Environ. Sci. Technol. **2000**, *34,* 1396−1400

Valuing Mortality Risk: Theory and Practice†

JAMES K. HAMMITT*
Center for Risk Analysis, School of Public Health, Harvard University, 718 Huntington Avenue, Boston, Massachusetts 02115

Environmental economists measure the monetary value of reduced mortality risk using the "value of a statistical life" (VSL) defined by individuals' preferences for small changes in risk and income. The theoretical foundation and empirical methods for estimating VSL and its dependence on age, income, baseline mortality risk, and latency of the risk to be altered are reviewed.

Downloaded via 207.241.233.247 on October 29, 2020 at 04:41:14 (UTC).
See https://pubs.acs.org/sharingguidelines for options on how to legitimately share published articles.

Introduction

Many environmental regulations are intended to prevent human fatalities that may be caused by exposure to chemicals, radiation, and other agents. Compliance with regulations typically imposes costs on producers and/or consumers who must install control equipment or alter operating practices. How can one determine whether the lives saved are worth the increased costs?

The economic approach to valuing life-saving was proposed by Schelling (*1*) in an article suggestively entitled "The Life You Save May Be Your Own". Schelling observed that for environmental regulations and other life-saving programs, one cannot know whose life will be "saved". The question is not how to value prevention of a specific death but how to value small changes in mortality risk across a population.

In accordance with "consumer sovereignty" (the principle that individuals are the best judges of their own interests), economic research has concentrated on estimating the rate at which an individual would trade his own money for small changes in his own mortality risk (within a defined time period). An individual's preferences for wealth and mortality risk are illustrated in Figure 1. The point X represents the individual's initial wealth and mortality risk. The indifference curve separates combinations of wealth and mortality risk into two regions. The individual prefers points above the indifference curve to his initial position and disprefers points below it. Under reasonable assumptions described in the next section, the indifference curve slopes downward and is convex to the origin.

The individual's rate of tradeoff between wealth and risk is characterized by the slope of the indifference curve. The most he would pay to reduce his risk by an amount Δp is Δw. For small values of Δp, $\Delta w \approx (\mathrm{d}w/\mathrm{d}p)\Delta p$. The rate of tradeoff ($\mathrm{d}w/\mathrm{d}p$) is called the value of a statistical life (VSL). If an individual's VSL is \$5 million, he would pay up to $\Delta w = \$50$ to reduce his risk of dying this year by $\Delta p = 10^{-5}$. Because VSL (the slope of the indifference curve) is not constant, this value applies only to small changes in risk. It does not imply that the individual would pay \$5 million to avert certain death this year, nor that he would accept certain death in exchange for \$5 million. It does imply that 100 000 similar people would together pay \$5 million to eliminate a risk that would be expected to randomly kill one among them this year.

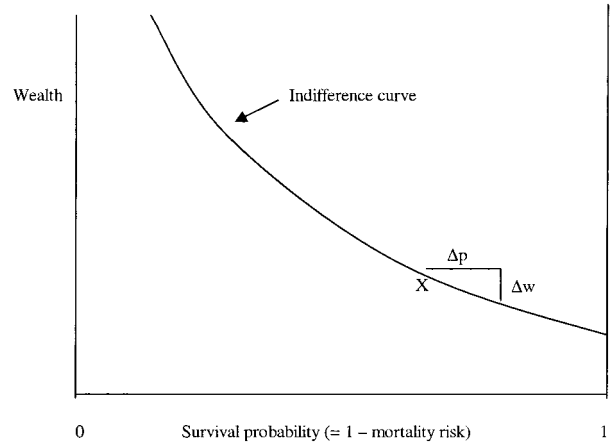

FIGURE 1. Preferences for wealth and mortality risk.

VSL is not a universal constant but varies by individual and circumstance. In the next section, the standard model of VSL is presented and used to examine how an individual's VSL should, in theory, depend on the latency and baseline magnitude of mortality risk as well as on income and age. The principal empirical methods and findings with respect to the magnitude of VSL and its dependence on baseline risk, income, and age are reviewed in the following section.

