

The Effect of Income on the Value of Mortality and Morbidity Risk Reductions

Review Draft

June 29, 2015

Prepared by:

Lisa A. Robinson, Harvard University (Center for Risk Analysis)
(lisa.a.robinson@comcast.net)

James K. Hammitt, Harvard University (Center for Risk Analysis)
and Toulouse School of Economics (LERNA)
(jkh@harvard.edu)

Prepared for:

Neal Fann
Office of Air and Radiation
U.S. Environmental Protection Agency

Under subcontract to:

Industrial Economics, Incorporated
2067 Massachusetts Avenue
Cambridge, MA 02140
Contact: James E. Neumann, Principal
(jneumann@indecon.com)

ACKNOWLEDGEMENTS

This report was drafted by Lisa A. Robinson and James K. Hammitt under subcontract to Industrial Economics, Incorporated (IEc) for the U.S. Environmental Protection Agency (EPA) (Contract No. EP-D-14-032, Work Assignment No. 0-02). The report builds on research IEC completed in 2012 for EPA. The IEC Project Director is James E. Neumann; Lindsay Ludwig is providing substantial technical assistance. The EPA Work Assignment Manager is Neal Fann. In addition to those listed above, we thank Chris Dockins, Bryan Hubbell, Amy Lamson, and Nathalie Simon of EPA for their detailed review and insightful comments on earlier drafts.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	2
EXECUTIVE SUMMARY	4
1.0 INTRODUCTION.....	5
1.1 Background	5
1.2 Conceptual Framework	7
2.0 INCOME ELASTICITY FOR MORTALITY RISK VALUATION	11
2.1 Selection Criteria.....	11
2.2 Literature Review Results	18
2.3 Options for Application in EPA Analyses	23
3.0 INCOME ELASTICITY FOR MORBIDITY RISK VALUATION	25
3.1 Selection Criteria.....	25
3.2 Literature Review Results	26
3.3 Options for Application in EPA Analyses	28
4.0 PAST AND FUTURE REAL INCOME GROWTH	30
4.1 Sources of Data	30
4.2 Options for Application in EPA Analyses	34
5.0 SUMMARY AND CONCLUSIONS	36
REFERENCES.....	38

EXECUTIVE SUMMARY

When calculating the benefits of regulations and other policies, the U.S. Environmental Protection Agency (EPA) relies on estimates of individual willingness to pay (WTP) to the extent possible, consistent with the economic theory that forms the foundation for benefit-cost analysis. For mortality and morbidity risk reductions, these values are generally expressed as the value per statistical case (VSC), referred to as the value per statistical life (VSL) for mortality risks.

Because both theory and empirical evidence suggest that individual WTP will increase with real income, EPA requires an approach to adjust these values to reflect income changes over time. This adjustment involves two inputs: an estimate of the change in value associated with a change in real income (the income elasticity), and an estimate of the change in real income. The approach currently used by EPA was initially developed in 1999; this report builds on a series of reviews completed since that time. These include several reviews of the valuation and income elasticity literature conducted by Industrial Economics, Incorporated and other members of the project team, as well as a 2011 EPA Science Advisory Board review of EPA's approach for estimating the VSL.

This report provides the results of a new criteria-driven review of the income elasticity literature and suggests options for updating EPA's approach. Our starting point is criteria developed for selecting studies to estimate the VSL, building on the 2011 Science Advisory Board report and more recent research. We adapt these criteria to reflect the goals of this project, then apply them to identify relevant studies that either report income elasticities or provide the data necessary to easily derive them. We use more stringent criteria for the mortality risk valuation studies than for the morbidity risk valuation studies, because the mortality risk valuation literature is substantially larger and more well-developed. As a result, the results for morbidity risks are less certain.

For mortality risks, we find one wage-risk study, five stated preference studies, and one meta-analysis that meet most or all of our criteria. These studies provide elasticities ranging from zero to 1.4. For morbidity risks, we find five individual studies that meet our less stringent criteria, providing elasticities ranging from close to zero to 1.1.

This report suggests options for using these results to estimate income elasticities for mortality and morbidity risk reductions, as well as data sources that can be used to estimate past and potential future real income growth. These options include using the results of the full range of studies, or focusing on those studies that appear to provide the most useful results. Each option involves some advantages and limitations, suggesting that whichever is selected should include an approach for assessing the effects of uncertainty.

1.0 INTRODUCTION

When calculating the benefits of regulations and other policies, the U.S. Environmental Protection Agency (EPA) relies on estimates of individual willingness to pay (WTP) to the extent possible, consistent with the economic theory that forms the foundation for benefit-cost analysis. For mortality and morbidity risk reductions, WTP for a reduction in the risk of an adverse health effect is generally expressed as the value per statistical case (VSC), referred to as the value per statistical life (VSL) for mortality risks.

Because both theory and empirical evidence indicate that individual WTP is likely to increase with real income, EPA requires an approach for adjusting these values to reflect income changes over time.¹ This adjustment involves two inputs: an estimate of the change in the VSC associated with a change in real income (the income elasticity), and an estimate of the change in real income. This report reviews the literature and discusses options for updating EPA's estimates of both inputs.

In this introductory chapter, we provide background information and describe the conceptual framework for these adjustments. In the following chapters, we discuss the available estimates of income elasticity, focusing first on the value of mortality risk reductions and then on the value of morbidity risk reductions. Each chapter describes the criteria we use to select studies, identifies the studies that meet our selection criteria, and discusses options for estimating elasticities for use in EPA analyses. The fourth chapter discusses approaches for estimating past and future changes in real income. The final chapter summarizes our results and conclusions.

1.1 Background

This report builds on previous updates of EPA's income adjustment factors prepared by Industrial Economics, Incorporated (IEC) for EPA's Office of Air and Radiation (OAR) (Kleckner and Neumann 1999, Kleckner and Neumann 2000, Neumann and Brennan 2004, and Ludwig and Neumann 2012). Each update reflects new research evidence as well as advice from a series of expert panels, as described in more detail in Ludwig and Neumann (2012).² In particular, this report reflects our evolving understanding of "best practices" as well as recent research results, building on an EPA White Paper that addresses the value of mortality risk reductions (EPA 2010) and a review of that paper by the EPA Science Advisory Board Environmental Economics Advisory Committee (SAB-EEAC) (Kling et al. 2011).

¹ Changes in "real" income reflect the change in purchasing power, net of the effects of inflation.

² The 2012 update has not yet been peer reviewed; prior to initiating that review, EPA decided to commission the update contained in this report to ensure full consideration of newly emerging evidence. The work completed by Ludwig and Neumann in 2012 remains relevant and is incorporated into this report.

As noted in EPA’s *Guidelines for Preparing Economic Analyses* (2014, p. B-4), for mortality risk reductions EPA currently uses elasticities derived from IEc’s 1999 review, which was developed to support estimates of the benefits and costs of the Clean Air Act.³ More detail on EPA’s approach for both mortality and morbidity risk reductions is provided in the documentation for the model OAR uses to estimate health-related benefits – the Environmental Benefits Mapping and Analysis Program (BenMAP) (EPA 2015). Other EPA program offices use the same approach in their analyses.

The first input into the income adjustment is an estimate of the income elasticity of WTP to reduce the risk of adverse health effects. Because this elasticity may depend on the duration and severity of the effects as well as other factors, EPA currently relies on three sets of elasticity estimates: one for nonfatal risks associated with acute (minor) health conditions, one for nonfatal risks associated with chronic (more severe) health conditions, and a third for fatal risks. Each set of factors includes “high” and “low” values as well as a central estimate. The values currently provided in EPA’s BenMAP model and used throughout the Agency are provided in Table 1.1; the notes indicate the air pollution-related health conditions BenMAP currently includes in each category.

Table 1.1. Current BenMAP Income Elasticity Estimates

Health Endpoint	Low Estimate	Central Estimate	High Estimate
Minor Health Effect ^a	0.04	0.15	0.30
Severe and Chronic Health Effects ^b	0.25	0.45	0.60
Premature Mortality ^c	0.08	0.40	1.00
Source: EPA (2015), Table 4-13, p. 4-60.			
Notes:			
(a) Includes asthma exacerbation, acute bronchitis, acute respiratory symptoms (minor restricted activity days), lower respiratory symptoms, and upper respiratory symptoms.			
(b) Includes chronic bronchitis and chronic asthma.			
(c) Often characterized as a triangular distribution with a resulting mean estimate of approximately 0.48.			

As described in Kleckner and Neumann (1999), the elasticity estimates for nonfatal effects reflect the range from eight studies published between 1975 and 1997, including three stated-preference surveys, two studies of risk-averting behaviors, and three studies that model the demand for health care. For mortality, the values are based on the range from seven stated-preference studies and two literature reviews published between 1979 and 1998. These studies reflect data collected over 20 years ago, which are not likely to reflect current conditions. In addition, as discussed later in this report, the data and methods available, as well as the standards for best practices, have since evolved significantly, and many additional studies have now been completed.

³ Although the *Guidelines* cite the 2000 review, the elasticities it reports are from the 1999 review.

The second input into the income adjustment is an estimate of real income growth. Two time frames are relevant: an historical period that reflects the time that has elapsed between when the study data were originally collected and the base year for the analysis, and a projection period that reflects the time that will elapse between the analytic base year and each year for which impacts are estimated.⁴ The projection period, for example, would be relevant for an analysis completed in 2015 which may provide values expressed in 2014 dollars but estimate policy impacts over the next 20 or 30 years.

The BenMAP documentation does not discuss how OAR estimates changes in real income over previous years. However, EPA generally relies on estimates of per-capita gross domestic product (GDP) calculated using population estimates from the U.S. Census Bureau and real GDP estimates from the Bureau of Economic Analysis (BEA). For future years, BenMAP currently relies on Standard and Poor's projections of GDP changes occurring after the year 2010 (EPA 2015, p. 4-60).⁵ The projected change in GDP is divided by the Woods and Poole projected change in the total U.S. population to estimate future GDP per capita.⁶ Other EPA offices generally follow this same procedure in their economic analyses.

1.2 Conceptual Framework

Of the two inputs needed to adjust the value of mortality and morbidity risk reductions for changes in real income, income elasticity is the more difficult to estimate. It requires considering the appropriate functional form of the relationship between WTP and income, related theory, and available empirical evidence. In contrast, estimating the change in real income simply requires selecting among the available income measures and related data sources. Thus in this section, we focus on introducing the framework for estimating income elasticity; approaches for estimating real income growth are described in Chapter 4.

Income elasticity measures the proportional change in WTP for an outcome (e.g., a 1 in 10,000 annual change in mortality risk) associated with a small proportional change in income (e.g., one percent).⁷ It does not measure the extent to which a richer person may reduce his or her mortality

⁴ We use the term "base year" to refer to the most recent year for which data on actual growth in real income are available, which will generally be the year prior to the year in which the analysis is conducted. In many cases, the dollar year used in the analysis will be the same as this base year. For example, for an analysis conducted in 2015, the analyst would inflate all values to 2014 and also adjust for reported changes in real income through 2014. For years 2015 and beyond, the analysis would be conducted in real dollars, with adjustment for expected changes in real income but not for inflation.

⁵ From the documentation, it appears that the BenMAP model has not been updated to reflect actual rather than projected GDP per capita growth after 2010 (EPA 2015).

⁶ See <http://www.woodsandpoole.com/pdfs/CED12.pdf> for more information.

