Willingness to Pay for Environmental Health Risk Reductions when there are Varying Degrees of Life Expectancy: A White Paper

prepared by

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I. Introduction

The U.S. Environmental Protection Agency (EPA) is in the process of revising its *Guidelines for Preparing Economic Analyses* and as such is revisiting the guidance offered on valuing mortality risk reductions for environmental policy.[1] There are many aspects to these revisions that will be addressed with external advisors including the Science Advisory Board – Environmental Economics Advisory Committee (SAB-EEAC). The issue addressed in this white paper is the role of life expectancy when valuing mortality risk reductions accruing to adults.[2] Current guidance directs analysts to apply a value of statistical life (VSL) estimate when calculating the benefits associated with a reduction in mortality risk for use in a benefit-cost analysis (BCA).[3] However, by reducing the risk of a fatality, most policies actually extend lives rather than save them, *per se*. That is, the reduction in a particular pollutant that results in cleaner air or water, for example, extends individuals lives beyond some premature death that would have otherwise occurred. In some cases, the change in life expectancy will be relatively large – say, 20 or 30 years – whereas in others the change will be relatively small – perhaps as small as 1 year or even less. This raises the issue of whether EPA's constant VSL approach is the most appropriate methodology to use and whether other scientifically sound approaches exist to value mortality risk reductions from environmental policy.

Resolving the issue of how to treat changes in life expectancy of varying lengths in benefit cost analyses is important to EPA as it pursues its regulatory agenda. First, there is some evidence to suggest that reductions in ozone exposure have very small impacts on life expectancy. The proposed rule for the Ozone National Ambient Air Quality Standards (NAAQS) is expected in early 2007 and consequently the valuation issue has immediate relevance. Second, the life expectancy issue is likely to arise in subsequent air rules reducing exposure to ozone and particulate matter as well as in other rulemakings. Finally, this consultation will have more general implications as noted above as EPA seeks to further refine its guidance on mortality risk valuation.

This white paper has been prepared for the SAB-EEAC in advance of their consultation on September 14-15, 2006. The purpose of the paper is to provide background information and context for the issue of valuing life extensions of varying lengths, and to review the economics literature related to the topic. [4]

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[1] See US EPA 2000a for the current version of the *Guidelines*.

[2] Differences in life expectancy changes are also important to consider when valuing mortality risks accruing to children. The focus in this paper is valuing mortality risks to adults, although consideration will be given to all age groups when generalizing the results of this consultation.

[3] A complete review of EPA's current guidance and practice on valuing mortality risks can be found in US EPA 2004.

[4] To gather the relevant literature, we conducted several searches of the economics literature dating back approximately 20 years using EconLit, the Social Sciences Citation Index, and other on-line search engines (e.g., Google). We also used results from a contract with Alpha-Gamma Technologies (contract 68-W-01-055) in 2005 in which the contractor was asked to collect all published and unpublished works related to mortality risk valuation.

The review of the economics literature in this paper springs from viewing differences in remaining life expectancy as differences in individual mortality risk, which in turn is a function of age and health.[5] Because the literature has often considered these aspects separately, we review and summarize economic findings on the role of baseline risk, age, and health status as they relate to the question of appropriate economic values for benefit-cost analysis. It is important to note that in this paper we do not debate the relative merits of various methodologies used to estimate values for mortality risk reductions (e.g., hedonic wage methods, stated preference surveys). Such debates are worthy, but beyond the scope of this paper.

The remainder of this paper is organized as follows: the next section provides some contextual background by discussing several regulatory scenarios in which the use of a constant VSL approach may be questionable due to the relatively short life expectancy changes that result. We next provide a short discussion on other perspectives to consider when determining how best to make decisions regarding mortality risk valuation. We then turn to a discussion of the mortality risk valuation literature with respect to the effects of baseline risks, age, and health status on willingness to pay estimates and end with a short summary.

II. Background and context

EPA is often required to prepare benefit-cost analyses for its rules and regulations by statute or by Executive Order. These analyses frequently require the monetization of health and mortality risks. The Agency currently uses a value of statistical life (VSL) to monetize fatal risks associated with regulatory actions, and applies the same value for all expected deaths averted in its primary analyses regardless of the expected changes in life extension. However, in many cases the Agency recognizes that one subpopulation or another may disproportionately benefit from the reduced exposure afforded by a rule and in this case it is not clear how well the constant VSL approach captures the preferences of the affected subpopulation. In some cases, the changes in life expectancy associated with a rule will not match well with those associated with the studies from which the VSL was derived. Given the degree to which life expectancy changes may vary from one group to another and assuming that the remaining quantity of life is a determinant of WTP for reduced mortality risk, a constant monetary value is perhaps not the most robust approach.[6]

Below are several scenarios meant to exemplify the types of situations faced by the Agency.

[5] We recognize that baseline risk differs according to race, gender, income, education, as well as other variables.

[6] Agency cost-effectiveness analyses, which now accompany benefit-cost analyses, have addressed remaining life expectancy by using life years and a modified quality-adjusted life year (QALY).

Ozone mortality

Monetizing health risk reductions when there are short changes in life expectancy has become a more pertinent issue as the Agency prepares to issue revised Ozone NAAQS. Although the benefits analysis has not yet begun for this rule, the Clean Air Science Advisory Committee (CASAC) continues its review of the relevant risk assessment literature. The use of the risk assessment literature in a benefits analysis, as well as the monetization of associated mortality risk reductions, will be the subject of a review to be conducted by a committee of the National Academies of Science.

While not yet complete, the CASAC review has revealed weak support in the literature for a mortality effect associated with long-term ozone exposure. This same review has indicated that there is stronger evidence to support a relationship between short-term (i.e., days to weeks) exposures to ozone and daily mortality rates. To some, this implies that the beneficiaries of reduced ozone levels are those with high background risks who would likely perish from some other cause in a short time frame – meaning that the change in life expectancy would be relatively short. However, this may not always be the case. If some individuals are in a temporary, reversible high risk category (e.g., suffering from pneumonia) they may recover and have a normal life expectancy if they survive ozone exposure during their illness. The specific causes of death and levels of life expectancy loss associated with short-term ozone exposures have not been demonstrated empirically. Still, there is some likelihood that at least a portion of the mortality impacts associated with short-term ozone exposures result in relatively short losses in life expectancy.