Analytics of VSL

The standard economic model of preferences for wealth and mortality risk (*2*−*4*) assumes that an individual's welfare can be represented by

$$U(p,w) = (1-p)u_{\mathrm{a}}(w) + pu_{\mathrm{d}}(w) \tag{1}$$

where p is the individual's chance of dying during the current period and $u_{\mathrm{a}}(w)$ and $u_{\mathrm{d}}(w)$ represent his utility as a function of wealth conditional on surviving and dying, respectively. The function $u_{\mathrm{d}}(\bullet)$ incorporates the individual's preferences for bequests and can incorporate any financial consequences of dying (such as medical bills or life insurance benefits). In this one-period model, wealth and income are treated as equivalent, but the difference between them can be important in multiple-period models.

The individual's VSL or marginal rate of substitution between p and w is derived by differentiating eq 1 holding utility constant to obtain

$$\mathrm{VSL} = \frac{\mathrm{d}w}{\mathrm{d}p} = \frac{u_{\mathrm{a}}(w) - u_{\mathrm{d}}(w)}{(1-p)u'_{\mathrm{a}}(w) + pu'_{\mathrm{d}}(w)} \tag{2}$$

where the prime indicates first derivative.

The numerator in eq 2 is the difference between utility if the individual survives or dies in the current period. The denominator is the expected marginal utility of wealth, that is, the utility associated with additional wealth conditional on surviving and dying, weighted by the probabilities of these events. Assuming that life is preferred to death and that greater wealth is preferred to less, both numerator and denominator are positive, and so VSL is positive and the indifference curve in Figure 1 slopes downward.

VSL depends on baseline risk and wealth. First, consider the effect of baseline risk. It is natural to assume that

† Part of the special issue on Economic Valuation.

* Corresponding author telephone: (617)432-4030, fax: (617)432-0190; e-mail: jkh@hsph.harvard.edu.

10.1021/es990733n CCC: \$19.00
© 2000 American Chemical Society
Published on Web 03/02/2000

$u'_a(w) > u'_d(w)$, that is, the increased utility provided by more wealth is larger if the individual survives and thus has the opportunity to spend it. If so, an increase in the baseline risk p decreases the value of the denominator (the expected utility cost of spending). The utility associated with survival (the numerator) is unaffected by baseline risk, so the individual would be willing to spend more money to reduce his mortality risk. This implies that the indifference curve is convex. For small changes in risk, the effect of baseline risk—the "dead-anyway" effect (*5*)—cannot be large. Assuming that $u'_d \geq 0$ (i.e., the individual prefers more wealth to less, even if he dies), the proportional effect of a change in baseline risk on VSL cannot be greater than the proportional change in the survival probability $(1 - p)$. For most individuals, the annual survival probability is greater than 99%, and so annual risk cannot be decreased by more than 1%.

VSL may depend on the health in which the individual expects to survive. Although one might anticipate that willingness to pay (WTP) to reduce mortality risk will be greater if the individual anticipates surviving in good health rather than poor, the reverse is also possible in theory. If poor health limits the individual's opportunity to improve his well-being by spending money, the marginal utility of wealth may be smaller if he survives in poor health than if he survives in good health. If so, the denominator of eq 2 is smaller if survival will mean poor health. As the numerator is also smaller, VSL for survival in poor health may be larger or smaller than VSL for survival in good health, depending on whether the effect of health on the marginal value of wealth outweighs its effect on the total utility of survival.

As with most goods, WTP for reduction in mortality risk depends on ability to pay and is likely to increase with wealth. The assumption that additional wealth is more valuable in life than as a bequest $[u'_a(w) > u'_d(w)]$ implies that the numerator of eq 2 increases with wealth. Most individuals are averse to financial risk. If so, the denominator declines with wealth [the second derivatives of $u_a(w)$ and $u_d(w)$ are negative], and VSL increases. If the individual is indifferent to financial risk, the denominator is constant and again VSL increases with wealth. Only in the implausible case in which the individual prefers to bear greater financial risk (for the same expected return) can the denominator increase with wealth, making the effect on VSL indeterminate.

