Valuing Mortality Risk Reductions in Global Benefit-Cost Analysis

Lisa A. Robinson, James K. Hammitt, and Lucy O'Keeffe

March 2018

Guidelines for Benefit-Cost Analysis Project
Working Paper No. 7

Prepared for the Benefit-Cost Analysis Reference Case Guidance Project
Funded by the Bill and Melinda Gates Foundation

Visit us on the web: https://sites.sph.harvard.edu/bcaguidelines/

Preface and Acknowledgements

The Bill and Melinda Gates Foundation (BMGF) is supporting the development of guidelines for the economic evaluation of investments in health and development, particularly in low- and middle-income countries ("Benefit-Cost Analysis Reference Case: Principles, Methods, and Standards," grant number OPP1160057). These guidelines will supplement the existing international Decision Support Initiative (iDSI) reference case, which provides general guidance on the overall framework for economic evaluation as well as specific guidance on the conduct of cost-effectiveness analysis.

This working paper is part of a series of methods papers and case studies being conducted to support the extension of the reference case to include benefit-cost analysis. The methods papers were reviewed by selected experts, posted online for public comment, discussed in a November 2017 workshop at Harvard University, then finalized. Although these papers will provide the basis for the benefit-cost analysis reference case guidance, the reference case may ultimately deviate from their recommendations in some cases.

This paper was prepared by Lisa A. Robinson, James K. Hammitt and Lucy O'Keeffe (Harvard T.H. Chan School of Public Health, Center for Health Decision Science and Center for Risk Analysis). For their careful review and very helpful comments on our October 2017 draft, we thank Anna Alberini, Margaret Conomos, Maureen Cropper, Scott Grosse, Markus Haacker, Dean Jamison, Margaret Kuklinski, Carol Levin, members of the London School of Hygiene and Tropical Medicine Economic Evaluation group (Michelle Remme, Catherine Pitt, Sedona Sweeney, Tom Drake, Fiammetta Bozzani, and Zia Sadique), Kip Viscusi, and Brad Wong. For many insightful discussions, we also thank the other members of our Leadership Team and our Advisory Group (https://sites.sph.harvard.edu/bcaguidelines/advisory-group/), our Gates Foundation Program Officer (David Wilson), and participants in the November 2017 workshop and in our sessions at the December 2017 Society for Risk Analysis meeting and the March 2018 Society for Benefit-Cost Analysis meeting.

More information on the project is available at https://sites.sph.harvard.edu/bcaguidelines/.

Executive Summary

Increasing life expectancy is a major goal of many policies implemented around the world. As a result, the value of reducing mortality risk has been extensively studied and several organizations have developed recommendations for estimating these values in benefit-cost analysis. However, both the recommendations and the underlying research primarily address high-income settings, raising questions about the extent to which the results are applicable in low- and middle-income countries. The recommendations are also diverse, reflecting differing methodological choices as well as differing policy contexts.

In this paper, we review the literature and develop recommendations for valuing mortality risk reductions to support the development of reference case guidance for benefit-cost analysis. Although we focus on values applicable in low- and middle-income countries, this work has implications for the values used globally.

As conventionally conducted, benefit-cost analysis is based on respect for individual preferences. Value is derived from the willingness of the individuals affected to exchange money for the benefits each accrues. Money is not important *per se*; rather, it reflects the resources available to spend on risk reductions and other goods and services. Spending on mortality risk reductions means that individuals – and the society of which they are a part – will have fewer resources available to spend on other things. Understanding these preferences is likely to be useful to decision-makers and stakeholders, regardless of whether the policy decision is ultimately made on other grounds.

This fundamental concept of individual willingness to pay (WTP) for changes in one's own risk has been obscured by the language economists use to describe these values. A reduction in mortality risk that accrues throughout a population decreases the expected number of deaths within a particular time period. Economists correspondingly convert estimates of individual WTP into estimates of the value per "statistical" life (VSL). The term "statistical" refers to small changes in the chance of dying, but is often misinterpreted. VSL is not the value that the individual, the society, or the government places on averting a death with certainty. Rather, it represents the rate at which an individual views a change in money available for spending as equivalent to a small change in his or her own mortality risk.

Valuation Concepts and Methods

Individuals' WTP presumably encompasses all of the impacts of the risk change on their wellbeing – including both the pecuniary effects (such as avoided out-of-pocket medical costs and losses in future earnings) and the non-pecuniary effects (such as continuing to experience the joys of life itself and delaying the pain and suffering associated with dying). It also reflects the trade-off between spending while alive and bequeathing money to others at death. These values vary across individuals and across different types of risk; there is no single value that is applicable to all contexts.

Because mortality risk reductions are not directly bought and sold in the marketplace, WTP estimates are generally derived using stated- or revealed-preference methods. Stated-preference studies typically employ survey techniques to ask respondents about their WTP for an outcome under a hypothetical scenario. Revealed-preference methods infer the value of nonmarket goods from observed behaviors and prices for related market goods. For example, wage-risk studies (often referred to as hedonic-wage studies) examine the additional compensation associated with jobs that involve higher risk of fatal injury. These studies use statistical methods to separate the effects of mortality risk on wages from the effects of other job and personal characteristics.

Conducting new primary research requires substantial time and expense; typically analysts instead rely on existing valuation studies. This approach is referred to as “benefit transfer” to indicate that the populations and policies studied are not necessarily identical to the population and policy considered in a particular benefit-cost analysis. Similar to the process used to estimate other parameter values in policy analysis, such transfers involve carefully reviewing the literature to identify high-quality studies that are suitable for use in a particular context, and determining whether and how to combine and adjust the results prior to application.

Population-Average Values

The value of mortality risk reductions is relatively well-studied; recent reviews suggest that over 200 studies have been completed globally. Because of the importance of these estimates, substantial attention has been paid to developing criteria for evaluating study quality and applicability, particularly in high-income settings. Relatively few studies have been conducted in low- and middle-income countries, however.

When evaluating policies to be implemented in lower income countries, benefit-cost analysts typically rely on one of two approaches: (1) they use the results of studies conducted in the country of concern if available; (2) they extrapolate from values from higher income countries, adjusting for differences in income. While the first option is preferable when studies from the country are of sufficient quality, the paucity of research in many settings means that analysts often follow the second option.

The starting point for this extrapolation is often either values developed for use in U.S. regulatory analyses or for application by OECD member countries. These values differ significantly, however, in terms of both the absolute amount and the relationship to income. In the U.S., central VSL estimates are generally between $9 million and $10 million (2015 U.S. dollars). For the OECD as a whole, the recommended central VSL estimate is $3 million (2005 U.S. dollars). Comparing these estimates to gross national income (GNI) per capita (expressed in international dollars for the same year and same population as each estimate) results in a VSL to GNI per capita ratio of 155 to 172 for the U.S. estimates and a ratio of 98 for the OECD estimate. The substantial difference in these ratios is attributable at least in part to the use of divergent approaches to developing these estimates, not solely differences in the incomes and preferences of these populations.

Because these values represent the trade-off between spending on mortality risk reductions and on other things, it would be nonsensical to expect that the values would be the same for individuals with substantially different income levels. For example, a $9 million VSL implies that the average U.S. resident is willing to pay $900 for a 1 in 10,000 mortality risk change, or 1.6 percent of U.S. GNI per capita, which was $57,900 in 2015 (international dollars). In a lower-income country, where GNI per capita may be substantially less, it seems implausible or impossible that the average individual would be willing to spend $900 on the same risk reduction, given other more essential needs. Overall, individual WTP per unit of risk reduction is expected to decrease as income decreases, resulting in a smaller VSL.

To extrapolate values across countries, analysts select an estimate (or estimates) of the degree of change in the VSL associated with a change in income; i.e., the VSL income elasticity. Although comparisons among high-income populations often find that VSL is less than proportional to income (an income elasticity of less than one), comparisons between populations with large income differences often find that VSL is more than proportional to income (an income elasticity of greater than one). An income elasticity greater than one implies that the ratio of VSL to GNI per capita is smaller among lower than in higher income populations. This seems reasonable given that lower-income individuals must devote a larger share of their incomes to more necessary or urgent expenses.