⁷ Income elasticity is often described as the percentage change in WTP associated with a one percent change in income. This definition is potentially misleading, however, because the elasticity may depend on the income change over which it is calculated.

or morbidity risk by more than a poorer person through investing in additional risk-reducing measures. That is, it measures the change in the *price* an individual is willing to pay, not the change in the *quantity* of risk reduction he or she is willing to purchase.

As noted earlier, individual WTP for morbidity or mortality risk reductions is generally expressed as the VSC (or VSL) in benefit-cost analysis. Calculating the change in the VSC associated with a change in real income requires an estimate of the elasticity over the income range considered. In BenMAP and other EPA applications, the VSC is adjusted for year-to-year changes in population-average real income, not for differences across population subgroups. This annual change is small (typically less than two percent per year) in comparison to the cross-sectional income differences within the population at a particular point in time.

Given this relatively small rate of year-to-year change, it seems reasonable to assume that the applicable income elasticity will be constant over time as well as across income levels. This assumption leads to the following formula:

$$VSC_b = VSC_a * (\text{income}_b / \text{income}_a)^{\text{elasticity}}$$

where “a” and “b” represent different years, and income is expressed in real terms (excluding the effects of inflation).

Whether elasticities vary significantly for different types of health effects is unclear. The observed differences across the relatively few empirical studies available may at least in part reflect sources of variation (and uncertainty) attributable to factors other than income. Some of these factors relate to study design and implementation; others relate to the difficulties inherent in controlling for the myriad risk and individual characteristics that affect individual WTP.

Although the relationship between WTP and income has been investigated previously, we are not aware of a detailed theoretical exploration of either the extent to which income elasticity may differ between fatal and non-fatal effects or the extent to which it may differ across non-fatal effects of varying severities and durations. Previous work generally focuses on environmental improvements or mortality risk reductions rather than morbidity, and centers on issues such as whether income elasticity is greater than 1.0 (i.e., whether WTP increases at a faster rate than income), the extent to which income elasticity explains observed discrepancies between WTP and willingness to accept compensation (WTA), and the relationship of income elasticity to financial risk aversion.⁸

⁸ See, for example, Flores and Carson (1997), Hammitt, Liu, and Liu (2000), Eeckhoudt and Hammitt (2001), Horowitz and McConnell (2003), Costa and Kahn (2004), and Kaplow (2005).

Applying different elasticities to different health effects implies that the relative values of the effects will shift over time. For example, applying a larger elasticity for mortality risk reductions than for morbidity risk reductions means that the value of the former will grow at a faster rate than the latter. However, because fatal and non-fatal outcomes differ in several dimensions, there is no reason to assume that the income elasticities are identical. One potential reason for variation may be the relationship to earnings. While death generally eliminates future earnings (excluding, for instance, royalties), non-fatal effects will have varying impacts. Health conditions of greater severity and duration are more likely to limit participation in one's usual activities, and may more significantly affect employment and earnings. Hence an individual's WTP to avert chronic risks may be more sensitive to income than WTP for acute effects. The effects on nonmarket production and leisure time as well as other factors may also influence the relationship between WTP and income.

Other issues relate to the design of the valuation studies themselves. For example, some stated-preference studies elicit a one-time payment to avert an episode of short duration (such as an asthma exacerbation), while others elicit an annual payment to reduce the risk of chronic illness. Respondents may pay less attention to their budget constraint when answering questions about the former than the latter. The same is true if the valuation scenario is designed to elicit larger payments for other reasons (such as for a very large reduction in risk). Respondents may become more cognizant of the effect of the payment on their ability to buy other goods and services as the amount becomes a more significant proportion of their total budget, influencing the extent to which the WTP they report is affected by their income.

Given the lack of well-developed theoretical expectations, we rely on empirical research to explore these elasticities. We first search the literature for potentially relevant studies then assess them for quality and applicability, following a four step process.

- 1) Develop criteria for selecting high quality, suitable valuation studies, where "quality" refers to adherence to generally accepted best practices for data collection and analysis, and "suitability" refers to the match between the populations and risks studied and the populations and risks addressed in EPA analyses.
- 2) Identify potentially relevant studies, by searching bibliographic databases, previous literature reviews, and reference lists, and contacting leading researchers.⁹
- 3) Evaluate these studies against the criteria developed under step 1, and report the income elasticity estimates provided by each study that meets the selection criteria.

⁹ We exclude studies that do not report income elasticity and that do not report data from which this elasticity can be easily calculated.

- 4) Suggest alternative approaches for developing income elasticity estimates for application by OAR and other EPA program offices.

Because the value of morbidity risk reductions is less well-studied than the value of mortality risk reductions, our implementation of these steps varies depending on the type of risk reduction considered. We discuss the process and results for mortality risk reductions in Chapter 2 and for morbidity risk reductions in Chapter 3. Chapter 4 then discusses approaches for estimating changes in real income over time, and Chapter 5 summarizes our findings and conclusions.

2.0 INCOME ELASTICITY FOR MORTALITY RISK VALUATION

The value of mortality risk reductions is relatively well-studied and has been the subject of many previous analyses and reviews. As a result, we are able to build on past work to develop selection criteria, select potentially relevant studies, and derive recommendations, as described below.

2.1 Selection Criteria

Our starting point is criteria previously developed for selecting studies to value mortality risk reductions, commonly referred to as the VSL. The VSL is the marginal rate of substitution between money and mortality risk in a defined time period, typically calculated by dividing an individual's WTP for a small change in his or her own mortality risk by the risk change. For example, if an individual is willing to pay \$900 for a 1 in 10,000 change in risk of dying this year, then that person's VSL is \$9.0 million ($= \$900 \div 1/10,000$). The same approach can be used to estimate the VSC for changes in nonfatal risks. The resulting estimates are not the value of saving an individual's life, or preventing a case of illness, with certainty. Rather, a "statistical life" or a "statistical case" is the sum of small risks across many individuals. The key measure is individual WTP for a reduction in one's own risk; the estimates are reported per statistical case by convention.¹⁰

Previous reviews suggest that the number of VSL studies conducted globally is approaching 200.¹¹ Because mortality risk reductions often account for a large fraction of the quantified benefits of environmental, health, and safety regulations, substantial attention has been paid to developing criteria for evaluating study quality and applicability. Related work pertinent to U.S. regulatory analyses includes EPA's White Paper on valuing mortality risk reductions (EPA 2010), the SAB-EEAC review of that paper (Kling et al. 2011), a recent update of the U.S. Department of Transportation's (DOT's) VSL guidance (DOT 2014), and a review conducted for the U.S. Department of Health and Human Services (HHS) (Robinson and Hammitt 2015).

Despite the growing number of studies, relatively few address illness-related risks from environmental or other causes. The 2011 SAB-EEAC report emphasizes the need to tailor VSL estimates to the characteristics of the risks and of the populations affected. This suggests that EPA should focus on studies that address illness-related risks from environmental causes (e.g., air pollution), and that address the population subgroups most likely to be affected by a particular policy or regulation (e.g., the elderly, those with pre-existing health conditions, those who live in more polluted areas). However, in a recent review that applies criteria derived from the SAB-EEAC report and related work, we found that the VSL literature is not yet well-enough

¹⁰ Because the term "VSL" is often misinterpreted as the "value of a life," some have proposed replacing it with the "value of mortality risk" (VMR) or the "value of risk reduction" (VRR) (see, for example, Cameron 2010, Kling et al. 2011).

¹¹ See Viscusi and Aldy (2003), EPA (2010), Lindhjem et al. (2011), and Viscusi (2015).

developed to support such differentiation (Robinson and Hammitt 2015). Thus we include studies that address both injury-related and illness-related risks in developing income elasticity estimates, regardless of whether the cause is environmental, and focus on studies that provide estimates for the general U.S. population rather than for subgroups that may be disproportionately affected by some policies.

As discussed in more detail below, although the criteria we use in this report build on the criteria recommended in the SAB-EEAC report, they are not identical. Some differences reflect the differing goals of each report. The 2011 SAB-EEAC report (and the underlying EPA 2010 White Paper) focuses on `developing estimates of the VSL itself, whereas we focus on income adjustments for application to the VSL estimates currently applied by EPA (provided in EPA 2014).¹² Other differences relate to the evolution of the literature, which has provided additional insights into some of the issues discussed by the SAB-EEAC.

The criteria applied in this report are summarized in Table 2.1. Below, we explain the rationale for each criterion, noting where these criteria differ from those suggested in the 2011 SAB-EEAC review. In most cases (such as determining whether a study is published in English), application of these criteria is straightforward; whether a particular study meets the criterion involves a clear “yes/no” determination. In other cases, more judgment is needed. These latter cases include determining whether the study is adequately representative, controls appropriately for confounding factors, and provides sufficient evidence of validity (Criteria 3, 6, and 10 below). For a few studies, making such judgments is particularly difficult. In these cases, we include the studies that arguably do not meet our criteria in presenting our results, describe their advantages and limitations, and discuss the implications of omitting them. Throughout this process, we reject studies that do not report estimates of income elasticity nor provide the data needed to easily calculate such elasticities.

¹² The SAB notes that “[c]onsistent with its recommendations on VRR [value of risk reductions], the SAB recommends that EPA attempt to characterize the distribution of income elasticity and how it varies with risk and individual characteristics using one or more of the approaches described for characterizing VRR.” (Kling et al. 2011, p. 21)

Table 2.1. Selection Criteria for Value of Mortality Risk Reduction Studies

<p>General Criteria</p> <ol style="list-style-type: none"> 1. Be written in English. 2. Be publicly available. 3. Based on a sample of the general U.S. population. <p>Criteria for Revealed-Preference Studies</p> <ol style="list-style-type: none"> 4. Use hedonic methods that address the trade-off between wages and job-related risks. 5. Rely on high-quality risk data, equal or superior to the Census of Fatal and Occupational Injuries. 6. Control for potentially confounding factors, such as nonfatal injury risk as well as both industry and occupation. <p>Criteria for Stated-Preference Studies</p> <ol style="list-style-type: none"> 7. Elicit values for private risk reductions that accrue to the respondent. 8. Express the risk change as a probability, not as life extension. 9. Estimate willingness to pay, not willingness to accept compensation. 10. Provide evidence of validity, including sensitivity of willingness to pay to changes in risk magnitude.
--

General Criteria: These criteria relate to the context in which the income elasticity estimates are likely to be applied. Because EPA’s analyses are intended to inform decision-makers and the general public, those reviewing the analyses must be able to access and read the underlying data sources. Criterion 1, “be written in English,” directly relates to this accessibility and is consistent with the SAB-EEAC recommendations (Kling et al. 2011, p. 15).

Criterion 2, “be publicly available,” is somewhat broader than the criteria suggested by the SAB-EEAC, who suggest limiting the search to the peer-reviewed literature. However, the SAB-EEAC also notes that unpublished studies may have some advantages, particularly because they provide more recent results and may incorporate methodological improvements (Kling et al. 2011, p. 20). Thus we include publicly-accessible working papers and reports as well as peer-reviewed articles for two reasons. First, most studies currently available as working papers will be published in the near future, and ignoring them excludes the most up-to-date research, as recognized by the SAB-EEAC. Second, the factors considered by referees for peer-reviewed journals may differ in some respects from the factors of interest for policy analysis. For example, journals are often concerned about innovation and may accept exploratory work based on non-representative samples, whereas we are interested in best practices that are likely to lead to valid and reliable results for the U.S. population. This means that some studies that are suitable for our needs may not be accepted for publication. We note the publication status of the papers in presenting our results; most have now been published.

