Self Protection and Averting Behavior, Values of Statistical Lives, and Benefit Cost Analysis of Environmental Policy

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Working Paper Series

Working Paper # 03-02
March, 2003

U.S. Environmental Protection Agency
National Center for Environmental Economics
1200 Pennsylvania Avenue, NW (MC 1809)
Washington, DC 20460
http://www.epa.gov/economics

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Abstract:

Individuals can be observed in a variety of activities that affect their health and safety. Protective behavior is evident in motorist choice of automobile type, safety equipment such as seat belts, and speed of travel. Choices concerning safety helmets, cigarette smoking and installation of fire alarms change risks of death that individuals experience. Choice of residence when housing markets encompass Superfund sites influences the amount of risk that individuals face. Visits to health clinics for preventive care can reduce risks to health. The purpose of this paper is twofold. The first purpose is to review studies which estimate values of mortality risks based on the tradeoffs which individual consumers make. The second purpose is to assess how useful the estimates are for BCA of environmental policy and suggest directions for future research.

Subject Area Classifications:
Health
Valuation

Keywords:
averting behavior
value of statistical life

Prepared for "Economic Valuation of Mortality Risk Reduction: Assessing the State of the Art for Policy Applications," an Environmental Policy and Economics Workshop held by the U.S. Environmental Protection Agency in Silver Spring, MD, on November 6-7, 2001 under EPA Cooperative Agreement R-82957201-0. Comments from Paul Hansen, Bryan Hubbell, Magnus Johannesson, Ted Miller, Laura Taylor, John Whitehead, workshop participants at EPA, Lund University, Stockholm School of Economics, and University of Kentucky, and several anonymous EPA reviewers are appreciated. Helpful comments were also received from participants in a Southern Committee on Resource and Environmental Economics session at the Southern Economic Association meetings held in New Orleans, LA on November 24-26, 2002. Nicole Owens deserves special thanks for her encouragement and support in her role as project officer. I alone am responsible for the views in this paper.

Introduction

Individuals can be observed in a variety of activities that affect their health and safety. Protective behavior is evident in motorist choice of automobile type, safety equipment such as seat belts, and speed of travel. Choices concerning safety helmets, cigarette smoking and installation of fire alarms change risks of death that individuals experience. Choice of residence when housing markets encompass Superfund sites influences the amount of risk that individuals face. Visits to health clinics for preventive care can reduce risks to health. The purpose of this paper is twofold. The first purpose is to review studies which estimate values of mortality risks based on the tradeoffs which individual consumers make. The common feature is that the estimates of values of small changes in mortality risks are implied by observable consumer behavior as individuals protect themselves against, or avert, risk. These values of mortality risks, for convenience, are sometimes referred to as "values of life" or "values of statistical life" (VSL). Interest in estimates of these values exists, in part, because the U.S. Environmental Protection Agency (EPA), the Department of Transportation, and other agencies evaluate policies and regulations that are expected to have impacts on individuals' health and safety and their mortality risks. Benefit cost analysis (BCA) of such policy requires VSL estimates. The second purpose is to assess how useful the estimates are for BCA of environmental policy and suggest directions for future research.

This review is made with a constructively critical eye. Although we economists find it particularly easy to be critical, I think it is potentially too costly to go with our tendency in this type of review because we risk fostering the mistaken notion that the

whole methodology and entire body of evidence on VSL are unreliable. A destructively critical review that only points to shortcomings and fails to clearly describe accomplishments can be counter productive. Such a review can make it easier for critics of BCA to disregard accomplishments, mistakenly abandon valuation, and promote an absolutist position that the concept of valuing mortality risks is immoral.[1] A case can be made that economists take for granted that we substantially agree that individual willingness to pay for changes in risk is the best way to think about valuing the policy benefits and that sound, theoretically based methods exist for estimating VSL[2]. A great deal has been learned about valuing mortality risks since estimation of willingness to pay for risk changes began nearly 30 years ago.

Frameworks for Estimating Values of Mortality Risks Based on Averting Behavior

The thought of inferring individuals' values of reductions in mortality risks from their behavior intended to influence risk is appealing. Situations in which risk is at least partly a matter of choice provide opportunities to analyze behavior and estimate the willingness to pay (WTP) for risk reductions or willingness to accept (WTA) compensation for risk increments. These situations can involve choices among various types of work in the labor market, or the situations can involve choices in consumption

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[1] The ethical foundation for benefit cost analysis can be found in teleology. One form of teleology is utilitarianism in which goodness can be judged on the basis of choosing alternatives that maximize the good for all. A deontologist, in contrast, might object that any tradeoff of risk for money or time is morally objectionable and the concept of VSL for use in BCA is wrong; see Brandt-Rauf and Brandt-Rauf (1980).

[2] If we fail to emphasize what we know and what we agree on while striving to improve the practice of economics, we risk having the whole approach dismissed as we are viewed as just squabbling, see *The Economist* (1997).

activity. Self protection or averting behavior in consumption, i.e. household production, is the focus of this paper. The theory for understanding these activities is built on the foundation laid by Becker (1965) in his theory of allocation of time and Ehrlich and Becker (1972) in their theory of self-insurance and self-protection.

Smith's (1991) "Household Production Functions and Environmental Benefit Estimation" and Freeman's (1993, Chapter 4) "Models for Indirect Benefit Estimation" provide broad reviews of the theory and use of household production approaches to valuing environmental changes. Cropper and Freeman's (1991) "Environmental Health Effects" and Freeman's (1993, Chapter 10) "Valuing Longevity and Health" provide careful reviews of approaches to valuing changes in health risks, and in particular, to estimating values of changes in mortality risks, VSLs. The literature is extensive and well developed and I will not attempt to review it again in this paper. Instead, I will simply describe the two closely-related models that guide thinking about valuing changes in mortality risks.

The Basic Model

A basic model with the present period and one future period captures the essence of estimating risk tradeoffs in consumption.[3] Let the individual maximize expected utility, E(U), that consists of utility in the first period, $U(C_1,S)$, and expected utility in the second period, $PU(C_2)$, where U is a well-behaved single period utility function, C_i is composite consumption in period i, i=1,2, P is the probability of survival to period 2, and

[3] The model is only sketched here. For a more complete presentation see Blomquist (1979). For a more complete discussion of this approach including refinements, see Freeman (1993, Chapter 10).

S protective health or safety activity in which the individual can engage. The production function for changing P is left general as P=P(S). P′, the marginal product of averting behavior, is the reduction in the mortality risk. P′ is assumed to be positive and diminishing. Averting activity can affect utility directly with U_S negative if S generates disutility or U_S positive if averting activity generates utility.

$$\mathbf{E(U) = U(C_1,S) + PU(C_2)} \qquad (1)$$

Differentiating equation 1, holding E(U) constant, and solving for dC_1/dP yields

$$\mathbf{dC_1/dP = - U(C_2) / \lambda P} \qquad (2)$$

where λ is the marginal utility of consumption (or income.) Equation 2 shows the marginal rate of substitution between consumption and the probability of survival, or the marginal willingness to tradeoff consumption for reductions in mortality risk (increases in the probability of survival.) Several implications follow. (1) Willingness to pay for reductions in mortality risk is not a single value but depends on several factors that vary among individuals and circumstances. (2) The tradeoff depends on the base level of risk and will be smaller as the probability of survival increases. (3) The tradeoff depends on future consumption, but it increases with increases in the utility of future consumption (or income or earnings) and not directly with future earnings. Changes in the marginal utility of income may act to partly offset this effect.