Adjusting a base VSL for income differences requires an income estimate for the population to which the base VSL applies, an income estimate for the target population, and an estimate of the rate at which VSL changes as income changes; i.e., the average income elasticity over the relevant income range. The formula is:

$$VSL_{target} = VSL_{base} * (Income_{target} / Income_{base})^{elasticity}$$

(equation 1)

It is often convenient to work with ratios of VSL to income rather than VSL itself. The relationship can be derived from the formula above; it is:

$$(VSL_{target} / Income_{target}) = (VSL_{base} / Income_{base}) * (Income_{target} / Income_{base})^{(elasticity - 1)}$$

(equation 2)

VSL is likely to differ across countries for many reasons other than variation in income. For example, differences in life expectancy, health, economic and social support, religion, and culture across individuals as well as across countries are likely to affect these values. However, the effects of these factors are poorly understood and at present there seems to be no adequate conceptual basis for adjusting VSL for any between-countries differences except income.

It is unclear whether the uncertainty in the resulting VSL estimates is large relative to the uncertainty in other parameter values used in benefit-cost analysis. In some cases, the estimates of net benefits may be sensitive to these values; in others, whether a policy yields net benefits or which policy yields the greatest net benefits may not change regardless of which value is used.

Adjustments for Age and Life Expectancy

The estimates featured in the discussion above are population-average values for adults. Because the number of life years remaining for younger or older individuals may be much larger or smaller respectively, intuition suggests that different values may be applicable. However, both theory and empirical work indicate that the relationship is uncertain. Research conducted largely in high-income countries suggests that values for children may exceed the average for adults by perhaps a factor of two, values for working age adults may follow an inverse “U” pattern that peaks in middle-age, and values at older ages may remain constant, increase, or decrease. However, the results across studies are inconsistent and raise questions about the robustness of these findings. For low- and middle-income countries, little empirical research is available and it is unclear whether the same patterns are likely to hold.

In applied work, one frequently applied simplifying assumption is that the value of mortality risk reduction increases with life expectancy (or decreases with age). To implement this approach, often a constant value per statistical life year (VSLY) is used, derived from the VSL using simple assumptions. This VSLY is then multiplied by the change in life expectancy associated with the policy to estimate the value of mortality risk reductions for individuals in different age groups. Assuming VSLY is constant provides a rough proxy for the effects of age and life expectancy, but is not supported by theory nor the available empirical research.

Benefit-cost analyses conducted in low- and middle-income countries must at times also address deaths around the time of birth, which raise difficult normative questions as well as empirical issues. We know very little about parental WTP to avert the death of a fetus or a newborn. One option is to apply the VSL and VSLY estimates described above to deaths that occur at or subsequent to birth (applying the VSLY estimate to life expectancy at age zero), and to value deaths that occur prior to birth at zero. Additional sensitivity analysis is likely to be desirable that tests the effects of assigning positive values to deaths prior to birth.

Recommendations and Priorities for Future Research

Ideally, the value of mortality risk reductions in low- and middle-income countries would be derived from multiple high-quality studies of the population affected by the policy, given the likelihood that these values will vary depending on characteristics of the society, the individuals affected, and the risk. However, extrapolation from studies of other populations is often needed given the gaps in the available research. To ease comparison with the findings of other benefit-cost analyses as well as examine related uncertainties, our recommendations include conducting a standardized sensitivity analysis as described in more detail below.

In the near-term, we recommend that analysts proceed as follows when estimating VSL in low- and middle-income countries.

1) ***Use context-specific values as the central estimates if available.*** Ideally, the values used in benefit-cost analysis should be derived from a criteria-driven review of the WTP literature, that identifies high-quality studies that are suitable for the context, taking into account the characteristics of the risks and of the affected population.

2) ***Apply default values: (a) if context-specific values are not available, and (b) in a standardized sensitivity analysis even if context-specific values are used as the primary estimates.***[1] The default values should include the following:
    a. VSL = 160 * GNI per capita in the target country.
    b. VSL = 100 * GNI per capita in the target country.
    c. VSL extrapolated from a U.S. estimate to the target country using an elasticity of 1.5.

    The use of a constant ratio across countries under options (a) and (b) is equivalent to assuming that income elasticity is 1.0; recent work appears to be coalescing around this value. The ratio in option (a) is based on U.S. data, and reflects concerns that the lower VSL estimates found in many studies result from publication-selection bias. The ratio in option (b) is based on meta-analysis conducted by the OECD. Option (c) reflects the elasticities found in extrapolating from a U.S. VSL to the VSLs from studies in low- and middle-income countries.

    These three estimates should be used in sensitivity analysis even if context-specific values are featured, to allow comparison of the results under this second option to the primary results from the first option and across analyses.

    In developing these values, analysts should use GNI per capita estimates measured using purchasing power parity (international dollars) when transferring estimates across countries, to best represent the resources available. The results should be reported in the local currency as well as in international dollars.

    It often requires several years for policy impacts to fully manifest. Analysts should also project the change in real income (measured as GNI per capita) that occurs over this time period and adjust the VSL estimates accordingly, using the same approaches as above.

[1] These options are designed for application in low- and middle-income countries. Approaches designed for application in high-income countries are referenced in the main text of this paper as well as in our scoping report (Robinson et al. 2017a).

3) ***If the policy disproportionately affects the very young or the very old, conduct sensitivity analyses using VSLY estimates.*** The approaches discussed above yield population-average estimates, whereas some policies disproportionately affect the very young or the very old. In such cases, analysts should, at minimum, conduct sensitivity analysis using a constant VSLY derived from the VSL estimates that result from recommendations 1 and 2; i.e., the central context-specific estimates (if any) and the estimates that result from the standardized sensitivity analysis. This constant VSLY should be calculated by first estimating the population-average VSL for the country affected by the policy, then dividing the VSL by the undiscounted future life expectancy at the average age of the adult population in that country.

4) ***If the analysis addresses deaths around the age of birth, assess the sensitivity of the results to alternative assumptions.*** While the VSL and VSLY estimates described under the above recommendations can be used in this case, analysts should also explore the impact of assigning positive values to mortality risk reductions that occur prior to birth.

5) ***Address other sources of uncertainty*:** While recommendations 1 through 4 address uncertainties related to the effects of income and age or life expectancy, they do not address other differences between the risks and populations studied and the risks and populations addressed by the analysis. These differences should be explored both qualitatively and quantitatively. Analysts should also indicate the implications for decision-making; i.e., the extent to which the uncertainties affect the estimated net benefits of a policy or the ranking of alternative policies.

Over the long term, more research is needed that explicitly addresses the value of mortality risk reductions in low- and middle-income countries. To support and encourage such studies, research methods tailored to this context should be further developed.

1) ***Conduct additional research on WTP for mortality risk reductions in low- and middle-income countries:*** Substantial additional research is needed on the value of mortality risk reductions in these countries, given the importance of these estimates in policy analysis and the likely differences in preferences across members of different populations.

2) ***Develop protocols for the conduct of these studies that are tailored to low- and middle-income settings.*** To encourage additional research and ease its implementation, more work is needed on developing approaches for data collection and analysis that can be feasibly implemented in low- and middle-income settings, which will provide reasonably valid and reliable results. Such approaches should be tailored to the likely resources available and take into account the characteristics of these populations as well as the risks they face.

3) ***Develop an easily accessible repository for valuation studies*,** that includes primary research as well as research that synthesize the results. Many researchers in low- and middle-income countries may not have easy access to these studies, so will find it difficult to conduct the careful review that is

needed to determine whether studies are applicable in particular settings and to form the foundation for new research.

Such additional research will help analysts, decision-makers, and other stakeholders better understand the preferences of those affected, which can aid in policy implementation as well as evaluation. It also moves away from focusing largely on the effects of income differences, and encourages greater attention to other sources of variation such as differences in cultural norms and other context-specific factors.

Table of Contents

1.0 Introduction

Increasing life expectancy is a major goal of numerous policies, regardless of whether they are implemented in high-, middle-, or low-income countries. The value of the associated risk reductions often account for a substantial share of the benefits of environmental, public health, safety, and other policies.[2] Thus it is not surprising that these values have been extensively studied; nor is it surprising that several organizations have developed recommendations for estimating these values in particular contexts.

However, these recommendations are diverse, reflecting variations in approach as well as in the values held by different populations. In high-income countries, the divergence results largely from methodological choices, including differences in the criteria used to evaluate the available research, in the approach used to combine estimates across studies, and in the extent to which the resulting estimates are adjusted for the characteristics of the risks addressed and the populations affected. For low- and middle-income countries, little research is available. Values are usually extrapolated from estimates for high-income countries by applying relatively simple assumptions. The results may vary substantially due to differing choices regarding the estimate used as a starting point and the assumptions used in the extrapolation.