Criterion 3, “based on a representative sample of the general U.S. population,” reflects EPA’s interest in developing estimates for application in analyses of regulations and other national

policies, which typically affect the general population.¹³ We select studies that rely on probability samples of the adult U.S. population, rather than convenience samples or samples of small local areas. We exclude studies that address adult WTP to reduce risks to children, because the VSL estimates to which EPA applies these elasticities reflect adult WTP for reductions in their own risks (see EPA 2014). The available studies do not use consistent definitions of “adult,” however. For example, some include older teens, and some exclude adults above typical retirement age. Where the sample frame is national, but the extent to which the study is “adequately” representative is particularly questionable (e.g., because it is restricted to a very narrow age range or includes only men), we list the study in our results and note its limitations and the implications of including or excluding it.

Criteria for revealed-preference studies: For studies that rely on market behavior to estimate the VSL, under Criterion 4 we limit the scope to those that consider the trade-off between compensation and job-related risks, controlling for influencing factors. Some revealed-preference studies instead evaluate averting behaviors; i.e., defensive measures or consumer products used to protect against perceived risks. These studies are applied infrequently in policy analysis due to concerns about their limitations, such as difficulties in estimating the magnitude of the risk change and the need to separately estimate the value of key inputs such as the time spent in the activity (see Viscusi and Aldy 2003 and Blomquist 2004 for reviews).¹⁴ Thus we exclude averting behavior studies from consideration. This criterion is implicit in the SAB-EEAC 2011 review, which does not address averting-behavior studies.

Under Criterion 5, we limit the studies to those that rely on risk data at least as good as the Census of Fatal Occupational Injuries (CFOI). The CFOI was implemented in 1992 by the Bureau of Labor Statistics (BLS), and is based on review of a comprehensive set of records supplemented by additional confirmation of the data.¹⁵ Thus it represents a substantial improvement over the data sources previously available. This criterion is consistent with the SAB-EEAC recommendations (Kling et al. 2011, p. 19).¹⁶

¹³ As discussed earlier, the SAB-EEAC (Kling et al. 2011, pp. 14-18) notes that ideally the studies would address the specific population affected by each policy; however, the VSL literature is not yet well-enough developed to support such differentiation. This criterion excludes wage-risk studies based on extremely dangerous jobs or specific causes of death, as the SAB-EEAC recommends. In discussing sampling issues, the SAB-EEAC also suggests developing a criterion that reflects the precision of the estimate. Rather than express this as a selection criterion, we provide information on standard errors when summarizing the results from the selected studies.

¹⁴ Similar concerns affect the use of studies that consider the relationship between property values and mortality risks.

¹⁵ See Viscusi (2004) and Viscusi (2013) for more detailed discussion of the advantages of the CFOI in comparison to other data sources. Although both our criterion and the criterion recommended by the SAB-EEAC allow for use of other data sources that are equivalent to or better than the CFOI, we are not aware of another national U.S. data source that currently meets this standard.

¹⁶ This criterion excludes studies based on Society of Actuaries data as recommended by the SAB-EEAC (Kling et al. 2011, p. 17).

Criterion 6, related to controls for potentially confounding factors, requires some judgment. Consistent with the SAB-EEAC (Kling et al. p. 18) we consider whether the study addresses nonfatal injury risks and controls for both industry and occupation, as well as other potentially important confounding factors. Given the number of factors that can influence the relationship between wages and risks, there is no clear dividing line between studies that do, and do not, provide sufficient controls (see Cropper Hammitt and Robinson 2011 and Viscusi 2015 for more discussion). Thus we describe the characteristics of the models used in presenting the results for the wage-risk studies.

Note that many wage-risk studies do not provide income elasticities. This literature is dominated by cross-sectional studies that compare workers across industries and/or occupations at a particular point in time, and use the wage rate as the dependent variable. For elasticity, a model specification is needed that instead predicts WTP based on income and other variables. Depending on functional form, the coefficient on income can then be used to estimate elasticity. Generally, longitudinal studies or meta-analysis are needed to distinguish differences in income and in risk to estimate income elasticity. In evaluating the available meta-analyses as well as individual studies, we consider whether they address the study characteristics discussed above, either by using them as selection criteria or by controlling for them in the modelling.¹⁷

Criteria for stated-preference studies: For studies that rely on surveys, under Criterion 7 we select those that elicit individual WTP for reductions in the respondent's own risks.¹⁸ We exclude studies that instruct the respondent to consider risk reductions that accrue to the community of which he or she is a part, or that elicit the respondent's WTP for risk reductions that accrue to others. This criterion addresses the framing of the WTP questions, not the characteristics of the risk-reducing program described in the survey. The risk reduction may result from a government program or a private good; what matters is whether the respondent is instructed to only consider his or her own risks in answering the WTP questions.

This criterion reflects issues related to both the conceptual framework for benefit-cost analyses and the limitations of the available research. As conventionally conducted, benefit-cost analysis is based on the principle of consumer sovereignty, which assumes that each individual is the best judge of his or her own welfare. This principle means that benefit values should be based on the preferences of those affected for changes in their own risks.

The treatment of altruism in such analyses raises difficult questions, as recognized by the SAB-EEAC (Kling et al. 2011, pp. 2, 12-13). The implications depend on whether it is pure (non-

¹⁷ Study selection has been a major concern in expert panel reviews of VSL meta-analyses (EPA 2006, Cropper et al. 2007, and Kling et al. 2011).

¹⁸ This criterion is implicit in the criteria for revealed preference studies, because the focus on wage-risk studies means that all of the selected studies address an individual's willingness to trade-off changes in earnings for changes in his or her own risks.

paternalistic) or paternalistic. A pure altruist would care about how those affected value the costs imposed on them as well as the benefits they receive, while a paternalistic altruist cares only about some aspects of others' well-being (Jones-Lee 1991, Bergstrom 2006). Generally, it is not appropriate to include purely altruistic WTP to reduce risk to others in benefit-cost analysis, unless one also counts the altruistic losses associated with the costs they bear. Including WTP that reflects paternalistic motives may be more acceptable. However, more work is needed to distinguish between pure and paternalistic altruism in conducting empirical research.

This criterion is narrower than the criteria suggested by the SAB-EEAC, which indicate that EPA should include studies of both public and private risk reductions when estimating the VSL (Kling et al. 2011, pp. 2, 12-13). One reason for narrowing the focus is the above concerns about the difficulty of distinguishing between pure and paternalistic altruism in empirical work. Another is concerns about the results of recent empirical research. In particular, some studies find (counterintuitively) that WTP for a private risk reduction is higher than WTP for a public program that also affects others (see, for example, the reviews in Svensson and Johannson 2010 and Lindhjem et al. 2011). This finding suggests that respondents may not understand or accept the scenario presented by the researchers; for instance, they may not believe that the public program will be effective. More research is needed to resolve these issues and address concerns about the validity of the results.

Under Criterion 8, we also limit our selection of stated-preference studies to those that express the risk change as a probability (or frequency) rather than as life extension. We are aware of only one U.S. study (Morris and Hammitt 2001) that directly elicits values for life extension.¹⁹ While it suggests that the life extension approach is promising, more work is needed, in particular to ensure that respondents understand that the risk reduction affects each year of life rather than adding time at the end of the life when one's quality of life is likely to have declined. While not explicitly discussed in the 2011 SAB-EEAC report, this criterion is consistent with the recommendations of an earlier SAB report (Cropper et al. 2007) as well as a National Academies study commissioned by EPA (National Academies 2008), which each address the limitations of the available value per statistical life-year (VSLY) research.

Criterion 9 requires that stated-preference studies elicit WTP rather than WTA, consistent with the SAB-EEAC recommendations (Kling et al. 2011, p. 16).²⁰ Because government policies and regulations typically involve expenditures for improvements from the status quo rather than compensation for damages, WTP is conceptually the more appropriate measure. WTP is also

¹⁹ We focus here on primary research, not on the common practice of deriving a value per statistical life year (VSLY) from a VSL estimate using simple assumptions about the relationship between the VSL and life expectancy.

²⁰ This criterion primarily affects the selection of stated-preference studies because revealed preference studies typically address a market equilibrium rather than a change that can be characterized as WTP or WTA. However, Kniesner, Viscusi, and Ziliak (2014) find that there is not a significant divergence between WTP and WTA when estimated using revealed preferences for job-related risks.

more frequently studied and the estimates are generally considered more reliable; the large and variable differences between estimated WTP and WTA are poorly understood (Horowitz and McConnell 2002, Tuncel and Hammitt 2014).²¹

Finally, under Criterion 10, we require that stated-preference studies provide evidence of validity, consistent with the discussion in the SAB-EEAC report (Kling et al. 2011, pp. 5-6, 16). A major concern is that respondents may not report their true WTP because the payment is hypothetical. In addition, research suggests that survey respondents often do not understand small probabilities. Thus we focus in particular on scope tests that indicate whether estimated WTP is sensitive to the magnitude of the risk reduction. Economic theory suggests that WTP should increase almost proportionately to the size of the risk change, as long as WTP is a small proportion of income (see Hammitt and Graham 1999, Corso, Hammitt, and Graham 2001). This means that the VSL will be relatively constant as long as the risk change is small enough that income does not significantly constrain WTP.

Scope tests are important for two reasons. First, sensitivity to scope has long been a concern in stated preference research (see, for example, National Oceanic and Atmospheric Administration 1993), and the inclusion of such tests is generally considered to be a component of best practices as discussed in the SAB-EEAC report. Thus the use of a scope test is both a direct indicator of the extent to which respondents understand the scenario and an indirect indicator of the extent to which the researchers understand the importance of addressing this concern.

Second, the common practice of applying the same VSL (and VSC) regardless of the size of the risk change (as long as the change is small) relies on this assumption of proportionality. If, for example, a study finds that a 1 in 10,000 risk change is valued at \$900 and a 1 in 100,000 risk change is valued at \$90, then the same VSL (\$9 million) results in both cases. If the smaller risk change is instead valued at \$200, then the associated VSL would be \$20,000,000. In that case, if the analyst is persuaded that the respondents understood the risk change (and that theoretical expectations are incorrect), then he or she would need to apply different VSL estimates for risks of different sizes – a significant departure from well-established and widely-used current practices.

It seems more likely that respondents find it difficult to understand these small risk changes, and that inadequate sensitivity of WTP to risk magnitude (and hence the difference in the estimated VSL) results from this lack of comprehension. This suggests that studies that do not demonstrate sufficient sensitivity to scope should be excluded when developing estimates for policy analysis. We select only those studies that (1) include an internal or external scope test, and (2) find that WTP is at least somewhat sensitive to the change in risk, highlighting those that find that the

²¹ While standard economic theory suggests that WTP and WTA will be similar in many cases, prospect theory suggests that the endowment effect and loss aversion may lead to substantial differences.

change in WTP is close-to-proportionate to the risk change as demonstrating particularly strong evidence of validity.²²

As is the case for the revealed preference studies, we apply the same criteria to the available stated preference meta-analyses as to the individual studies, considering whether the meta-analyses use these characteristics as selection criteria or control for them in the modelling. Where meta-analyses include both revealed and stated preference studies, we consider the criteria that apply to both types of studies.

While these criteria do not explicitly address the date when the studies were completed, they do so implicitly. The first wage-risk study that relied on CFOI data was published in 2003 (Viscusi 2015); thus Criterion 6 (data at least equal in quality to the CFOI) effectively limits our selection of revealed-preference studies to those published in 2003 or later. The starting point is not as clearly defined for the stated-preference studies. However, we exclude studies published in 1993 or earlier for several reasons. First, they were conducted before the issuance of an expert panel report (National Oceanic and Atmospheric Administration 1993) that significantly influenced the conduct of stated-preference studies. Studies completed after that time are more likely to meet Criterion 10, related to evidence of validity. Second, most of the older studies use small, specialized samples that are not representative of the overall U.S. population. Third, preferences elicited over 20 years ago may not accurately reflect preferences at the present time.

