Policy Monitor

How US Government Agencies Value Mortality Risk Reductions

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Introduction

Each year, US government agencies promulgate health and safety regulations that impose hundreds of millions of dollars of costs on the national economy. A key issue in developing these regulations is determining whether the value of the associated risk reductions and other benefits exceeds the value of the resources diverted from other purposes. This article explores one component of this benefit-cost comparison: the approaches used by federal agencies to estimate the value of changes in the risk of premature mortality.

After introducing key concepts, the article describes current federal agency practices. It first summarizes US government-wide guidelines for valuing mortality risk reductions and then discusses the practices of individual agencies in more detail. It focuses largely on the approaches used by the US Environmental Protection Agency (EPA). The EPA is responsible for a substantial proportion of all federal life-saving regulations, and mortality risk reductions account for the majority of the monetized benefits for most of its economically significant rules.

Key Concepts

Most major life-saving regulations reduce mortality risks across a wide population and result in a small change in risk for many affected individuals. Economists have developed the concept of a "statistical life" as a method for aggregating these small changes. For example, a regulation that reduces risks by one in one hundred thousand on average throughout a population of a hundred thousand individuals can be described as saving one statistical

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life—as can an effort that achieves an average risk reduction of one in ten thousand throughout a population of ten thousand. Thus a statistical life is an analytic construct; its value is not equivalent to the value of saving the life of a particular individual.

The Value of Statistical Life

In regulatory analysis, the value of reduced mortality risks usually takes the form of a "value per statistical life" (VSL). If, for instance, each member of a population of a hundred thousand was willing to pay \$50 on average for a one in one hundred thousand decrease in his risk of dying during the next year, the corresponding VSL would be \$50 × 100,000 or \$5 million. Generally, economists estimate these values using either revealed or stated preference studies. Revealed preference methods use data from market transactions or observed behavior to estimate the value of nonmarketed goods. For example, in compensating wage differential (or wage-risk) studies, researchers compare earnings across different industries to estimate the additional wages paid to workers in riskier jobs, using statistical methods to control for the effects of other factors (such as education) on earnings. Stated preference methods use contingent valuation surveys or similar approaches that ask respondents to report their willingness to pay (WTP) for reduced risks under hypothetical scenarios. The VSL is most often estimated from studies of compensating wage differentials; however, a smaller number of studies estimate the VSL using contingent valuation surveys.

Agencies face three challenges in valuing mortality risks: they must select appropriate studies from the available literature, they must adapt the study estimates to the regulatory context, and they must combine the results into a point estimate, a range of values, or a probability distribution for use in their analyses. As discussed later in this article, these decisions are influenced by current government-wide guidance and constrained by the available empirical research.

Perhaps the most important and controversial challenge is determining how to address differences between the types of risks studied and the types of risks addressed by federal regulations. For example, compensating wage studies address the risk of accidental deaths among workers who are, on average, in their mid- to late thirties. However, the individuals affected by air pollution regulations are likely to be much older, may face higher baseline risks from conditions unrelated to pollution, and may experience several years of morbidity (e.g., from heart disease or cancer) prior to death. In addition, exposure to pollution may be less voluntary and controllable than the choice of a job.

The Value of a Statistical Life Year

The value per statistical life year (VSLY) is an approach for adjusting VSL estimates to reflect differences in remaining life expectancy and involves calculating the value of each year of life extension. Because the degree of life extension is usually closely related to the age of the affected individuals, VSLY is often interpreted as an approach for adjusting VSL to reflect age differences. It is generally derived by applying simple assumptions to VSL estimates based on Moore and Viscusi (1988).

More specifically, the VSLY is derived by dividing the VSL by the discounted expected number of life-years remaining for the average individual studied. This approach assumes that the VSL is the sum of the present value of each life-year (the VSLY) weighted by the probability that an individual survives to that year, which is equivalent to assuming that the value of each remaining life-year is constant.[1] The resulting VSLY is then applied to the expected number of discounted life years saved by the regulation (i.e., to the predicted increase in discounted life expectancy).

An example of this approach appears as a sensitivity analysis in the EPA's retrospective assessment of the Clean Air Act (EPA 1997). Assuming that the VSL is \$4.8 million (in 1990 dollars), the remaining life expectancy averages thirty-five years for the population studied, and the VSL estimate reflects a 5-percent discount rate, the EPA obtained a VSLY of \$293,000. If the average individual whose life is extended by the program would survive for an additional fourteen years (as a result of reduced exposure to pollutants), the present value of the risk reductions would be \$2.9 million (i.e., the discounted value of fourteen years $\times$ \$293,000 per year). In other words, under this approach, the total value of the mortality risk reduction would be \$4.8 million for a younger individual who would survive for thirty-five additional years, and \$2.9 million for an older individual who would survive for only fourteen more years.