We explore the available research and alternative approaches for its application in this paper. While we focus on estimating the value of mortality risk reductions in low- and middle-income countries, our review also has implications for analyses that address higher income countries. This paper is one in a series of methods papers which will ultimately be used to develop guidance on the conduct of benefit-cost analysis in global health and development. Information on the overall project, the benefit-cost analysis framework and related normative assumptions, and on the role of benefit-cost analysis in decision-making, is provided in our scoping report (Robinson et al. 2017a) and on the project website: https://sites.sph.harvard.edu/bcaguidelines/.

Before proceeding, a few notes: one on terminology, and a second on converting estimates across currencies and time periods.

1.1 Terminology

As discussed in more detail later, the value of small changes in mortality risk is usually expressed as the value per statistical life (VSL). This term has led to substantial confusion. It is a money measure of the value to an individual of a small reduction in his or her own mortality risk within a defined time period. VSL is not the value of a "life" or a statement of moral worth; nor is it the value that the government, the analyst, or the individual places on preventing certain death.[3] It represents the rate at which

[2] These values are also at times used to derive thresholds for health-related cost-effectiveness analysis, which is often utilized to prioritize spending. See Claxton et al. (2016) and Robinson et al. (2017b) for more discussion.

[3] For example, "all lives have equal value" is a statement of moral worth, and uses a different definition of value than that discussed in this paper. See Robinson et al. (2017a) for more discussion of the underlying normative framework and its implications for role of benefit-cost analysis in decision-making.

individuals are willing to trade their own money (or other valuable factors like time) for small changes in their survival probability for a specified period (such as the current year). Such trades are commonplace. Illustrations include choices about whether to buy protective equipment (such as bicycle or motorcycle helmets), to drive more slowly, to walk farther to a less contaminated water source, or to use more expensive but less polluting fuels.

VSL is typically calculated by taking an estimate of an individual's willingness to pay (WTP) for a small change in his or her own mortality risk (such as $300) and dividing it by the risk change (such as a 1 in 10,000 reduction in the chance of dying this year), which yields a $3 million VSL ($300 divided by 1 in 10,000). This translation of individual WTP into a VSL estimate can obscure the fundamental concept; i.e., that the values used in benefit-cost analysis should reflect individual preferences for the effect of a policy – the $300 for a 1 in 10,000 risk reduction in this case.

Over the years, many alternative terms have been suggested, but none have been widely accepted or used.[4] For example, some authors have recommended terms such as the "value the per standardized mortality unit" (VSMU) (Jamison et al. 2013) or the "value of mortality risk" (VMR) (U.S. Environmental Protection Agency (USEPA) 2010a) to refer to an individual's willingness to exchange income for mortality risk.[5] To connect the concepts and estimates presented in this paper with the well-established VSL literature, we use that term where relevant, but more generally refer to the value of mortality risk reduction to clarify this concept. Research recently completed by the USEPA suggests that this term may be better understood by members of the general public than the alternatives.[6]

1.2 Converting Values Across Currencies and Time Periods

In the discussion that follows, we assume that the estimates developed in this paper will be used in benefit-cost analyses with two objectives: (1) to support country-level policy choices by providing results measured in the local currency; and (2) to allow cross-country comparisons by providing results in a common currency. Because the data available for estimating costs and benefits may be reported for different years as well as in different currencies, analysts must also adjust for inflation to support both objectives. The first objective requires that all benefits and costs be measured in a way that is consistent with local conditions, including the preferences of those affected and the opportunity costs of the policy. The second objective requires converting these estimates into measures that reflect the relative resources available to those in each country over the time period of interest.

[4] In the United Kingdom, VSL is usually described as the value of a prevented fatality (VPF) and VSLY as the value of a life year (VOLY).

[5] A standardized mortality unit is a 1 in 10,000 risk change; the VMR is at times expressed as WTP for a 1 in 1 million risk change, but other units are possible.

[6] This work was conducted by the U.S. Environmental Protection Agency (USEPA), following the recommendations of its independent Science Advisory Board (Kling et al. 2011). Based on the results presented by Nathalie Simon (National Center for Environmental Economics, USEPA) on March 16, 2018 at the Society for Benefit-Cost Analysis annual meeting, it appears that USEPA will recommend the term "value of reduced mortality risk" (VRMR). The USEPA report will be posted on its website when available: https://www.epa.gov/environmental-economics/environmental-economics-reports.

Two frequently-used methods to convert values to a common currency are: (1) relying on market exchange rates to convert to U.S. dollars; or (2) relying on estimates of purchasing power parity to convert to international dollars. Rather than simply reflecting the market price for exchanging currencies, the latter is an index designed to represent what money can purchase in different economies.[7] In the country of concern, an international dollar would buy a comparable quantity of goods and services as a U.S. dollar would buy in the United States.

When high-quality estimates of the value of some component of the benefit-cost analysis are not available for the local context (e.g., VSL or the opportunity cost of a resource), it may be necessary to extrapolate from an estimate of that value in another context, often a higher-income country (this extrapolation is often called benefit-transfer, as discussed later, but can be used for costs as well). For this purpose, market exchange rates or purchasing power parity may be appropriate, depending on the component. For a non-market component (such as mortality risk reduction) or a market input that is not traded outside the local context (such as some labor inputs, e.g., for haircuts), purchasing power parity seems to provide the most appropriate comparison relative to other goods and services. For market inputs that are traded outside the local context (e.g., globally traded commodities such as petroleum), market exchange rates seem to provide a better measure of opportunity cost.

For comparing the results of benefit-cost analyses across different contexts, either market-exchange rates or purchasing-power parity may be appropriate, depending on the objective of the comparison. If the objective is to embed the comparison in a larger benefit-cost analysis so as to determine which policy is most economically-efficient (i.e., yields the largest positive net benefits), then market-exchange rates seem appropriate).[8] Alternatively, if a donor wishes to compare the merits of supporting a project in one country or another, purchasing power parity, which is a better measure of real consumption and wellbeing, may be more appropriate.

The question of how to compare analytic results between contexts is beyond the scope of this paper, and requires coordinating with other teams that are developing costing guidance under companion projects.[9] The results of these discussions will be reported in the guidance document to be developed in the subsequent phase of this project.

Another issue relates to adjusting for changes in economy-wide prices over time. This issue involves two subcomponents: (a) what measure of inflation should be used; and (b) how should inflation adjustments and currency conversions be sequenced? Note that we assume that all costs and benefits will be inflated

---

[7] For more information on the calculation of purchasing power parity rates, see http://pubdocs.worldbank.org/en/242881493822925477/PPP-brochure-2017-webformat.pdf.

[8] In other words, the goal is to explore whether the policy passes the Kaldor-Hicks potential compensation test; i.e., whether those who gain under the policy could in theory compensate those who lose. In this case, presumably any compensation would be arranged using market exchange rates. See Robinson et al. (2017a) for more discussion.

[9] These teams include the International Decision Support Initiative and the Global Health Costing Consortium; see http://www.idsihealth.org/resource-items/idsi-reference-case-for-economic-evaluation/ and https://ghcosting.org/pages/standards/reference_case.

to a given currency year (typically the most recent year for which inflation estimates are available, often the year prior to the current year), then expressed in real dollars (absent inflation) when projecting impacts over future years.[10] Working in real dollars avoids the uncertainties associated with predicting future inflation rates.

On the first question, typically either a gross domestic product (GDP) deflator or a consumer price index (CPI) is used. The GDP deflator is a measure of the price level for all domestically produced, final goods and services in a country over a given period of time (e.g., one year). The CPI is typically a measure of the price level for a basket of consumer goods and services, taking into account the changes in price for each item in a pre-selected group. The World Bank reports CPIs and GDP deflators for 217 countries, although the time periods covered vary.[11,12] Because benefits, such as mortality risk reductions, are presumably consumed locally, the CPI seems appropriate.

On the second question, the analyst faces two choices when transferring estimates across countries: to first inflate the value in the original source-country currency to the year used in the analysis, then convert to the target-country currency, or to first convert the value to the target-country currency used in the analysis then inflate it to the appropriate year using the index in the target country. Because the values reflect production and consumption opportunities in the country from which they are derived, it seems sensible to first inflate in the original currency and then convert the resulting value into the target-country currency. We follow this approach as needed to develop the values reported in this paper.