2.2 Literature Review Results

For the VSL studies, the starting point for our literature review was the studies considered in Robinson and Hammitt (2015), which applies selection criteria that are almost identical to those used for this report. That review covered studies completed through early 2014. To identify newer studies, we searched the EconLit bibliographic database and Google Scholar for subsequently published articles and reports, and contacted VSL researchers to locate working papers and forthcoming work.²³ We also used the citations in each paper to identify additional studies.

As detailed in Robinson and Hammitt (2015), in that review we identified 16 U.S. wage-risk studies, of which six met our selection criteria. However, most were cross-sectional studies that do not support estimation of income elasticities. We also identified one meta-analysis of the wage-risk studies. We found seven stated-preference studies, of which three provided stronger

²² External scope tests compare WTP between subsamples of respondents presented with different risk changes, while internal scope tests compare WTP for different risk changes from the same respondents. External tests are preferred because internal tests can be influenced by a respondent's effort to provide internally consistent responses.

²³ We thank Glenn Blomquist, Trudy Cameron, Lauraine Chestnut, Mary Evans, Sandra Hoffmann, Jason Shogren, and W. Kip Viscusi for their responses to our inquiries. For the VSL studies, our search terms included "VSL," "value of life," "value per statistical life," and "value of statistical life," for January 2014 to the present. The search was completed in March 2015.

evidence of validity. In the searches conducted subsequently to support this report, we found that many of the unpublished studies identified in our previous review have now been published, but did not identify any additional U.S. studies that provide income elasticity estimates.²⁴

The studies that meet our selection criteria and report estimates of income elasticity are listed in Table 2.2 and discussed in more detail below. This list differs somewhat from the list in Robinson and Hammitt (2015), which focused on estimating the VSL rather than income elasticities. All of these studies meet the criteria that involve “yes/no” determinations. However, we also include studies that do not fully adhere to those criteria that require greater application of judgment (Criterion 3, 6, and 10), as discussed in Section 2.1, but that have some advantages in the context of estimating income elasticity. In the “comment” column, we highlight key issues related to the match between the study and these selection criteria, and discuss these concerns further below. All of these studies have been published in peer reviewed journals; we did not identify any unpublished studies that both meet our selection criteria and provide VSL income elasticity estimates.²⁵

²⁴ The references in Robinson and Hammitt (2015) have been updated to reflect the published versions of these studies.

²⁵ Although the Viscusi (2015) meta-analysis was published in a peer-reviewed journal, the search strategy included both published and unpublished articles. It appears that only one of the 17 studies he included has not been published.

Table 2.2. Income Elasticity Estimates for Mortality Risk Reductions

Study	Method (scenario)	Income Elasticity (standard error)	Comments
Wage-Risk Studies			
Kniesner, Viscusi, and Ziliak (2010, p. 28) ^(a)	Wage-risk	Mean = 1.44 (NA) Range (from highest to lowest income quantile) = 1.23 to 2.24 ^(b)	Includes only male heads of household.
Viscusi (2015, p. 38)	Wage-risk meta-analysis	Random-effects model: ^(c) Mean VSL: 0.829 (0.131)[0.438] Preferred VSL: 1.136 (0.225)[0.572] Fixed-effects model: Mean VSL: 0.763 (0.119)[0.467] Preferred VSL: 1.060 (0.226)[0.616]	Addresses most criteria either in selecting studies for inclusion or through controls in the statistical modelling.
Stated Preference Studies: Stronger Evidence of Validity			
Corso, Hammitt, and Graham (2001) ^(d)	Stated preference (risks from motor vehicle accidents)	0.41 (0.19) ^(d) (dot array) 0.00 (0.18) (logarithmic scale)	Change in WTP is close-to-proportionate to risk change for these visual aids.
Hammitt and Haninger (2010, p. 73, 75)	Stated preference (pesticides and motor vehicles, risk to self)	0.123 (0.106) ^(e)	Change in WTP is close-to-proportionate to risk change.
Cameron and DeShazo (2013, p. 100) ^(f)	Stated preference (sudden death)	0.66, 0.68 (NA) (depending on income change) ^(g)	Does not explicitly test whether change in WTP is proportionate to change in risk; provides other evidence of validity.
Stated Preference Studies: Weaker Evidence of Validity			
Corso, Hammitt, and Graham (2001) ^(d)	Stated preference (risks from motor vehicle accidents)	-0.00 (0.19) ^(d) (linear scale)	WTP is less than proportionate to risk change.
Alberini et al. (2004, p. 787)	Stated preference (risks from unidentified causes)	0.26 (0.13), 0.33 (0.14) ^(h) (depending on model specification)	Includes only individuals age 40 and older; change in WTP is less than proportionate to risk change.
Chestnut et al. (2012, p. 410, 411)	Stated preference (cancers and heart attacks)	0.3 (0.1), 0.4 (NA) ⁽ⁱ⁾ (depending on model specification)	Includes only individuals age 35 to 84; change in WTP is less than proportionate to risk change.

Notes:

NA = Not available.

(a) This is one of several articles by Kniesner and colleagues that relies on the same data sources; it focuses specifically on estimating income elasticities as well as on addressing other sources of heterogeneity.

(b) Calculated by Kniesner et al. by regressing VSL on average family income for each quantile, and multiplying the resulting coefficient on family income by the ratio of family income to the VSL. Standard errors are not reported.

(c) Robust standard errors in parentheses; standard errors clustered by article in brackets. Mean VSL is the bias-corrected estimate at the mean of the explanatory variables; preferred VSL controls for workers' compensation and nonfatal injury and for appropriately calculated and clustered standard errors. The random effects model has the most statistically significant income effects.

(d) Income elasticity and standard error by authors using mean income from Table 1 and income coefficient in Table 3. Excludes the subsample that received no visual aid, because WTP is not sensitive to risk change (income elasticity = 0.46 (0.19)). For all four aids combined, income elasticity is 0.19 (0.09) (Table 4).

(e) Not statistically significantly different from zero.

(f) This is one of a series of articles based on the same research. The authors describe it as their "main" or "flagship" paper (see Cameron and DeShazo 2012, Ludwig and Neumann 2012).

(g) Arc elasticity for simulated income changes. Standard errors are not reported.

(h) Standard errors calculated using income coefficients from Table 9.

(i) Standard error for elasticity of 0.3 calculated using Table 8; elasticity of 0.4 is from Table 7 which does not provide the information needed to calculate the standard error.

Wage-risk studies: The majority of the individual wage-risk studies that meet our criteria do not provide estimates of income elasticity, because they are cross-sectional (comparing individuals in different occupations and industries at a particular point in time) and typically use the wage rate as the dependent variable in the modeling. Either longitudinal research or meta-analysis is needed to provide variation in wage (and income) separate from variation in job risk and hence estimate income elasticity. We identify one longitudinal study (Kniesner, Viscusi, and Ziliak 2010) and one meta-analysis (Viscusi 2015) that generally meet our criteria for revealed preference studies, with some exceptions as discussed below.

Kniesner, Viscusi, and Ziliak (2010) focus explicitly on VSL heterogeneity, exploring how it varies with income and other worker and job characteristics. They combine CFOI risk data with longitudinal data on individual wages, industry and occupation, and demographic characteristics from the Panel Study of Income Dynamics, and use quantile regressions that allow the VSL to vary with the wage rate. They find that elasticities increase with income, exceeding a value of 1.0 in all cases and reaching a value greater than 2.0 for the highest income quantile. Such longitudinal data has an important advantage: because it tracks individuals over time rather than comparing across individuals, it captures how individuals' unobservable personal characteristics affect the trade-offs they make between wages and risks. This study meets all of our selection criteria with one exception. It includes only male heads of household, so is not necessarily representative of the general population (Criterion 3). The extent to which VSL income elasticity varies between men and women is uncertain.

Viscusi's (2015) meta-analysis includes 17 U.S. wage-risk studies that rely on CFOI data and controls for whether they address potentially confounding variables such as workers' compensation and nonfatal injury as well as other study characteristics.²⁶ Thus this study adheres to most of our criteria, either by using the criteria for individual studies in selecting those to include in the meta-analysis or by controlling for these characteristics in the modelling.²⁷ Importantly, Viscusi addresses the potential effects of reporting or publication bias, which may result when a researcher reports only a subset of his or her findings or when journals are unwilling to publish findings that depart significantly from previous results or appear inconsistent with theory. Viscusi provides income elasticity estimates derived from both random-

²⁶ All included studies are wage-risk studies conducted in the U.S. using CFOI data, and meet criteria 1, 2, 4 and 5. Some of the included studies, such as the Kniesner et al. study discussed in the text, are not nationally-representative samples (Criterion 3); some do not control for both occupation and industry and for other important influencing factors (Criterion 6). While Viscusi (2015) controls for the inclusion of non-fatal risks and workers compensation in the meta-analysis, as well as other factors, he does not appear to control for whether the risk variable addressed both occupation and industry.

²⁷ An earlier study, which did not apply these selection criteria (Doucouliagos, Stanley, and Viscusi 2014), found evidence of statistically-significant publication bias in estimating the income elasticity of VSL. Viscusi (2015) finds that selecting only those studies that rely on the higher quality CFOI risk data limits the effects of such bias, emphasizing the importance of selection Criterion 5.

and fixed-effects models, finding that the random-effects model has more statistically-significant income effects. He also provides results based on all estimates from each study as well as based on his “preferred” specification. In the latter, he sets variables related to key study characteristics at 1.0, including whether they control for workers’ compensation and nonfatal injury, and whether they provide appropriately calculated and clustered standard errors. We provide all four sets of estimates in Table 2.3, but the “preferred” elasticity estimates (with mean values of about 1.1) better adhere to our selection criteria by controlling for important study characteristics.

Stated-Preference Studies: In our review of the stated-preference research, we found five studies that meet most or all of our selection criteria and either report income elasticity estimates or provide data from which income elasticity can be calculated. In Table 2.2, we first provide the estimates from the studies that fully meet our selection criteria. These include the subsamples that received the more effective visual aids from Corso et al. (2001) as well as Hammitt and Haninger (2010). Both are nationally-representative surveys and find that WTP is close-to-proportional to changes in risk magnitude. A third national survey, Cameron and DeShazo (2013), relies on a complex valuation strategy that includes illnesses of varying severities and durations, requiring specialized modeling techniques that make it difficult to determine whether WTP is proportional to the risk change. However, in a detailed Handbook that supplements their journal articles (Cameron and DeShazo 2012), they provide evidence that respondents understand the scenarios and are sensitive to changes in risk magnitude. In these three studies, the income elasticities range from about 0.0 to 0.7, lower than the values found in the wage-risk studies.

We identify two additional studies, Alberini et al. (2004) and Chestnut et al. (2012), which report income elasticity estimates but do not fully meet two of our selection criteria. Both survey only older adults, rather than the general population (Criterion 3). In addition, although they each report the results of scope tests, they find that the change in WTP is much less than proportionate to the change in risk (Criterion 10).²⁸ We also provide the results from one subsample from Corso et al. (2001) that received a less effective visual aid. The income elasticities in these studies range from about 0.0 to 0.4, at the lower end of the range found in the other stated preference studies. However, dropping those that provide less evidence of validity would not affect the overall range.