PM mortality

Many rules promulgated by the Office of Air and Radiation have as their goal the reduction of mortality risks associated with exposure to ambient levels of fine particulates. Long-term exposure to particulate matter (PM) pollution is thought to have a significant effect on adult mortality risk (Krewski et al. 2000). It has long been recognized that a large proportion of the deaths averted with a reduction in PM pollution – approximately 80% – accrue to individuals over 65 years of age (US EPA 1997; 1999). Generally, little information is available on the health status of the affected population so it is difficult to say what the expected change in life expectancy would be for these individuals.

A recent analysis by Hubbell (2006) demonstrates these points by providing estimates of life expectancy changes at different ages associated with the implementation of the Heavy Duty Engine/Diesel Fuel Regulations.[7] While the primary goal of the paper is to demonstrate a cost-effectiveness analysis approach, the author estimates life expectancy changes for the different age groups affected by the rules as part of his calculations. Since no information is available on the underlying health status of the affected

[7] The Heavy Duty Engine/Diesel Fuel regulations were proposed by EPA in 2000 (US EPA 2000b).

population, Hubbell adopts life expectancy estimates for the different age groups published by the Centers for Disease Control. This analysis reveals that life expectancy changes range from 5 years to 47.5 years with an average change in life expectancy equal to about 15 years. The discounted life expectancy changes range from 4.7 years to almost 26 years.

Hence, any future PM rules may benefit from a better understanding of methods for valuing changes in life expectancy of varying lengths.

Drinking Water

A recently promulgated drinking water regulation highlights a situation where mortality benefits are concentrated among subpopulations with relatively high baseline risks, and hence shorter than average life expectancies. EPA's economic analysis of the Long Term Enhanced Surface Water Treatment rule assessed the benefits of reducing exposure to *Cryptosporidium* in drinking water supplies. While cryptosporidiosis is generally non-fatal, the analysis notes that, "in some occurrences, cryptosporidiosis can be fatal, particularly among subpopulations such as Acquired Immunodeficiency Syndrome (AIDS) patients, the elderly with other underlying illnesses, and other immuno-compromised individuals" (US EPA 2005, pp. 5-5). Sources estimate that the *Cryptosporidium* infections are associated with a fifty percent mortality rate in the immuno-compromised.

Given the available data, the economic analysis assumed that all of the quantified deaths avoided from the rule are lives saved in sensitive subpopulations. The mortality benefits from the rule are responsive to the underlying (or baseline) mortality rate for AIDS, as was noted in an appendix to the analysis. While this baseline has dropped dramatically since the time of the Milwaukee outbreak, it still remains higher than the general population. Life expectancy or expected life years lost was not included in the analysis. The cost-effectiveness analysis applied a quality adjusted life years (QALY)-type measure, but it was modified so that life years lost were based on healthy cohorts regardless of the health status of the affected population. This is consistent with Office of Management and Budget (OMB) Circular A-4:

> When CEA [cost-effectiveness analysis] is performed in specific rulemaking contexts, you should be prepared to make appropriate adjustments to ensure fair treatment of all segments of the population. Fairness is important in the choice and execution of effectiveness measures. For example, if QALYs are used to evaluate a lifesaving rule aimed at a population that happens to experience a high rate of disability (i.e., where the rule is not designed to affect the disability), the number of life years saved should not necessarily be diminished simply because the rule saves the lives of people with life-shortening disabilities. Both analytic simplicity and fairness suggest that the estimated number of life years saved for the disabled population should be based on average life expectancy information for the relevant age cohorts (OMB 2003, pp. 13).

EPA applied its default VSL approach to estimate the monetized mortality benefits.

It is worth noting that drinking water rules that reduce viral and bacterial infections (e.g., EPA's proposed Ground Water Rule[8]) tend to reduce risks to infants and young children. In these situations, the change in life expectancy could be relative large in comparison with life expectancy changes experienced by the adult populations represented in typical valuation studies. Children's health valuation is beyond the scope of this paper, however.

IV. Other Perspectives

While this white paper focuses on valuation for benefit-cost analysis, there are many possible principles to guide decisions on reducing risk or allocating health care. The literature on this topic is enormous, spanning economics, ethics, medicine, public health and other fields, but a recent article on rationing flu vaccines highlights various ethical principles (Emanual and Wertheimer, 2006). These principles include "saving the most lives," "saving the most life years," "saving the most quality life years," and prioritizing by economic productivity or some other measure of contributions to society. Principles might also focus on equity, such as saving the most vulnerable or seeking to ensure that everyone has sufficient opportunity to reach certain life stages or a certain age (e.g., "fair innings"). The choice of guiding principle(s) may depend upon the context of the decision, including the ability to distinguish among affected individuals, and the opportunity to deliberate before taking action.

When deciding on a methodology or metric, one approach is to consider various allocations or decision rules behind a "veil of ignorance" where one does not know what their position in society will be with respect to wealth, age, health status, race or other characteristics. Sunstein (2004) adopts this framework to argue that government policies should focus on statistical life-years rather than statistical lives in assessing policies that reduce mortality risk. It is argued that choosers from behind the veil of ignorance would generally prefer policies that reduce mortality risks to the young over the old, making life years highly relevant to making choices across public risk reduction programs. Sunstein is intentionally vague on what "focus" means and suggests that programs saving more life years would not always be preferred over those saving fewer. Pratt and Zeckhauser (1996) (more below) posit that high baseline mortality risk will lead to higher willingness to pay for risk reductions through an expected marginal utility of wealth effect. The authors use an original position argument (i.e., behind a veil of ignorance) to suggest that this be accounted for in benefit-cost analysis. Some empirical analyses have tried to put respondents in an original position when eliciting preferences over health states (e.g., Pinto-Prades and Abellan-Perpinan, 2005).

