted utility function based on a Taylor's series expansion, Viscusi and Evans demonstrate that for injuries severe enough to generate a lost workday injury, the injury lowers the marginal utility of income in the ill health state. Based on these results, we then assume an explicit characterization of utility where utility in the healthy state is $U(Y) = \alpha \ln[Y]$ and utility in the unhealthy state is $V(Y) = \ln[Y]$, where clearly if $\alpha > 1$ then ill health lowers utility and the marginal utility of income. For the full sample, we estimate that $\alpha = 1.077$ with a small standard error of 0.009. Estimates which vary by the type of warning label shown to the workers

indicate that ill health lowers the marginal utility from 4 to 9 percent, which we demonstrate below has fundamental consequences for issues such as the optimal level of insurance.

b. Evidence from Consumer Products - Evans and Viscusi (1991)

Using a sample of data from Viscusi, Magat, and Huber, we also estimate the impact on utility of relatively minor injuries arising from the use of household chemical products. Consumers were asked to evaluate either a toilet bowl cleaner or an insecticide. The survey presented consumers with two different formulations of the product. The product formulations varied only along two dimensions: the risk of injury posed by the use of the product and the price. The products were fictitious, but the labels were professionally printed, and they appeared to be commercially sold brands. For each product, the interviewer identified two potential injuries that might result from the product's misuse. For subjects with children under the age of five, the types of injuries were eye burns and child poisonings for the toilet bowl cleaner, and inhalations and child poisonings for the insecticide. For subjects without small children, the child poisoning risks were replaced by gassings for the toilet bowl cleaner and skin poisonings for the insecticide. Consumers were asked how much they were willing to pay for a safer product. The answers to these questions equate the expected utility for two product formulations, where respondents indicate their willingness to pay for several alternate reductions in risk. Because these survey questions defined four points along the same expected utility tradeoff, we are able to estimate the structure of the utility function in greater detail than in Viscusi and Evans. In particular, this greater flexibility enables us to nest a monetary equivalent model of health effects within a state-dependent utility function so that both potential ramifications of ill health can be jointly determined.

Using this data set, we characterized utility in the unhealthy state as being a function of two parameters, where $V_i(Y) = (1+\beta_i) U(Y-L_i)$. With this formulation of utility, if $\beta_i<0$ and $L_i=0$, consumers view the injury strictly from a health-state perspective, whereas if $\beta_i=0$ and $L_i>0$, poor

6

health is simply tantamount to a drop in income, which is a very special case of health state-dependence.

Using three different utility functions (logarithmic, linear, and quadratic), we find that for the minor injuries considered, consumers treated the injury as simply a drop in income. The estimates for the monetary loss equivalent range from $486 for a gassing injury caused by a toilet bowl cleaner to $2537 for a child poisoning from insecticide use.

IV. ECONOMIC IMPLICATIONS OF STATE-DEPENDENT UTILITY

Knowing the shape of the utility function and how the monetary loss equivalent varies with income allows us to estimate a number of different values of policy interest. As with present estimates from market data, one can determine the implicit value of a statistical injury. In addition, one can also answer questions about the income effects on the value of an injury and the value of non-marginal changes in the risk level.

a. The Implicit Value of a Statistical Injury

The fundamental issue for decision analysts in health and medical policy is what value one should place on reducing such risks. When analyzing policies designed to alter risks to life and health, the most useful metric by which to express this value is in dollars of compensation required per unit of risk. There are two measures frequently utilized in policy analysis which are expressed in this ratio. The first is the amount a consumer would pay for the certain elimination of a risk. The second measure is the amount consumers are willing to pay for marginal changes in risk ($\delta Y/\delta P$) given an expected utility locus. Using the formulation of expected utility expressed on the left-hand-side of equation (3), the marginal valuation of a statistical injury is easily calculated as

$$(5) \qquad Z = \frac{\delta Y}{\delta P} = \frac{U(Y) - V(Y)}{(1-P)\ U'(Y) + P\ V'(Y)}.$$

In regressions of wages on workplace risks, the regression coefficient on the risk variable can be easily transformed to obtain an estimate of the local rate of tradeoff $\delta Y/\delta P$. Consequently, the second formulation of the implicit value of injury has been the most frequently utilized estimate of the economic valuation of health.

Given an explicit characterization of utility, the implicit value of an injury based on equation (5) can also be calculated from survey data. For a lost workday injury, the logarithmic utility function estimates indicate that the implicit value of an injury is $13,343 in 1982 dollars. This number is very similar to estimates of the implicit value of an injury obtained from market studies of nonfatal workplace injuries (Viscusi (1992)).