Maximization is subject to the budget constraint, that the present value of expenditures on consumption and averting behavior, $C_1 + qS + d\,C_2$, cannot exceed the present value of income, wT + dwT + A, where q is the cost of averting behavior, d is the factor that discounts the amount in period 2 back to the present, w is the wage rate, T is

time available for work in each period, and A is the present value of nonlabor income. The cost of averting behavior, q, is composed of a money cost "m" and a time cost, awt, where "a" is a factor which relates the value of time in averting activity to the wage rate, and "t" is the time input into averting activity.

The first order condition of interest is:

$$\mathbf{P'U(C_2) / \lambda = q - (U_S / \lambda).} \quad (3)$$

The left-hand side of equation 3 is the marginal benefit of averting activity and the right-hand side is the marginal cost. The value of a gain in the probability of survival (or reduction in mortality risk), is $U(C_2) / \lambda$, which is the monetary value of the utility of future consumption. Let this value be V so that

$$\mathbf{V \equiv U(C_2) / \lambda.} \quad (4)$$

Notice that if equation 1 is solved for V we have

$$\mathbf{V = [q - (U_S / \lambda)] / P'}. \quad (5)$$

If for convenience of comparability we evaluate V for a unit (0-1) change in P, then V is an estimate of VSL. So, the value of a change in mortality risk for a unit change in P is

$$\mathbf{VSL = [m + awt - (U_S / \lambda)] / P'}. \quad (6)$$

If, for example, the sum of the components of cost is $400 per period and the change in the mortality risk per period is 0.0002, then the VSL estimate is $2 million.

Each component of the equation presents challenges in estimating VSL. The marginal monetary cost, m, is sometimes negligible for averting activity. It is sometimes estimated by an annual average cost. Marginal inputs of time, t, are sometimes small and sometimes substantial. The value of time spent in producing changes in mortality risks

can equal the market wage rate, w, for the individual, or be some proportion of it, aw, as in motor vehicle travel. The monetary worth of the marginal utility of the averting activity, U_S / λ, may be trivial, or may be a major cost, such as has been the case with manual (nonpassive) seat belts in cars. Estimating P′ may be simple if expert estimates are available and individuals engaging in averting behavior perceive the changes in risks to be the same as the experts. Any misperception of risk makes estimating the perceived P′ more challenging. I will discuss several of these components that are typically necessary for estimating VSL based on averting behavior. Despite the considerable effort that has gone into estimating some components in many studies, I will recommend that more research be done on some of the components in future research.

The Life Cycle Model

While a model with one future period is useful for understanding the basic tradeoff between mortality risk and consumption, a multi-period model with uncertain lifetime allows derivation of individual WTP for changes in mortality risks that would occur at different stages of the life cycle. Life-cycle models can define, for example, the individual WTP now for a change in the conditional probability of survival in 10 years. These models can be useful for considering environmental policy that is expected to reduce future mortality risks. From life-cycle models have followed several implications that have shaped expectations about VSL estimates. Some testable implications are[4]: (1) generally WTP declines with age, (2) under plausible conditions WTP exceeds

[4] See Freeman (1993, Chapter 10) for a more complete presentation of life cycle models. The list of implications given above is based on his summary on page 334.

discounted present value of future earnings, (3) WTP declines with latency, the length of time in the future when risk will be reduced, and (4) WTP now for a risk reduction in year t is equal to WTP in year t for that risk reduction discounted back to the present.

Current research continues to probe. For example, Johansson (2001b) uses a life-cycle model to demonstrate that, in contrast to the first implication listed above, there is no obvious age pattern for WTP for mortality risk reductions over the life cycle. Bresnahan and Dickie (1995) discuss the implications of endogenous risk and other issues in using values based on averting behavior in policy evaluation. In this paper I will review estimates of VSL based on self protection and averting behavior. I will comment on some of the issues in using the basic model. I will note some of the results that are surprising given the implications of life-cycle models, at least as we currently understand them.

Estimates of Values of Mortality Risks based on Self-Protection and Averting Behavior in Consumption

Previous Reviews

Interest in estimates of values of mortality risk reductions has produced several relatively recent reviews.[5] Viscusi's (1993) survey of the literature covers all types of studies and includes a summary of studies based on tradeoffs in consumption, or what he

[5] For early reviews see Blomquist (1981, 1982), Jones-Lee (1985) and Fisher, Violette, and Chestnut (1989). Here I report the more recent reviews, concentrate on the studies of averting behavior in consumption, and the average values of this type of study found in the reviews. Below I will compare these averting behavior studies to wage-risk and stated preference studies and discuss the best estimates.

calls "outside of the labor market", see my Table 1 (based on Viscusi, 1993, Table 5, p.1936). There are seven early studies on highway speeds, seat belt use/nonuse, smoke detectors, housing prices and air pollution, and auto purchases. The average of the VSL estimates shown in Table 1 is $1.6 million in year 2000 dollars.[6]

Miller (1990) reviewed VSL estimates from all types of studies also and based on 47 (unadjusted) VSL estimates he considered sound, he found an average VSL of $3.9 million in 2000 dollars for the U.S. Using the previously-reviewed studies and 21 additional estimates, Miller (2000) does a meta-analysis. My Table 2 shows the international studies in his study as an indication of the world wide interest in estimating VSL, see Miller (2000, Table 1, p. 34). The average of the 12 countries shown plus the U.S. is also $3.9 million in 2000 dollars. Differences in income, base risk levels, opportunities for reducing risk, availability of health care, culture, and other factors can influence values of mortality risks. The fact that Miller finds the average VSL to be similar is interesting, but should not be interpreted as strong evidence for VSL being equal in all countries. On the contrary, Miller reports an estimate for Taiwan that is less than 30% of that for the U.S.

Elvik's (1995) performs a meta-analysis of 169 estimates of values of mortality risk changes. Table 3 is based on his summary of 11 averting behavior studies, see Elvik (1995, App. C, p. 19). The average of the VSL estimates he reports is $3.0 million 2000 dollars if all values except for children and motorcyclists are included. One feature of

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[6] Throughout this paper estimates are reported in 2000 U.S. dollars. The annual average Consumer Price Index for all urban consumers for all items is used to convert values from studies with VSL reported in dollars for another year.

Elvik's review is that he notes whether or not each study has a test of rationality, or risk perception, and whether the analysis uses individual or aggregate data. Elvik considers studies with these characteristics to have high relative validity. Two VSL estimates for adults are given the high rating and they are less than the average for the group, Blomquist's (1979) $1.0 million and Blomquist and Miller's (1992) $2.8 million.

The most recent review, by de Blaeij et al. (2002), is a meta-analysis of all types of studies that estimate VSL based on a tradeoff related to traffic safety. A modified summary from that study is shown in Table 4, see de Blaeij et al. (2002, Table 1). In Table 4 I have omitted four studies and 10 estimates that are included in the de Blaeij et al. study because the estimates are inferred from agency programmatic decisions rather than individual behavior. While this type of study reveals something about public decision making, the values are different in nature from the values estimated from individual self protection, averting behavior. The public tradeoffs do not inform us about individual WTP. de Baeij et al. report that the average of the VSL estimates in their table 1 is $4.7 million 2000 dollars. I calculate that the weighted average of estimates with and without the public tradeoffs implies that the preferred average VSL excluding the public tradoffs is a bit lower, $4.2 million, for the values shown in my Table 4.

A Review of Recent Studies

Table 5 shows my summary of eight relatively recent studies that estimate VSL based on averting behavior in consumption. Hedonic analysis of prices of cars that have various fatality risks, analysis of motorists' use of safety equipment, analysis of bicyclists' use of helmets, analysis of highway speeds and fatalities, and hedonic analysis

of prices of houses with various cancer risks due to nearby Superfund sites are the methods used to estimate VSL. The range of values for adults is something less than $1.7 million to $7.2 million in year 2000 dollars. The average value for adults is approximately $4.5 million if $1.5 million is used for the speed/fatality study and averages are used for the two studies with a range reported. Four very recent studies are worth more detail.