Benefit-cost analysis relies upon aggregating private trade-offs to assess public programs. An alternative is to directly elicit public preferences for investments in risk reductions or allocating resources devoted to health. There is no reason that our "public preferences" must be constrained by or systematically linked to our "private preferences," and some authors have found substantial differences between the two (e.g., Strand 2004). Some suggest that it is inevitable that preferences change as the decision context moves from a private setting to a collective one (Nord 2005). A recent review finds that studies show a

[8] See http://www.epa.gov/safewater/disinfection/gwr/regulations.html .

public preference for saving younger lives, giving life years more weight at younger ages, and favoring those with dependents (Dolan, et al. 2005). Some of these preferences may be reflected in health metrics commonly used in cost-effectiveness analysis. Life years, and combined mortality-morbidity metrics such as quality-adjusted life years (QALYs) and disability-adjusted life years (DALYs), all give more weight to the young compared to the old. The degree to which QALY maximization reflects public preferences more generally is questionable (Dolan, et al. 2005). Because QALYs, DALYs, and willingness to pay are all based on utility maximization, distributional consequences and ethical considerations may need to be considered in supplemental analyses.[9]

III. High baseline risk

This section focuses specifically on the role of high baseline mortality risks in mortality risk valuation, mostly in the context of a static expected utility model and largely without explicitly considering age or health conditions. Building on the earlier work of Jones-Lee (1974) and Weinstein et al. (1980), Pratt and Zeckhauser (PZ) (1996) use a standard one-period expected utility model to examine the effects of risk and wealth on willingness to pay (WTP) for reduced mortality risks, as follows:

$$U(p,w) = (1-p)U_a(w) + pU_d(w) \qquad (1)$$

where p is the probability of dying and w is wealth. U_a and U_d are utility in the alive and dead states, respectively, each a function of wealth. The marginal rate of substitution between wealth and risk, or marginal willingness to pay for risk reduction is:

$$dw/dp = (U_a(w) - U_d(w)) / ((1-p)U'_a(w) + pU'_d(w)) \qquad (2)$$

where $U'_a(w)$ and $U'_d(w)$ are the marginal utilities of wealth in the alive and dead states.

The numerator is the difference in utility between alive and dead states and the denominator is the expected marginal utility of wealth. The general assumption is that absolute utility is higher when alive than when dead, $U_a(w) > U_d(w)$ and that $U'_a(w) > U'_b(w)$, so life is preferred to death at any level of wealth and the marginal utility of wealth in life is higher than in death.

The expected marginal utility of wealth, the denominator, diminishes with risk while the numerator is constant. WTP for mortality risk reductions is therefore increasing in risk. PZ term this the “dead-anyway” effect reflecting that a high risk individual is more likely to bear costs in the state in which they are “dead anyway.” The general implication of the dead anyway effect is that estimated WTP for fatal risk reduction is larger for those with high baseline probabilities of death. As other authors have noted, however, the effect is

[9] The need for distributional analyses to accompany BCA and cost-effectiveness analysis is widely noted, including in EPA’s *Guidelines for Preparing Economic Analyses* (UE EPA 2000a). Hofstetter and Hammitt (2002) offer some specific questions to consider.

not likely to be large for most individuals (Hammitt, 2000). PZ also note that there is no dead-anyway effect in the presence of perfect contingent claims markets.

Breyer and Felder (2005) also examine the relationship between baseline risk and WTP. Noting that the PZ finding is premised on incomplete contingent claims markets, they model individual preferences for risk reduction under more general conditions. Generally, Breyer and Felder find that the relationship between WTP and baseline risks exhibits:

- the dead-anyway effect,
- a "constrained bequest" effect suggesting that the marginal utility of wealth may be higher upon death than upon survival due to bequest motives and the presence of human capital, and
- an income effect that changes marginal utilities of wealth in both the survival state and the death state depending on the individual's participation in contingent claims markets.

One robust finding is that individuals without a bequest motive exhibit increasing WTP for survival as baseline risk increases. On the whole, Breyer and Felder show that the relationship between WTP and baseline risk is generally ambiguous, depending greatly on bequest motives and the presence of insurance markets.

Eeckhoudt and Hammitt (EH) (2001) use a model of competing risks to examine the effect of background risks on WTP. Letting p be a "specific mortality risk" (e.g., a workplace accident) and Π be the "competing" or background risk from all other causes, the chances of surviving both risks can be expressed as $(1-p)(1-\Pi)$. Dying from either cause is then $1-(1-p)(1-\Pi)$ giving rise to the expected utility function:

$$E(U) = [1-(1-p)(1-\Pi)]U_d(w) + (1-p)(1-\Pi)U_a(w). \tag{3}$$

Under this specification, willingness to pay to reduce the specific risk p increases with p. However, assuming that there is some bequest motive ($U'_d>0$), then an increase in the background risk Π reduces willingness to pay for the specific risk. The intuition is that an increase in background risk reduces the probability that the individual will survive to enjoy the reduction in specific risk. This can be interpreted as a "why bother" effect that is opposite to the PZ dead-anyway effect. EH argue that the empirical work typically ignores the role of competing risks, but that any bias is likely to be small if background risks are low as is the case for most hedonic wage studies. In other cases, however, where the baseline (or competing) risk is large, this why-bother effect may be substantial.

As noted in Evans and Smith (2006), the key difference between the PZ formulation and that of EH is in how multiple risks are modeled. If individuals face a background risk of p and a specific risk Π should survival be characterized as $(1-p-\Pi)$ or $(1-p)(1-\Pi)$? The former essentially assumes that there are three immediate outcomes for one lottery: survival, death from the background risk, and death from the competing risk. In this case mortality risks from any number of causes are substitutes. Evans and Smith term this a "translating interpretation" of health risks.

The alternative modeling approach, used by EH, assumes a compound lottery.[10] Although the model is static, risks can be viewed as being resolved "sequentially" in the sense that one must survive one to face the other. In this case multiple health risks are complementary. Evans and Smith label this a "scaling interpretation" of multiple risks because risks are scaled by the probability of surviving other mortality risks.

Evans and Smith present a general model that can accommodate both interpretations with background risk as a function of age. In doing so, they demonstrate that increasing background risks does not necessarily lead to a clear "why bother" effect, and that in this case the relationship between background risk and willingness to pay is ambiguous. Ultimately, the choice between models becomes a question of which better represents how people form their subjective risk perceptions in the face of multiple risks. Evans and Smith present a general model that accommodates both frameworks, and then test the scaling and translating hypotheses using data from the Health and Retirement Survey. Results suggest that the appropriate risk interpretation may vary by demographic group. When the analysis allows individuals to differ in how they used information, there does not appear to be a single framework that adequately describes the assessment process for all respondents. Based on their findings, the authors urge caution in drawing broad conclusions about background risks (in the context of age) and VSL.