These VSLY calculations, although easy to implement, assume that the VSL is proportional to the discounted remaining life expectancy. As discussed elsewhere in this volume, economic theory places no such restrictions on the VSL, and the available empirical evidence indicates that the relationship between VSL and life expectancy, or age, is more complex. In addition, because it suggests that saving the life of an elderly individual is worth less than saving the life of a younger individual (who has more remaining life years), such adjustments have been contentious when applied in a public policy setting.

Government-wide Guidance

The US Office of Management and Budget (OMB) has primary responsibility for coordinating and reviewing regulatory analyses across federal agencies. The OMB's role is framed by *Executive Order 12866, Regulatory Planning and Review* (1993). This executive order directs agencies to evaluate alternative strategies for all economically significant regulations, which include those with a predicted annual impact on the economy of \$100 million or more or with other types of significant effects. The executive order requires the analysis of benefits and costs but its concerns go beyond economic efficiency. It requires agencies to consider distributive impacts and equity as well as nonquantifiable effects.

Current OMB Guidance

Guidance on implementing *Executive Order 12866* is provided in the OMB's *Circular A-4, Regulatory Analysis* (2003). The *Circular* is intended to assist analysts in conducting good

[1]Formally, the approach assumes that the VSL at age j is, $\mathrm{VSL}_j = \sum_{t=j}^{T} q_{j,t}(1+\delta)^{j-t}\mathrm{VSLY}$, where $q_{j,t}$ is the probability that an individual at age j survives to age t and δ is the discount rate. VSLY can be factored out of this expression, and $\sum_{t=j}^{T} q_{j,t}(1+\delta)^{j-t}$ is the discounted remaining life expectancy.

regulatory assessments and to promote consistency across agencies. While the OMB treats some of the guidance as mandatory, it also recognizes that agencies may lack the data and resources necessary to fully comply with many of the recommendations. Thus the OMB suggests preferred practices, yet allows agencies to exercise some discretion in determining how to conduct their analyses as long as sufficient justification is provided for the approach. Ultimately, each individual regulatory analysis is the result of negotiations between the OMB and the agency during the OMB review process.

Circular A-4 discusses a wide range of issues, such as identifying alternative policy strategies, assessing various types of costs and benefits, and analyzing distributional impacts. It includes sections that directly address benefits valuation (briefly summarized below), as well as related topics such as selecting a discount rate and assessing uncertainty.

The *Circular* describes principles that agencies should consider in reviewing the research used to support benefit valuation. For example, it provides lists of criteria for evaluating revealed and stated preference studies as well as for transferring benefit estimates from the studies to different policy contexts. These criteria address whether the study is consistent with economic theory, uses appropriate methods for data collection and analysis, and considers outcomes similar to those anticipated from the proposed rulemaking. Separately, the OMB has issued guidance on quality control and peer review (OMB 2002, 2004), which (in combination with *Circular A-4*) increases the emphasis on assessing the quality and suitability of studies used for valuation. The OMB notes, however, that ultimately the selection of appropriate values will depend on the professional judgment of the analyst because each study is likely to have both strengths and weaknesses. *Circular A-4* repeatedly emphasizes the need to discuss the rationale for selecting a particular approach and to assess associated biases or uncertainties.

In the *Circular*, the OMB also discusses the valuation of mortality risk reductions and suggests that agencies present both VSL and VSLY estimates. The OMB notes that these values are subject to continued research and debate and indicates that agencies should describe the limitations of their chosen approach. The *Circular* reports that the range of VSL estimates found in the literature is generally between $1 million and $10 million; as a result, regulatory agencies generally use values from within this range.

In addition, *Circular A-4* discusses options for adjusting VSL estimates to reflect differences between the scenarios addressed in the research literature and the specific regulatory scenarios being assessed. The *Circular* notes that the available empirical research supports quantitative adjustments to VSL estimates only for changes in income over time and for time lags in the incidence of health impacts. It includes cautions on the application of age adjustments and suggests the use of larger VSLY estimates for older individuals. It also requires that agencies complete a cost-effectiveness analysis as well as a benefit-cost analysis. In cost-effectiveness analysis, regulatory costs are divided by a nonmonetary benefit measure (such as lives or life-years saved) to compute the cost per unit of effect (e.g., the cost per life-year saved), whereas benefit-cost analysis assigns a monetary value to each type of benefit.

The "Senior Discount" Debate

While the OMB was developing *Circular A-4*, a controversy erupted over the "senior discount" implicit in age-adjusted VSL estimates used by the EPA. The EPA's preferred VSL estimates do not vary by age. However, for many air pollution rules, most of the reduction in premature mortality is likely to accrue to individuals aged sixty-five and over rather than to the younger working-age individuals included in most VSL studies. In some of its regulatory assessments, the EPA presented sensitivity analyses based on research suggesting that older individuals are willing to pay less for life-saving interventions than younger adults (e.g., Jones-Lee 1989; Jones-Lee et al. 1993). Many observers objected to this use of lower VSL estimates for older persons in policy analysis. The controversy garnered attention from the media and Congress; advocacy groups ran ads showing "seniors on sale" and, in the fiscal year 2004 Appropriations Bill (H.R. 2673), Congress prohibited the EPA from funding analyses that made these adjustments.