Speeds on Interstate Highways. One recent study was presented by Ashenfelter and Greenstone (2002) at the 2001 symposium in honor of Sherwin Rosen at the University of Chicago and revised as an NBER working paper. They estimate the VSL from changes in speeds on interstate highways. In 1987 federal law was changed to allow states to raise the speed limit on rural interstates from 55mph to 65mph. Their estimates are based on laws being changed so that motorists can make tradeoffs for time savings at the expense of bearing greater mortality risks. Motorists are assumed to base their behavior on the actual tradeoff of risks realized. This assumption is the same as is typically used in the labor market in which workers are assumed to make the tradeoff between higher wages and the mortality risks that actually occur.[7]

Ashenfelter and Greenstone analyze speeds and road fatalities for 28 states for which they can get data for the period 1982-1993. Based on models which include state-by-road-type and year-by-road-type fixed effects, they estimate that speeds increased by approximately 3.5% (2 mph) and fatalities increased by approximately 35% in states

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[7] While one can question the assumption and attempt to obtain the subjective estimates of risk or adjust for perception bias, the tradeoff is no more *ex post* than the typical estimate from self protection and averting behavior or the labor market.

which adopted the higher speed limit. They calculate the time savings associated with the increase in speeds, approximately 125,000 hours saved per life lost. This tradeoff between time gained and life lost implies an upper bound on VSL of approximately $1.7 million in year 2000 dollars if time is valued at the wage rate.

Ashenfelter and Greenstone argue that their empirical analysis should be interpreted as reflecting the preferences of the median driver/voter. The estimate is an upper bound because the tradeoff is observed only for states and drivers in which the value of the time savings exceeds the value of the fatalities. Motorists would not trade off the mortality risks if the risks were worth more than the savings in time. State legislators would not permit the tradeoff if they thought the mortality risks were worth more than the savings in time. In the second part of their paper they attempt to recover the structural estimates of the VSL based on analysis of the tradeoff in each of the states. The estimates of this "average" tend to be slightly lower than the upper bound estimate, but they are imprecisely estimated.

Ashenfelter and Greenstone's upper bound estimate of $1.7 million appears to be reasonably robust statistically, but their estimate depends on values used for valuing motorist' time, number of passengers per vehicle, and perceptions of risks and time savings as well. These parameters matter. To adjust for the average number of occupants per vehicle from the assumed value of 1 to the average number of 1.7 would increase their VSL estimate by 70%. To adjust for the value of time from the assumed ratio of 1 for (value of time)/wage to 0.6 as used in Blomquist, Miller, and Levy (1996) would decrease their VSL estimate to only 60% of what it is. While these two

adjustments just about offset one another, if an adjustment is made for misperception of risk by motorists and the value of 1.634 is used as in Blomquist, Miller, and Levy (1996), then their upper bound estimate of VSL would be $2.8 million in 2000 dollars.

Ghosh, Lees, and Seal (1975) used observed speeds on British motorways to estimate VSL 26 years ago and their estimate is shown as $1.1 million in 2002 dollars in Table 3. Although it is not as sophisticated as Ashenfelter and Greenstone's, both averting behavior study contribute to what is now considered something we know, that VSL is greater than discounted foregone earnings.

Residential Location and Superfund Sites. Gayer, Hamilton, and Viscusi (2000, 2002) analyze the housing market surrounding Superfund sites in Grand Rapids, Michigan. They use a specially-constructed, expert measure of cancer risk as well as distance measures and other proxies for physical risk. They find that the proxies for risk can explain about half the variation in expert risk and that housing with less (either proxy or expert statistical) risk sells for higher prices. After the release of the EPA Remedial Investigation, premiums for safer locations imply values of statistical *cancer* of approximately $4.3 - 5.0 million in 2000 dollars. Estimates are much higher if prerelease risk perceptions are used. This estimate is especially relevant to BCA of environmental policy because it is inferred from valuing reductions in environmentally-related cancer risks rather than VSL from other averting behavior.

Bicycle Helmets. Jenkins, Owens, and Wiggins (2001) calculate the VSL implied by use of bicycle helmets and find it to be approximately $4.3 million in 2000 dollars for adults who purchase and wear the helmets. They consider their estimate to be a lower

bound because buyers (and presumably users) find it worth at least as much as the cost to gain the added protection. Including time and disutility costs would increase the implied value and reinforce the claim that the estimate is a lower bound if only money costs are relevant to the use decision. However, their estimated VSL is an *upper* bound for bicyclists who are not buyers (and users) under the same assumption of time and disutility costs being equal to zero. If potential time and disutility costs are important for all bicyclists and those costs are different for users and nonusers, then their estimate is not necessarily an upper bound for nonusers. Because the calculations are based on aggregate data, it is not clear what the VSL is for the average bicyclist. This aspect aside, their study is noteworthy in that it is one of only a few that estimate VSL for children and the only published study that I know of that infers a value from bicycle helmet use by individuals.

Motor Vehicle Models and Occupant Safety. An ambitious hedonic study of prices of motor vehicles and associated fatality rates by Mount, Weng, Schulze, and Chestnut (2001) seeks to estimate VSL for household members of different ages. They build upon earlier related analysis and devote more attention to household use of the vehicles and distribution within the household. A noteworthy characteristic of their study is the set of detailed estimates of mortality risks that account for differences in vehicle use by various members of households. Another advantage of their study is the inclusion of a wider range of motor vehicles than only passenger cars and a rich set of driver characteristics. Their preliminary estimates of VSL are among the highest of the recent studies. Their point estimate of VSL for adults is $7.2 million in 2000 dollars.

As noted at the beginning of this section reviewing recent averting behavior in consumption studies, the range of values for adults is something less than $1.7 million to $7.2 million in year 2000 dollars as reported in Table 5. The simple average value for adults is approximately $4.5 million if $1.5 million is used for the speed/fatality study and averages are used for the two studies with a range reported. The range for what I consider to be the best estimates is not much different. Despite the case that Ashenfelter and Greenstone make that their estimate is an upper bound, some of their estimates of the average VSL are not much different from their upper bound. In addition, their estimate is from behavior in traffic and not directly related to behavior related to environmental risks. If their estimate is adjusted for risk misperception, it would be about $2.8 million in 2000 dollars. So, I consider about $2 million to be at the lower end of the range. The VSL estimate adjusted for risk from Blomquist, Miller, and Levy is $4.6 million. The VSL estimate adjusted for risk from Mount et al. is $7.2 million and I consider it to be at the upper end of the range. The Gayer, Hamilton, and Viscusi estimate of $4-5 million for cancer is the estimate most directly related to environmental risks. Presumably the VSL is greater than the value of a statistical case of cancer because not all cancer results in death. So, I think the best estimate of VSL from averting behavior in consumption is that it is probably close to $4 million in year 2000 dollars. One aspect of the recent estimates worth noting is that the best estimates are greater than values estimated in earlier studies of averting behavior in consumption. One of the reasons for the increase in average values is the greater use of hedonic approaches compared to estimation of based on risk related behavior combined with calculations that use other related

parameters such as values of time, number of vehicle occupants, and disutility costs. At this time, I think both types of analysis are equally valuable.

Risk Perception and Values Implied by Averting Behavior in Consumption.

A crucial element in estimating VSLs from self protection and averting behavior is the amount risk changes when the individual engages in the activity. Atkinson and Halvorsen (1990, fn.2), for example, explicitly acknowledge that they assume that the automobile purchaser's perception of risk is consistent with actual risk in making their VSL estimates. Their estimates, as do others' estimates, depend directly on this assumption. It is no secret that individuals can have difficulty understanding risk and making decisions involving risk. However, my assessment is that this imperfection is not fatal for estimating VSL based on observable behavior in product markets and using this information in BCA.