Liu and Nielson (2006) extend the discussion in a different direction. By including both public and private risk reduction opportunities they allow mortality risk to be endogenously determined. Private investments in risk reduction create what PZ called a "high payment" effect: higher baseline risk prompts private safety investments thereby lowering overall wealth and increasing the marginal utility of wealth. Willingness to pay for additional risk reduction is therefore reduced, in opposition to the dead anyway effect. Accounting for these competing effects, Liu and Nelson show that willingness to pay may either rise or fall with baseline risk, depending on the available risk reduction technologies.

In a rare direct test of the dead-anyway effect, Smith and Evans (2003) estimate VSL using a hedonic wage function that incorporates individual expectations about general mortality risks. The empirical approach uses respondent's death after their reported labor market behavior as an instrument for the individual's unobserved knowledge about immediate health threats. While the results generally support the presence of a dead-anyway effect, the authors do not believe the analysis provides a robust estimate of its size.

In some empirical work it is difficult to distinguish between the effect of baseline mortality risk and the presence of chronic health conditions. Alberini et al. (2004) elicits WTP to reduce mortality risks and finds that persons with certain chronic health conditions are willing to pay at least as much or more than those without the conditions. The authors suggest this may be because having certain chronic conditions reduces survival probability (i.e., increases baseline mortality risk), which will tend to raise WTP.

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[10] Evans and Smith credit this structure to Sussman (1984) and it is developed more fully in the life-cycle consumption literature.

The study is unable to test specifically for the role of baseline mortality risk, however. An earlier study (Krupnick et al. 2002) find that WTP was generally insensitive to health status (and, presumably, to the effect of those chronic conditions on baseline mortality risk). These studies are further discussed below.

On the whole, high baseline risk seems to have a theoretically ambiguous effect on willingness to pay for risk reduction. The outcome may depend on the extent of contingent claims markets, bequest motives, how multiple risks are subjectively evaluated, and opportunities for private risk reductions. Empirical work is only suggestive of the presence of a dead-anyway effect and there are no robust estimates of its magnitude. Assessing the relationship between high baseline risks and willingness to pay for risk reduction is further complicated by highly correlated factors such as age and health status, which are discussed next.

Even if WTP estimates for those with high baseline mortality risks were robust and plentiful, larger questions remain about their appropriateness for economic analysis. As noted earlier, Pratt and Zeckhauser (1996) argue that dead-anyway effect should be mitigated to maximize social welfare. Other authors point out that this is an important, but limited conclusion because many other considerations, such as risk equity, could also be part of a social compact behind the veil of ignorance (Ramsberg 2002). Hammitt and Treich (2006) further highlight some fundamental implications of heterogeneous baseline risks and risk reductions in benefit-cost analysis.

IV. Age

As mentioned above, age is a determinant of baseline risk and clearly has implications for life expectancy – age and life expectancy are generally negatively correlated. As such, review of the literature may shed light on the life expectancy issue.

It has sometimes been conjectured that older individuals should be willing to pay less for a reduction in mortality risk given the fewer number of life years they have remaining compared to younger people (Moore and Viscusi, 1988). Although this reasoning may have some intuitive appeal, the relationship between age and the value of statistical life has not definitively been resolved in the literature to date. This issue has been considered by the Agency on a number of occasions (USEPA, 2000c; USEPA 2003), and while the selected papers discussed below provide some insights, it appears as though the evidence in the literature remains mixed.

A number of authors have used life cycle consumption models as the theoretical basis for describing the effect of age on VSL estimates with many noting that the relationship can become quite complex as various assumptions about the optimal consumption path over time, individual time preferences and risk aversion are relaxed. Early work by Shepard and Zeckhauser (1984) explores the relationship between VSL and age in two “polar” cases: one in which an individual is self sufficient and is unable to borrow against future income and the other being the case of perfect annuity markets. Assuming constant optimal consumption over time, they find an inverted, u-shaped relationship between

VSL and age in both cases, although in the latter case they find that VSL peaks at age 25 whereas in the former case VSL peaks around age 40. Because individuals are able to borrow against future income in the case of perfect annuities, the age-VSL relationship is somewhat dampened in the perfect markets scenario in comparison to the other. Cropper and Sussman (1988; 1990) and Rosen (1988) also find that VSL declines for older ages.

Johannson (2002) shows in his theoretical work that, regardless of whether or not a market for actuarially fair insurance exists, the relationship between VSL and age is ambiguous. The relationship could be strictly positive, negative, zero or something more complex depending on the consumption pattern and the utility derived from consumption at various ages.

Empirical work specifically exploring the relationship between age and VSL has provided mixed results. In a stated preference survey of 930 residents from Hamilton, Ontario aged 40 to 75 years, Krupnick et al. (2002) find that WTP for mortality risk reductions does not change significantly with age until age 70, after which it drops by 30 percent. Applying the same survey to a national sample of U.S. residents, Alberini et al. (2004) again find no difference in the WTP for younger age groups and a 20 percent reduction for those aged 70 and over; however, this difference was not statistically significant. Pooling the results of the two surveys resulted in a statistically significant 25 percent reduction in WTP for the 70 and older age group.

A number of recent papers have also explored the effect of age on VSL estimates using a hedonic wage framework. Viscusi and Aldy (2003) in a review of more than 60 studies of mortality risk estimates from 10 countries discuss several studies that explicitly examine this relationship using labor market data and a hedonic framework. In these original studies, the authors include an interaction term of mortality risk and age in their regression. Again the results are mixed, with 3 of the 8 studies reporting insignificant results and the other five showing a statistically significant, negative relationship between age and the return to risk.[11] As noted by Aldy and Viscusi (2006) and Viscusi and Aldy (2006), however, the results from these studies imply negative VSL estimates for individuals ranging in age from 42 to 60 years – an implausible result.

Smith et al. (2004) explore the age-VSL relationship using a hedonic wage model accounting for heterogeneity of risk preferences applied to data from the Health and Retirement Study. Although they are unable to calculate meaningful VSL estimates for younger age groups in their sample, they find that VSL estimates increase with age for older individuals in age groups spanning 50 to 65 years old with estimates ranging from $7.4 million to $14.2 million.[12] They do not, however, report whether these estimates are statistically significantly different from one another.

[11] See Table 10 in Viscusi and Aldy (2003).
[12] Smith et al. (2004) find negative and significant VSLs for the youngest age group aged 26-44 and insignificant estimates for those aged 45-50. The authors attribute this result to the fact that the sample may not adequately capture the wage-risk tradeoffs for these age group as a number of spousal responses comprise the observations for these age categories.