The remainder of this paper consists of the following:

- Chapter 2 discusses basic concepts and methods used for valuation.
- Chapter 3 explores approaches for estimating population-average values in low- and middle-income countries.
- Chapter 4 investigates the relationships between these values and age and life expectancy.
- Chapter 5 summarizes the discussion and recommendations, and suggests priorities for future research.

The appendices provide more detailed information on the literature review summarized in Chapter 3, as well as tables with country-by-country VSL estimates for 2015.

[10] The currency year will likely differ from the base year used when discounting to calculate present or annualized values. In most cases, the base year for discounting should be the first year in which the policy is implemented; i.e., when costs and/or benefits first begin to accrue.
[11] For CPIs using 2010 as the base year, see https://data.worldbank.org/indicator/FP.CPI.TOTL.
[12] For GDP deflators, the base year varies; see https://data.worldbank.org/indicator/NY.GDP.DEFL.ZS.

2.0 Basic Concepts and Methods

Valuing mortality risk reductions requires first defining the outcome to be valued, then determining the appropriate conceptual framework and methods for valuation. We briefly introduce these issues in this chapter, building on the discussion in our scoping report (Robinson et al. 2017a) as well as in a recent examination of the theoretical foundations (Hammitt 2017).

2.1 "Statistical" Lives

In benefit-cost analysis as well as in cost-effectiveness analysis and other types of economic evaluation, the starting point for valuing mortality risk reductions is typically an estimate of the change in the likelihood of death in a defined time period for those individuals affected by the policy. This risk change can be aggregated over the affected population to calculate the expected number of deaths the policy averts in a specified period. It also may be possible to estimate the age or life expectancy of those affected, and to calculate the expected number of life years gained.

In discussing these calculations, researchers often use the term "statistical" to emphasize the role of probability; most policies reduce the risk incurred by the affected population rather than preventing identifiable deaths with certainty. The specific individuals who would have died without the policy generally cannot be identified either before or after the policy is implemented. Because death can be delayed but not prevented, reducing deaths in one year necessarily increases deaths in future years; the policy increases the life expectancy of those affected rather than reducing the likelihood that they will ever die. Policies can prevent or reduce the chance of deaths from particular causes, but doing so necessarily increases the chance of death from other causes.

For example, if a policy leads 10,000 individuals to each experience a risk reduction of 1 in 10,000 in a given year, then one statistical life is "saved" (10,000 * 1/10,000 = 1). This means that, if in the absence of the policy, three out of 10,000 people are expected to die in that year, then with the policy two of these 10,000 people are expected to die. The number of "statistical lives saved" – one in this case – is simply the reduction in the expected number of deaths in that year.

Consistent with the benefit-cost analysis framework, the value of these risk reductions is based on individuals' willingness to trade-off spending on other goods and services for reductions in their own risks.[13] VSL is the ratio of the amount of money an individual would give up in exchange for a small reduction in mortality risk, such that he or she is no better and no worse off with the reductions in mortality risk and money remaining than without the exchange. In other words, VSL is an individual's marginal rate of substitution between wealth and the risk of dying in a defined time period.[14]

---

[13] Exceptions include cases where the affected individuals may lack the judgment needed to assess the effects of changes in wealth and changes in risk on their own wellbeing, such as young children, those with cognitive impairments, or those dealing with addiction.

[14] The units used to express this rate of substitution are arbitrary. It is conventional to measure the rate in dollars per one-unit change in probability of death (i.e., between one and zero), but it can be measured as dollars per 1 in

Presumably, individual WTP for a reduction in mortality risk accounts for both the pecuniary effects of the risk change (including avoided out-of-pocket medical and other expenses and losses in future earnings) and the non-pecuniary effects (including continuing to experience the joys of life itself and delaying the pain and suffering associated with dying). It also reflects the trade-off between spending while alive and bequeathing money to others at death. These values are likely to vary across individuals and also across different types of risk; for example, individuals may value a risk that is viewed as voluntary and controllable differently than a risk that is not.

For small changes in risk, VSL can be approximated by dividing WTP by the risk change.[15] An individual who is willing to pay $300 for a 1 in 10,000 reduction in his or her risk of dying in the current year has a VSL of $3 million ($300 WTP ÷ 1/10,000 risk change). For risks that accrue throughout a population, the value of the risk reduction is equal to the sum of each individual's WTP for the risk reduction he or she experiences. This sum can be divided by the total number of expected deaths averted to estimate the average VSL within that population. For example, if a population of 10,000 is willing to pay, in the aggregate, $30 million in a given year for a risk reduction that is expected to result in 10 fewer deaths in that year, VSL would average $3 million ($30 million divided by 10 cases).

One question that arises in this context is whether and how to include preferences for risk reductions that accrue to others. The role of altruism in benefit-cost analysis raises difficult conceptual issues.[16] A pure altruist would care about how those affected weigh both the benefits and costs they accrue, which is likely to lead to the same conclusions as an analysis that considers only self-regarding preferences (Jones-Lee 1991, Bergstrom 2006). A paternalistic altruist may instead weight some impacts (such as improved health or increased longevity) differently than do the individuals affected. Given that such paternalistic preferences are likely to vary across individuals as well as across decision-makers and other stakeholders, typically analysts report the unweighted results and allow others to decide how to weight them. These and related issues are addressed in our scoping report (Robinson et al. 2017a) as well as in our separate methods paper on distributional concerns (Robinson, Hammitt, and Adler 2018).

2.2 Valuation Methods

Because mortality risk reductions are not directly bought and sold in the marketplace, estimates of individual WTP are generally derived using stated- or revealed-preference methods (see Cropper,

---

10,000 or any other change in probability. Analogously, speed can be measured in meters per second or kilometers per hour.

[15] Estimates of willingness to accept compensation (WTA) are also consistent with the benefit-cost analysis framework. However, WTP is estimated more frequently in empirical research and typically used to value improvements from the status quo. See Viscusi (2015a), Hammitt (2015), and Knetsch (2015) for more discussion.

[16] Some VSL studies (conducted largely in high-income settings) address risk reductions to the community at-large, but the results at times seem nonsensical. Some researchers find counterintuitively that WTP for a private risk reduction is higher than WTP for a public program that also benefits others (see, for example, Svensson and Johansson 2010, Lindhjem et al. 2011). This result suggests that respondents may not fully accept the scenario presented in the survey; for instance, they may believe that the public program will be ineffective or that others should bear the costs.

Hammitt, and Robinson 2011 for more discussion). Stated-preference methods typically employ survey techniques to ask respondents about their WTP for an outcome under a hypothetical scenario. For example, a survey may ask respondents whether they would purchase a safety enhancement (such as improved air bags) that would reduce their risk of death from a motor vehicle accident if the price were "X" dollars. Such methods are attractive because researchers can tailor them to directly value the outcome(s) of concern; surveys can describe particular health risks from specific causes (such as poor sanitation rather than a motor vehicle accident) and also target respondents with particular characteristics (such as geographic location, health status, age, or income). A key concern is that respondents may have little incentive to respond accurately because the payment is hypothetical. Conducting a study that yields accurate and reliable results requires careful design and implementation.

Revealed-preference methods infer the value of nonmarket goods from observed behaviors and prices for related market goods. For example, wage-risk studies (often referred to as hedonic wage studies) examine the additional compensation associated with jobs that involve higher risks of fatal injuries, using statistical methods to separate the effects of these risks on wages from the effects of other job and personal characteristics.[17] While this use of market data has the advantage of relying on behavior with real consequences, it may be difficult to find a market good that can be used to estimate the value of the outcome of concern. For example, wage-risk studies address deaths resulting from job-related injuries among workers, while many policies instead affect illness-related deaths and may disproportionately affect those who are much younger or older than those who typically participate in the labor force.

An alternative measure is the human capital approach. This approach was widely-used in older analyses, but is not consistent with the benefit-cost analysis framework and we do not discuss it in detail in this paper. It estimates the value of a change in mortality risk based solely on the value of lost production, rather than relying on estimates of individual WTP. It does not include the value that individuals place on survival other than the loss in income (and the associated consumption), such as the joy of living more generally.