First, an impressive amount of evidence exists that reveals that individuals respond to risk in expected ways. By this I mean they respond in the expected direction and they respond more, the greater is the risk. Analysis of motorist use of protective equipment such as safety belts and child safety seats, for example, typically shows that motorists protect more when expected benefits are greater such as when traveling at higher speeds and protect less when it costs more such as using child safety seats on older children who should be fitted with larger seats and can protest confinement more effectively, see Blomquist (1990). When individuals have something like their own health and safety at stake, they tend to act as if they perceive risks in ways that indicate

their perceptions are positively correlated with expert estimates of the risks.

However well individuals perceive increases and decreases in risk and rank them correctly, their ability to perceive risk in a cardinally correct way is questioned. For example, Lichtenstein et al. (1978) found that when individuals' perceptions of risks are compared to expert estimates of risks, low risks tend to be overestimated and higher risks tend to be underestimated. Other differences between individual perceptions and expert estimates exist and the relationships have been estimated. Thus, my second reason for thinking that averting behavior is useful despite imperfect perceptions of risk is that, as part of the sensitivity analysis, the estimates of VSL can be adjusted using the relationships between individual perceptions and expert estimates. If individual risk estimates are known to be 20% lower than the expert risk estimates, then the VSL can be recalculated with the lower risk. The rationale is that the lower risk is the level on which the individual is basing behavior and making tradeoffs. I used the Lichtenstein et al. (1978) estimates in my review of estimates of the VSL to allow policy makers an alternative to VSL estimates based on expert risk estimates, see Blomquist (1982). Ideally, the individual's perceived risk is the risk appropriate for estimating the VSL.

If the policy maker believes that the adjusted risk is preferred, then the VSL can be estimated based on it. Relying on the Lichtenstein et al. relationship, however, is not wholly satisfactory. Benjamin and Dougan (1997) would question adjusting risks in this way. They reanalyze the Lichtenstein data and show that differences between individual perceptions and expert estimates disappear if the risks are limited to risks in the person's age group. They find there is no perception "bias." Hakes and Viscusi (1997) also

reanalyze augmented Lichtenstein et al. data using a Bayesian learning approach. They find that the differences between the individual perceived risks and expert risks are explained by the actual population mean death risk, the discounted lost life expectancy associated with the cause of death, and the age-specific hazard rate. The more specific is the expert, statistical risk estimate is to the individual, the less is the "bias." My point is not that we should necessarily stop using the Lichtenstein et al. study, but that we know something about the relationship between individual perceived risk and expert estimates of risk and that we can use those relationships in making estimates of the VSL based on averting behavior in consumption. Before the Benjamin and Dougan's reexamination of risk perception bias, Miller (1990) used the Lichtenstein study as the basis for adjusting VSL estimates for perception bias in his critique of wage-risk estimates. Blomquist, Miller and Levy (1996) presented VSL estimates for adults, children, and motorcyclists unadjusted and adjusted for perception bias. After the reexamination of Lichtenstein et al., Miller (2000), in his review and analysis of VSL across countries, uses VSL estimates which are not adjusted for perception bias, but he allows for misperception through various regression specifications. Mount et al. (2001) estimate VSLs for children, adults, and senior adults based on a hedonic analysis of motor vehicle prices and their own extremely detailed estimates of risks of fatal and nonfatal accidents. They report their VSL estimates based on expert statistical risks and on risks corrected for perception bias. They consider their best estimates to be ones based on adjusted risks.

Economists have paid a great deal of attention to perception of environmental risks. Smith and Johnson (1988) evaluated how Maine residents form perceptions about

radon risks. They found support for a modified form of a Bayesian learning model and further that individuals who took mitigating action reported lower perceived risks. Brookshire, Thayer, Tschirhart, and Schulze (1985) estimated the impact of a risk notification program on perceptions of earthquake risks in the California housing market and found that the implicit values of risk after notification were comparable to the contingent values. Dickie and Gerking (1996) found that the formation of risk beliefs about skin cancer depends on complexion and sunlight exposure, and link the risk beliefs to estimates of willingness to pay for avoiding skin cancer. Viscusi and Evans (1998) studied nonfatal health risks associated with a toilet bowl cleaner and an insecticide. They estimated the relationship between the stated (expert) risk and perceived risk and reported a relationship in a way similar to Lichtenstein et al. except that it is for the risks associated with the products being studied. They report the willingness to pay values implied by both the stated risk and stated risk adjusted for perception bias.

Averting behavior through job choice in the labor market provides another example of attention to risk perception. Gegax, Gerking, and Schulze (1991) survey workers to get data on individuals' perceived mortality risks of specific jobs and wages rather than use observed frequencies to estimate occupation or industry average fatality rates.[8] This study and the other examples illustrate that studies of risk belief about averting behavior and valuation of risks can be combined to the advantage of better VSL

[8] Mrozek and Taylor (2002) find in their meta-analysis that the estimated effect of using worker's self-assessed risk on the VSL estimates is not robust across specifications. However, in their sample only the Gegax, Gerking, and Schulze (1991) and Moore and Viscusi (1988) studies used perceived risk. They define their best estimates based on studies using expert risk because of their concern that too few wage-risk studies use perceived risk.

estimates.

If the concern is great enough about the relationship between expert estimates and individual risk perception for a particular activity, then an additional project component is worth funding. A suggestion for future funded research is to encourage study designs that combine together a study of the risk perceptions associated with the particular averting behavior and a study that estimates the VSL. Perhaps estimates of VSL based on averting behavior are now refined enough that the confidence interval around the risk estimate is large enough due to potential perception bias that it is worth more investment in perception in each study. This component is unnecessary if risk perception bias is thought to be only a small contributor to the confidence interval. It is unnecessary if the relationship between perceived risk and expert estimates of risk are thought to be known precisely enough that after correction, this source of error is thought to be only a small contributor. If it is worth the investment, then the EPA should expect a risk perception component in averting behavior studies. Given the examples described above, precedent exists for such research design.

The final reason that potential problems with risk misperception are nonfatal to estimating VSL based on averting behavior in consumption is that the standard is not one of perfection. Alternative estimates implicit in the labor market and estimates elicited in hypothetical markets can contribute to our understanding of the VSL, but they are not perfect. Another alternative, the democratic process has much to commend it, but preference revelation through the political process is not perfect either.

Concern about risk perception bias must be thought through carefully. I think it is

straightforward that if perceived risks and expert risks match well for averting behavior studies, then these studies can reveal the values that individuals place on changes in their own mortality risks, and the estimated values can be used in BCA to evaluate environmental programs which reduce similar risks. If risk perceptions are biased and the bias is known, then the values implied by the biased perceptions are the VSL estimates that are appropriate for BCA because they reflect the tradeoff that individuals thought they were making. I think this adjustment is appropriate if the "correction" can be made in a convincing manner. Agreement with this adjustment probably depends on assessments of how convincing the corrections are. When evidence exists that individuals are willing to pay for perceived risks even though expert estimates are much lower, it poses a policy problem discussed by McClelland, Schulze, and Hurd (1990) and Portney (1992). The problem is that, from an expert perspective, resources might be wasted. Regardless of this policy problem if the proximate objective is to estimate individual WTP to reduce mortality risk, then VSLs implied by tradeoffs of perceived risk are appropriate.

Values of Reductions in Mortality Risks for Children and Senior Adults

Children

Children and senior adults are currently of special interest for environmental policy. My review of recent studies shown in Table 5 includes four that estimate VSL for special groups. Carlin and Sandy (1991) analyze mothers' use and nonuse of child safety seats for their children. Based on their analysis they find that their estimates of time and

money use costs and external estimates of the reduction in mortality risks for the children imply a VSL for children of approximately $0.8 million in 2000 dollars. They report that their estimate of mothers' VSL for their children who are under the age of five years is approximately 87% of my (Blomquist, 1979) estimate of VSL for adult drivers based on use and nonuse of seat belts.[9] While their study is thoughtfully executed, they do not include an estimate for mothers' disutility costs of using child safety seats and they add the cost of raising a child. These are two drawbacks of the study that lead me to rely more on other estimates.