Viscusi and Aldy (2006), using hedonic models in which older and younger workers face different market offer curves, account for potential differences in safety-related productivity among workers of different ages and in so doing explore the relationship between age and measures of both injury and fatality risk. Using fatality measures from the Bureau of Labor Statistics Census of Fatal Occupational Injuries, they are able to construct a fatality risk variable for different age groups for 2-digit SIC industries. Matching these data with detailed data from the Current Population Survey Merged Outgoing Rotation Group data files, they find an inverted, u-shaped relationship between VSL and age for workers aged 18 to 62 years, with the peak of $9.0 million occurring for individuals aged 35 to 44 years.

Aldy and Viscusi (2006) extend the standard life cycle consumption model to account for effects of specific job-related risk on a worker's chance of survival and wages by incorporating job risk as a choice variable. They hypothesize that since older workers have lower lifetime incomes, they will have a lower WTP for a given risk reduction. Although the model reveals that the pure age effect on VSL is ambiguous as in other life cycle consumption models, they are able to sign the relationship through their empirical results. Using the same data sources reported above, they find an inverted, u-shaped pattern for VSL estimates with the peak occurring for individuals aged 35 to 44 years. They also find an increasing trend with year of birth indicating that over time the VSL has increased.

Kniesner, Viscusi and Ziliak (2006) explore the effect of lifetime patterns of consumption on VSL by augmenting the standard hedonic wage equation with household consumption expenditures. Their augmented wage equation does not have the same interpretation as a standard wage equation. Rather, it yields the effect of mortality risk changes on wages conditional on the quantity of consumption. The 1997 wave of the Panel Study of Income Dynamics is the source for their individual level data on wages, industry, occupation, and demographic characteristics as well as consumption whereas the Census of Fatal Occupational Injuries is the source of on the job mortality risk. Their regressions yield an inverted u-shaped relationship between VSL and age as well, with a peak in value occurring for the 47-51 year old age group. Interestingly, however, they find that the relationship flattens out at older ages and that the decline is not nearly as steep as the increase at younger ages. That is, they find that individuals in the oldest age category (individuals aged 57-65 years) have higher VSLs than those in the four categories below age 37. To better understand the role of individual consumption on the shape of the lifetime VSL distribution, they then perform a series of simulations and non-parametric regressions. They find that the flattening out of the VSL distribution mirrors that of lifetime consumption.

Several papers specifically examine the notion of valuing life years. Moore and Viscusi (1988) extend the hedonic framework to account for the number of life-years at risk in the event of an on the job fatality. Specifically, they weight the fatal risk measure by the worker's remaining life expectancy. Their model also incorporates insurance benefits accruing to surviving dependents. Their results yield an average implicit value of an additional year of life ranging from $170,000 to $200,000 (1986$).[13] They also note, however, that these values depend on the remaining life expectancy for the individual and report that workers expecting to survive an additional 35 years have a marginal present value of a one-year life extension equal to $11,000 whereas that value is approximately $400,000 for an older worker expecting to survive an additional 5 years. These values are also dependent on the worker's rate of time preference.

Aldy and Viscusi (2006) calculate age-specific VSLYs. They note that their finding of a u-shaped relationship between VSL and age conflicts with the standard assumption of the typical constant value of statistical life-year (VSLY) approach that the VSL is decreasing with age at all ages. Taking their age-specific VSLs, they annuitize the values using age-specific life expectancy and a discount rate of 3 percent to perform their calculations. Although they also find an inverted u-shaped pattern for the age-specific VSLYs, they also report that the VSLY for workers aged 62 years is higher than those for workers aged 39 years or less.

While these studies offer some (albeit mixed) evidence of the potential relationship between age and WTP for fatal risk reductions, the hedonic studies in particular are of limited application to the issue of valuing life expectancy changes of different lengths since they exclude by design individuals aged 65 and over. Furthermore, since hedonic studies focus on working populations, one can surmise that individual included in these studies are relatively healthy – healthy enough to be working. Stated preference studies have the potential to address more senior populations, but in practice they have not elicited preferences of people over age 80.

V. Health Status

Finally, we examine the impact of pre-existing health outcomes on WTP for mortality risk reductions, recognizing that these impacts may not be independent of age and baseline risk.

Following Bleichrodt, et al. (2003) , we refer to the condition of interest (i.e., the condition affected by the particular pollutant under consideration) as the *index condition*. We use the term *comorbidity* to refer to the *other* health condition (or conditions) that may exist. For example, the index condition may be respiratory illness and the co-morbidity may be high blood pressure. The comorbidity need not be related to the index condition. Our interest is in index conditions that result in mortality.

Bleichrodt et al. (2003) use a single-period expected utility model in which an individual experiences a comorbidity with either certainty, randomly, or related to the index condition. Assuming that people are risk averse,WTP for an index condition is higher in the presence of comorbidities. They intuit that we should devote resources to treating a healthy person as opposed to a sick person because the healthy person's treatment will not be impeded by the pre-existing condition. However, they show that this does not

[13] The implicit value of a life year is calculated as the implicit value of life divided by remaining life expectancy.

hold theoretically. And, in fact, the WTP to treat an index condition is higher in the presence of a comorbidity.

Hammitt (2000) shows that the relationship between VSL in a sick versus healthy state is uncertain, depending on the marginal utility of wealth in the healthy or ill state compared to the total utility in the two states. Strand (2006) also shows that the results are ambiguous. According to Strand VSL is greater when sick than when healthy if the utility of consumption is lower in the healthy state (if, for example, the individual has greater opportunities for work).

DeShazo and Cameron (2005) extend the Bleichrodt, et al. framework to the case where there is a recurrence of the same illness. They show that WTP for the index condition will be lower in the presence of a comorbidity because individuals will devote resources to preventing the recurrence of the comorbidity. Hence, the theoretical evidence is mixed as to the impact of comorbidities on willingness to pay for an index risk reduction.