When utility in the unhealthy state is tantamount to a drop in income, as it is for eight minor injuries we consider in the consumer products data set, the implicit value of a statistical injury is always within 1 percent of the estimated value of the monetary loss equivalent. This is not surprising given the small probability of an injury and the relative size of L_i in comparison to Y. To see this formally, let $V(Y)=U(Y-L)$, where L is the monetary loss equivalent. These expressions are then inserted into equation (5), and the size of the derivative $\delta Y/\delta P$ is a function of the values for $U(Y-L)$ and $U'(Y-L)$. If we approximate $U(Y-L)$ and $U'(Y-L)$ with a second-order Taylor's series about Y, and assume the third derivative of utility with respect to income is zero, these approximations produce the following approximation for the derivative:

$$(6) \qquad \frac{\delta Y}{\delta P} = L \, \frac{U'(Y) - (L/2) \, U''(Y)}{U'(Y) - (PL) \, U''(Y)}.$$

In many instances, Y is defined as yearly income and therefore, for most utility functions, the second derivatives are small relative to the marginal utility of income. The ratio $[U'(Y)-(L/2)U''(Y)]/[U'(Y)-(PL)U''(Y)]$ in equation (6) is consequently close to 1, and the derivative $\delta Y/\delta P$ is close to L.

The above definition of the derivative $\delta Y/\delta P$ also suggests that if one assumes declining marginal utility of income, the estimate of the ratio $[U'(Y)-(L/2)U''(Y)]/[U'(Y)-P L U''(Y)]$ from

8

equation (6) will be greater than one for P<1/2. In most situations dealing with risks to health, P tends to be small and therefore, the estimated value of the derivative $\delta Y/\delta P$ should be greater than the value of the estimated monetary loss equivalent. The difference in the two values will increase (decrease) as the value of L increases (declines).

b. **The Value of Non-marginal Risk Changes**

Many government policies designed to reduce the risks to life and health produce more than marginal changes in risks. Examples of such regulations are mandatory child restraint and seat belt use laws. In these instances, benefit–cost analysis becomes difficult with present value of statistical life estimates based solely on valuations of incremental risk changes.

However, with utility-based values of health, the analysis is easily conducted. In the survey setting outlined for equations (3), workers respond with income value K for a given increase in risk to Q. Using the parameter estimates for the utility functions in ill and good health, we can easily construct predicted values for K for any given change in the risk level.

Using the mean values of worker characteristics and the full sample estimates of the state-dependent utility functions found in Viscusi and Evans, we can verify a number of theoretical predictions about the value consumers place on non-marginal risk changes. For example, the amount consumers must be compensated for a non-marginal increase in risk increases at a declining rate, whereas workers are willing to pay successively smaller amounts for additional risk decreases. Both these results are predicted in the theoretical literature (see Viscusi, Magat, and Huber).

The ability to measure the value of non-marginal changes in risk also allows us to illustrate the vast difference between a consumer's willingness to pay for a reduced risk and the willingness to accept a higher risk. First, consider a worker who faces a certain risk of injury on the job. This worker is willing to pay $9300 for the certain elimination of the risk. However, a worker in a risk-free job must receive over $21,000 to be moved to a job with a certain risk of injury. Even

in cases where the change in risks is not as dramatic we still observe differences between the willingness to pay and accept. Consider a worker with a yearly risk of injury of 0.15 (about twice the size of the sample risk). The implicit value of an injury for the complete elimination of the risk is $11,400 while the implicit value from a doubling of the risk is $14,500. In both cases, the magnitude of the risk change is identical, yet the implicit values of the statistical injury are very different.

When utility in the unhealthy state is tantamount to a drop in income, as it is for the eight minor injuries we report, the implicit value of a statistical injury based on marginal changes in risk is very similar to estimates based on non-marginal changes in risk. Again, this is not a surprising result given the small stakes. These results are reviewed in Evans and Viscusi (1991).

c.   The Income Elasticity of the Value of an Injury

Individuals differ in their attitudes toward health risks just as their preferences for other goods differ. This heterogeneity has two principal implications for public policy decisions affecting risks to life and health. First, the appropriate values of life and health will vary with the characteristics of the population at risk. Second, many of the differences are systemic. The primary concern in the economic literature has been with variations due to differences in wealth. If safety is a normal economic good, then individual risk-dollar tradeoffs should be an increasing function of income, as shown in Viscusi (1979).

Using the definitions of the implicit value of an injury outlined in equation (5), we can calculate the income elasticity of the value of an injury for both the health-state and monetary loss equivalent cases. The explicit equations defining these values are found in Viscusi and Evans. When injuries are evaluated from a health-state perspective, we find that the income elasticity of the value of reducing risks of job injury is about 1.0.