In response, the OMB issued a memorandum advising agencies against adjusting the VSL for age (Graham 2003). This memorandum suggested that more recent research (ultimately published in Alberini et al. 2004a) did not fully support the VSL age adjustment found in earlier studies. It indicated that, when VSLY estimates are used instead of VSL, the yearly values are likely to be higher for senior citizens because "seniors face larger overall health risks from all causes and because they have accumulated savings and liquid assets to expend on protection of their health and safety" (Graham 2003, p. 2). The memorandum also noted that the OMB was developing requirements for cost-effectiveness analysis, which has the advantage of not requiring that a monetary value be placed on risk reductions (although such values are implicit in the ultimate regulatory decision).

However, the guidance in this OMB memorandum, which was eventually incorporated into *Circular A-4*, does not necessarily eliminate the use of different values for younger versus older individuals. When VSLY estimates are applied, the total value of a risk reduction is equal to the product of the VSLY estimate and the discounted number of life-years saved. Unless the VSLY estimates for older individuals are large enough to compensate for the smaller number of life-years remaining, the use of VSLY estimates will result in lower values for older individuals. In addition, the measures most commonly used to value premature mortality in cost-effectiveness analyses are based on life-years lost (see Institute of Medicine 2006) and thus also result in smaller values for older persons.

The number of rules subject to these OMB requirements is small but their economic impact is substantial. For example, in fiscal year 2004, the OMB reviewed only six final rules that were economically significant, included monetized estimates of health or safety benefits, and were subject to *Executive Order 12866* (OMB 2005). However, the OMB calculated that the annual costs of these rules totaled approximately \$3.5 billion and their monetized benefits totaled between \$12 billion and \$107 billion (2001 dollars). Of these six rules, three were the EPA air pollution rules for which reduced mortality risks accounted for a significant fraction (roughly 90 percent) of total monetized benefits. Data for other years show a similar pattern; the EPA air pollution rules account for a significant proportion of all economically significant health and safety regulations and their monetized benefits are attributable primarily to reductions in premature mortality.

The EPA's Approach

The EPA has devoted considerable attention to developing methods for estimating the value of reductions in the risks of premature mortality. While the studies that are used as the basis for these estimates have remained relatively constant over time, the EPA's approach to adjusting the estimates has evolved as the result of continuing research and expert review.

The EPA's Base Estimates

The EPA's VSL estimates are based largely on work completed in the early 1990s to support its retrospective and prospective analyses of the impacts of the Clean Air Act (EPA 1997, 1999a; summarized in more detail in Industrial Economics, Incorporated [IEc] 2001). Reflecting research conducted by Viscusi (1992, 1993), the EPA identified twenty-six VSL estimates suitable for use in its analyses, of which twenty-one were from wage-risk studies and five were from contingent valuation studies.

The mean VSL estimates from these studies ranged from \$0.6 million to \$13.5 million with an overall mean of \$4.8 million (1990 dollars). When updated to 2005 dollars using the Consumer Price Index, the mean of this range is \$7.2 million, with a minimum of \$0.9 million and a maximum of \$20.2 million. The wage-risk studies provide values scattered throughout this range, but the estimates from the contingent valuation studies tend to cluster towards the lower end (see Appendix Table A1).

These estimates rely primarily, but not entirely, on studies of US workers, and focus on accidental deaths. The workers studied are, on average, in their mid- to late-thirties and their average income varies from close to \$10,000 to over \$40,000 (in 1990 dollars), reflecting the differing populations and job categories addressed by each study. Almost all of the studies address job-related risks. The magnitude of the risks average from about one in one hundred thousand to about seven in ten thousand annually, and tend to cluster around one in ten thousand.

The studies vary in other ways (e.g., sample sizes used, characteristics of the underlying data, extent to which they adjust for potentially significant variables such as the availability of workers' compensation) that may affect both their quality and their suitability for use in environmental policy analysis. They also were designed to address a variety of different concerns, such as investigating the effects of gender, unionization, job type, location, and/or risk perceptions on VSL estimates. The nature of these concerns, in turn, affected the data incorporated into the study design and the variables used in the statistical analysis.

The approach developed for the Clean Air Act analysis, based on these twenty-six VSL estimates, was ultimately incorporated into the EPA's *Guidelines for Preparing Economic Analysis* (EPA 2000a). For many years, the central tendency (or mean) VSL estimate used in EPA regulatory analyses was derived from this range of values, adjusted as needed for inflation.