In terms of empirical analysis, there is also relatively little to draw upon. Three key studies are Alberini et al. (2004), Krupnick et al. (2002) and DeShazo and Cameron (2005). All three use stated preference survey methods to assess willingness to pay for environmental risk reductions. Alberini et al. and Krupnick et al. are based on the same survey project. Alberini et al. implement a survey of adults between the ages of 45 and 80 in both the United States and Canada. Individuals are given their baseline risk of dying for their age and gender, and are asked their willingness to pay to reduce that risk by either 1 in 1000 or 5 in 1000. Individuals are also asked for their subjective health risk and if they have been diagnosed with any of a number of chronic conditions (comorbidities). Unlike the models discussed above that rely on an expected utility framework these authors use a life-cycle consumption model to model behavior. The theoretical framework provides ambiguous guidance as to expected results. People in poorer health have a higher probability of dying and hence higher willingness to pay to reduce that probability. However, we know little about how those in poorer health adjust their consumption or time path of consumption and therefore little can be said about the overall expected effect.

Results show that people with a family history of a chronic illness (other than cancer) have a willingness to pay that is 26 to 37 percent greater than those without the condition, depending on whether the survey was conducted in the U.S. or Canada. Hospital admission in the last year or an emergency room visit in the last five years for a heart or lung condition increases WTP by 63 percent in the U.S. only. A family history of cancer has no impact on results. In the U.S. sample high blood pressure (for oneself) increases willingness to pay by 1/3, whereas none of the other individual health variables affect willingness to pay. None of the individual health variables, including high blood pressure, affect WTP in the Canadian sample. Overall, this provides weak support for there being any differential affect on willingness to pay for an index condition in the presence of co-morbidities.

Krupnick et al. (2002) analyze the Canadian results, only with a slightly different survey than discussed in the Alberini et al. study above. They show that having cancer increases WTP. However, none of the other individual health variables are significant.

DeShazo and Cameron (2005) also provide evidence on this issue using a stated preference survey of U.S. individuals who are asked a host of questions about pre-existing conditions, baseline probabilities, and willingness to pay for risk reductions. They use an option price model that allows individuals to modify their consumption profile over a time path (as opposed to choosing one profile at a point in time in the expected utility framework). Results show how WTP for an intervention is affected by whether or not an individual has experienced the same illness – a recurrence of the index condition. While this in not quite a comorbidity, it can still shed some light on the issue. They find that having the disease increases WTP (by decreasing the utility associated with lost life-years). However, having other illnesses tends to decrease WTP for the index condition because it raises the marginal utility of wealth.

Overall, the theoretical results are ambiguous with respect the expected impact of co-morbidities on willingness to pay for an index condition. In addition, the empirical support is weak at best that willingness to pay is greater in the presence of other conditions.

VI. Summary

On the whole there is a rather unclear picture of how willingness to pay for reduced mortality risk varies with baseline risks, age, and health status. While theoretical and empirical studies have advanced our knowledge and provided insights, they are unable to consider all key aspects of the issue simultaneously, and it is therefore difficult to draw broad, clear conclusions. The literature reviewed here suggests the following:

- The effect of baseline risk is ambiguous under more general models, although willingness to pay increases in baseline risks in the simplest case. There are concerns that those with high baseline risks would spend profligately for risk reductions, and that analyses of public safety programs should adjust the expressed willingness-to-pay values of these groups downward (Pratt and Zeckhauser 1996). The extent to which such an adjustment is appropriate depends largely upon whether a dead- anyway effect is exhibited in estimated willingness to pay for risk reductions. Empirically, it is not clear whether individual willingness to pay for reduced mortality risk is sensitive to baseline risks, nor what the drivers of that sensitivity might be. Nor do we know whether EPA's default VSL approach over- or under-states the willingness pay of those with high baseline risks of death.

- The relationship between WTP and age may take an inverted u-shape, but this result is not universal. Some research shows no such relationship and where it is found the underlying studies may have limited application for environmental policies (e.g., hedonic studies generally support this finding but do not cover the full population).

- The relationship between WTP and health status is ambiguous and depends on assumptions about marginal utility of wealth in the two states. Empirical evidence is very limited.

Looking beyond benefit-cost analysis, information on public preferences suggests that "saving" young lives is preferred to saving older ones; however, this is not the same question as whether "saving" lives of those with reduced life expectancies is preferred to saving those with average life expectancies, as reduced life expectancies can also be associated with lower baseline health due to preexisting conditions. Also, various metrics exist for incorporating life expectancy into a cost-effectiveness framework where the objective function is defined by the decision maker. There has thus far not been much progress made in integrating public preferences into benefit-cost analysis, although many recommend complementing benefit-cost analysis by providing information on cost-effectiveness.

Appendix: Summary of Prior Advice from SAB on Related Topics

U.S EPA, Science Advisory Board (SAB). 2000. An SAB Report on EPA's White Paper *Valuing the Benefits of Fatal Cancer Risk Reduction*. (www.epa.gov/sab/pdf/eeacf013.pdf)

"The Committee's general conclusion is that estimates of the value of a statistical life (VSL) derived from wage-risk tradeoff studies should not be taken as precise estimates of the value of reducing the risk of fatal cancers, because of differences in the nature of the risks being valued and in the socio-economic characteristics of the affected populations, and because of various sources of uncertainty. It is the judgment of all but one member of the Committee, that, on the basis of the current literature, the only risk characteristic for which adjustments to the VSL can be made is the timing of the risk. Other risk-related adjustments suggested in the white paper are not adequately supported by the literature. With regard to population characteristics, the Committee believes that it can be appropriate to adjust the value of projected statistical lives saved in future years to reflect higher incomes in those years, but not for cross-sectional differences in income. Thus the Committee does not believe that the current literature supports adjustments to the VSL for differences in age, health status, or risk aversion. Any appropriate adjustments that are made for timing and income growth should be part of the Agency's main analysis while any other proposed adjustments should be accounted for in the sensitivity analysis recommended by the Committee.