Three studies estimate VSL for both adults and children. In Blomquist, Miller, and Levy (1996) we analyze motorists' use and nonuse of safety equipment. We get a best estimate of VSL for children less than five years of age based on use and nonuse of child safety seats and belts of $3.7 million in 2000 dollars. This value is approximately 32% greater than the best estimate of VSL for adults of $2.8 million based on driver use and nonuse of seat belts. If the imprecisely estimated point estimate for child safety seat use only (not combined with harness use), then the VSL for children is roughly twice the VSL for adults. Jenkins, Owens, and Wiggins (2001) estimate parents' VSL for their bicycling children as approximately $2.9 million, a value that is less than the VSL of $4.3 million for bicycling adults who buy and use bicycle helmets, but their estimate is based on aggregate data and ignores utility/disutility of wearing helmets. Mount et al. (2000) estimate VSL based on a hedonic analysis of motor vehicle prices. They use detailed

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[9] Their estimate of $0.8 million is 80% of my estimates as shown in Tables 1, 3, and 4. I think the 7 percentage point difference is due to rounding.

vehicle, driver, and vehicle use data along with an intertemporal adjustment based on Moore and Viscusi's (1988) article to estimate VSLs for adults and children. Their estimate for children of $7.3 million is slightly greater than the estimate for adults of $7.2 million. Because the difference for the adults and children is due to the intertemporal adjustment, it is not as convincing as the estimate of that for adults that is based on the detailed vehicle, driver, and use data. After considering the limited number of estimates we have for children, my hunch is that the VSL for children is greater than the VSL for adults and at least one third greater.

Given the limited number of estimates of VSL for children, it is worth trying to glean something from the estimates of values of children's health. Liu et al. (2000) design and implement a stated preference study in Taiwan to estimate a mother's WTP for medicine that would prevent her from getting another case of the cold she typically gets and her WTP for medicine that would prevent her child from getting another case of the cold the child typically gets. They find that for comparable colds a mother is WTP approximately twice as to prevent her child's cold as her own. Agee and Crocker (2001) analyze data from the 1991 National Maternal and Infant Health Survey to estimate smokers' substitution rates between own consumption and own health, between own consumption and their children's exposure to tobacco smoke, and between own health and their children's health. They estimate that parents value their children's health twice as much as their own health. The measure of health is parents' rating of child health and not mortality risk, but surely the parents, mostly mothers, perceive that mortality risk increases with poorer health. The risk would be of fatal acute episodes associated with

respiratory attacks and of fatal chronic diseases which develop later in children's lives. A stated preference study of acute bronchitis by Dickie and Ulery (2001) also finds parental altruism toward their children and that WTP for avoiding episodes is less for parents than for their children. The value for their children is about twice the value for themselves. These three morbidity studies are consistent with the mortality risk studies of child safety seat/belt use that find that VSLs are greater, or at least not less, for children compared to adults.

Senior Adults

Few estimates of VSL exist for senior adults. The only study I am aware of that estimates VSL based on self protection, or averting behavior, in consumption is Mount et al. (2000). Based on a hedonic analysis of motor vehicle prices using detailed vehicle, driver, and vehicle use data and an adjustment using the Moore and Viscusi intertemporal model they estimate that VSL for senior adults is approximately $5.2 million. This preliminary estimate is less than the estimate for all adults. However, the difference for seniors is partly due to the intertemporal adjustment.

The only study I am aware of that estimates a VSL for older adults based on risk compensating wage differentials is by Smith, Kim, and Taylor (2001). Their analysis of data from the Health and Retirement Survey and the Bureau of Labor Statistics yields estimates of VSL for all workers in the sample of approximately $6 million in year 2000 dollars. This estimate is within the range of estimates in reviewed in the Mrozek and Taylor (2002) meta-analysis and other labor market studies such as those in Viscusi's (1993) review. Their VSL estimates for workers who are 51-65 years of age are greater

than for all workers and roughly twice the size of VSL for all workers. Their study does not include older seniors such as individuals over 75. More empirical and theoretical research is warranted because these estimates come from one study and are inconsistent with the implications of the life cycle model of VSL as normally interpreted. Implications from the life cycle model are being reconsidered. Recent papers by Johansson (2001a, 2001b), for example, demonstrate that the assertions that there are strong theoretical grounds for the view that VSL falls with age too strong. He shows that the implication that VSL declines with age is sensitive to assumptions about consumption over the life cycle. If consumption is not constant, then the VSL can decrease, stay constant, or increase with age.

The stated preference study of Canadian adults by Krupnick et al. (2002) in finds much lower values for adults of different ages, but a similarity is that they too find that the VSL does not change much with age during the 50s and 60s.[10] They find it is about 30% lower for individuals aged 70 and over compared to younger adults. In another stated preference study, Johannesson and Johansson (1997) elicit a premium Swedish adults are willing to pay for a program that would extend life expectancy by one year conditional upon reaching age 75. They too do not find much change in value with age, but in contrast to Krupnick et al., they find that WTP increases slightly with age.

In addition to future research on VSL for children and senior adults, I recommend a formal study of the ethics and practicality (politics?) of using different VSLs for

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[10] If the emphasis is on quality of life, an alternative to using different VSL for individuals who differ in age would be estimate QALYs directly, see Johannesson (1996).

different groups in BCA. The theory of using the values of the individuals who receive the benefits and bear the costs of policy is clear when the goal is maximizing efficiency. It is the basis for using individual WTP. However, what is the ethical basis for using population average values in some cases and values of specific subpopulation groups in other cases? *If* the primary beneficiaries of a policy that improves air quality are smokers and smokers have lower VSL than nonsmokers, is the policy evaluated with those lower values? *If* the primary beneficiaries of remediation of a Superfund site are nonminority poor and the VSL for them is lower than for individuals with higher income, is the policy evaluated with those lower values? Liu et al. (2000) find that in Taiwan mothers' WTP for preventing illness is 20% higher for their sons than for their daughters. *If* the same relationship is found in the U.S., is EPA going to use higher values for boys? Notice how the previous concern for the representativeness of the estimates from a set of individuals is replaced by concern for estimates for individuals with a specified characteristic. I think the political pressures of policy analysis have produced practices such that the value of a study that addresses this practice explicitly would improve policy analysis and decision making. Economists contribute best on matters of efficiency and distributional impacts. I am confident economists can continue to contribute to understanding how the VSL differs by characteristics of the individuals. I am not as confident that policy makers have a well developed conceptual framework for applying the different VSL estimates to policy. My hunch is that a consistent conceptual approach may be one that recognizes that benefit-cost analysis takes place within a particular society and the legal framework of that society, see Zerbe (1991). Within such a context different VSL would

be used for different types of individuals when evidence shows that the estimates of VSL differ and when the legal and regulatory framework indicate that different values are to be applied.

Values of Mortality Risk Reductions Based on Averting Behavior in Consumption Compared to Averting Behavior in the Labor Market and Stated Preferences

The focus of this review is on estimates of VSL based on self protection or averting behavior in consumption. One aspect of the recent estimates reported in Table 5 that is worth noting is that the simple average of the VSL estimates for adults of $4.5 million and what I think is probably the best estimate of about $4 million is close to the range of estimates based on averting behavior in the labor market. $4 to $5 million in 2000 dollars is within the range of studies reviewed by Mrozek and Taylor (2002) and Viscusi (1993). It is a bit higher than the estimates in the range of $1.5 - 2.5 million based on best practice in Mrozek and Taylor, but they place a greater weight on studies that control for more occupation and industry characteristics and those studies tend to yield lower estimates of VSL. The VSL estimate of about $4 million from averting behavior in consumption is also close to Miller's (2000) average of $3.9 million in 2002 dollars based his review of studies of all three (consumption, labor, and stated preferences).