VSL represents the rate at which an individual would be willing to pay for an infinitesimal mortality risk reduction. WTP for a discrete reduction can be evaluated as the integral of the individual's WTP for a series of infinitesimal changes between the initial and final risk levels. WTP for each successive increment will be smaller than for the one before, because the individual has less remaining wealth and smaller baseline risk. The wealth effect is likely to be much larger than the dead-anyway effect.

Accounting for Latency. The simple model of VSL is defined in terms of income and mortality risk in a single period. Many environmental risks are characterized by a latency period between the time an individual is exposed to the agent and the time when he may die from its toxic effect. Since preventive measures must be undertaken before the exposure occurs, there is often a need to determine WTP now to reduce the risk of future fatality.

The appropriate procedure to account for latency is to value the risk change using the VSL representing the individual's value when the risk change occurs and to adjust for the time—value of money and the chance that the individual will die before then (*6*). The adjustment is made by discounting the future value of the risk reduction back to the time when the expenditure must be incurred. For example, assume that pollution-control equipment could reduce an individual's risk of cancer by 1 chance in 100 000, that the cancer would prove fatal 20 years after exposure, and the individual can earn a 5% annual return on investment. If the individual would be willing to pay \$50 in 20 years time to reduce a contemporaneous fatality risk of 1 in 100 000 (i.e., his VSL 20 years from now will be \$5 million), then the amount he would be willing to pay now is the present value of \$50, about \$19 ($= \$50 \times 1.05^{-20}$). This amount should be multiplied by the probability that the individual will survive the intervening 20 years, since the risk reduction is of no benefit in the event that he dies of other causes before the environmental pollutant could have killed him. This survival factor is typically much less important. For the average American, it is greater than 0.7 if the individual is younger than 55 (*7*).

Accounting for Age. A number of investigators have examined how tradeoffs between income and mortality risk are expected to vary over the life cycle (e.g., refs *8*–*11*). These theoretical models represent the individual's lifetime utility as the present value of his utility in each time period. Utility within a time period depends on consumption, which is limited by current income, savings and inheritance, and ability to borrow against future earnings. The individual seeks to maximize lifetime utility by allocating his wealth to consumption and savings.

Two factors influence the life-cycle pattern of VSL. First, the number of future life years at risk declines as one ages, so the benefit of a unit decrease in current-period mortality risk declines. Second, the opportunity cost of spending on risk reduction also declines with age as savings accumulate and the investment horizon approaches. The net effect may cause VSL to fall or rise with age.

In models that assume an individual can borrow against future earnings, VSL declines monotonically with age. For example, Shepard and Zeckhauser (*9*) calculate that VSL for a typical American worker falls by a factor of 3 from age 25 to age 75. If individuals can save but not borrow, VSL rises in early years as the individual's savings (and earnings) increase before it ultimately declines. In this case, Shepard and Zeckhauser (*9*) find that VSL peaks near age 40 and is less than half as large at ages 20 and 65.

Ng (*11*) argues that the rate at which individuals discount their future utility is likely to be smaller than the rate of return to financial assets, whereas Shepard and Zeckhauser (*9*) assume these rates are the same. If the utility-discount rate is less than the rate of return, individuals should save more when they are young and consume more when old. Under these conditions, VSL may not peak until age 60 or so (*11*). Even if individuals discount future utility at the rate of return, younger people might be anticipated to save more and spend less on reducing mortality risk because of the greater range of future financial contingencies they face.

Environmental improvements often reduce individuals' mortality risk for many years. These continuing risk reductions may be valued by determining WTP for each annual risk reduction using the age-appropriate VSL and discounting the annual WTP values to account for the time value of money and the probability of surviving to each age, as for other latent risk reductions.