Despite limitations of the VSL estimates, these seem to offer the best available basis at present for considering the value of fatal cancer risk reduction. We therefore recommend that the Agency continue to use a wage-risk-based VSL as its primary estimate, including appropriate sensitivity analyses to reflect the uncertainty of these estimates." (pp. 1-2)

U.S. EPA, Science Advisory Board (SAB). 2001. Arsenic Rule Benefits Analysis: An SAB Review. EPA-SAB-EC-01-008. (http://www.epa.gov/sab/pdf/ec01008.pdf)

"We believe the central estimate of $6.1 million for the value of a statistical life (VSL) is appropriate. On the question of whether to add a value for cancer morbidity before death, we do not believe that there is an adequate basis in the literature for doing this. But we can endorse adding estimates of the medical costs of treatment and amelioration for fatal cancers to the VSL as a lower bound on the true value of avoiding fatal cancer." (pp. 5-6)

(More detail on pp. 17-18)

U.S. EPA, Science Advisory Board (SAB). 2004a. Review of the Revised Analytical Plan for EPA's Second Prospective Analysis - Benefits and Costs of the Clean Air Act 1990-2020. EPA-SAB-COUNCIL-ADV-04-004. (http://www.epa.gov/sab/pdf/council_adv_04004.pdf)

- Uncertainty analysis for VSLs requires VSL estimates corresponding to the risk and populations similar to those in the analysis: the distribution of existing point estimates is "unlikely to be appropriate for this purpose." There are very few, if any, appropriate values.
- EPA should not exclude VSL studies because they are "unsuitable." They lean toward the Viscusi-Aldy meta-analysis although they note that because it relies on wage-risk studies it may not provide the last word. We should not rely exclusively on Kochi et al, which has not been peer-reviewed and published. Developing a model that includes relevant variables should be a priority for future research and meta-analysis efforts.
- Adjustments for future changes in income levels should be considered placeholders because they are based on limited empirical evidence. In the future, we should make adjustments based on a formal model of preferences.

(pp. 2-3 with additional information from pp 50-58)

U.S. EPA, Science Advisory Board (SAB). 2004b. Review of the Environmental Economics Research Strategy of the U.S. Environmental Protection Agency. EPA-SAB-040007. (http://www.epa.gov/sab/pdf/sab_04007.pdf)

"Regarding the Agency's priorities in the area of mortality valuation, the impact of age on the VSL is an important, policy-relevant topic. Any environmental regulation that saves lives in proportion to the age distribution of deaths in the U.S. will primarily extend the lives of older people. (Fifty percent of the deaths in the U.S. occur after age 75.) Regarding the impact of health status and co-morbidity on the VSL, the important issue here is whether environmental pollution causes chronic illness or simply increases mortality risk for people who have pre-existing chronic conditions. When environmental contaminants cause a disease, it is theoretically desirable to value the risk of contracting the illness (such as cancer) which will entail both morbidity and a reduction in life expectancy. If pollutants differentially affect mortality risk for those with a pre-existing condition (e.g., cardiovascular disease), then efforts should be put on measuring the impacts of the health state on the value of increasing life expectancy.

There are three topics in the area of mortality risk valuation that the committee believes deserve attention even though they are not mentioned in the EERS. The first concerns the reliability of existing estimates of the VSL, which rely on labor market and on stated preference studies. The Agency has recently commissioned re-analyses of data from compensating wage studies (Black, Galdo and Liu 2003) and of data from contingent valuation studies of mortality risks. Examination of these results may suggest that emphasis should be placed on developing newer, more reliable estimates of the VSL.

The second research topic concerns the issue of marginal versus non-marginal risk valuation. Emphasis in the literature is on valuing small changes in risk of death, on the order of 1 in 10,000 per year or smaller. The agency, however, uses these estimates to value regulations that, together, account for much larger risk reductions. To illustrate, *The Benefits and Costs of the Clean Air Act 1970-1990* (USEPA 1997) predicted that air quality regulations issued between 1970 and 1990 reduced mortality by 200,000 lives in 1990. When a VSL of $4.8 million (1990 USD) was applied to these statistical lives, the WTP in 1990 for mortality risk reductions occurring in that year was estimated to be approximately $16,000 (1990 USD) for a family of four.[14] This was because the VSL was applied to a non-marginal reduction in risk of death (on average, a 1/1,000 reduction). Similarly large benefit estimates may arise when one adds together WTP for the risk reductions associated with the 1990 Clean Air Act Amendments, the Tier II Emissions standards, the Heavy Duty Engine Diesel Rule, the Off-Road Diesel Rule and Clear Skies. In short, while a single regulation may confer marginal risk reduction benefits, the set of environmental regulations evaluated over a 10-year period may confer non-marginal benefits, and should be evaluated accordingly.

The third research topic concerns the impact of income on the VSL. Historically EPA has adjusted future values of the VSL to allow for income growth. Such adjustments require estimates of the income elasticity of WTP for mortality risk reductions. We believe that this is a topic that requires additional research.

(pp. 3-4)

[14] The total value of the statistical lives saved, $1 trillion, when divided by the population of the U.S. in 1990, implies a WTP of approximately $4,000 per person.

References

Alberini, Anna, Maureen Cropper, Alan Krupnick, and Nathalie B. Simon. 2004. "Does the Value of a Statistical Life Vary with Age and Health Status? Evidence from the US and Canada." *Journal of Environmental Economics and Management,* 48: 769-792.

Aldy, Joseph E., and W. Kip Viscusi. 2006. "Adjusting the Value of a Statistical Life for Age and Cohort Effects." *RFF Discussion Paper #06-19,* Washington, DC.

Bleichrodt, Hans, David Crainich, and Louis Eeckhoudt. 2003. "Comorbidities and the Willingness to Pay for Health Improvements." *Journal of Public Economics*, 87: 2399-2406.

Breyer, Freidrich and Stefan Felder. 2005. "Mortality Risk and the Value of a Statistical Life: The Dead-Anyway Effect Revis(it)ed." *The Geneva Risk and Insurance Review*, 30: 41-55.

Centers for Disease Control. 2006. Life Tables. Available at: http://www.cdc.gov/nchs/products/pubs/pubd/lftbls/life/1966.htm. Accessed August 16, 2006.

Cropper, Maureen L. and Frances G. Sussman. 1988. "Families and the Economics of Risks to Life." *The American Economic Review,* 78(1): 255-260.

Cropper, Maureen, and Frances G. Sussman. 1990. "Valuing Future Risks to Life." *Journal of Environmental Economics and Management,* 19: 160-174.

Dolan, Paul, Rebecca Shaw, Aki Tsuchiya, and Alan Williams. 2005. "QALY Maximisation and People's Preferences: a Methodological Review of the Literature." *Health Economics*, 14: 197-208.

Eeckhoudt, Louis R. and James K. Hammitt. 2001. "Background Risks and the Value of a Statistical Life." *The Journal of Risk and Uncertainty*, 23(3): 261-279.

Emanuel, Ezekial J. and Alan Wertheimer. 2006. "Who Should Get Influenza Vaccine When Not All Can?" *Science*, 312: 854-855.