This review suggests that high quality VSL studies potentially suitable for application to EPA policies provide a broad range of elasticities, ranging from about 0.0 to 1.4. The studies using wage differential estimates yield larger elasticities (0.8 to 1.4) than those relying on stated preferences (0.0 to 0.7). Thus these estimates, particularly those from the wage-risk studies, tend

²⁸ We exclude Hammitt and Graham (1999) and Viscusi et al. (2014) due to concerns about sensitivity to scope (Criterion 10). Hammitt and Graham indicate that respondents are largely insensitive to the risk change; Viscusi et al. do not provide information on the extent to which WTP is sensitive the risk change.

to be higher than those currently included in BenMAP (which range from 0.08 to 1.0) and used throughout EPA, reflecting the substantial evolution of the literature since the estimates were developed in 1999.²⁹

As discussed in Hammitt and Robinson (2011), elasticities larger than 1.0 mean that individuals' WTP for small mortality risk reductions becomes a larger fraction of income as income increases, which appears consistent with the notion that wealthier individuals are able to invest more in risk-reducing measures once they satisfy basic needs. Values greater than 1.0 are also more consistent with the literature on the coefficient of relative risk aversion for financial risks (see, for example, Kaplow 2005).

2.3 Options for Application in EPA Analyses

For use in benefit-cost analysis, EPA requires a central (or “best”) estimate of VSL income elasticity, reasonable lower and upper values for use in sensitivity analysis, and a distribution of values for use in probabilistic analysis. There are numerous ways in which the results of the studies discussed above could be used to develop these estimates; below we focus on two options to provide a starting point for further discussion. Many other options, such as rounding the central income elasticity estimate to 1.0, are also possible.

Option 1: Rely on the results from the Viscusi (2015) meta-analysis, using the preferred estimates from the random-effects model and the standard errors clustered by article. This analysis has the advantage of combining the results from several studies and addresses concerns related to publication bias. A drawback is that it does not incorporate any uncertainty about model specification. In addition, it assumes that the elasticities found in wage-differential studies of injury-related risks are appropriate for illness-related risks from environmental causes, and disregards the results of the stated-preference studies.

Option 2: Rely on the results from all seven studies in Table 2.2, using the mid-point value as the central estimate and the smallest and largest values as the reasonable lower and upper estimates for uncertainty analysis. This approach considers studies that address risks from a variety of causes, including both illness- and injury-related risks. A drawback is that it treats the mean estimates from the extreme studies as bounds, neglecting the uncertainty in these estimates. However, ignoring the uncertainty in these extreme estimates may help to avoid using too large an uncertainty range; the estimated means from the extreme studies may be biased because of the selection effect (i.e., the smallest estimated mean may be small in part because the random error associated with that study is negative).

²⁹ The U.S. Department of Transportation (DOT) currently relies only on wage-risk studies to estimate the VSL, and applies an elasticity estimate of 1.0 (DOT 2014).

The estimates that result from each approach are provided in Table 2.3.³⁰

Table 2.3. Options for Estimating Mortality Risk Income Elasticities

Option	Central Estimate	Reasonable Lower and Upper Estimates
Rely solely on Viscusi (2015)	1.1 (random-effects model, preferred specification)	0.6, 1.7 (central value minus or plus clustered standard error)
Rely on range from all seven studies	0.7 (midpoint between lowest and highest reported mean values)	0.0, 1.4 (lowest and highest reported mean values)

For probabilistic analysis, which distribution is most appropriate will depend in part on which estimates are selected. There are many possible options. It seems desirable to choose a distribution for which the mean and/or median are close to the central estimate and for which the reasonable lower and upper estimates are near the tails of the distribution; e.g., at the 10th and 90th percentiles, respectively. The distribution should assign zero probability to values less than zero and also to sufficiently large values. Options for developing this distribution should be considered once the range of income elasticity estimates to be applied is selected.

³⁰ In the tables summarizing the options, we round to one decimal place. As indicated in the tables that present the results from the individual studies, they vary in the number of significant figures they report.

3.0 INCOME ELASTICITY FOR MORBIDITY RISK VALUATION

The value of morbidity risk reductions has received substantially less attention than the value of mortality risk reductions; far fewer studies are available. As a result, the available research is not likely to meet the relatively stringent selection criteria we apply to the VSL studies. Below, we discuss the selection criteria we use in this case, the studies that meet these criteria, and the resulting recommendations.

3.1 Selection Criteria

Because the value of morbidity risk reductions is less well-studied, we apply less stringent selection criteria, while understanding that this approach may affect our confidence in the estimates. We are unaware of any recent comprehensive review of morbidity risk valuation studies; however, our experience with this and previous reviews indicates that relatively few studies are available. In Table 3.1, we summarize the criteria we apply then note how they differ from the criteria for the VSL studies. The SAB-EEAC report discussed in the previous chapter does not explicitly address morbidity risks, but many of its recommendations are relevant to these studies.

Table 3.1. Selection Criteria for Value of Morbidity Risk Reduction Studies

<p>General Criteria</p> <ol style="list-style-type: none"> 1. Be publicly available. 2. Be written in English. 3. Be conducted in the U.S. <p>Criteria for Stated-Preference Studies</p> <ol style="list-style-type: none"> 4. Elicit values for private risk reductions that accrue to the respondent. 5. Estimate willingness to pay, not willingness to accept compensation.
--

Our general criteria are similar to those applied to the VSL studies. The one exception is that, rather than focusing on studies that address the national population, we also include U.S. studies that are limited to particular localities.³¹ We focus on stated preference studies because of the concerns about averting behavior studies noted in the previous chapter, and because the wage-risk studies generally focus on fatal rather than nonfatal injuries.³² We again select only studies that address WTP rather than WTA. Because very few studies are available, we select all that meet these criteria, without further screening for evidence of validity. However, we again

³¹ Many of the quantified morbidity risk reductions in air pollution and other analyses affect children rather than adults; however, the valuation studies EPA currently applies address values for adults. In our selection criteria, we again focus on values for adults, in part for consistency and in part because few studies report elasticities separately for children. However, we include some studies that combine estimates of WTP for both adults and children in the models used to estimate income elasticity.

³² Wage-risk studies often control for nonfatal injury rates, and may provide values for nonfatal injuries expressed as the overall injury rate, the rate for injuries severe enough to result in a lost workday, or the rate of lost workdays, rather than as values for injuries of particular types.

exclude studies published in 1993 or earlier, given the likely methodological improvements and changes in preferences over time as discussed in Chapter 2.

3.2 Literature Review Results

For morbidity risks, our starting point is the U.S. studies completed after 1993 that were included in IEC's previous work on income elasticity, as listed in Ludwig and Neumann (2012). We then searched for additional studies, following the same process (and contacting the same researchers) as described in the section on mortality risk reductions.³³ The studies that meet our selection criteria and provide estimates of income elasticity are listed in Table 3.2. All of these studies use stated preference methods to elicit values for particular health conditions; the available meta-analyses do not meet our selection criteria. Four have been published in the peer-reviewed literature; the Dickie and Hubbell (2004) results are from a working paper.

³³ Because the most recent comprehensive review of income elasticity studies for morbidity was Neumann and Brennan (2004), this search covered January 2004 to the present. In EconLit we searched for "willingness to pay" and "injury" or "illness" as well as for "willingness to pay" and condition names related to those noted in Table 1.1 ("asthma," "bronchitis," "respiratory," and "COPD"). In Google Scholar, which has limited options for refining searches, these terms yielded thousands of results. Our review of the first several pages indicated that most of the studies were not relevant to this project; the few that were are ones that we had already identified and reviewed. Thus we did not review the remaining Google Scholar results in detail. The search was completed in March 2015.

Table 3.2. Income Elasticity Estimates for Morbidity Risk Reductions

Study	Method	Health Effect(s)	Sample	Income Elasticity (standard error)
Dickie and Hubbell (2004, pp. 10, 20)	Stated preference	Acute respiratory symptoms and bronchitis (children and adults combined)	Hattiesburg, Mississippi (n=284)	0.500 (0.0465), 0.499 (0.0464), 0.512 (0.0464), 0.511 (0.0501) ^(a)
Dickie and Messman (2004, pp. 1159, 1163)	Stated preference	Acute respiratory symptoms and bronchitis (children and adults combined)	Hattiesburg, Mississippi (n=284)	0.154 (0.045), 0.0773 (0.052), 0.217 (0.061), 0.141 (0.046) ^(a)
Chestnut et al. (2006, p. 140)	Stated preference	Respiratory and cardiovascular hospitalizations (adults)	Northern California (n=397)	1.06 (0.26) ^(b)
Hammitt and Haninger (2007, p. 1172)	Stated preference	Foodborne illness (risk to self)	U.S. households (without children, n=4,934; with children, n=1,160)	0.031 (0.046), 0.040 (0.151) ^(c)
Blomquist et al. (2011)	Stated preference	Asthma symptoms (adults)	Convenience sample (parents); Kentucky (adults) (n=263)	0.47 (0.18) ^(d)

Notes:

NA=Not available.

(a) Elasticities based on models that combine results for children and adults (other estimates in table are for adults only). Both papers are based on the same data set, but consider different model specifications.

(b) Derivation is not discussed in detail. Standard error derived from Table 8 (model 2) using mean WTP (Table 6) and mean household income (Table 7).

(c) Not statistically significantly different from zero.

(d) Estimates provided by Blomquist et al. via email for adult risk at sample mean age and income for a 10 percent change in income, based on logit regressions with age effects and controls (Table 5, Column 2, and Table 6). Standard error estimated assuming income elasticity is proportional to the estimated income coefficient in Table 5.

The results in Table 3.2 suggest that there is substantial variation and uncertainty regarding the income elasticities appropriate for nonfatal health effects, both because the estimates cover a wide range (0.03 to 1.06) and because of issues related to study design. Only one is national; the others are based on small local samples, and we did not screen these studies for quality using the more stringent criteria applied to the VSL studies. All address episodes of relatively short duration. Most of the studies do not appear to explore the sensitivity of WTP for morbidity risks to the risk change. Hammitt and Haninger find that the change in WTP is less than proportional to the change in risk; Bloomquist et al. report that WTP increases as the efficiency of the treatment increases.

These values cover roughly the same range as the values from the older studies of minor and severe effects that are now the basis of EPA's estimates (see Table 1.1), with some higher values. We exclude a meta-analysis that addresses acute health effects (Van Houtven et al. 2006) because it incorporates studies that do not meet our selection criteria. It includes several studies

completed over 20 years ago as well as several conducted outside of the U.S. However, it finds elasticities of 0.7 or 0.9 depending on the model specification, at the higher end of the range in Table 3.2.

These estimates suggest that WTP for morbidity risk reductions may be less sensitive to income changes than WTP for mortality risk reductions; elasticities smaller than 1.0 indicate that a one percent change in income is likely to be associated with less than a one percent change in WTP.

For the VSL, the number of U.S. studies is large enough that we were able to identify studies that meet relatively stringent selection criteria. For morbidity, this is not the case. The limited number of U.S. studies available, the lack of studies of chronic conditions, and the issues related to their quality, raises questions about whether it would be sensible to include studies conducted outside of the U.S. in estimating elasticities for morbidity valuation. Our selection criteria focus on U.S. studies due to concerns about the effects of differences in culture, health care systems, population-average income and other factors across countries, including those with relatively high incomes. While expanding our selection to include non-U.S. studies may increase the number of estimates considered, it seems likely that these values will be within the relatively broad range indicated by Table 3.2.