Although wage-risk studies have tended to produce estimates of VSL greater than estimates from averting behavior in consumption, there is some reason to believe that the estimates from the labor market are too high. Shogren and Crocker (1991, 1999)

emphasize the importance of endogenous environmental risk and its implications for self protection as a lower bound on the value of risk reductions. Shogren and Stamland (2002) offer a reason for *upward* bias in risk compensating wage studies. They demonstrate that if workers differ in their individual, private ability to reduce risk and the ability is unobservable by employers, then a market wage must be offered to attract the marginal worker who faces the most risk of those employed. If the average risk of all workers is used to estimate a VSL, then risk is lower than that faced by the marginal worker and the VSL estimate is biased upward. If unbiased estimates from the labor market are even lower than the meta-analysis of Mrozek and Taylor indicates, then more thought about the difference between them and the higher estimates from the recent averting behavior studies is warranted.

The de Blaeij et al. (2000) meta-analysis of estimates of VSL finds that stated preference, or contingent valuation, studies yield higher estimates of VSL than estimates of VSL implied in studies of self-protection or averting behavior. Miller (2000) reports coefficients from his regression meta-analysis that imply that VSL estimates based on wage-risk tradeoffs are significantly and substantially higher than the VSL estimates based on averting behavior in consumption. He finds that the VSL estimates based on stated preferences are higher yet. Based on experience my interpretation of the evidence is that both averting behavior and stated preference approaches can yield useful estimates. Stated preference studies in their rawest, most naive form are subject to "yea saying" hypothetical bias. For example, for the simple, stark, hypothetical purchase in our experiment with the private good, sunglasses, we find strong evidence of hypothetical

bias relative to actual purchases. Significant numbers of individuals say they will purchase at the stated price, and then, in fact, do not purchase when given the opportunity, see Blumenschein et al. (1998). My assessment is that the extent of "yea saying" depends on the quality of the stated preference study and the success in incorporating into the design what has been learned in more than 25 years of development of the technique. In particular, one explanation for the stated preference VSLs being greater than the implied VSLs is the absence in early stated preference studies of specific countermeasures to "yea saying" that have been developed recently. If recent research on countermeasures is indicative, then future stated preference studies need not yield estimates of the VSL which are greater than values implied by averting behavior due to hypothetical bias.[11] A "cheap talk" script about how individuals tend to say yes appears to have mitigated the tendency to say yes in experiments about contributions for environmental goods, see Cummings and Taylor (1999). A self rating of certainty (a 1-10 scale) allows Champ et al. (1997) to classify only individuals who rate themselves as very sure (10) they would donate and then to find that there is no statistical difference between them and those who actually make donations to a public good. In our sunglasses experiment, we use a simpler format consisting of first "yes" or "no" and then a follow up "probably sure" or "definitely sure" (for the choice made). We find no statistically significant difference between the "yes" responses for which the respondent was "definitely sure" and actual purchases, see Blumenschein et al. (1998).

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[11] Other factors may cause the estimates from the approaches to differ, but the contribution of hypothetical bias will shrink if countermeasures are effective.

The result that hypothetical bias appears to be mitigated by calibrating the responses to treat the "yes, probably sure" response as "no" is confirmed by Blumenschein et al. (2001). They conduct a field experiment comparing hypothetical and real purchase decisions for a pharmacist-provided asthma management program among 172 asthmatics in Kentucky. They test a calibration function that was estimated in an earlier study and find that it reduces the extent of hypothetical bias, but does not perform as well as calibration by stated certainty Presumably if countermeasure to hypothetical bias such as cheap talk and calibration by stated certainty continue to be effective and others are developed, then a future meta-analysis of VSL would show less difference between stated preference and averting behavior estimates.

Meta-Analysis

Meta-analysis can be a useful tool for economists. Its strengths are its quantitative nature and breadth. Meta-analysis contributes another type of information and another way to view studies in addition to critical, analytical literature reviews. On these points I agree with advantages that Stanley (2001) describes in his review of meta-analysis. It seems to me that meta-analysis is best when all studies are the same quality. Its roots are in medical clinical trials with rigorous standards and controls for acceptability and pooling results essentially to increase sample size. Caution is warranted in applying the same technique to studies which estimate VSL when standards of what constitutes acceptable quality vary from discipline to discipline, journal to journal, book publisher to book publisher, agency to agency, and desk drawer to desk

drawer - wherever that desk might be. Whether the study has withstood the rigors of editing and refereeing of one of the premier journals or sits as an obscure, untested working paper, they count the same in some meta-analyses. I considered advising that if a meta analysis of averting behavior in consumption is worth doing, it should be done by statisticians who are well trained in meta-analysis and have not contributed to the literature on estimating VSL. Statisticians can use EconLit, the Internet, other search tools, and contact individuals and organizations which might be aware of unpublished studies. I considered suggesting that after the meta-analysis is complete, that economists who have expertise in the theory and practice of estimating VSL from averting behavior in consumption should be asked to review and analyze the results of the meta-analysis. They should be asked to draw upon their knowledge to judge specific studies with respect to quality and assess the literature given any insights from the meta-analysis. This practice would foster the best of what comprehensive, systematic, theoretically agnostic, and ultra-democratic quantitative meta-analysis has to offer and the best of what intentionally judgmental and professionally subjective qualitative narrative reviews have to offer.

I think such a strict division of labor, however, would reflect an unnecessarily skeptical view of the power of the professional ethic within economics. The meta-analysis by Mrozek and Taylor (2002) is not the first good meta-analysis related to estimating benefits of environmental policy, but it is exemplary in that it recognizes the differences between pooling randomized clinical trial data in medicine and quantitatively

analyzing a variety of studies that estimate VSL in economics.[12] It combines inclusiveness of meta-regression analysis with desirable quality control through use of judgment based on knowledge of the theory, econometrics, data, and the nature of the policy.

The meta-analysis of 25 VSL estimates related to road safety by de Blaeij et al. (2000) produced several results: (1) stated preference studies yield higher estimates of VSL than studies of averting behavior in consumption or work, (2) WTP is greater for private goods such as cars compared to more public goods such as roads, and (3) VSL increases with increases in baseline risk. While caution is warranted because some of the estimates are from studies of public decisions rather than individual self protection or averting behavior, the results suggest what might be learned from a broader meta-analysis that includes studies unrelated to road studies also. Miller's (2000) analysis, which focuses mostly on the effect of income, yields a result similar to the first observation of de Blaeij et al. (2000) that stated preference studies yield higher estimates than studies of self protection in the labor market or consumption activity.

A fresh, comprehensive meta-analysis of studies that estimate VSL based on self-protection and averting behavior in consumption could be useful. It should include early studies such as those by Portney (1981), Ippolito and Ippolito (1984), and Smith and Gilbert (1985). The meta-analysis should include stated preference studies in which self protection and averting behavior in consumption are fundamental to the constructed

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12 See Smith and Huang (1995), for example, for a meta-analysis of estimates of values of changes in air pollution based on hedonic analysis of housing prices.

choice. It should include the aggregate risk-risk, health-health studies because they reflect estimates based on the sum of combined behaviors, see Viscusi (1994). Risk-risk studies are based on analysis of highly aggregated data. The level of aggregation is a disadvantage in that little specific information can be gleaned from the analysis about how tradeoffs between income and mortality risks are made. The level of aggregation is an advantage in another way though in that the aggregate risk-risk tradeoff estimate reflects the net effect of numerous possible behaviors and their interactions. This net effect includes behavior related to environmental risks, traffic safety risks, job risks, and others.