Not surprisingly, human capital estimates are typically much smaller than VSL estimates. For example, the World Bank and Institute for Health Metrics and Evaluation (2016) estimates the costs of air pollution around the world, and finds that these costs total $225 billion per year using the human capital approach and $5.11 trillion per year using VSL estimates. In the U.S., Grosse et al. (2009) found that the present value of future lifetime production for a 40 to 44 year old is $1.2 million if both market and nonmarket production are included; $0.8 million if only market production is included (2007 U.S. dollars, 3 percent discount rate). These values are much smaller than the U.S. population-average VSL estimates

[17] Another revealed-preference approach considers averting behaviors; i.e., defensive measures or consumer products used to protect against perceived health risks, such as the use of seat belts or motorcycle helmets. These studies are applied infrequently in benefit-cost analysis due to concerns about their limitations, including the difficulty of estimating the size of the risk change associated with many behaviors and the need to separately estimate the value of key inputs such as the time spent in the activity. Research that addresses other market goods (such as property values) faces similar challenges.

for individuals of about the same age (in the same dollar year), which are around $8 million (see, for example, USEPA 2010a).

While reporting human capital estimates along with VSL estimates may be useful in some settings, the relationship between human capital and VSL is complex (see Hammitt 2017). The VSL is not necessarily a simple sum of lost earnings and the value of other pecuniary and nonpecuniary effects; it also reflects the interactions between these effects and between spending while alive and bequeathing money to others at death.

2.3 Benefit Transfer and Research Synthesis

Because conducting new primary research requires substantial time and expense, typically analysts rely on existing valuation studies. This approach is referred to as “benefit transfer” to indicate that the populations and policies studied are not necessarily identical to the population and policy considered in the benefit-cost analysis.

As is the case when estimating other parameter values, such transfers involve carefully reviewing the literature to identify high-quality studies that are suitable for use in a particular context, and determining whether and how to combine and adjust the results prior to application. “Quality” is evaluated by considering the likely accuracy and reliability of the data and methods used; “suitability” involves exploring the similarity of the risks and the populations affected. There are no firm guidelines; benefit transfer relies heavily on the informed judgment of the analyst and requires clear disclosure and discussion of related uncertainties and their implications.

Various methods can then be used to combine the values and apply them in benefit-cost analysis. In some cases, the range and mid-point values from a criteria-driven literature review may be applied directly with or without adjustment to better fit the policy context; in other cases meta-analysis or structured expert elicitation may be used to explore the variation in the estimates and to guide their application (see Robinson and Hammitt 2015a).

In the following chapters, we use this benefit transfer framework to explore the options for valuing mortality risk reductions in low- and middle-income countries. We first consider the estimation of population-average values, then discuss adjustments for age and life expectancy. The final chapter summarizes our findings and provides our recommendations.

3.0 Population-Average Values

Many government agencies, international organizations, and individual researchers have reviewed the VSL literature and developed recommendations for its application. Typically, these recommendations involve estimating a population-average value for the country of concern and adjusting for income differences over time or across countries. As discussed in Chapter 2, we expect these values to vary by income because they reflect the willingness of the affected individuals to exchange money for the risk reductions they would accrue – reducing the resources they have available to purchase other goods and services. Adjustments are infrequently made for other characteristics of those affected or of the risk, due to gaps and inconsistencies in the research literature.

In this chapter, we first discuss the base VSL estimates used in transferring estimates across countries with differing income levels, then discuss the assumptions used to adjust for income differences. Ideally, analysts would instead rely on estimates derived from studies of the population of concern, applying the benefit transfer framework. The references in the discussion of base values in section 3.1 as well as the review in Appendix A provide examples of the application of this framework, and can be adapted for use in different settings.

In the discussion that follows, we provide estimates in the currency and year reported in the source document. We convert the values to international dollars for comparability where noted. These adjustments follow the procedures discussed in section 1.2. In applying these values, analysts should first update the values for inflation and real income growth to the currency year used in the analysis, then adjust for real income growth in future years.

3.1 Base VSL Estimates

The value of mortality risk reductions is relatively well-studied; recent reviews suggest that over 200 studies have been completed globally. Because of the importance of these estimates, substantial attention has been paid to developing criteria for evaluating study quality and applicability. Many government agencies (particularly in high-income countries) have published guidance on estimating VSL when assessing regulatory and other policies (for review, see Narain and Sall 2016, Robinson et al. 2017a). For low- and middle-income countries, values are often extrapolated from the estimates used by either U.S. regulatory agencies or the OECD. We focus on the U.S. and OECD estimates below because they are based on reasonably comprehensive reviews of the literature and are frequently used in international benefit transfers. With the exception of the U.S. Environmental Protection Agency estimates, they are also based on relatively recent research.

U.S. regulatory agencies typically derive recommended values by reviewing the literature and identifying a range of values and a central estimate from selected studies (U.S. Environmental Protection Agency (USEPA) 2010, U.S. Department of Health and Human Services (USDHHS) 2016, U.S. Department of Transportation (USDOT) 2016). These estimates rely largely on U.S. wage-risk studies and are between

$9 million and $10 million if expressed in 2015 U.S. dollars.[18] The OECD has taken a different approach, focusing on stated-preference studies conducted globally and using meta-analysis to combine the results (OECD 2012). The authors recommend that, for analyses that address the OECD as a whole, the base VSL should be $3 million (2005 U.S. dollars).

In Table 3.1, we report the range of values from these sources and compare them to GNI per capita for the same year and the same countries.[19,20] For the U.S., we report the estimates for the three major regulatory agencies that have developed related guidance. For the OECD, we report the estimates recommended for use in benefit transfer for those analyses that address all OECD countries. Rather than adjusting to the same dollar year (which requires making assumptions about the relationship to changes in real income as well as inflation), we report the values provided in the source documents and use the relationship to GNI per capita in that year to compare the estimates.

Table 3.1. Comparison of VSL to GNI per capita: U.S. and OECD

Source (dollar year)	VSL estimate (range)	GNI per capita[a]	Ratio of VSL to GNI per capita	WTP for 1 in 10,000 risk change	WTP as percent of GNI per capita
USEPA (2010) (2006 USD)	$7.4 million[b] (±$4.7 million[c])	$47,390	156 (57, 255)	$740 ($270, $1,210)	1.6% (0.6%, 2.6%)
USDHHS (2016) (2014 USD)	$9.3 million ($4.4 million, $14.2 million)	$56,160	166 (78, 253)	$930 ($440, $1,420)	1.7% (0.8%, 2.5%)
USDOT (2016) (2015 USD)	$9.6 million ($5.4 million, $13.4 million)	$57,900	166 (93, 231)	$960 ($540, $1,340)	1.7% (0.9%, 2.3%)
OECD (2012) (2005 USD)	$3.0 million ($1.5 million, $4.5 million)	$30,601	98 (49, 147)	$300 ($150, $450)	1.0% (0.5% to 1.5%)

Notes:
a. GNI per capita in international dollars (purchasing power parity) for the same year as the estimate, as reported by the World Bank.
b. USEPA (2016) notes that this value would be $9.7 million if updated to 2013 dollars, but does not report the associated range. USEPA is currently updating the basis for its VSL estimates.
c. Standard deviation.
d. If updated to 2015 U.S. dollars, the central USDHHS VSL is $9.4 million, or 162 times GNI per capita ($57,900) in that year. This updated estimate relies on the approach described in USDHHS (2016), which uses the U.S. consumer price index to adjust for inflation, measures income based on workers' earnings (rather than GNI or GDP per capita), and applies an income elasticity of 1.0.

[18] See Table 3.1 for U.S. values in the same currency year as reported in the source documents. Caution is needed when comparing values across sources; the same approach may result in estimates that vary because they are reported for different currency years or are adjusted for changes in real income using different data sources and assumptions.
[19] Unless otherwise noted, all GNI per capita estimates are expressed in current international dollars based on purchasing power parity, as reported by the World Bank (https://data.worldbank.org/indicator/NY.GNP.PCAP.PP.CD?locations=US).
[20] As discussed later, many different income measures are available. We use GNI per capita throughout this report because consistently derived estimates are available and easily accessible for a large number of countries.

In the discussion that follows, we use the USDHHS 2015 estimate ($9.4 million) as the U.S. base value, because it is derived from the most recent review and includes evaluation of both stated- and revealed-preference studies. However, relying instead on the USEPA or USDOT values would lead to very similar results, given the similarity of the estimates. These estimates are also very similar to the U.S. value of $9.6 million (2015 U.S. dollars) recommended in the Viscusi and Masterman meta-analyses discussed in the next section.