Recently, researchers have completed several analyses that use statistical methods to combine data from various VSL studies (often called "meta-analyses"). These studies include Mrozek and Taylor (2002), Kochi et al. (2006), and Viscusi and Aldy (2003), each of which uses a somewhat different methodology and reports different ranges of best estimates. For example, Mrozek and Taylor (2002) report a mean VSL of \$2.6 million (1998 dollars) for the average worker, Kochi et al. (2006) report a mean of $5.4 million (2000 dollars) with a standard deviation of $2.4 million, and Viscusi and Aldy (2003) report means ranging from $5.5 million to $7.6 million (2000 dollars) depending on the model specification used.

The EPA has begun to use these meta-analysis results when assessing the impacts of its air pollution rules (e.g., EPA 2004, 2005a) while continuing to rely on the twenty-six studies for other rules, such as those addressing drinking water (e.g., EPA 2005b). When applying the meta-analysis results, the EPA uses a range of estimates, anchored at $1 million (near the lower end of the range from Mrozek and Taylor) and $10 million (near the upper end of the range from Viscusi and Aldy), with a mean of $5.5 million (1999 dollars).

This approach results, in part, from the advice of a special panel of the EPA's Science Advisory Board (Cameron et al. 2004). In its review of the plans for the EPA's *Second Prospective Analysis* of the Clean Air Act, this panel suggested that the agency focus primarily on the results of Viscusi and Aldy (2003) meta-analysis and also incorporate lessons learned from the other studies. This approach is also consistent with the range reported in the OMB's *Circular A-4* discussion of values to be used in regulatory analysis.

Over time, various aspects of the EPA's approach have been reviewed by independent committees of its Science Advisory Board (e.g., Cropper 2001; Schmalensee 1993; Stavins 1999, 2000), and have been subject to extensive public comment. Most of these reviews suggested that additional research is needed to refine the base VSL estimates, but did not provide a specific alternative that could be applied in the near term. In addition, many of the reviews discussed the differences between the scenarios studied and the scenarios addressed by the EPA regulations, as described below.

The EPA's Adjustments for Scenario Differences

Throughout the development of the EPA's VSL estimates, the agency and its advisory panels have struggled with issues related to the differences among the scenarios being assessed. The populations and risks affected by the EPA's regulations differ in several important ways from those addressed by the studies (EPA 2000b; IEc 2001). As noted earlier, the twenty-six studies focus largely on the risks of accidents affecting middle-aged workers. In contrast, the EPA's policies affect premature mortality from illnesses that may be spread more widely throughout the population or concentrated in younger or older age groups. The populations may differ not only in their age, but also in their income, health status, and/or degree of risk aversion. The types of health risks may differ in their timing or duration, in their voluntariness or controllability, and in the extent to which they are dreaded. For example, air pollution controls will not immediately reverse all the effects of a lifetime of exposure, and many pollution-related illnesses (such as cancers) may be particularly dreaded because they include a period of morbidity prior to death.

Because only limited data are available on the effects of these varying scenarios, it is not possible to modify the VSL estimates from the research literature to reflect most of these differences. The EPA has adjusted its base estimates for income growth and for any delays in the incidence of risk reductions (often referred to as cessation lags) in most regulatory analyses; adjustments for other factors (in either the base case or sensitivity analysis) have been made in only a few cases. The effects of these other factors are instead described qualitatively.

This approach is consistent with the advice of several EPA advisory panels. For example, two Science Advisory Board groups (Cropper 2001; Stavins 2000) did not support an adjustment for voluntariness and controllability included in sensitivity analysis of the benefits of the EPA's rule governing arsenic in drinking water.[2] More generally, the Science Advisory Board's Environmental Economics Advisory Committee (Stavins 2000) suggested that the available evidence supported quantitative adjustments only for income growth and cessation lag when valuing cancer-related fatalities.

With regard to age adjustments, the position of the EPA's advisory panels has changed over time. In response to the concerns about the equitable treatment of younger and older individuals, the EPA has discontinued its use of VSLY estimates as well as VSL age adjustments in recent analyses. The following sections discuss in more detail the issues related to VSL adjustments for age, income, and time lags.

Age Adjustments

As noted in the earlier discussion of the senior discount debate and its effect on the OMB's guidance, age adjustments have been a particularly contentious issue. While the average age of the population included in the VSL studies is in the mid- to late-thirties, some EPA regulations have disproportionate effects on different age groups. Most significantly, for air rules addressing particulate matter, roughly 80 percent of the reduction in premature mortality may occur among individuals over age sixty-five (EPA 1999a).