Factors that should be considered in the meta-regression analysis are: base risk level, amount of change in risk, adjustment for any risk perception bias, upper bound or lower bound or average nature of the estimate, how time is valued, how utility or disutility or jointness in consumption is treated, and characteristics of individuals such as age. The meta-regression analysis should consider contextual characteristics such as latency, dread, degree of control, and other factors that might be important distinguishing characteristics of environmental risks. Lastly, the study should combine the meta-regression analysis with judgmental review of the studies. Such a meta-analysis of averting behavior in consumption could then be compared to the reviews of the labor market studies and reviews of stated preference studies.

The Research Portfolio

What may appear to be impossible, valuing life, for practical purposes is

straightforward. People, as individuals and as societies, make choices all the time in which they implicitly make tradeoffs between changes in their mortality risks and valuable time and money. Estimates of these values of changes in mortality risks, or alternatively, values of statistical lives, come from analysis of jobs with different wages and risks, consumption decisions involving changes in risk and time and money, and from direct questioning involving risk-money tradeoffs in constructed or experimental markets. The estimates come from a large number and a wide variety of studies. This broad nature of the evidence is a strength. To ignore the prospect of new information from observable behavior in implicit markets for risk and to rely on only one approach would indicate a lack of appreciation for how we achieved the understanding we have now. To invest in research on only one type, say stated preference, would make the research investment portfolio a risky one. Estimates of the VSL based on willingness to pay are considerably more reliable than, say, 20 years ago. When the whole of the literature on VSL is viewed, the strength is the quantity and variety of estimates, see Blomquist (2001). Future research should include a variety of approaches. Tension exists between scholars probing the edges of our understanding and practitioners who must make decisions and defend them in the face of demand for perfect estimates. A tendency is to favor one method as the best and defend it. Because we do not know exactly what future research will bring, the temptation to pursue a strategy of investing in only the "best" method is risky. Prudent investors who are at all risk averse diversify. Research on estimating values of mortality risks based on self protection and averting behavior in consumption belongs in the research portfolio. My overarching

recommendation is: research on self protection and averting behavior in consumption should be a vital part of current and future research on valuing mortality risks.

A summary of my other recommendations for research at the EPA, Department of Transportation, and anywhere there is interest in estimating values of mortality risks includes six specific suggestions[13]. (1) Risk perception. Consider having a component of each research project to address risk perception with respect to the tradeoff behavior and type of individuals who are going to be studied. The component might involve elicitation of subjective risks if concern warrants. (2) Utility and Disutility. Consider having a component of each research project to address nonpecuniary benefits and costs with respect to the tradeoff behavior and individuals to be studied. (3) Time Costs. Consider having a component of each research project to address the amount and value of time involved in the tradeoff behavior for the type of individuals to be studied. (4) Population and Users. Consider having a component of each research project to address characteristics of individuals whose tradeoff behavior is going to be analyzed relative to individuals who will benefit or bear the costs of the policy. (5) Ethics. Consider the economic theory, ethics, and practicality of using different values of mortality risks for different types of individuals in benefit-cost analysis. (6) Meta-analysis. Conduct a meta-analysis of studies that includes estimate values of mortality risk reduction based on self protection and averting behavior in consumption.

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[13] In this paper I have tried to demonstrate that the view that VSL estimates from studies of averting behavior in consumption are "too low" should be reconsidered. Because they are lower than typical estimates from stated preference studies, I recommend that stated preference studies incorporate direct countermeasures to potential hypothetical bias. This recommendation is not part of the summary because it does not pertain directly to studies of averting behavior.

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Table 1. Viscusi's Summary of Studies Based on Averting Behavior Outside the Labor Market

Author (Year)	Nature of Risk, Year	Component of the Monetary Tradeoff	Average income Level[a]	Implicit Value of Statistical Life ($ millions)[a]
Ghosh, Lees, & Seal (1975)	Highway speed-related accident risk, 1973	Value of driver time based on wages rates	N/A	0.1
Blomquist (1979)	Automobile death	Estimated disutility of seat belts and time costs	$38,404	1.0[b]
Dardis (1980)	Fire fatality risks without smoke Detectors, 1974-1979	Purchase price of smoke detectors	N/A	0.8
Portney (1981)	Mortality effects of air pollution, 1978	Property values in Allegheny Co. PA	N/A value of life for 42-year-old male	1.0
Ippolito & Ippolito (1984)	Cigarette smoking risks, 1980	Estimated monetary equivalent of effect of risk information	N/A	0.9
Garbacz (1989)	Fire fatality risks without smoke detectors, 1968-1985	Purchase price of smoke detector	N/A	2.6
Atkinson & Halvorsen (1990)	Automobile accident risks, 1986	Prices of new automobiles	N/A	5.1

[a] All money values are reported in year 2000 US dollars. Values are multiplied by 1.287 to convert from the December 1990 dollars reported by Viscusi to 2000 dollars using the Consumer Price Index for all urban consumers.

[b] This value is also reported in 2000 dollars. It converts the estimate in 1978 dollars reported in Blomquist (1979) to 2000 dollars. The value reported by Viscusi assumed the estimate was reported in 1972 dollars.

Source: Based on Viscusi (1993), Table 5.

Table 2. Miller's Summary of Best or Mean Values from All Types of International Studies Excluding the U.S.[a]

COUNTRY Author (Year)	Method	Value Chosen (millions of 2000 US $)
AUSTRALIA		
Kneisner & Leeth(1991)	Wage-risk	3.1
AUSTRIA		
Weiss *et al.* (1986)	Wage-risk	5.1
Maier *et al.* (1989)	Stated preference	3.9
CANADA		
Cousineau (1992)	Wage-risk	4.5
Martinello & Meng (1992)	Wage-risk	6.9
Meng (1989)	Wage-risk	4.0
Meng & Smith (1990)	Wage-risk	6.4
Vodden *et al.*(1993)	Wage-risk	3.9
DENMARK		
Kidholm (1995)	Stated preference	4.3
FRANCE		
Desaigues & Rabl (1995)	Stated preference	3.9
JAPAN		
Kneisner & Leeth(1991)	Wage-risk	12.2
NEW ZEALAND		
Miller & Guria (1991)	Stated preference	1.5
Miller & Guria (1991)	Averting behavior	1.6
Guria *et al.* (1999)	Stated preference	2.4
SOUTH KOREA		
Kim (1985)	Wage-risk	1.0
Kim & Fishback (1999)	Wage-risk	0.8
SWEDEN		
Johannesson *et al.* (1997)	Stated preference	4.3
Persson & Cedervall (1991)	Stated preference	2.3
Persson *et al.* (1995)	Stated preference	5.2
Soderqvist (1994)	Stated preference	1.3
SWITZERLAND		
Schwab-Christe (1995)	Stated preference	8.5
TAIWAN		
Hsueh & Wang (1987)	Wage-risk	1.7
Liu & Smith (1996)	Wage-risk	1.0
UNITED KINGDOM		
Ghosh *et al.* (1975)	Averting behavior	1.9
Jones-Lee *et al.* (1983)	Stated preference	4.0
Jones-Lee *et al.* (1995)	Stated preference	3.0
Maclean (1979)	Stated preference	2.8
Marin & Psacharopoulos (1982)	Wage-risk	4.2
Melinek (1974)	Wage-risk	1.6
Melinek (1974)	Averting behavior	1.8

[a] Values reported are either means are best values chosen based on Miller's judgement.
[b] Values are in year 2000 US dollars. The values are converted from Miller's table using the Consumer Price Index for all urban consumers by multiplying by 1.130.

Source: Based on Miller (2000), Table 2.