While the U.S. values are relatively similar, they are larger relative to income than the OECD estimate. This difference is attributable at least in part to the use of divergent analytic approaches; the effects of income alone are likely to be smaller as discussed below. The U.S. and OECD estimates reflect significant differences in the criteria used to select studies, the extent to which they rely on revealed- or stated-preference research, and the methods used to synthesize the results across studies (qualitative review vs. meta-analysis).[21]

These recommended values change periodically as new studies are completed and researchers develop new insights into best practices. For example, the USEPA is in the process of updating its estimates based on meta-analysis of selected studies and advice from its expert panels (EPA 2016, Khanna et al. 2017). In addition, researchers are now updating the database and meta-analysis that underlies the OECD estimates.[22]

When applying these estimates in other settings, a key question is the extent to which they should be adjusted for variations in the risks and populations affected. The consensus in the reviews and guidance documents referenced above is that the available evidence is not sufficient to support adjustment for most differences. The one exception is income. Many, if not most, guidance documents and other reviews suggest that these estimates should be adjusted for differences in population-average income, although not for cross-sectional differences in income within a country.[23]

3.2 Adjustments for Income Differences

As introduced earlier, VSL reflects individuals' willingness to trade income for mortality risk reductions, necessarily reducing their spending on other goods and services. Given this framing, it seems unlikely that these values would remain constant across populations with substantially different incomes. For example, the values above suggest that the average U.S. resident is currently willing to pay over $900

[21] The difference between the USDHHS and OECD estimates may also reflect the screening or selection criteria used. For example, the OECD analysis does not consider whether the results of scope tests suggest that WTP estimates are close-to-proportional to the risk change, which (as discussed in Appendix A) can be viewed as indicating the extent to which respondents understand the outcome they are being asked to value.

[22] Email from Ståle Navrud, February 8, 2018.

[23] The approach described in this section is typically used to estimate the effects of population-average real income growth over time or of real income differences across countries. While it could also be used to estimate values for different income groups within a country, such adjustments are rarely made because they are viewed as inequitable. However, using the same value for different income groups ignores the variation in the values that each group may place on the risk reductions it receives, leading to potentially inaccurate conclusions regarding their preferences.

for a 1 in 10,000 mortality risk change. In a low-income country, where GNI per capita is substantially less, it seems implausible (impossible in very poor countries) that the average individual would be willing to spend $900 on the same risk reduction, given the necessity for spending on more basic needs. Overall, individual WTP per unit of risk reduction should decrease as income decreases, resulting in smaller values.

One question that arises in this context is how to best estimate the income of those affected by a policy (see Hammitt 2017). The approach used generally should be tailored to the outcome to be valued. In many cases the most appropriate measure may be estimates of individual or household earnings or consumption. However, when transferring estimates across countries, analysts require easily-accessible and consistently-measured default estimates of population-average income to adjust for differences in the resources available to individuals. In this case, often either GDP per capita or GNI per capita is used. GDP represents net domestic production, while GNI also includes monetary inflows and outflows from abroad, and hence is a more inclusive measure.

The World Bank provides consistently-measured estimates of these values for many years and most countries. For 2015, if measured using purchasing power parity, it provides estimates of GDP per capita for 185 countries, and of GNI per capita for 182 countries.[24] Because GNI per capita is a more comprehensive measure, it appears more appropriate for adjusting for income when transferring values across countries.

Adjusting a base VSL for income differences requires estimates of the average income for the population to which the base VSL applies, average income for the target population, and an estimate of the rate at which VSL changes as income changes; i.e., the average income elasticity over the relevant income range. The formula is:

$$VSL_{target} = VSL_{base} * (Income_{target} / Income_{base})^{elasticity}$$

(equation 1)

It is often convenient to work with ratios of VSL to income rather than VSL itself. The ratio of VSL to income depends on the income elasticity and can be derived from the formula above: it is:

$$(VSL_{target} / Income_{target}) = (VSL_{base} / Income_{base}) * (Income_{target} / Income_{base})^{(elasticity - 1)}$$

(equation 2)

[24] The number of countries covered varies by year. For GNI per capita measured in current international dollars, see: https://data.worldbank.org/indicator/NY.GNP.PCAP.PP.CD. For GDP per capita measured in current international dollars, see: https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD.

For example, if we use the 2015 USDHHS estimate noted in Table 3.1 to estimate the VSL for an income level of $1,025 (the World Bank's dividing line between middle- and low-income countries as of that year), applying an elasticity of 1.5, equation 1 would be as follows:

$$\$0.022 \text{ million} = \$9.4 \text{ million} * (\$1{,}025 / \$57{,}900)^{1.5}$$

If instead we work with the second equation using the same values, the result would be a ratio of 21.6 in the target country:

$$21.6 = (\$1{,}025/\$57{,}900)^{0.5} * 162$$

Multiplying that ratio by the income level in the target country leads to the same VSL estimate as equation 1.

$$21.6 * \$1{,}025 = \$0.022 \text{ million}$$

The same formulae can be used to extrapolate these values over time. In this case, the base VSL and income level are for the starting year, and the target VSL and income level are for a future year. Commonly, analysts assume that the same elasticity estimates apply over time as across different populations at the same point in time.

Table 3.2 illustrates the sensitivity of the extrapolation to the value of the income elasticity. To construct the table, we began with the USDHHS VSL of $9.4 million and extrapolate to the values for an income level of $1,025, using the associated U.S. GNI per capita estimate ($57,900) and different elasticities. We again use $1,025 as the target income level because the World Bank used this value as the dividing line between low- and middle-income countries based on 2015 data.[25]

Table 3.2. Effect of Income Elasticity[a]

	Extrapolated VSL for income = $1,025[b]	**Ratio of VSL to income = $1,025**	**WTP for 1 in 10,000 risk change**	**WTP as a percent of income = $1,025**
Elasticity = 0	$9.4 million	9,200	$940	92%
Elasticity = 0.5	$1.3 million	1,200	$130	12%
Elasticity = 1.0	$170,000	160	$17	1.6%[c]
Elasticity = 1.5	$22,000	22	$2.20	0.2%
Elasticity = 2.0	$2,900	2.9	$0.29	0.03%

Notes:
a. Estimates are for illustration only; see text for more discussion. Results rounded to two significant digits.
b. Extrapolated from a U.S. VSL of $9.4 million and U.S. GNI per capita of $57,900, based on the 2015 USDHHS values noted in Table 3.1.
c. An income elasticity of 1.0 means the ratio is constant; e.g., the starting point (U.S. VSL = $9.4 million) yields a WTP estimate of $940 for a 1 in 10,000 risk change, which is also 1.6 percent of U.S. GNI per capita.

[25] As noted earlier, all calculations are based on values reported using purchasing power parity rather than market exchange rates for currency conversions unless otherwise noted. However, the World Bank instead uses market exchange rates (calculated using its Atlas method) when categorizing countries by income level.

As illustrated by Table 3.2, changes in the income elasticity can change the results by orders of magnitude. Hammitt and Robinson (2011) reported that the then-existing studies found VSL income elasticities ranging from as low as 0.1 to greater than 2.0. More recent reviews seem to be coalescing around estimates closer to 1.0.

Several recent reports have combined different base estimates with different elasticities to estimate the VSL in low- and middle-income countries. Table 3.3 summarizes the estimates used and the results.

Table 3.3. Recent Approaches for Estimating VSL in Low- and Middle-Income Countries

Report	Central Base Estimates[a]			Central Income Elasticity Estimates[a]	
	Source	VSL (dollar year)	Income level (measure)	Source	Elasticity[b]
OECD (2016)	OECD (2012)	$3.0 million (2005 USD)	Not reported (OECD GDP per capita, PPP)	OECD (2012) meta-analysis and additional review	Low-income: 1.0 Middle-income: 0.9 High-income: 0.8
World Bank and IHME (2016)[c]	OECD (2012)	$3.83 million (2011 USD)	$37,000 (OECD GDP per capita, PPP)	Narain and Sall (2016) review	Low- and middle-income: 1.2 High-income: 0.8
Viscusi and Masterman (2017b)	Viscusi (2015b)	$9.6 million (2015 USD)	$55,980 (U.S. GNI per capita, MER)	Viscusi and Masterman (2017b) meta-analysis	All income levels: 1.0
Masterman and Viscusi (2018)	Viscusi (2015b)	$9.6 million (2015 USD)	$55,980 (U.S. GNI per capita, MER)	Masterman and Viscusi (2018) meta-analysis	GNI per capita <$8,809: 1.0 GNI per capita ≥$8,809: 0.85[d]

Notes:
PPP = purchasing power parity, MER = market exchange rate
a. Central or recommended best estimates highlighted in each study; each also examines uncertainty in the elasticity estimates.
b. Income levels defined using World Bank categories.
c. The Lancet Commission on Pollution and Health (Landrigan et al. 2018) uses the same approach.
d. From base model recommended for use for inter-country transfers by the authors.