Empirical Estimates of the Value of Life Saving

Estimates of VSL have been obtained using two approaches—revealed and stated preferences. Revealed-preference methods are based on the assumption that individuals choose the alternative that best satisfies their self-interest. Stated-preference methods, of which contingent valuation (CV) is the most common, rely on surveys in which individuals are asked how they would act if facing a hypothetical choice.

Estimates of VSL using both approaches range between about \$100 000 and \$10 million. Reviewers of this literature conclude that the most reasonable values are \$1.6–8.5 million (*12*; 1986\$) and, more recently, \$3–7 million (*13*; 1990\$).

Some observers find these values implausibly large. For example, a uniform VSL of $5 million implies that a family of four would annually spend about $2100 of its $40 000 income to reduce mortality risk of each member by 10% [annual mortality risk for U.S. residents averages about 1.9×10^{-3} for ages 25−44 and 2.7×10^{-4} for ages 1−14 (*7*)]. This is a large change in risk, roughly equivalent to eliminating the adults' motor-vehicle-fatality risk and reducing the children's risk by half. Because VSL falls with income and baseline risk, the family would pay slightly smaller amounts for each infinitesimal risk increment making up the 10% reduction. As noted above, however, the effect of the change in baseline risk is very small. The effect of wealth could theoretically be large, but empirical estimates suggest that the proportional change in VSL is no greater than the proportional change in wealth (*13*), about 5% in this example.

Revealed Preference. Revealed-preference studies of VSL require that individuals choose between alternatives that differ in mortality risk and money. Most have examined the incremental pay workers receive for accepting hazardous jobs, although choices among consumer products (e.g., cigarettes, smoke detectors, automobiles) and seat-belt use have also been examined (*12*, *13*).

Revealed-preference estimates are viewed as more credible than stated-preference estimates because they rely on real behavior, so the individual has experience and an incentive to inform himself about the attributes of available choices. Nevertheless, individuals may be poorly informed about the differential mortality risks associated with the choices they face. Also, although the analyst observes the alternatives that individuals choose (e.g., the jobs they hold), he does not observe the alternatives they reject and the attributes of those alternatives. If an individual has no realistic alternative to a hazardous job, one cannot infer that he prefers his current job to a safer one with lower pay.

Studies of compensating wage differentials may suffer from data and statistical limitations. Fatality risk is generally based on industry or occupational averages, which are likely to conceal much variation between jobs (*14*). Inability to control for all the other job attributes that may be correlated with fatality risk leads to potential biases (*15*). For example, many studies do not control for nonfatal injury risk. This omission biases estimated VSL upward because part of the observed wage differential compensates for injury risk, which is positively correlated with fatality risk. The bias is estimated as 20−150% using actuarial data on risks to U.S. workers (*16*) and as 100% using survey data on perceived risks to Taiwanese workers (*17*).

Comparing estimates from different studies as a function of sample−mean income (wealth is typically not measured) and occupational−fatality risk suggests that VSL increases with income, as anticipated, but decreases with baseline risk (*18*). The decrease with baseline risk implies that self-selection of more-risk-tolerant workers to more hazardous jobs offsets the dead-anyway effect, which increases an individual's VSL as his risk increases. (The dead-anyway effect depends on an individual's total mortality risk, not the risk from a single source, but occupational risk is likely to be a large component of total risk for workers in high-risk jobs.) As summarized in Table 1, wage differential studies that examine these issues find that VSL is positively related to income and negatively related to baseline risk and age.

Stated Preference. Stated-preference methods are extremely flexible, as individuals can be questioned about how they would choose in a great variety of hypothetical situations. The hypothetical nature of the choice is also the greatest weakness of these methods, as individuals may be unfamiliar with the choices and have insufficient incentive to provide thoughtful answers.