As the result of its own research and negotiations with the OMB during the regulatory review process, the EPA included sensitivity analyses of the effects of age adjustments (adjusting VSL and/or applying VSLY estimates) in several of its reports prior to the development of *Circular A-4*. The Tier 2 rule governing air emissions from motor vehicles (EPA 1999b) is one example of a regulatory analysis that includes age adjustments in sensitivity analysis.[3]

While certain of the older EPA analyses report VSLY estimates, research suggests that such calculations are overly simplistic. In particular, some studies have indicated that there is an inverse U shaped relationship between age and the VSL, which peaks in middle age (e.g., Jones-Lee 1989; Jones-Lee et al. 1993). Another study (Alberini et al. 2004a) found that US respondents over age seventy were willing to pay about 20 percent less than individuals aged forty to seventy to reduce their risk of premature mortality; however, this result was not statistically significant.

The EPA has used these studies to adjust VSL estimates in illustrative analyses. For example, for the heavy-duty diesel rule (EPA 2000c), the EPA used VSL age adjustments

[2]One Science Advisory Board group (Cropper 2001) recommended adding medical treatment costs to VSL estimates to reflect the impacts of morbidity prior to death; however, this adjustment has been rarely applied.

[3]Several other EPA policy analyses (not technically subject to *Circular A-4* because they are not regulatory proposals) also include these adjustments in sensitivity analysis, such as the retrospective assessment of the Clean Air Act (EPA 1997), the prospective assessment of the Clean Air Act (EPA 1999a), and the Clear Skies legislative proposals (EPA 2003b).

based on Jones-Lee (1989) and Jones-Lee et al. (1993) in sensitivity analysis, which reduced its primary benefits estimate by 10 or 40 percent, depending on the adjustment factor applied. In a sensitivity analysis for regulations addressing emissions from large spark ignition engines (EPA 2002), the agency used a more complicated approach that reflected initial results from the work of Alberini et al. (2004a) as well as the adjustment factor from Jones-Lee (1989). In this case, the EPA combined the age adjustments with a lower base VSL ($3.7 million instead of $6.1 million) that included only the five contingent valuation studies (see Appendix Table A1). As a result, the age-adjusted values for both younger and older individuals were substantially lower than the base estimates for all age groups.

As discussed above, because these and other approaches to age adjustments have raised serious concerns about the equitable treatment of younger and older individuals in policy decisions, the EPA has not used VSLY estimates or VSL age adjustments in its more recent analyses. This evolution of the EPA's practices is consistent with the advice of its advisory panels. For example, a 1993 review of the EPA's approach to the retrospective analysis of the Clean Air Act suggested that the VSL should be adjusted to reflect the number of life years saved (Schmalensee 1993). A similar suggestion was contained in a 1999 review of the EPA's guidelines for economic analysis, which recommended that age adjustments be included in sensitivity analysis (Stavins 1999). However, a subsequent panel reviewing the valuation of cancer-related fatalities indicated that, rather than relying on simple VSLY calculations, "the theoretically appropriate method is to calculate WTP for individuals whose ages correspond to those of the affected population" and "urges that more research also be conducted on this topic" rather than recommending the implementation of adjustments based on currently available studies (Stavins 2000, p. 8). The Environmental Economics Advisory Committee of the EPA's Science Advisory Board is now revisiting this issue, and is expected to recommend against the use of VSLY estimates.

Valuing risks to children raises additional concerns. For example, measuring a child's own WTP for his or her health risk reductions is problematic—it is more feasible to measure adult WTP for reducing risks to children. However, parents' values for their children may be higher than their WTP to reduce their own risks and may differ from societal values (see EPA 2003a). Because of the lack of relevant research, the EPA and other agencies generally use the same values for both adults and children. The OMB's *Circular A-4* indicates that the values for children should be at least as large as the values used for adults.

Income Adjustments

Income has a clear and measurable effect on the VSL: as income increases, WTP for risk reductions usually increases. While this effect could be measured both cross-sectionally (across individuals or subpopulations) and longitudinally (over time), most studies are cross-sectional. However, using different VSL estimates for individuals with different incomes is controversial and has raised issues about the equitable treatment of richer and poorer segments of the population in policy decisions. Thus the EPA does not make cross-sectional adjustments in its analyses.

Instead, the EPA uses the cross-sectional data to estimate the longitudinal change in VSL likely to occur as real per capita income (measured by gross domestic product [GDP]) changes over time. This adjustment involves estimating the percentage change in the VSL that is associated with a 1 percent change in income (i.e., its income elasticity). Because most studies suggest that this elasticity is less than one, several EPA analyses have used a distribution of income elasticity estimates with a mode of 0.40 and endpoints at 0.08 and 1.00 (EPA 1999a). The EPA typically first adjusts the VSL estimates to a common base year (often 1990), and then applies the adjustment for real income growth over the future time period considered in the analysis. The same estimates of income-adjusted VSL are then used for all members of the population affected by the rulemaking.