Table 3.3 reflects a substantial division in the literature. The first two reports combine data from the OECD (2012) meta-analysis of VSL stated preference studies with elasticities derived from that study and further review of the literature. A significant concern in these reports is the reasonableness of the resulting estimates; i.e., whether the VSLs estimated by combing the base VSL with the elasticities appear consistent with VSL estimates from studies conducted in low- or middle-income countries. In general, these comparison studies were conducted in middle-income countries; few VSL studies have been conducted in low-income countries.

The final two studies use a different approach. Both rely on global sets of VSL studies and use meta-analysis to combine the results. Viscusi and Masterman (2017b) consider wage-risk studies; Masterman and Viscusi (2018) consider stated preference studies. In each analysis, they consider the effects of publication-selection bias, which occurs whenever researchers or journals tend to reject estimates that fall outside of a range deemed acceptable.[26] The authors conclude that the only wage-risk studies that are not subject to significant bias use data from the U.S. Census of Fatal Occupation Injuries (CFOI).[27] Meta-analysis of studies using this data source yield a U.S. VSL ($9.6 million in 2015 U.S. dollars) that is similar to the estimates currently used by U.S. regulatory agencies, but higher in proportion to income than the OECD estimates.

Viscusi and Masterman explore VSL income elasticities in both studies. They find that elasticities are likely less than one in higher income countries and one or greater in lower income countries. Note, however, that neither of their databases include studies conducted in countries that are currently classified as low-income.[28]

In discussing the implications for benefit transfer, Viscusi and Masterman (2017b) recommend using an elasticity of 1.0 based on the wage-risk literature because "it is tractable and because we fail to reject the hypothesis that the international elasticity is equal to 1.0 in any of our specifications" (Viscusi and Masterman 2017b, p. 244). In their study that relies on stated preference research, Masterman and Viscusi (2018) suggest instead using a two-step function, based on their analysis of elasticities across income groups. If the income level of the target country is greater than or equal to $8,809 (2015 U.S. dollars), they suggest that analysts first transfer the $9.6 million estimate using an income elasticity of 0.85. If the income level is below $8,809, then analysts should take the VSL for the income level of $8,809 (a VSL of about $2 million), then use an elasticity of 1.0 to adjust it further to the income level of concern. As indicated in the table, these values are derived using market exchange rates rather than purchasing power parity for currency conversions.

Thus the analyses summarized in Table 3.3 reflect very different approaches:

- The first two studies (from OECD and the World Bank) treat at least some of the research conducted in lower income countries as providing reasonably valid VSL estimates, and test the extent to which the combination of a base value and income elasticity leads to VSL estimates that are consistent with these results. The base VSLs and elasticities they test are based on substantial review and evaluation of the literature.

---

[26] For example, a set of all VSL estimates would be expected to have a normal distribution, but the tendency to not report zero or negative values will truncate this distribution and bias the published estimates. While theory suggests that the VSL will always be positive, the use of random sampling will at times result in observations of negative values. Viscusi and Masterman correct for this bias by including the standard error of each observation in their model specifications.

[27] In addition to being a census rather than a sample, the CFOI involves substantial confirmation of the data.

[28] Of the 68 wage-risk studies in Viscusi and Masterman (2017b), only two were from middle-income countries, based on the World Bank's 2015 classifications. The remainder were from countries categorized as high income. Masterman and Viscusi (2018) includes 85 stated preference studies, including those identified in the review discussed in Appendix A. They do not report the distribution of studies by country income classification, but note that well over half the estimates are from high-income countries and the remainder are from middle-income countries.

- The second two studies (from Viscusi and Masterman) also include data from higher and lower-income countries but test for reporting bias in the estimates. Statistical corrections for these biases lead to similar elasticity estimates but much higher VSLs, because the base VSL is more than double the base for the other studies.

An additional difficulty relates to practical application. As noted above, the OECD and World Bank studies use purchasing power parity to convert currencies, while Viscusi and Masterman use market exchange rates. These conversions lead to significantly different income estimates, particularly for low-income countries. As examples, Table 3.4 provides estimates for countries in different income categories.

Table 3.4. Currency Conversion Examples

Country (World Bank Income classification)	**GNI per capita (2015)**	
	Purchasing Power Parity (international dollars)	**Market Exchange Rates** (U.S. dollars)
United States (high-income)	$57,900	$56,290[a]
India (middle-income)	$6,060	$1,600
Malawi (low-income)	$1,120	$340

Source: World Bank DataBank, https://data.worldbank.org/indicator/NY.GNP.PCAP.PP.CD?end=2016&locations=US-IN-MW&start=2003 and https://data.worldbank.org/indicator/NY.GNP.PCAP.CD?end=2015&locations=US-IN-MW&start=2014, as viewed March 2018.
a. These estimates rely on the World Bank's Atlas method, which averages exchange rates over three years and accounts for the difference between the rate of inflation in the country and the international inflation (see https://datahelpdesk.worldbank.org/knowledgebase/articles/378832-the-world-bank-atlas-method-detailed-methodology). If instead estimated using the exchange rate for the same year as used in the calculations that rely on purchasing power parity, the U.S. values would be identical regardless of whether purchasing power parity or market exchange rates were applied.

As is evident from the table, the differences between the two GNI per capita estimates tends to be larger as the income level of the country decreases. These differences make it difficult to compare the results of the studies summarized in Table 3.3. For example, if Masterman and Viscusi had used purchasing power parity for currency conversions in their analysis, it would likely change their results. Simply converting their threshold (the $8,809 in Table 3.3) is not adequate to account for these differences.[29]

In general, the income elasticity describing the difference between VSL in the target country and the base depends on whether income is measured using the market exchange rate or purchasing power parity. For the usual case in which income in the target country is larger when converted using purchasing power parity than the market exchange rate, but is smaller than the base income, the income elasticity calculated using purchasing power parity is further from one than the income elasticity calculating using the market exchange rate. When the income elasticity using the market exchange rate

[29] The authors have not run their models using international dollars based on purchasing power parity. Email from Clayton Masterman, March 14, 2018.

is greater than one, the income elasticity using purchasing power parity is larger; when the income elasticity using the market exchange rate equals one, the income elasticity using purchasing power parity also equals one.

However, the magnitude of the difference does not seem to be large. If the income elasticity calculated using the market exchange rate is one, the income elasticity using purchasing power parity is also one. If the market exchange rate income elasticity is 1.2, the purchasing power parity income elasticity would be about 1.3 for India and Malawi; if it is 0.85, the purchasing power parity income elasticity would be about 0.8 for India and Malawi.[30]

3.3 Review of Individual Studies

In Appendix A, we report the results of our review of studies conducted in low- and middle-income countries. The starting point for our work was the articles identified in previous reviews (including those listed in Table 3.3).[31] We then searched the literature for studies conducted in the 172 countries categorized as low- or middle-income by the World Bank in any of the past 20 years (see Appendix B). We found 17 stated-preference studies and eight wage-risk studies that meet our selection criteria. These 25 studies were conducted in 15 countries, all of which are now middle- or high-income. Hence the available studies represent the preferences of only a small fraction of the population globally.

Our review raises questions about the quality of several of these studies, suggesting that the results are highly uncertain. For example, many of the stated preference studies do not test the sensitivity of WTP to the size of the risk reduction, and several of those that do perform this test find that the results are insensitive. Some of the wage-risk studies rely on only a single year of risk data or appear to combine data from sources that may be somewhat incompatible. These and other concerns are discussed in more detail in Appendix A.

Review of the income estimates these studies report suggests that the mean income level of the populations studied may differ significantly from mean national income and from estimates of GNI per capita, as documented in Appendix C. Thus the common practice of using GNI (or GDP) per capita to estimate income when transferring values across countries may introduce substantial uncertainty. Ignoring this problem for the moment, we find that the ratios of the VSL estimates from each study to country-level GNI per capita cover a wide range, from about 4 to about 720.