TABLE 1. Estimated Direction of Effects of Income, Baseline Risk, and Age on VSL

study	income	risk	age
Compensating wage differential			
Thaler and Rosen (*45*)			−
Olson (*46*)		−	
Marin and Psacharopoulos (*47*)	+		
Arnould and Nichols (*48*)		−	−
Garen (*14*)	+[a]		
Other revealed preference			
Blomquist (*49*)	+		+
Contingent Valuation			
Jones-Lee et al. (*26*)	+		+
Smith and Desvousges (*27*)	+	−	
Gerking et al. (*50*)	+	+	+
Appel et al. (*51*)	+		
Buzby et al. (*52*)			−
Johannesson et al. (*53*)			+
Lee et al. (*54*)	+		+
Lee et al. (*55*)	+		
Hammitt and Graham (*21*)	+		−

[a] VSL increases with schooling and experience.

The most commonly used stated-preference method is CV, in which survey respondents are asked to choose between alternatives that differ in the attribute to be valued and in cost. Many economists have expressed skepticism about CV, particularly when it was used to value damages associated with the *Exxon Valdez* oil spill. These damages were determined to include so-called "passive-use" losses suffered by people who had no direct contact with the affected region (*19*).

CV has been used to value a range of mortality risks, beginning with Acton's 1973 study of emergency response services for heart attacks (*20*). The most common application has been to transportation risks, although risks associated with food, medical technologies, hazardous waste, and other sources have also been examined (*21*).

CV results can be sensitive to apparently inessential aspects of the choice (e.g., question ordering and the format in which risks are presented) but insensitive to essential aspects, such as the quantity of the good to be valued (*19*, *21*−*25*). For estimating VSL, the apparent insensitivity of WTP to the magnitude of risk reduction is important because the estimated VSL (WTP divided by risk reduction) will strongly depend on the magnitude of the reduction specified in the survey.

Standard theory (reviewed above) suggests that WTP for mortality risk reduction should be nearly proportionate to the magnitude of the change in probability (i.e., VSL should be insensitive to small changes in baseline risk). The modest number of studies that have tested for sensitivity to magnitude have found that estimated WTP is usually much less than proportionate to the change in probability, and in some cases WTP is not even statistically significantly related to the magnitude of risk reduction (*21*).

In a leading study, Jones-Lee et al. (*26*) questioned 1005 British respondents about their WTP to reduce mortality risk on a foreign bus trip. Mean estimates of WTP to reduce mortality risk by 4 and 7 per 100 000 (from an initial level of 8/100 000) are £137 and £155, respectively. Estimated WTP is only 15% larger for the 75% larger risk reduction, and VSL is alternatively estimated as £3.4 million and £2.2 million. (Trimmed means of £64 and £97, respectively, lead to more similar estimates of VSL, £1.6 million and £1.4 million.) Median WTP for the two risk reductions are equal (£50). Half the respondents indicated no sensitivity to magnitude, with 42% providing the same WTP for both risk reductions and 8% stating greater WTP for the smaller reduction.

Similarly, in a careful study of WTP to reduce risk associated with proximity to a hazardous waste facility, Smith and Desvousges (*27*) estimated that WTP was virtually the same for different respondents presented with reductions in the probability of premature death that differed by as much as 2 orders of magnitude. In a study of WTP for a program to minimize industrial hazardous waste, Loomis and DuVair (*28*) did find that the same individuals would pay more for a larger risk reduction, although the difference in WTP was much less than proportionate to the change in risk.

There are several possible explanations for the inadequate sensitivity of CV-estimated WTP to variations in risk reduction. One is that the magnitude of the risk change is not adequately communicated to respondents. Psychological research suggests that people have limited appreciation for numerical differences in magnitude (*29*, *30*). Investigators have used several types of visual aids to communicate changes in risk, but there has been little testing of the effect of these devices on respondent comprehension and responses (*21*, *28*). Second, a respondent may not treat the specified probabilities as applicable to him but may form a posterior risk estimate combining his prior belief and the information presented in the question (*31*−*33*). In this case, even if a respondent's stated WTP is proportionate to his estimate of the risk change, it will not be proportionate to the risk reduction specified in the survey. Consequently, it is impossible to estimate the respondent's value per unit risk reduction unless his posterior risk estimate can be ascertained. Finally, respondents may not value changes in risk levels in a manner that is consistent with expected-utility theory (which underlies eq 1). However, alternative models of choice are locally linear in the probabilities (except perhaps at zero risk) and consequently predict that WTP should be nearly proportionate to the risk increment, for small changes in risk (*34*).