3.3 Options for Application in EPA Analyses

For EPA benefit-cost analyses, it is useful to have not only a central (or “best”) estimate of the income elasticity, but also reasonable upper and lower values for use in sensitivity analysis and a distribution of values for use in probabilistic analysis. In the past, EPA has used different elasticity estimates for chronic and acute effects; however, all of the studies that meet our selection criteria are for acute effects. As a result we suggest that EPA not distinguish between acute and chronic effects in estimating income elasticity given the limited evidence available. While there are many ways in which the results of the studies discussed above could be used to develop these estimates, below we focus on two options to provide a starting point for further discussion. Again, other options are possible, such as using a central income elasticity estimate of 1.0.

Option 1: Combine the elasticity estimates for mortality and morbidity risk reductions and apply the full range to morbidity risks. This approach recognizes that although the health effects are significantly different, the literature on income elasticity is much stronger for mortality risk reductions. In addition, given that chronic effects are likely to more severely restrict work and other activities than the acute effects addressed by the available morbidity valuation studies, it is conceivable that the income elasticity would be higher for chronic than acute effects. However, as discussed in Chapter 1, theoretical expectations are unclear.

Under this approach, we would combine the values from the approach selected for mortality risks with the values from taken from Table 3.2, then pick the smallest and largest values of this

combined set to calculate estimates for application to both chronic and acute morbidity, and use the mid-point of the range as our best estimate.

The relatively wide range of elasticities that results may be appropriate, given the substantial uncertainty associated with the limitations of the available morbidity valuation literature as well as the lack of a well-developed theoretical basis for differentiation. As discussed in the section on mortality risk valuation, this approach again ignores the uncertainty in the high and low mean values.

Option 2: Rely on the mean results from the five morbidity risk valuation studies in Table 3.2, using the mid-point value as the central estimate and the smallest and largest values in uncertainty analysis. This results in a somewhat narrower range of elasticities. In addition to the issues raised above regarding the quality and applicability of the available morbidity valuation literature, this approach assumes that values for chronic effects will be within the same range as the elasticities for acute effects. Under this option, a somewhat lower range of elasticities will be used for morbidity than for mortality risk reductions.

The estimates that result from each approach are provided in Table 3.3.

Table 3.3. Options for Estimating Morbidity Risk Income Elasticities

Option	Central Estimate	Reasonable Lower and Upper Estimates
Rely on range of estimates from both morbidity and mortality valuation studies	0.9 or 0.7 (depending on mortality valuation approach)	0.0, 1.7 or 1.4 (depending on mortality valuation approach)
Rely on range of estimates from morbidity valuation studies only	0.5 (midpoint between highest and lowest reported mean values)	0.0, 1.1 (lowest and highest reported mean values)

For probabilistic analysis, the appropriate distribution is again uncertain and numerous options are possible. As for mortality risks, it seems desirable to choose a distribution for which the mean and/or median are close to the central estimate and the reasonable lower and upper estimates are near the tails, assigning zero probability to values less than zero and to sufficiently large values. What distribution is most appropriate will depend on the overall approach for estimating the income elasticity of the value of morbidity risk reductions.

4.0 PAST AND FUTURE REAL INCOME GROWTH³⁴

In addition to elasticity estimates, the income adjustment requires estimates of the change in real income over time. These data are needed for two periods: the time that has elapsed between when the data in the valuation studies were originally collected and the base year, and the time that will elapse between the analytic base year and each year for which impacts are estimated. In other words, both actuals and projections are required. Below, we first describe alternative data sources and then discuss the recommendations.

4.1 Sources of Data

We rely on well-established government sources for these estimates. Ideally, we would apply the same income measure as used in the valuation studies from which the elasticity measures are derived, which are based on individual or household earnings.³⁵ In its benefit-cost analyses, EPA instead currently relies on estimates of per capita GDP, which represents the final market value of the goods and services produced in the U.S. divided by the size of the population.

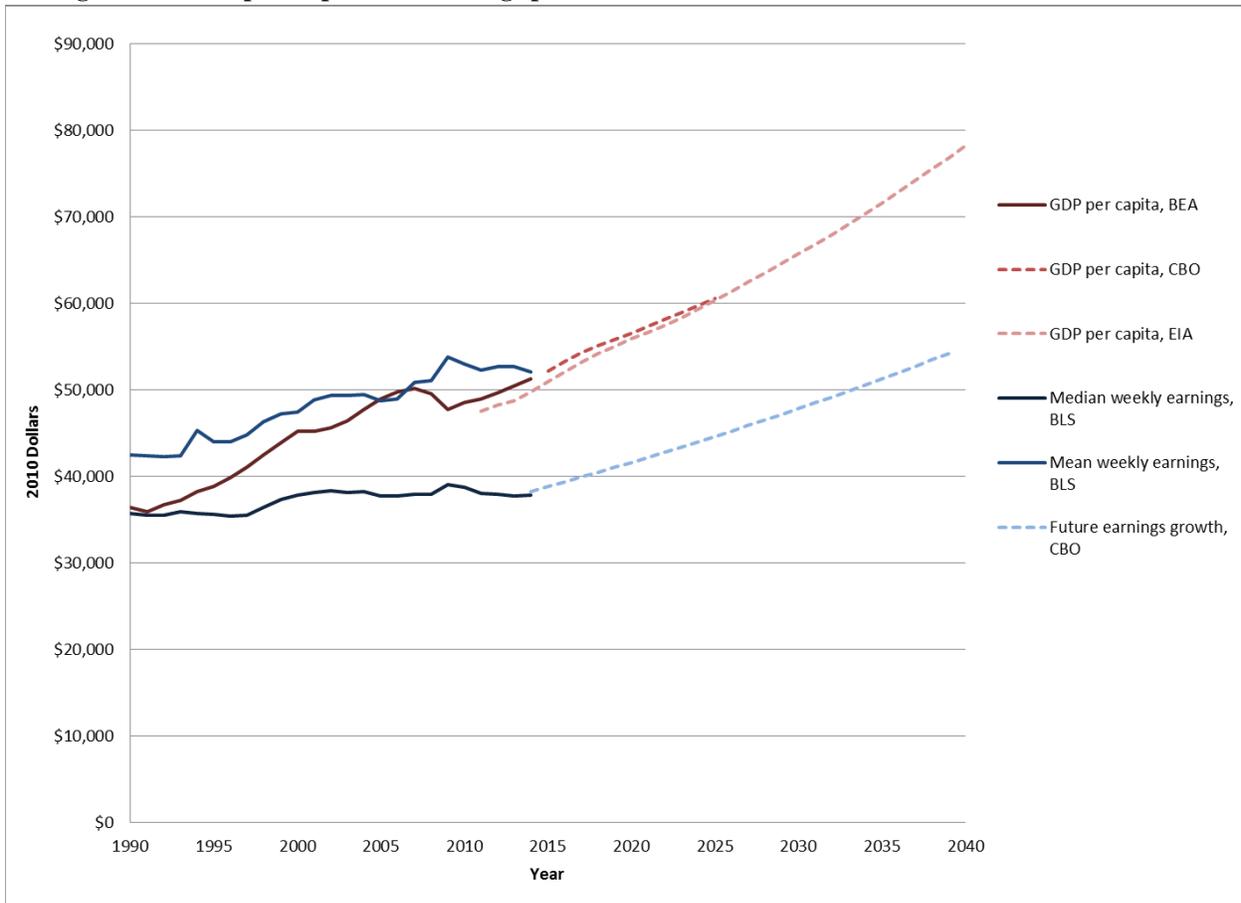
This historic reliance on GDP estimates resulted in part because GDP projections were more readily available at the time the approach was developed, and in part because the rate of change in earnings appeared similar to the rate of change in per capita GDP. However, in developing its recent VSL guidance, DOT (2014) identified a source of earnings projections which it now uses in its income adjustments – the Congressional Budget Office’s (CBO’s) yearly *Long-Term Budget Outlook* reports – which we discuss along with sources for GDP-based estimates below. To adjust for real income growth in previous years, DOT relies on median earnings data from the Current Population Survey (CPS).

Figure 4.1 presents alternative sources of historical and projected GDP and earnings data, each of which is discussed below.

³⁴ The analysis in this section was conducted by Lindsay Ludwig of IEc. More information on these measures is available in Ludwig and Neumann (2012).

³⁵ Although WTP depends on wealth rather than solely current earnings, the elasticity estimates cited in the previous chapters are based on reported earnings.

Figure 4.1. GDP per Capita and Earnings per Worker



For historical GDP per capita (1990 through 2014), we present the most recently released GDP estimates from BEA and population estimates from the U.S. Census Bureau.³⁶ For future years (2015 through 2025), we present two sets of estimates. The first uses GDP projections from a supplement to CBO’s *Budget and Economic Outlook: 2015 to 2025* (CBO 2015) and population projections from the U.S. Census Bureau.³⁷ The second uses GDP and population projections from the U.S. Energy Information Administration’s (EIA’s) *Annual Energy Outlook 2014*, which covers a longer time period (through 2040).³⁸

³⁶ BEA, “Table 1.1.6. Real Gross Domestic Product, Chained Dollars” (<http://www.bea.gov/itable/index.cfm>); U.S. Census Bureau, “1990-2000 Monthly Intercensal National Population Estimates by Age and Sex Files for Internet Display;” “Table 1. Intercensal Estimates of the Resident Population by Sex and Age for the United States: April 1, 2000 to July 1, 2010” (US-EST00INT-01), and “Table 1. Annual Estimates of the Resident Population for the United States, Regions, States, and Puerto Rico: April 1, 2010 to July 1, 2014” (NST-EST2014-01). Viewed March 2015.

³⁷ U.S. Census Bureau, “Table 1. Projections of the Population and Components of Change for the United States: 2015 to 2060” (NP2014-T1) (<https://www.census.gov/popest/index.html>). Viewed March 2015.

³⁸ The EIA population projections include armed forces overseas, while the Census population projections do not. For consistency, we use the EIA projections for both GDP and population in these calculations.

For historical earnings per worker, we provide median and mean estimates from the CPS. The CPS reports usual weekly earnings for full-time employed wage and salary workers, which we multiply by 52 to estimate annual earnings.³⁹ As is evident from the figure, mean earnings generally exceed median earnings because U.S. earnings are skewed, with a small proportion of the population having high earnings. For future years, we present CBO's estimate of growth in real earnings per worker from their *2014 Long-Term Budget Outlook* (CBO 2014, Table A.1). CBO estimates an annual growth rate of 1.4 percent between 2014 and 2039, and of 1.3 percent if averaged over 2014 through 2089.⁴⁰ In the figure, we apply the 1.4 percent rate to the 2013 estimate of median earnings from the CPS.