Time Lag Adjustments

Another difference between the accidental deaths addressed by most VSL studies and the impacts of some environmental contaminants is the possibility of a time lag between changes in exposure and changes in premature mortality. This lag is often referred to as "latency" when the results of exposure are not immediately manifest. However, in its analyses, the EPA is usually concerned instead with the "cessation lag," which refers to the delay between decreased exposure and achievement of the full reduction in health risks.

The most extensive research on cessation lag relevant to the EPA's regulations addresses cigarette smoking, and suggests that the duration of this lag may differ significantly from the latency period. For example, an expert panel that reviewed the EPA's rule for arsenic levels in drinking water noted that smoking studies suggest that "the latency between initiation of exposure and an increase in lung cancer risk is approximately 20 years. However, after cessation of exposure, risk for lung cancer begins to decline rather quickly" (Cropper 2001, p. 5). The EPA's subsequent analysis (reported in EPA 2005b) suggested that 80 percent of the lung cancer benefits were likely to accrue prior to twenty years after cessation of exposure.

Until recently, there was little research that directly addressed the effects of such lags on VSL estimates. Thus, for many years, the EPA used simple discounting to account for this effect. For example, if the pollution reduction occurred in the current year but a portion of the risk reduction occurred five years later, then the VSL would be discounted to reflect the five-year delay, using the same discount rate as applied elsewhere in the analysis.[4] Recent studies would appear to support the use of discounted values for delayed impacts (e.g., Alberini et al. 2004b; Hammitt and Liu 2004), although the estimates of the extent of the discount vary.

The EPA is now revising its *Guidelines for Preparing Economic Analysis* (2000a), as well as updating its approach for its next prospective analysis of the Clean Air Act, and has asked the Environmental Economics Advisory Committee of its Science Advisory Board to further assess these issues. To support this effort, the EPA completed a review of the VSL literature (Dockins et al. 2004) that summarized recent studies and meta-analyses. The EPA also funded research on the robustness of estimates from wage-risk and contingent valuation studies (Alberini 2004; Black, Galdo, and Lin 2003), as well as from studies of averting behavior (i.e., measures that individuals undertake to avoid or mitigate risks, such as the use of seat belts) (Blomquist 2004). The EPA subsequently convened a group of statisticians to

[4] *Circular A-4* generally requires that agencies report the results using two alternate discount rates (3 and 7 percent) and also report the undiscounted values over time.

address the use of meta-analysis (EPA 2006) and conducted a review of the literature on the relationship between life expectancy and the VSL (Dockins et al. 2006). The committee's review is ongoing, and its final report on the use of meta-analysis and adjustments for life expectancy is expected sometime in 2007.

Approaches Used by Other Agencies

Other agencies promulgate fewer economically significant rules that require valuing the risk of premature mortality. Between October 2003 and September 2005, four agencies (in addition to the EPA) prepared final rules with quantified health and safety benefits that were reviewed by the OMB (OMB 2005, 2006). These agencies included the Food and Drug Administration (FDA) and the Centers for Medicare and Medicaid Services (CMS) in the Department of Health and Human Services (HHS), as well as the National Highway Traffic Safety Administration (NHTSA) and the Federal Motor Carrier Safety Administration (FMCSA) in the Department of Transportation (DOT). An earlier review, covering the period between January 2000 and June 2004, reported similar patterns in agency promulgation of major health and safety rules (Robinson 2004).

The HHS Agencies (the FDA and the CMS)

The FDA does not provide formal internal guidance for economic analysis, but it applies a similar approach across many of its rules. For premature mortality, the agency often uses a VSL estimate of $5 million, without specifying a dollar year, and occasionally provides alternative estimates using higher or lower values (see, e.g., FDA 2003, 2004, 2005). This estimate is roughly in the middle of the $1 million to $10 million range cited in *Circular A-4* (OMB 2003).

The FDA rarely adjusts its VSL estimates for scenario differences, although it has addressed cessation lag (e.g., in its trans-fat rule, FDA 2003), and added the cost of cancer treatment ($25,000) and an adjustment for psychological factors ($5,000) to the VSL for a rule on X-rays (FDA 2005). Thus, while its base VSL estimates are similar to those used by the EPA, the values ultimately applied by the FDA may be quite different because of the income growth and other adjustments made by the EPA. A few FDA analyses have presented alternative estimates of the value of mortality risk reductions using VSLY as well as VSL estimates (e.g., FDA 2003).

However, VSLY estimates are a key component of the FDA's approach for valuing nonfatal risk reductions. The FDA first assesses the quality-adjusted life year (QALY) gains associated with reducing the risk of each nonfatal health condition, and then uses VSLY estimates to value each QALY. The FDA next adds medical costs to these monetized QALYs to determine the total benefits per statistical case of illness averted (see Institute of Medicine 2006 for more information). The FDA follows this process primarily because of the scarcity of WTP estimates for the health effects of concern.