As summarized in Table 1, CV estimates are positively related to income, as anticipated. CV estimates often suggest that VSL increases with age, as implied by some models of life cycle valuation (e.g., ref *11*).

Value of a Statistical Life Year. To account for differences in life expectancy among potential beneficiaries of environmental improvements, efforts have been made to estimate a value per statistical life year (VSLY). One approach is to derive a value from estimates of VSL assuming individuals value reductions in current mortality risk in proportion to the number of future life years at risk. For a typical worker with a VSL of $5 million and a life expectancy of 40 years, VSLY = $125 000. If the individual discounts the value of future life years at 5% annually, his discounted life expectancy is about 18 years and VSLY = $275 000. Moore and Viscusi (*35*, *36*) estimated the discount rate and WTP for mortality risk reduction jointly using labor-market data and assumptions about the workers' life expectancies; they obtained discount rates of 10−12% and VSLY of $175 000. Dreyfus and Viscusi (*37*) examined household choices among automobiles that differ in fatality risk and estimated discount rates of 11−17% and VSLY of $370 000−500 000. The empirical finding that VSL may be constant or increasing with age (Table 1) suggests that an individual's VSLY is not constant but increases with age.

Research Needs

Although the basic theory of individuals' own WTP for reductions in their own mortality risk is well-established, a number of conceptual and methodological questions remain. First, there has been relatively little investigation of the extent to which WTP depends on characteristics of the risk other than probability. Differences in morbidity associated with the cause of death (e.g., between heart attacks and cancer) presumably lead to differences in WTP to reduce each risk. In addition, there is evidence that public concern about mortality risks is influenced by a number of qualitative attributes, such as whether the risk is controllable by the risk bearer, is assumed voluntarily, results from a process that also benefits the risk bearer, results from a familiar technology, has latent effects, and has catastrophic potential (*38*). The extent to which morbidity and qualitative factors influence individual WTP has received only limited attention (*39*−*41*).

Second, questions about whether and how to differentially value risks to different populations are unresolved. VSL is based on individuals' preferences between safety and other desired goods. In principle, failure to use individually appropriate VSLs can lead to requiring more or less safety than individuals would choose for themselves, if they had to pay the costs. In practice, environmental health risks are usually evaluated by treating all premature fatalities identically, in part because of limited ability to predict differences in risk to different populations for many environmental pollutants. Evidence that the mortality effects of particulate air pollution are concentrated among the elderly has stimulated interest in accounting for differences in life expectancy, perhaps by using VSLY.

Alternative approaches to valuing mortality risk are used in other areas of public health and medicine. In industrialized countries, longevity benefits are often quantified using "quality-adjusted life years" that account for differences between individuals in life expectancy and health (*42*). In developing countries, there is growing use of "disability-adjusted life years", which count years lived in young adulthood—when individuals may contribute most to society—as more valuable than years lived in childhood or at advanced ages (*43*). These alternatives provide relative values of reducing risk to different populations but do not directly address the question of whether a particular risk reduction is worth its cost. That judgment is often made by comparing the cost-effectiveness (i.e., the cost per quality- or disability-adjusted life year gained) of a proposed action to benchmarks based on the cost-effectiveness of alternative interventions (*42*). On this basis, interventions that cost less than $50 000−100 000 per quality-adjusted life year are often considered desirable in the United States.

Values are rarely differentiated on the basis of wealth or income, in part because doing so may conflict with legal and ethical precepts. One case where values have been adjusted for income is in evaluating the damages due to global climate change. For example, Fankhauser (*44*) valued premature fatalities in different geographic regions using VSLs between $100 000 and $1.5 million, depending on per capita income.