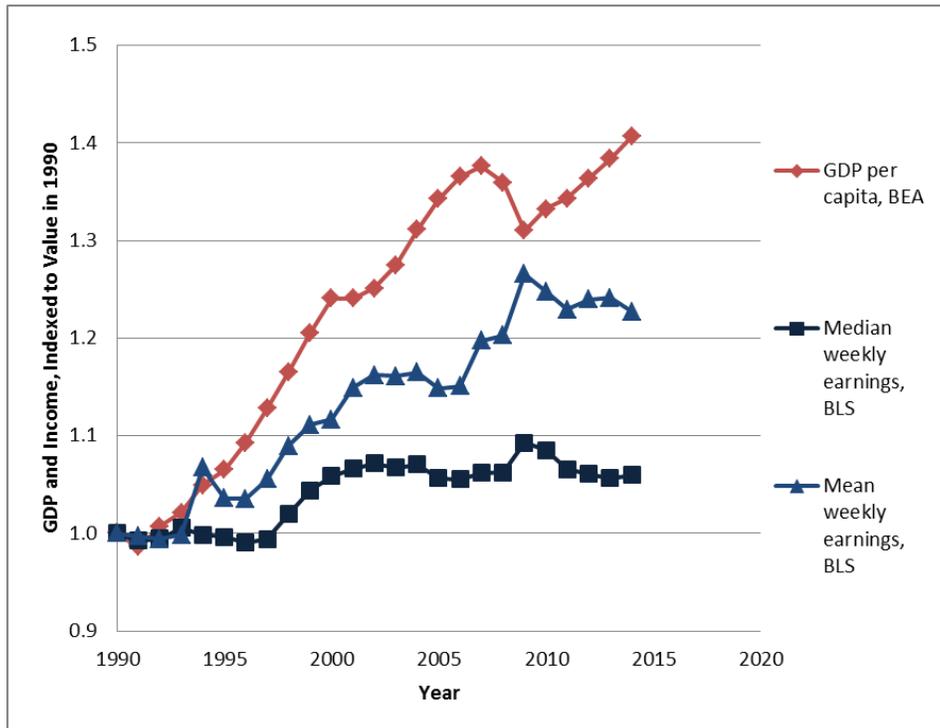
This predicted growth rate for earnings is very similar to the predicted rate for per capita GDP. Averaged over the projected time period, the CBO estimates yield a GDP per capita growth rate of 1.5 percent; the EIA estimates yield a 1.7 percent rate.

In Figure 4.2, we compare the historical growth rates of per capita GDP and earnings, indexed to their respective 1990 values. The figure indicates that, over the time period addressed, the growth in per capita GDP has outpaced the growth in median earnings. It has also outpaced the growth in mean earnings, although to a lesser degree and not as consistently. It is unclear whether these trends will continue.

³⁹ BLS "Table 1. Median usual weekly earnings of full-time wage and salary workers by sex, quarterly averages, seasonally adjusted" (<http://www.bls.gov/news.release/wkyeng.t01.htm>) as viewed March 2015, and "Table A-5. Usual weekly earnings of employed wage and salary workers by sex, race, and detailed Hispanic or Latino ethnicity and Non-Hispanic ethnicity, annual average, not seasonally adjusted" (1990-2014). Provided by Steve Hipple, BLS, via email February 11, 2015 (<http://www.bls.gov/cps/earnings.htm>).

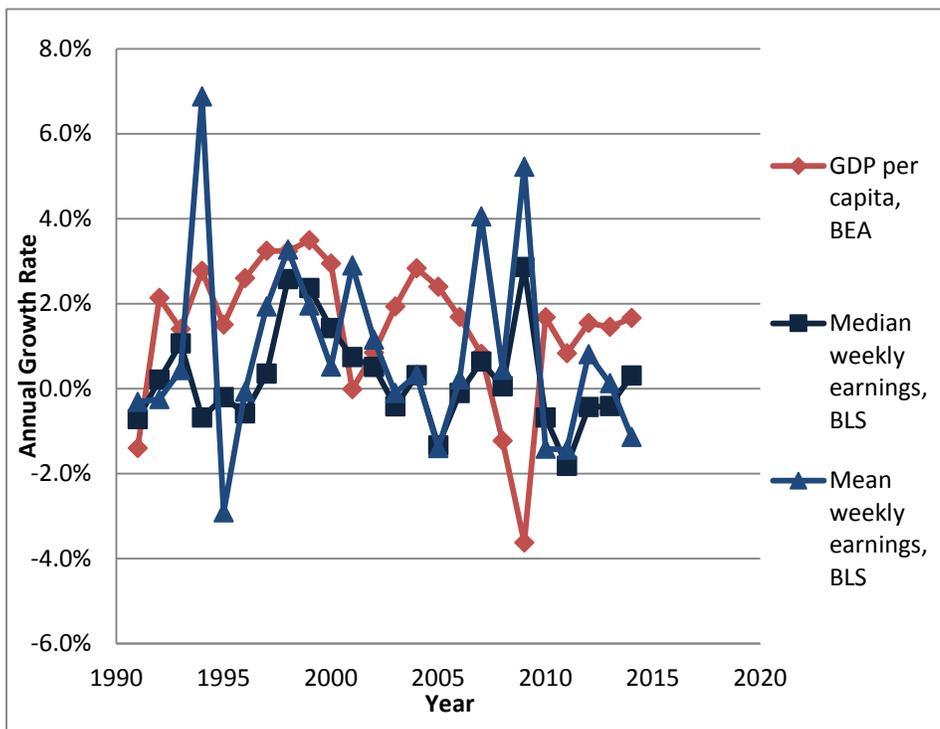
⁴⁰ CBO (2014, p. 111) notes that: "The growth rates projected for the labor supply, the capital stock, and total factor productivity are consistent with CBO's projection for the average growth of labor productivity (real output per hour worked): 1.9 percent a year over the 2014–2024 period and 1.8 percent a year thereafter. Trends in prices, in the growth of nonwage compensation (such as employer-provided health insurance), and in average hours worked imply that real earnings per worker will grow more slowly than labor productivity: by an average of 1.5 percent a year over the 2014–2024 period and 1.4 percent a year over the 2014–2039 period." In a footnote, CBO states further that "Trends in prices are important in projecting those measures because real earnings per worker are calculated here using the CPI-U, and real output per hour is calculated using the GDP deflator. CBO projects that the CPI-U will grow 0.4 percentage points faster per year than the GDP deflator over the long term."

Figure 4.2. GDP and Earnings Indexed to 1990 Values



In Figure 4.2, we use the same data to illustrate the variation in annual growth rates over time.

Figure 4.2. GDP and Earnings Annual Growth Rates



4.2 Options for Application in EPA Analyses

Developing recommendations for estimating real income growth involves three interrelated decisions. We describe the options below.

GDP versus earnings: The first question is whether to rely on estimates of changes in GDP per capita or of changes in earnings. Relying on GDP per capita would be consistent with current practices, while relying on changes in earnings is more consistent with the basis for the income elasticity estimates from the underlying studies, which generally calculate elasticities based on changes in individual or household earnings.⁴¹ If earnings are used, median values may be preferable as more likely to be representative. Any policy option may affect only a subset of the population, and the mean for a population subgroup may be closer to the median than to the mean for the overall population. For the overall population, the mean is significantly affected by the relatively small number of individuals with exceptionally high earnings.

Data source for GDP projections: The second question is relevant only if a GDP per capita measure is used, and relates to the choice among the two data sources for future growth rates. As discussed above, EIA forecasts GDP and population growth farther into the future than does CBO.

Presentation of annual values versus rates: The third question relates to whether to include values for each future year or to apply a single constant annual growth rate. Currently, BenMAP includes a table that reports income adjustment factors for each year, which combine the income elasticity estimates with data on projected real GDP per capita for that year (see EPA 2015, p. 4-61). Other EPA analyses rely on similar tables. Using a single growth rate (combined with the range of elasticity estimates described in the prior chapters) may be easier to update and to communicate to users, particularly if the rate can be easily derived from accessible, publicly-available data. Year-by-year projections must be recalculated whenever new data become available.

For example, instead of relying on a look-up table including individual adjustment factors for each of the next 20 or 30 years, EPA analysts could apply a growth rate derived from whichever of the sources discussed earlier is relevant. Currently, these would include the 1.4 percent growth rate for earnings from the CPS, the 1.5 percent GDP per capita growth rate from CBO, or the 1.7 percent GDP per capita growth rate from EIA, depending on which data source is selected as the basis for the estimates. The relevant source can be identified as part of the BenMAP documentation and/or Agency guidance, so that users can update these rates if desired. Given the

⁴¹ Ideally, elasticities would be calculated based on wealth rather than earnings, encompassing all of the resources available for spending on risk reductions and other goods and services. However, wealth is very difficult to measure and generally not included in the empirical studies.

relatively small differences in these rates, it may be sensible to use a single rate rather than a distribution.

Table 4.1 summarizes these choices.

Table 4.1. Options for Estimating Real Income Growth

Option	Source for Previous Years	Source for Future Years	Measure of Annual Growth
GDP per capita	BEA and Census	CBO (10 years) or EIA (25 years)	Constant growth factor (e.g., 1.5 or 1.7 percent) or year-to-year values
Earnings	CPS (median)	CBO (25 or 75 years)	Constant growth factor (e.g., 1.4 percent)

5.0 SUMMARY AND CONCLUSIONS

Adjusting the value of mortality and morbidity risk reductions for changes in real income requires two inputs: an estimate of the change in value associated with a change in real income (the income elasticity), and an estimate of the change in real income. The first input is more difficult to estimate: theoretical expectations are unclear, and the results of empirical research are diverse.

To develop elasticity estimates, we searched the literature for potentially relevant studies then assess their quality and applicability. We used more stringent criteria for the mortality risk valuation studies than for the morbidity risk valuation studies; the mortality risk valuation literature is substantially larger and more attention has been paid to developing recommended best practices. The value of morbidity risk reductions has received substantially less attention; far fewer studies are available and they generally focus on small subpopulations and a limited number of acute health conditions. As a result, we are less confident of the elasticity estimates for morbidity risks.

For mortality risks, we find one wage-risk study, one wage-risk meta-analysis, and five stated preference studies that meet all or most of our criteria, providing elasticities ranging from 0.0 to 1.4. The studies using wage differentials yield larger elasticities (0.8 to 1.4) than those relying on stated preferences (0.0 to 0.7). For morbidity risks, we find five stated preference studies that meet our less stringent criteria, providing elasticities ranging from 0.03 to 1.06.

As a starting point for further discussion, we suggest two options for estimating income elasticity for mortality risk reductions. The first is to rely on the results from the Viscusi (2015) meta-analysis; the second is to rely on the results from all seven studies that meet most or all of our selection criteria. The first option would yield a central income elasticity estimate of 1.1; the second would yield a central estimate of 0.7.

We also suggest two options for estimating income elasticities for morbidity risk reductions. The first is to combine the elasticity estimates for mortality and morbidity risk reductions and apply the full range to morbidity risks, recognizing the limitations of the morbidity-related research. The second is to rely on the results from the five morbidity risk valuation studies that we identified. The first approach would yield a central income elasticity estimate of 0.7 or 0.9 (depending on the approach selected for mortality risk reductions); the second would yield a central estimate of 0.5.

For both mortality and morbidity, EPA requires reasonable lower and upper values for use in sensitivity analysis, and a distribution of values for use in probabilistic analysis. The values to be used will depend on the approach selected for developing central estimates, as well as the information provided studies that underline this approach.

Developing recommendations for estimating real income growth involves addressing three interrelated decisions. The first question is whether to rely on estimates of changes in GDP per capita or of changes in earnings. Relying on GDP per capita would be consistent with current practices, while relying on changes in earnings is more consistent with the basis for the income elasticity estimates from the underlying studies. If GDP per capita estimates are used, then EPA will need to choose among the available sources for estimating future growth rates; only one source appears to be available for projecting real growth in earnings. The third question relates to how the estimates will be presented: as a look-up table with yearly values, or as a constant annual rate.

In sum, the VSL literature is well-developed and provides several sources of income elasticity estimates that are likely to be useful in EPA benefit-cost analyses. The morbidity valuation literature is substantially less robust, raising more difficult questions related to characterizing the effects of income on related values. For both mortality and morbidity, the estimates of income elasticity can then be combined with well-established sources of estimates of past and potential future real income growth, to adjust the available values.