In recent analyses (e.g., FDA 2003, 2004, 2005), the FDA has applied VSLY values ranging from about $100,000 to $500,000 per life-year. The low end of this range is based on estimates occasionally used in the health economics literature (see FDA 2003), while the higher values are derived from its VSL estimates using the same simple VSLY approach as described earlier.

Another HHS agency, the CMS, develops few economically significant rules with health and safety impacts; most of its programs involve transfers (e.g., from taxpayers to Medicare and Medicaid recipients) and hence are not subject to the OMB requirements for regulatory analysis. In its immunization rule (CMS 2005), the CMS applies the same VSL estimate as the FDA ($5 million), noting that it is roughly the mid-point of the range of values suggested by the OMB.

The DOT Agencies (the NHTSA and the FMSCA)

Both the NHTSA and the FMCSA rely on the DOT-wide guidance for their base VSL estimates. The DOT currently recommends the use of a $3.0 million VSL—noting that this value is imprecise and should be used as "a guide for thoughtful decision-making" (DOT 2002, p. 1). Its approach is based largely on the results of Miller (1990), with adjustments for inflation and newer studies. Miller's 1990 estimates vary from those used by the EPA because he applies different criteria to determine which studies to include, and adjusts the results to address certain limitations of the studies. The DOT indicates that it continues to review the literature and consider whether changes to this value are needed (DOT 2002).

In contrast to the EPA and the HHS agencies, these DOT agencies primarily address injury-related accidental deaths rather than deaths from illness. Hence, the scenarios they assess are in some respects more similar to the scenarios addressed by available VSL studies. The DOT agencies do not, however, adjust their values for relevant scenario differences (such as changes in real income over time) but instead add on certain costs that may not be reflected in the VSL estimates.

Both the NHTSA and the FMCSA adjust the DOT's base VSL estimate to reflect lost productivity and various types of expenditures, although the details of the adjustments vary slightly. Under the assumption that the VSL estimates include the expected loss of after-tax wages and household production (i.e., unpaid work in the home), the agencies first subtract estimates of these productivity losses from the base VSL estimate. They then add updated estimates of crash-related losses in market and household productivity as well as other expenditures, such as those related to medical treatment, emergency services, insurance administration, workplace disruption, and litigation (NHTSA 2002, Zaloshnja and Miller 2002). After these adjustments, the per victim value for fatal injuries becomes approximately $2.7 million to $3.3 million (depending on the type of crash) excluding property damage (2000 dollars). Each agency recalculates these adjusted estimates periodically and applies the results across subsequent analyses (see, e.g., FMCSA 2005, NHTSA 2005). In recent assessments, these agencies also include sensitivity analyses using higher values.

Similar to the FDA, these DOT agencies use VSLY estimates to determine the monetary value of QALY gains when addressing nonfatal (rather than fatal) risk reductions. However, the details of their approaches differ substantially, as described in Robinson (2004).

Summary and Conclusions

Current OMB guidance suggests that VSL estimates range from about $1 million to $10 million. Review of agency practices suggests that they generally use values that fall within this range. For example, the central tendency of the range of twenty-six estimates used in many EPA analyses is $7.2 million (2005 dollars), while the mean EPA estimate based on recent meta-analyses is $5.5 million (1999 dollars). The FDA generally uses an estimate near the middle of the range ($5 million, no dollar year reported), while the DOT has consistently applied a lower value ($3 million in recent guidance).

The EPA adjusts its base VSL estimates to reflect income growth over time and any time lags between the reduction in exposure and the reduction in incidence. In contrast, the FDA adjusts for these differences infrequently. The DOT agencies do not make these adjustments, but add other expenditures to VSL estimates. Adjustments for age have been a particularly contentious area, and the EPA has discontinued the practice of including these adjustments in sensitivity analyses in response to concerns about the equitable treatment of younger and older individuals in policy analysis.

This review leads to several conclusions. First, the value of reducing premature mortality risks has been relatively well studied. In contrast, analysis of the costs and benefits of major regulations requires that agencies address a number of other complex and difficult issues for which data may be more limited. For example, agencies may need to assess the risks to human health associated with contaminants whose effects are only partially understood, or determine the costs of industry compliance despite limited ability to foresee technological innovations. In comparison, the number of VSL studies is large and provides useful information on the possible range of values. However, more research is needed to address the specific scenarios reflected in federal regulations.

Second, experience with the debate over age adjustments suggests that it is difficult for agencies to ignore equity issues when valuing mortality risks. Economists often argue that benefit-cost analysis is best suited for assessing economic efficiency, and that it is preferable to address concerns related to equity and the distribution of impacts separately. While studies of individual WTP indicate that the VSL varies with age and income, using different VSL estimates for different segments of the population has led some observers to question the fairness of policy deliberations. As a result, federal agencies generally apply the same mean VSL estimates across all individuals potentially affected by their regulations—regardless of age, income, or other characteristics.