Turning to methodology, there is a need for research to clarify how individuals perceive differences in risk, in actual behavior and in hypothetical settings. Difficulties in communicating hypothetical risk reductions to survey respondents lead to varying estimates of VSL and diminish the credibility of CV estimates. The analogous condition for revealed-preference studies—that workers and other subjects accurately evaluate the risks of alternative choices—also merits further attention, perhaps by testing whether revealed-preference estimates are sensitive to indicators of risk comprehension.

Acknowledgments

I thank Scott Farrow, John Graham, Mitchell Small, and the reviewers for helpful suggestions; John Loomis for providing supplementary results from his study (*28*); and the U.S. Environmental Protection Agency for financial support. The views expressed in this paper may not represent Agency views or policy.

Literature Cited

(1) Schelling, T. C. In *Problems in Public Expenditure Analysis*; Chase, S. B., Ed.; Brookings: Washington, DC, 1968.
(2) Drèze, J. *Rev. Fr. Rech. Oper.* **1962**, *6*, 93−118.
(3) Jones-Lee, M. *J. Polit. Econ.* **1974**, *82*, 835−849.
(4) Weinstein, M. C.; Shepard, D. S.; Pliskin, J. S. *Q. J. Econ.* **1980**, *94*, 373−396.
(5) Pratt, J. W.; Zeckhauser, R. J. *J. Polit. Econ.* **1996**, *104*, 747−763.
(6) Cropper, M. L.; Sussman, F. G. *J. Environ. Econ. Manage.* **1990**, *19*, 160−174.
(7) *Health, United States*; National Center for Health Statistics, U.S. Department of Health and Human Services: Hyattsville, MD, 1998.
(8) Arthur, W. B. *Am. Econ. Rev.* **1981**, *71*, 54−64.
(9) Shepard, D. S.; Zeckhauser, R. J. *Manage. Sci.* **1984**, *30*, 423−439.
(10) Rosen, S. *J. Risk Uncertainty* **1988**, *1*, 285−304.
(11) Ng, Y.-K. *J. Econ.* **1992**, *55*, 1−16.
(12) Fisher, A.; Chestnut, L. G.; Violette, D. M. *J. Policy Anal. Manage.* **1989**, *8*, 88−100.
(13) Viscusi, W. K. *J. Econ. Lit.* **1993**, *31*, 1912−1946.
(14) Garen, J. E. *Rev. Econ. Stat.* **1988**, *70*, 9−16.
(15) Leigh, J. P. *J. Environ. Econ. Manage.* **1995**, *28*, 83−97.
(16) Viscusi, W. K. *Public Policy* **1978**, *26*, 359−386.
(17) Liu, J.-T.; Hammitt, J. K. *J. Risk Res.* **1999**, *2*, 263−275.
(18) Liu, J.-T.; Hammitt, J. K.; Liu, J.-L. *Econ. Lett.* **1997**, *57*, 353−358.
(19) Arrow, K.; Solow, R.; Leamer, E.; Portney, P.; Radner, R.; Schuman, H. *Fed. Regist.* **1993**, *58*, 4602−4613.
(20) Acton, J. Evaluating Public Programs to Save Lives: The Case of Heart Attacks; Report R-73-02; Rand Corporation: Santa Monica, CA, 1973.
(21) Hammitt, J. K.; Graham, J. D. *J. Risk Uncertainty* **1999**, *18*, 33−62.
(22) Carson, R. T.; Mitchell, R. C. *J. Environ. Econ. Manage.* **1995**, *28*, 155−173.
(23) Baron, J. *Psychol. Bull.* **1997**, *122*, 72−88.
(24) Frederick, S.; Fischhoff, B. *Risk, Decis. Policy* **1998**, *3*, 109−124.
(25) Covey, J.; Jones-Lee, M. W.; Loomes, G.; Robinson, A. *Risk Decis. Policy* **1998**, *3*, 245−259.