Table 3. Elvik's Summary of Studies of Averting Behavior by Road Users

Author and Publication Year	Type of Unit[a]	Sample Size	Road User[b]	Test of Rationality[c]	Base Risk[d]	Risk Change[d]	VSL[e] (millions, US $)
Melinek (1974)	Aggr	1	Ped	No	0.035	0.0351.1	
Ghosh, Lees and Seal (1975)	Aggr	1	Car	No			
Jones-Lee (1977)	Aggr	1	Car	No	-	-1.1	
Blomquist (1979)	Indiv	5517	Car	Yes	-	-5.2	
Jondrow, Bowes & Levy (1983)	Aggr	1	Car	No	30.3	15.11.0[f]	
Winston and Mannering (1984)	Indiv	220	Car	No	-	-2.9	
Atkinson and Halvorsen (1990)	Aggr	112	Car	No	12	122.2	
Blomquist and Miller (1992)	Indiv	5378	Car	Yes	19	195.2	
	Indiv	934	Car-child[g]	Yes	7.4	3.32.8	
	Indiv	178	Motorcyclist[h]	Yes	3.6	2.66.5	
Dreyfus & Viscusi (1995)	Indiv	1775	Car	No	77	221.7	
					19.6	-5.5	

[a] The data unit is either aggregated or individual. An example of an aggregated data unit is average speed on highways.
[b] The type of roadway user can be pedestrian, car driver, or motorcycle rider. The Blomquist and Miller estimate of $6.5 million is inferred from drivers' use of child safety seats and belts for passengers who are less than 5 years of age.
[c] Tests examine understanding of probability concepts or conformity to normative axioms of rational choice.
[d] Deaths per 100,000 motor vehicles
[e] All money values are reported in year 2000 US dollars. Values are multiplied by 1.227 to convert from the 1992 dollars reported by Elvik to 2000 dollars using the Consumer Price Index for all urban consumers.
[f] This value is reported in 2000 dollars. It converts the estimate in 1978 dollars reported in Blomquist (1979) to 2000 dollars. The value of 1.2 reported by Elvik appears to be based on the assumption that the Blomquist estimate was reported in 1972 dollars.
[g] This value is inferred for children under 5 years based on driver use/nonuse of child safety seats and belts.
[h] This value is inferred for motorcyclists based on their use/nonuse of helmets.

Source: Based on Elvik (1995), Appendix, Part D.

Table 4. The de Blaeij et al. International Overview of Various Types of Studies of Road Safety.[a]

Authors	Country	Publication Year	Type of Data	No. of Study[c]	Range of VSL in 2000 US dollars[d] estimates	Single estimate	Lowest estimate		Highest estimate
Atkinson & Halvorsen	U.S.	1990	1986	RP	1	4.9			
Beattie, *et al.*	U.K.	1998	1996	SP	4				16.3
Blomquist	U.S.	1979	1978	RP	1	1.0[e]	1.4		
Blomquist & Miller	U.S.	1992	1987	RP	3				6.0
Carthy *et al.*	U.K.	1999	1997	SP	4		1.5		5.6
Corso, Hammitt & Graham	U.S.	2000	1999	SP	8		4.3		6.0
Desaigues and Rabl	France	1995	1994	SP	6		2.5		22.0
Dreyfus & Viscusi	U.S.	1995	1987	RP	1	4.4	0.9		
Ghosh, Lees & Seal	U.K.	1975	1974	RP	1	1.8			
Jara-Díaz, Gálvez & Vergara	Chili	2000	1999	SP	1	4.7			
Johannesson, Johansson, & O'Conor	Sweden	1996	1995	SP	4				6.8
Jondrow, Bowes & Levey	U.S.	1983	1983[b]	RP	1	2.0	5.6		
Jones-Lee, Hammerton & Abbott	U.K.	1983	1982	SP	11				10.9
Kidholm	Denmark	1995	1993	SP	3		0.6		1.2
Lanoie, Pedro & Latour	Canada	1995	1986	SP	2		0.8	3.3	
Maier, Gerking & Weiss	Austria	1989	1989[b]	SP	6		1.9		4.6
McDaniels	U.S.	1992	1986	SP	3		17		32.1
Melinek	U.K.	1974	1974[b]	RP	1	0.8	8.9		
Miller & Guria	New Zealand	1991	1990	SP	5				1.9
Persson & Cedervall	Sweden	1991	1987	SP	10		1.2	27.8	
Persson *et al.*	Sweden	1995	1993	SP	2		1.3		5.2
Persson *et al.*	Sweden	2001	1998	SP	1	2.5	4.5		
Schwab Christe	Switzerland	1995	1993	SP	1	1.0			
Schwab Christe & Soguel	Switzerland	1995	1994	SP	2				1.1
Viscusi, Magat & Huber	U.S.	1991	1991[b]	SP	1	9.8	0.9		
Winston & Mannering[5]	U.S.	1984	1988	RP	1	2.0			

[a]Many of the studies are also used in Elvik's (1995) literature review. Four studies containing 10 estimates of the VSL have been omitted from the table in the de Blaeij *et al.* study because they are estimates based on public decisions rather than individual behavior.

[b]Refers to the year of the study instead of the year of the data, due to missing information.

[c]SP refers to a stated preference study, and RP to a revealed preference study based on individual behavior.

[d] All money values are reported in year 2000 US dollars. de Blaeij *et al.* use GDP deflators to calculate the VSL in 1997 prices, and PPPs for 1997 to translate local currencies into 1997 U.S. dollars. Values are multiplied by 1.073 to convert from the 1997 dollars to 2000 dollars using the Consumer Price Index for all urban consumers.

[e] Blaeij et al. report the value from my study to be 1.6, but the value should be 1.0 for the reason given in Table 3, note f.

Source: Based on de Blaeij *et al.* (2002), Table 1.

Table 5. U.S. Studies of Self-Protection and Averting Behavior in Consumption that the Estimate Values of Statistical Life, 1990-2002, Listed in Chronological Order of Study

Author (Year)	Behavior and Tradeoff, Year	Best Estimate of VSL (range), 2000 US dollars, millions
Atkinson and Halvorsen (1990)	Hedonic analysis of car prices with fatality risk, 1978	$5.3 (4.6 - 5.4) typical car occupant
Carlin and Sandy (1991)	Child safety seat use with fatality risk reductions with time and money costs, 1985	$0.8 child under 5
Dreyfus and Viscusi (1995)	Hedonic analysis of car prices with fatality risk, 1988	$3.8 - 5.4 typical car occupant
Blomquist, Miller and Levy (1996)	Car seat belt use with fatality risk reductions and time and disutility costs, 1983	$2.8 - 4.6 adult* $3.7 - 6.0 child under 5* $1.7 - 2.8 motorcyclist* typical driver or rider
Gayer, Hamilton, and Viscusi (2000)	Hedonic analysis of housing prices with fatality risk near Superfund sites, 1988-93**	$4.7 (4.3 - 5.0) typical resident
Jenkins, Owens, and Wiggins (2001)	Bicycle helmet use with fatality risk reductions and costs, 1997	$4.3 adult $2.9 child 5-9 $2.8 child 10-14 users of helmets
Mount, Weng, Schulze, and Chestnut (2001, workshop paper)	Hedonic analysis of motor vehicle prices with fatality risks, 1995	$ 7.2 adult* $ 7.3 child* $ 5.2 elderly* typical vehicle occupant
Ashenfelter and Greenstone (2002)	Speeds and fatalities on interstate highways with higher speed limits, 1982-1993	$1.7 as upper bound typical vehicle occupant

*Higher value reflects adjusted for risk perception bias by multiplying by 1.634.
**Values after release of the Remedial Investigation of the Superfund sites. Values are for a statistical cancer case.
No adjustment is made for differences in base level risk.
Source: Author