REFERENCES

Alberini, A., M. Cropper, A. Krupnick, and N. Simon. 2004. “Does the Value of a Statistical Life Vary with Age and Health Status? Evidence from the U.S. and Canada.” *Journal of Environmental Economics and Management*. 48(1): 769-792.

Bergstrom, T.C. 2006. “Benefit-Cost in a Benevolent Society.” *American Economic Review*. 96(1): 339-351.

Blomquist, G. 2004. “Self-Protection and Averting Behavior, Values of Statistical Lives, and Benefit Cost Analysis of Environmental Policy.” *Review of the Economics of the Household*. 2: 89-110.

Blomquist, G.C., M. Dickie, and R.M. O’Conor. 2011. “Willingness to Pay for Improving Fatality Risks and Asthma Symptoms: Values for Children and Adults of all Ages.” *Resource and Energy Economics*. 33(2): 410-425.

Cameron, T.A. 2010. “Euthanizing the Value of a Statistical Life.” *Review of Environmental Economics and Policy*. 4(2): 161-178.

Cameron, T.A. and J.R. DeShazo. 2012. *Handbook to Accompany “Demand for Health Risk Reductions” and Related Papers*. Unpublished manuscript.

Cameron, T.A. and J.R. DeShazo. 2013. “Demand for Health Risk Reductions.” *Journal of Environmental Economics and Management*. 65: 87-109.

Chestnut, L.G. et al. 2006. “The Economic Value of Preventing Respiratory and Cardiovascular Hospitalizations.” *Contemporary Economic Policy*. 24(1): 127–143.

Chestnut, L.G., R.D. Rowe, and W.S. Breffle. 2012. “Economic Valuation of Mortality-Risk Reduction: Stated Preference Estimates from the United States and Canada.” *Contemporary Economic Policy*. 30(3): 399-416.

Congressional Budget Office. 2014. The 2014 Long-Term Budget Outlook.
(<https://www.cbo.gov/publication/45471>)

Congressional Budget Office. 2015. *The Budget and Economic Outlook: 2015 to 2025*. “January 2015 Baseline Forecast—Data Release (Calendar Year)” supplement.
(<https://www.cbo.gov/publication/49892>)

Corso, P.S., J.K. Hammitt, and J.D. Graham. 2001. "Valuing Mortality-Risk Reduction: Using Visual Aids to Improve the Validity of Contingent Valuation." *Journal of Risk and Uncertainty*. 23(2): 165-184.

Costa, D.L. and M.E. Kahn. 2004. "Changes in the Value of Life, 1940-1980." *Journal of Risk and Uncertainty*. 29(2): 159-180.

Cropper, M. et al. 2007. "SAB Advisory on EPA's Issues in Valuing Mortality Risk Reduction." Memorandum from the Chair, Science Advisory Board, and the Chair, Environmental Economics Advisory Committee, to EPA Administrator Stephen L. Johnson. EPA-SAB-08-001.

Dickie, M. and B. Hubbell. 2004. "Family Resource Allocation and the Distribution of Health Benefits of Air Pollution Control," Paper presented at the Association of Environmental and Resource Economists Workshop, "Distributional Effects of Environmental Policy."

Dickie, M. and V.L. Messman. 2004. "Parental Altruism and the Value of Avoiding Acute Illness: Are Kids Worth More Than Parents?" *Journal of Environmental Economics and Management*. 48: 1146-1174.

Doucouliafos, H., T. D. Stanley, and W. Kip Viscusi. 2014. "Publication Selection and the Income Elasticity of the Value of a Statistical Life." *Journal of Health Economics*. 33: 67-75.

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

Flores, N.E. and R.T. Carson. 1997. "The Relationship between the Income Elasticities of Demand and Willingness to Pay." *Journal of Environmental Economics and Management*. 33: 287-295.

Hammitt, J.K. and J.D. Graham. 1999. "Willingness to Pay for Health Protection: Inadequate Sensitivity to Probability?" *Journal of Risk and Uncertainty*. 18(1): 33-62.

Hammitt, J.K. and K. Haninger. 2007. "Willingness to Pay for Food Safety: Sensitivity to Duration and Severity of Illness." *American Journal of Agricultural Economics*. 89(5): 1170-1175.

Hammitt, J.K. and K. Haninger. 2010. "Valuing Fatal Risks to Children and Adults: Effects of Disease, Latency, and Risk Aversion." *Journal of Risk and Uncertainty*. 40: 57-83.

Hammitt, J.K., J-T Liu, J-L Liu. 2000. "Survival is a Luxury Good: The Increasing Value of a Statistical Life." Prepared for the NBER Summer Institute Workshop on Public Policy and the Environment.

Hammitt, J.K. and L.A. Robinson. 2011. "The Income Elasticity of the Value per Statistical Life: Transferring Estimates Between High and Low Income Populations." *Journal of Benefit-Cost Analysis*. 2: Art. 1.

Horowitz, J.K. and K.E. McConnell. 2002. "A Review of WTA/WTP Studies." *Journal of Environmental Economics and Management*. 44(3): 426-447.

Horowitz, J.K. and K.E. McConnell. 2003. "Willingness to Accept, Willingness to Pay, and the Income Effect." *Journal of Economic Behavior and Organization*. 51: 537-545.

Jones-Lee, M.W. 1991. "Altruism and the Value of Other People's Safety." *Journal of Risk and Uncertainty*. 4(2): 213-219.

Kaplow, L. 2005. "The Value of a Statistical Life and the Coefficient of Relative Risk Aversion." *Journal of Risk and Uncertainty*. 31(1): 23-34.

Kleckner, N. and J. Neumann. 1999. "Recommended Approach to Adjusting WTP Estimates to Reflect Changes in Real Income." Memorandum to J. Democker, Office of Air and Radiation, U.S. Environmental Protection Agency, from Industrial Economics, Incorporated.
(<http://www.epa.gov/ttnecas1/regdata/Benefits/background/klecknerandneumann1999.pdf>)

Kleckner, N. and J. Neumann. 2000. "Recommended Approach to Adjusting WTP Estimates to Reflect Changes in Real Income." Memorandum to J. Democker, Office of Air and Radiation, U.S. Environmental Protection Agency, from Industrial Economics, Incorporated.

Kling, C.L. et al. 2011. "Review of 'Valuing Mortality Risk Reductions for Environmental Policy: A White Paper' (December 10, 2010)." Memorandum to Lisa P. Jackson, EPA Administrator, from the EPA Science Advisory Board and Environmental Economics Advisory Committee. EPA-SAB-11-011.

Kniesner, T. J., W.K. Viscusi, and J.P. Ziliak. 2010. "Policy Relevant Heterogeneity in the Value of Statistical Life: New Evidence from Panel Data Quantile Regressions." *Journal of Risk and Uncertainty*. 40: 15-31.

Kniesner, T. J., W.K. Viscusi, and J.P. Ziliak. 2014. "Willingness to Accept Equals Willingness to Pay for Labor Market Estimates of the Value of Statistical Life." *Journal of Risk and Uncertainty*. 48(3): 187-205.

Lindhjem, H., S. Navrud, N.A. Braathen, and V. Biaisque. 2011. “Valuing Mortality Risk Reductions from Environmental, Transport, and Health Policies: A Global Meta-Analysis of Stated-preference Studies.” *Risk Analysis*. 31(9): 1381-1407.

Ludwig, L. and J. Neumann. 2012. “Updating Income Elasticity Estimates in EPA’s BenMAP Air Pollution Benefits Estimation System.” Memorandum to N. Fann, Office of Air and Radiation, U.S. Environmental Protection Agency, from Industrial Economics, Incorporated. (http://www.epa.gov/ttn/ecas/regdata/Benefits/IncomeElasticityUpdate_Recommendationswithappendices.pdf)

Morris, J. and J.K. Hammitt. 2001. “Using Life Expectancy to Communicate Benefits of Health Care Programs in Contingent Valuation Studies.” *Medical Decision Making*. 21: 468-478.

National Academies. 2008. *Estimating Mortality Risk Reduction and Economic Benefits from Controlling Ozone Air Pollution*. Committee on Estimating Mortality Risk Reduction Benefits from Decreasing Tropospheric Ozone Exposure. Washington D.C.: National Academies Press.

National Oceanic and Atmospheric Administration. 1993. “Report of the NOAA Panel on Contingent Valuation.” (Arrow, K., R. Solow; P.R. Portney, E.E. Leamer, R. Radner, and H. Shuman.) *Federal Register*. 58: 4601-4614.

Neumann, J. and S. Brennan. 2004. “Responding to SAB Council Comments on the May 2003 Draft Analytical Plan for the Section 812 Second Prospective - Options for Adjusting WTP Estimates to Reflect Changes in Real Income.” Memorandum to N. Smoke, Office of Air and Radiation, U.S. Environmental Protection Agency, from Industrial Economics, Incorporated.

Robinson, L.A. and J.K. Hammitt. 2015. “Valuing Reductions in Fatal Illness Risks: Implications of Recent Research.” *Health Economics*. In press.

Svensson, M. and M.V. Johansson. 2010. “Willingness to Pay for Private and Public Road Safety in Stated-preference Studies: Why the Difference?” *Accident Analysis and Prevention*. 42: 1205-1212.

Tuncel, T. and J.K. Hammitt. 2014. “A New Meta-Analysis on the WTP/WTA Disparity.” *Journal of Environmental Economics and Management*. 68(1): 175–187.

U.S. Department of Transportation. 2014. *Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in Departmental Analyses – 2014 Adjustment*. Memorandum to Secretarial Officers and Modal Administrators from P. Rogoff, Acting Under Secretary for Policy, and K. Thomson, General Counsel.

U.S. Energy Information Administration. 2014. *Annual Energy Outlook 2014*.

(<http://www.eia.gov/forecasts/aeo/>)

U.S. Environmental Protection Agency. 2006. *Report of the EPA Work Group on VSL Meta-Analyses*.

U.S. Environmental Protection Agency. 2010. *Valuing Mortality Risk Reductions for Environmental Policy: A White Paper (Review Draft)*. Prepared by the National Center for Environmental Economics for consultation with the Science Advisory Board – Environmental Economics Advisory Committee.

U.S. Environmental Protection Agency. 2014. *Guidelines for Preparing Economic Analyses*.

(<http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html>)

U.S. Environmental Protection Agency. 2015. *BenMAP: Environmental Benefits Mapping and Analysis Program – Community Edition User’s Manual*. Prepared for the Office of Air Quality Planning and Standards by RTI International. (http://www2.epa.gov/sites/production/files/2015-04/documents/benmap-ce_user_manual_march_2015.pdf)

Van Houtven, G., J. Powers, A. Jessup, and J-C Yang. 2006. “Valuing Avoided Morbidity using Meta-Regression Analysis: What can Health Status Measures and QALYs tell us about WTP?” *Health Economics*. 15: 775-795.

Viscusi, W.K. 2013. “Using Data from the Census of Fatal Occupational Injuries (CFOI) to Estimate the ‘Value of a Statistical Life’.” *Monthly Labor Review*. Bureau of Labor Statistics.

Viscusi, W.K. 2015. “The Role of Publication Selection Bias in Estimates of the Value of a Statistical Life.” *American Journal of Health Economics*. 1(1): 27-52.

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

Viscusi, W.K., J. Huber, and J. Bell. 2014. “Assessing Whether There is a Cancer Premium for the Value of a Statistical Life.” *Health Economics*. 23(4): 384-396.