(26) Jones-Lee, M. W.; Hammerton, M.; Philips, P. R. *Econ. J.* **1985**, *95*, 49−72.
(27) Smith, V. K.; Desvousges, W. H. *J. Polit. Econ.* **1987**, *95*, 89−114.
(28) Loomis, J. B.; duVair, P.; *Land Econ.* **1993**, *69*, 287−298.
(29) Kahneman, D.; Tversky, A. *Psychol. Rev.* **1973**, *80*, 237−251.
(30) Baron, J. *J. Risk Uncertainty* **1997**, *14*, 301−309.
(31) Viscusi, W. K. *Econ. Lett.* **1985**, *17*, 59−62.
(32) Viscusi, W. K. *J. Risk Uncertainty* **1989**, *2*, 235−263.
(33) Smith, V. K. In *The Social Response to Environmental Risk: Policy Formulation in the Age of Uncertainty*; Bromley, D. W., Segerson, K., Eds.; Kluwer Academic Publishers: Dordrecht, The Netherlands, 1992.
(34) Machina, M. J. *J. Econ. Perspect.* **1987**, *1*, 121−154.
(35) Moore, M. J.; Viscusi, W. K. *Econ. Inquiry* **1988**, *26*, 369−388.
(36) Moore, M. J.; Viscusi, W. K. *J. Risk Uncertainty* **1990**, *3*, 381−401.
(37) Dreyfus, M. K.; Viscusi, W. K. *J. Law Econ.* **1995**, *38*, 79−105.
(38) Slovic, P.; Fischhoff, B.; Lichtenstein, S. In *Judgment Under Uncertainty: Heuristics and Biases*; Kahneman, D., Slovic, P., Tversky, A., Eds.; Cambridge University Press: Cambridge, 1982.
(39) McDaniels, T. L.; Kamlet, M. S.; Fischer, G. W. *Risk Anal.* **1992**, *12*, 495−503.
(40) Savage, I. *J. Risk Uncertainty* **1993**, *6*, 75−90.
(41) Cropper, M. L.; Subramanian, U. *Public Choices between Lifesaving Programs: How Important are Lives Saved*?; Policy Research Working Paper 1497; World Bank: Washington, DC, 1995.
(42) Gold, M. R.; Siegel, J. E.; Russell, L. B.; Weinstein, M. C. *Cost-Effectiveness in Health and Medicine*; Oxford University Press: Oxford, 1996.
(43) Murray, C. L. *Bull. WHO* **1994**, *72*, 429−445.
(44) Fankhauser, S. *Valuing Climate Change: The Economics of the Greenhouse*; Earthscan: London, 1995.
(45) Thaler, R.; Rosen, S. In *Household Production and Consumption*; Terleckyj, N. E., Ed.; NBER: Cambridge, 1976.
(46) Olson, C. A. *J. Human Resour.* **1981**, *16*, 167−185.
(47) Marin, A.; Psacharopoulos, G. *J. Polit. Econ.* **1982**, *90*, 827−853.
(48) Arnould, R. J.; Nichols, L. M. *J. Polit. Econ.* **1983**, *91*, 332−340.
(49) Blomquist, G. *J. Polit. Econ.* **1979**, *87*, 540−558.
(50) Gerking, S.; DeHaan, M.; Schulze, W. *J. Risk Uncertainty* **1988**, *1*, 185−199.
(51) Appel, L. J.; Steinberg, P.; Powe, N. R.; Anderson, G. F.; Dwyer, S. A.; Faden, R. R. *Med. Care* **1990**, *28*, 324−337.
(52) Buzby, J.; Ready, R.; Skees, J. *J. Agric. Appl. Econ.* **1995**, *27*, 613−625.
(53) Johannesson, M.; Johansson, P.-O.; Lofgren, K.-G. *J. Risk Uncertainty* **1997**, *15*, 221−239.
(54) Lee, S. J.; Neumann, P. J.; Churchill, W. H.; Cannon, M. E.; Weinstein, M. C.; Johannesson, M. *Health Policy* **1997**, *40*, 1−12.
(55) Lee, S. J.; Liljas, B.; Neumann, P. J.; Weinstein, M. C.; Johannesson, M. *Med. Care* **1998**, *36*, 1162−1173.

Received for review June 30, 1999. Revised manuscript received January 4, 2000. Accepted January 10, 2000.

ES990733N