When the unhealthy state is equivalent to a reduction in income, the value of the income elasticities are lower if the monetary loss equivalent is not a function of income. In a recent paper

10

(Evans and Viscusi (1991)), we find that for the minor injuries considered above, the monetary loss equivalent values are indeed a function of income, and therefore the income elasticities of the implicit value of injury range from 0.17 for eyeburns from toilet bowl cleaners to 0.38 for skin poisonings from insecticide.

The size of the income elasticities that we estimate for the monetary loss equivalents and the marginal willingness to pay for safety are equal in magnitude to income elasticities for medical insurance estimated by Newhouse and Phelps, but are substantially smaller in magnitude to elasticities estimated in Viscusi and Evans. The larger values in Viscusi and Evans stem from the difference in the structure of the utility functions for these more severe injuries, which differed by more than a monetary loss equivalent in the case of a job injury.

There are a number of contexts where knowledge of the income elasticity of the value of injuries is useful. Government programs, for example, have differential impacts on the health of different groups. Moreover, these groups may have a different mix from the sample of workers used in establishing the value-of-injury reference point. In cases where an attempt is made to assign a value to the risk reduction benefits based on the individual's own valuation of the risk, the income elasticity estimates can be used to establish the magnitude of such variations.

Making such distinctions across income groups may be less controversial in intertemporal contexts. Suppose for example that we have a choice between preventing an injury of fixed duration to a person now or a person 10 years from now when his income will have doubled. This problem arises frequently in policy contexts, although not in as stylized a fashion. For example, the EPA must choose whether to focus its efforts on imminent hazards, carcinogenic or toxic exposure with a gestation period of one to two decades, or longer term risks such as changes in the earth's climate. Apart from the role of discounting, should we place the same value on health in each of these situations?

The conventional approach applied by government agencies is not to make any distinction. In fact, most government agencies that address long-term hazards have been reluctant to perform

11

such discounting since it reduces the present value of the benefits substantially. However, the same forces that lead to a rationale for discounting also create the need for increasing the value of health losses as well.

Suppose that the growth in societal income is g and that the riskless rate of discount is r. One would expect g<r since factors such as productivity growth due to capital investments rather than labor will induce some spread between societal income growth rates and interest rates. If the present implicit value of a statistical injury is denoted as Z, and the income elasticity of this value is close to 1, then in t years, the value of the injury will be $Z(t) = Z[(1+g)/(1+r)]^t$. Clearly in this instance, the loss in the benefit calculation due to the delayed nature of the benefits is at least partially offset by the growth in Z due to an income effect.

V. Conclusion

The growth in the use of survey data in economics has greatly expanded the scope of questions one can consider when analyzing how consumers value risks to life and health. Experimental data has the unique property that through the construction of the survey, researchers can observe multiple points along the same expected utility locus. Given an explicit characterization of utility in the healthy and unhealthy states of the world, the researcher can then estimate the entire structure of utility.

Knowledge of more than the local rates of tradeoff is important in a variety of policy contexts. The risk changes may be non-marginal. The baseline risk level and the income levels of those affected may differ from the sample of individuals used to estimate the value of health outcomes. Knowledge of utility functions enables one to make the extrapolations necessary for health benefit assessment.