Third, the use of different VSL estimates across agencies could lead to different levels of investment in life-saving regulations if the quantified estimates of benefits and costs were the only factors considered by policy-makers. For example, if two agencies were each considering a regulation with identical costs and mortality risk impacts, the agency using the lower VSL estimate might select a less costly option. In theory, the risks addressed by different agencies could have different monetary values due to variation in the nature of the risks and the populations affected. In reality, the differences across agencies appear instead to reflect variation in their approaches to addressing limitations in the available VSL research.

Finally, it is difficult to determine how the choice of a VSL estimate influences regulatory decisions, in part because many decisions are made at the same time that the analysis is undergoing review and revision. Although regulatory decisions are rarely based solely on the results of economic analyses, the variation in values argues for careful assessment and presentation of the uncertainty in the VSL estimates used throughout the regulatory development process.

Appendix Table A1 Selected characteristics of VSL studies used by the EPA (1990 dollars)

Study	Mean VSL estimate	Population studied	Valuation method	Average age of sample	Average income of sample	Type of risk	Mean risk
Kniesner and Leeth (1991)	$0.6 million	US manufacturing workers	Wage-risk	37 years	$26,226	Job-related	40/100,000
Smith and Gilbert (1984), based on Smith (1983)	$0.7 million	US metropolitan area workers	Wage-risk	NR	NR	Job-related	NR
Dillingham (1985)	$0.9 million	US workers	Wage-risk	36 years	$20,848	Job-related	10/100,000
Butler (1983)	$1.1 million	S. Carolina workers	Wage-risk	NR	NR	Job-related	5/100,000
Miller and Guria (1991)	$1.2 million	New Zealand residents	Contingent valuation	NR	NR	Road safety	NR
Moore and Viscusi (1988)	$2.5 million	US workers	Wage-risk	37 years	$19,444	Job-related	5/100,000
Viscusi, Magat, and Huber (1991)	$2.7 million	US residents	Contingent valuation	33 years	$43,771	Auto accidents	1/100,000
Marin and Psacharopoulos (1982)	$2.8 million	UK workers	Wage-risk	NR	$11,287	Job-related	10/100,000
Gegax, Gerking, and Schulze (1991)	$3.3 million	US workers	Contingent valuation	NR	NR	Job-related	70/100,000
Kneisner and Leeth (1991)	$3.3 million	Australian manufacturing workers	Wage-risk	NR	$18,177	Job-related	10/100,000
Gerking, de Haan, and Schulze (1988)	$3.4 million	US workers	Contingent valuation	NR	NR	Job-related	NR
Cousineau, Lacroix, and Girard (1992)	$3.6 million	Canadian workers	Wage-risk	NR	NR	Job-related	1/100,000
Jones-Lee (1989)	$3.8 million	UK residents	Contingent valuation	NR	NR	Auto accidents	NR
Dillingham (1985)	$3.9 million	US workers	Wage-risk	36 years	$20,848	Job-related	8/100,000
Viscusi (1978, 1979)	$4.1 million	US workers	Wage-risk	40 years	$24,834	Job-related	10/100,000
Smith (1976)	$4.6 million	US workers	Wage-risk	NR	NR	Job-related	10/100,000
Smith (1983)	$4.7 million	US workers	Wage-risk	NR	NR	Job-related	NR
Olson (1981)	$5.2 million	US workers	Wage-risk	37 years	NR	Job-related	10/100,000
Viscusi (1981)	$6.5 million	US workers	Wage-risk	NR	$17,640	Job-related	10/100,000
Smith (1974)	$7.2 million	US workers	Wage-risk	NR	$22,640	Job-related	NR
Moore and Viscusi (1988)	$7.3 million	US workers	Wage-risk	37 years	$19,444	Job-related	8/100,000
Kniesner and Leeth (1991)	$7.6 million	Japanese manufacturing workers	Wage-risk	NR	$34,989	Job-related	3/100,000
Herzog and Schlottmann (1990)	$9.1 million	US manufacturing workers	Wage-risk	NR	NR	Job-related	NR
Leigh and Folson (1984)	$9.7 million	US workers	Wage-risk	NR	$27,693	Job-related	10/100,000
Leigh (1987)	$10.4 million	US workers	Wage-risk	NR	NR	Job-related	NR
Garen (1988)	$13.5 million	US workers	Wage-risk	NR	NR	Job-related	NR

Sources: Derived from EPA (1997), table I-1, and Industrial Economics Incorporated (2001), exhibit 4-2. Average income and risk level are based on Viscusi (1993), tables 2 and 6, and additional review of the individual studies.

Notes: 1990 dollars. "NR" indicates "not reported;" however, many of these studies are based on data sources that are similar to those for which these variables are reported.

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