Evans, Mary F. and V. Kerry Smith. 2006. "Do We Really Understand the Age-VSL Relationship?" *Resource and Energy Economics*, 28: 242-261.

Hammitt, James K. 2000."Valuing Mortality Risk: Theory and Practice."*Environmental Science and Technology*, 34: 1396-1400.

Hammitt, James K. and Nicolas Treich. 2006. "Statistical vs. Identified Lives in Benefit-Cost Analysis," working paper.

Hofstetter, Patrick and James Hammitt. 2002. "Selecting Human Health Metrics for Environmental Decision-Support Tools." *Risk Analysis*, 22(5): 965-983.

Hubbell, Bryan. 2006. "Implementing QALYs in the Analysis of Air Pollution Regulations." *Environmental and Resource Economics,* 34(3): 365-384.

Johansson, Per-Olov. 2002. "On the Definition and Age-Dependency of the Value of Statistical Life." *The Journal of Risk and Uncertainty,* 25(3): 251-263.

Jones-Lee, Michael. 1974. "The Value of Changes in the Probability of Death or Injury," *Journal of Political Economy*, 82: 835-849.

Kniesner, Thomas J., W. Kip Viscusi, and James P. Ziliak. 2006. "Life-Cycle Consumption and the Age-Adjusted Value of Life." *Contributions to Economic Analysis and Policy*, 5(1): article 4. http://www.bepress.com/bejeap/contributions/vol5/iss1/art4.

Krewski, D., R.T. Burnett, M.S. Goldbert, K. Hoover, J. Siemiatycki, M. Jerrett, M. Abrahamowicz, and W.H. White. 2000. "Reanalysis of the Harvard Six Cities Study and the American cancer Society Study of Particulate Air Pollution and Mortality." *Special Report to the Health Effects Institute*, Cambridge, MA. July 2000.

Krupnick, Alan, Anna Alberini, Maureen Cropper, Nathalie Simon, Bernie O'Brien, Ron Goeree, and Martin Heintzelman. 2002. "Age, Health, and the Willingness to Pay for Mortality Risk Reductions: A Contingent Valuation Survey of Ontario Residents." *The Journal of Risk and Uncertainty*, 24(2): 161-186.

Liu, Liquan and William Neilson. 2006. "Endogenous private safety investment and the willingness to pay for mortality risk reductions." *European Economic Review*, forthcoming.

Moore, Michael J., and W. Kip Viscusi. 1988. "The Quantity-Adjusted Value of Life." *Economic Inquiry,* 26: 369-388.

Nord, Erik. 2005. "Some Ethical Corrections to Valuing Health Programs in Terms of Quality-Adjusted Life Years (QALYs)." *Ethics Journal of the American Medical Association*, 7(2).

OMB. 2003. "Circular A-4, Regulatory Analysis." Document 68, *Federal Register* 54023.

Pinto-Prades, Jose-Luis and Jose-Maria Abellan-Perpinan. 2005. "Measuring the Health of Populations: The Veil of Ignorance Approach." *Health Economics* 14(1): 69-82

Pratt, John W. and Richard J. Zeckhauser. 1996. "Willingness to Pay and the Distribution of Risk and Wealth." *Journal of Political Economy*, 104(4): 747-763.

Ramsberg, Joakim. 2002. “When Should Expenditure Per Life Saved Vary?” *Journal of Risk Research*, 5(3): 249-263.

Rosen, Sherwin 1988. “The Value of Changes in Life Expectancy.” *The Journal of Risk and Uncertainty,* 1: 285-304.

Shepard, Donald S. and Richard J. Zeckhauser. 1984. “Survival Versus Consumption.” *Management Science,* 30(4): 423-439.

Smith, V. Kerry and Mary F. Evans. 2003. “The Value of Life When Facing Death.” Working paper.

Smith, V. Kerry, Mary F. Evans, Hyun Kim, and Donald H. Taylor. 2004. “Do the Near Elderly Value Mortality Risks Differently?” *Review of Economics and Statistics*, February: 423-429.

Strand, Jon. 2004. “Public- and Private-good Values of Statistical Lives: Results from a Combined Choice-Experiment and Contingent-Valuation Survey.” Paper presented at the *2002 World Congress of Environmental and Resource Economists*.

Sunstein, Cass R. 2004. "Lives, Life-Years and Willingness to Pay," *Columbia Law Review* 104: 205-252.

Sussman, F.G. 1984. “A Note on the Willingness to Pay Approach to the Valuation of Longevity.” *Journal of Environmental Economics and Management*, 11: 84-89.

US EPA. 1997. *The Benefits and Costs of the Clean Air Act, 1970-1990.* Report to Congress.

US EPA. 1999. *The Benefits and Costs of the Clean Air Act, 1990-2010*. Report to Congress. EPA-410-R-99-001. (November).

US EPA. 2000a. *Guidelines for Preparing Economic Analyses.* EPA-240-R-00-003 (September).

USEPA. 2000b. *Control of Emissions of Air Pollution from 2004 and Later Model Year Heavy-duty Highway Engines and Vehicles, Final Rule.* http://www.epa.gov/oms/hd-hwy.htm#regs.

USEPA. 2000c. *Valuing Fatal Cancer Risk Reductions: SAB Review Draft.* January 21.

USEPA. 2003. *Children's Health Valuation Handbook*. EPA-100-R-03-003 (October)

US EPA. 2004. “Value of Statistical Life Analysis and Environmental Policy: A White Paper.” Paper prepared for presentation to SAB-EEAC on May 12-13, 2004. Available on-line at http://yosemite.epa.gov/EE/epa/eerm.nsf/vwRepNumLookup/EE-0483?OpenDocument.

US EPA. 2005. "Economic Analysis for the Long Term 2 Enhanced Surface Water Treatment Rule." Office of Water. EPA 815-R-06-001.

Weinstein, Milton C., Donald S. Shepard, and Joseph S. Pliskin. 1980. "The Economic Value of Changing Mortality Probabilities: A Decision-Theoretic Approach." *The Quarterly Journal of Economics*, 94: 373-396.

Viscusi, W. Kip, and Joseph E. Aldy. 2003. "The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World." *The Journal of Risk and Uncertainty,* 27(1): 5-76.

Viscusi, W. Kip, and Joseph E. Aldy. 2006. "Labor Market Estimates of the Senior Discount for the Value of Statistical Life." *RFF Discussion Paper #06-12*, Washington DC.