Figure 1

A Worker's Expected Utility Locus and Wage-Offer Curve
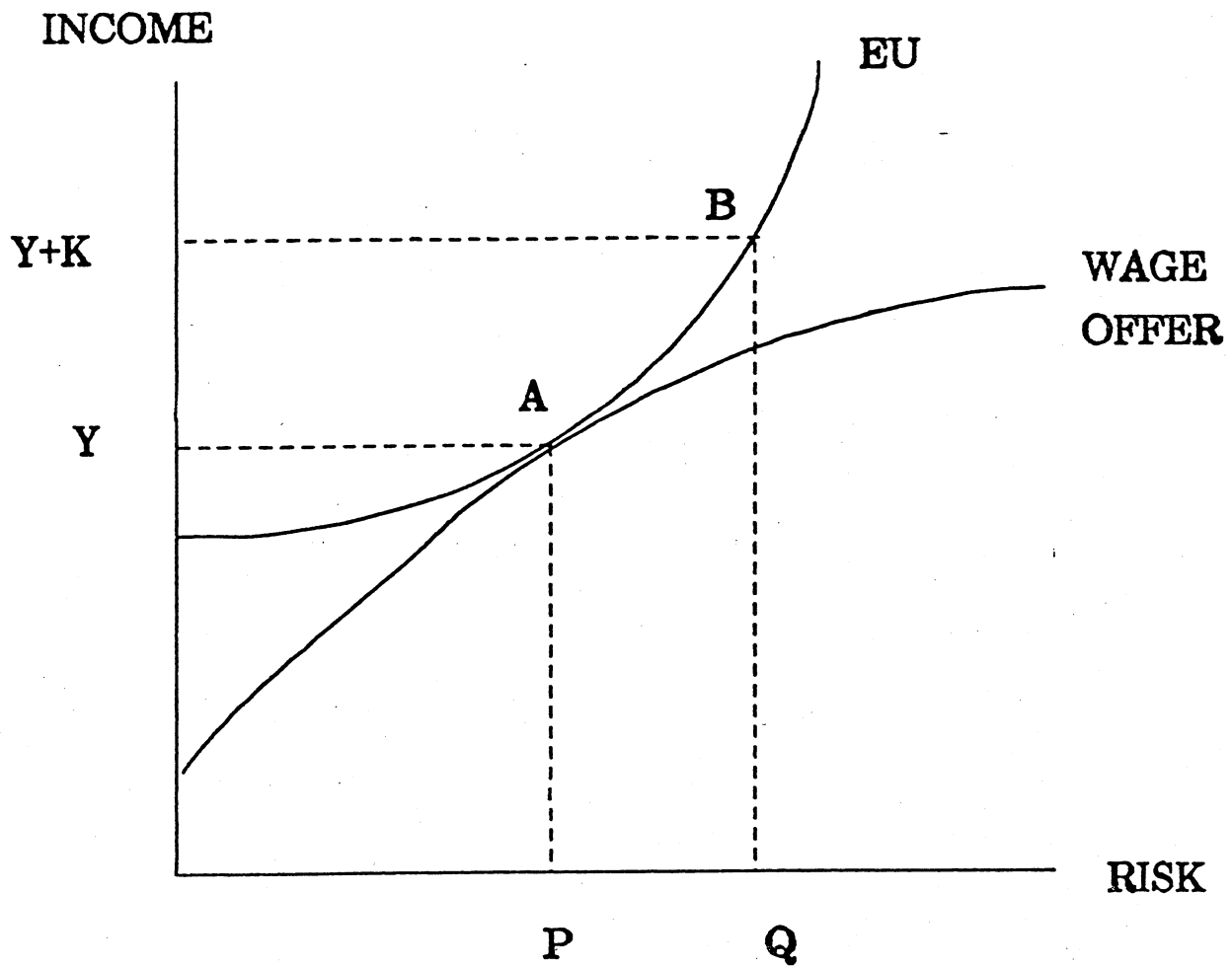
BIBLIOGRAPHY

Arrow, K.J. "Optimal Insurance and Generalized Deductibles," *Scandinavian Actuarial Journal*, 1-42, Reprinted in *Collected Works of Kenneth J. Arrow: Volume 3: Individual Choice Under Certainty and Uncertainty*, Cambridge, MA: Harvard University Press, 1984.

Cook, P.J., and D.A. Graham. "The Demand for Insurance and Protection: The Case of Irreplaceable Commodities." *Quart. J. Econ.* 91(1977):143-56.

Evans, W.N., and W.K. Viscusi. "Estimation of State Dependent Utility Functions with Survey Data," *Rev. Econ. and Statist.* 73(1991):94-104.

___. "Wealth Effects and the Value of Health," Working Paper, Department of Economics, University of Maryland, 1991.

Newhouse, J.P., and C.E. Phelps. "New Estimates of the Price and Income Elasticities of Medical Care Services," in R. Rosett, ed., *The Role of Health Insurance in the Health Services Sector*, New York: National Bureau of Economic Research, 1976:261-313.

Phelps, C.E. *The Demand for Health Insurance: A Theoretical Perspective*, Santa Monica, CA: Rand Corporation, 1973.

Spence, A.M. "Consumer Misperceptions, Product Failure, and Producer Liability," *Rev. Econ. Stud.* 44(1977):561-72.

Viscusi, W.K. "Wealth Effects and Earnings Premiums for Job Hazards," *Rev. Econ. and Statist.* 60(1978):408-13.

___. *Employment Hazards: An Investigation of Market Performance*, Cambridge: Harvard University Press, 1979.

___. *Fatal Tradeoffs*: Public and Private Responsibilities for Risk, New York: Oxford University Press, 1992 (forthcoming).

___, and W.N. Evans. "Utility Functions that Depend on Health Status: Estimates and Economic Implications," *Amer. Econ. Rev.* 80(1990):353-374.

___, W.A. Magat, and J.C. Huber. "An Investigation of the Rationality of Consumer Valuations of Multiple Health Risks," *Rand J. Econ.* 18(1987):465-79.

___, and C.J. O'Conner. "Adaptive Responses to Chemical Labeling: Are Workers Bayesian Decision Makers?" *Amer. Econ. Rev.* 74(1984):942-56.

Zeckhauser, R.J. "Medical Insurance: A Case Study of the Tradeoff Between Risk Spreading and Appropriate Incentives," *J. Econ. Theory.* 2(1973):10-26.