We also calculate the income elasticity needed to extrapolate from the ratios of VSL to GNI per capita found in high income countries to the ratios calculated for each of these studies. In these calculations, we use the 2015 USDHHS estimate as the base value. We first exclude studies that lead to implausibly

---

[30] The income elasticity using purchasing power parity (p) and using market exchange rates (m) are related as follows: $(p - 1) = (m - 1) [\log(y_m/x_m) / \log(y_p/x_p)]$, where y_m and y_p are income in the target country, x_m and x_p are income in the base country, and the subscripts m and p denote measurement using market exchange rates and purchasing power parity, respectively.

[31] Masterman and Viscusi (2018) then included the results of our review in their meta-analysis of stated preference studies.

high and low ratios of the VSL to GNI per capita. These include those where the ratio is above the U.S. ratio (160), given that it seems implausible that the ratio in substantially poorer countries would exceed the ratio for the U.S. Inspection of the ratios in Appendix C, Table C.3 suggests that the exact value of this threshold does not matter much, since we would exclude the same studies using any threshold between about 140 and more than 300. We also exclude those studies where the ratio is less than 20.[32] This lower bound reflects the expectation that the VSL would exceed the future earnings (and consumption) of the average individual; we assume that an adult of average age would have at least 20 years of life remaining in the countries of concern. Applying these thresholds excludes the results from seven of the 18 stated preference surveys (one of the 17 studies includes two surveys) and five of the eight wage risk studies from these comparisons.

The income elasticity implied by the comparison to the U.S. ratio (160) ranges from 1.1 to 2.5 with a mean of 1.5 and a median of 1.4. Thus the available research suggests that elasticities greater than or equal to one may be appropriate when extrapolating from high- to much lower-income settings, consistent with the thought experiment illustrated in Table 3.2.

It is difficult to validate these results without more high-quality research from middle- and low-income countries, which can be compared to the results of extrapolating from an estimate for a high-income country using alternative elasticities. In addition, more work is needed to better understand how factors other than income affect these values.

3.4 Conclusions and Implications

While ideally the value of mortality risk reductions would be derived from high-quality studies of the population affected by the policy, extrapolation from studies conducted in high-income countries will likely continue to be necessary in the near future given the paucity of studies in lower-income countries. Such extrapolation requires selecting a base VSL estimate, a measure of income (e.g., GNI per capita), and an income elasticity. Generally, a range of estimates should be used to reflect the substantial uncertainty in the results.

In Table 3.5, we summarize the ratio of VSL to GNI per capita using alternative approaches. First, we assume that the ratio of VSL to GNI per capita is equal to the U.S. or OECD level (a ratio of 160 or 100, respectively). This is equivalent to using these ratios as a base then applying an income elasticity of 1.0. We then show the results of applying the mean elasticity (1.5) calculated from the U.S. base VSL to the VSLs from the studies in our review (see Appendix A). In this example, we use four income levels to illustrate the results, spanning the range of income levels that the World Bank uses to divide countries

---

[32] The value of living a year seems likely to exceed the monetary value of consumption, because life is about much more than consumption of goods and services. This logic is consistent with the view that the human-capital approach to valuing life-saving provides a lower-bound estimate (see Chapter 2 for more discussion). Hammitt and Robinson (2011) use this approach to set a lower bound on estimates of VSL extrapolated from high- to low-income countries. Although this argument is appealing, standard economic models do not imply that VSL must exceed the expected value of future consumption (see Hammitt 2017).

into income groups. We assume these values are expressed as international dollars using purchasing power parity.

Table 3.5. Ratio of Extrapolated VSL Estimates to Income Using Alternative Approaches

Approach	GNI per Capita (2015 international dollars)			
	$1,000	$5,000	$10,000	$15,000
Ratio = 160[a]	$0.16 million (160 * GNI per capita)	$0.80 million (160 * GNI per capita)	$1.6 million (160 * GNI per capita)	$2.4 million (160 * GNI per capita)
Ratio = 100[b]	$0.10 million (100 * GNI per capita)	$0.50 million (100 * GNI per capita)	$1.0 million (100 * GNI per capita)	$1.5 million (100 * GNI per capita)
Base ratio = 160[a], Elasticity = 1.5[c]	$0.02 million (21 * GNI per capita)	$0.24 million (48 * GNI per capita)	$0.67 million (67 * GNI per capita)	$1.2 million (83 * GNI per capita)

Notes:
Results rounded to two significant digits.
a) U.S. VSL to GNI per capita ratio.
b) OECD VSL to GNI per capita ratio.
c) See Appendix A for derivation of elasticity.

Thus the range of approaches discussed above leads to a relatively wide range of VSL estimates, particularly in countries with very low incomes, indicating the substantial uncertainties in the estimates. More research is needed to better understand these values.

4.0 Valuing Risks at Different Ages

The estimates discussed in the prior chapter are generally population-average estimates for adults, while some policies disproportionately affect those who are much younger or much older. Because older individuals have fewer expected life years remaining than the average member of the population, intuition suggests that lower VSL estimates may be applicable. For those who are younger, intuition similarly suggests that higher VSL estimates may be applicable. However, both theory and empirical work indicate that the relationship is more complex and uncertain.

Because age and life expectancy are highly correlated, the two terms are often used interchangeably. It is important to keep in mind, however, that this relationship may be quite different across countries. For example, as of 2013, U.S. life expectancy at birth was about 79 years. At the mid-point (age 39), life expectancy was about 42 years (Arias et al. 2017). Not surprisingly, the population-average VSLs estimated in the U.S. generally reflect studies of adults whose average age is near this value.

In low- and middle-income countries, these relationships are likely to differ significantly. For example, in Ghana, life expectancy at birth was about 61 years; at age 39, it was about 35 years.[33] In the Central African Republic, life expectancy at birth was about 50 years; at age 39, it was about 30 years. More generally, the population-average age is likely to be lower in many low- and middle-income countries than in the U.S. and other high-income countries, as is remaining life expectancy at that age.

These estimates of life expectancy also reflect significant variation in the likelihood of surviving each year of age. For example, in the U.S., as of 2013 about 99 percent of live births were expected to survive to age 4. In Ghana, the rate was about 93 percent; in the Central African Republic, it was about 86 percent.

In the sections that follow, we first discuss issues related to estimating the effects of age and life expectancy on the VSL for the general population, focusing on research that addresses adults. We then discuss the issues that arise in estimating the value of risk reductions that accrue to young children and to newborns or the unborn.

4.1 Adjusting Adult Values for Differences in Age and Life Expectancy

In high-income countries, a fair amount of attention has been focused on the effects of age and life expectancy on the VSL, particularly for older adults. This attention stems in part from the substantial number of benefit-cost analyses that address air pollution abatement policies, which disproportionately affect older individuals. The U.S. VSL estimates discussed in the previous chapter are based largely on studies of working-age adults (e.g., between 18 and 65 years of age), while air pollution-related deaths occur largely among those who are older.

[33] Data for Ghana and the Central African Republic in 2013 retrieved from the World Health Organization's Global Health Observatory (http://apps.who.int/gho/data/view.main.60630?lang=en) in September 2017.

Some argue that the relationship between VSL and age should follow the pattern of consumption over the lifecycle, which is typically an inverse-U distribution (for more discussion, see Shepard and Zeckhauser 1982, 1984, Cropper and Sussman 1990, Hammitt 2007). Much of the empirical work that considers the trade-off between wages and risks across workers supports this model (e.g., Aldy and Viscusi 2008), as do some stated-preference studies (e.g., Bosworth et al. 2010, Cameron et al. 2010). However, the rates of increase and decrease and the age at which VSL peaks varies significantly across studies.

Stated-preference research is needed to address the relationships between age and VSL among individuals older than working age. (We discuss the research on children later.) For high income countries, the evidence is inconsistent. Some studies do not find statistically significant relationships between VSL and age for the elderly, while others find that the VSL increases or decreases among older individuals in varying patterns and amounts (see, for example, Evans and Smith 2006, Krupnick 2007).

Similarly, the studies reviewed in the prior chapter suggest that these relationships are uncertain in low- and middle-income countries. Of the 25 studies, 14 address the relationship between VSL and respondent age. (All studies address adults, but the age ranges considered vary.) Eight find a statistically significant effect of age on the VSL and six find insignificant results. Of the studies that find a statistically significant relationship, the results vary: four find a positive relationship and four find a negative relationship.[34]

When made, adjustments most often take one of two forms: VSL estimates that differ by age, or a value per statistical life year (VSLY) estimate that is multiplied by the change in expected years of life remaining.[35] In contrast to the VSL, which is the rate at which the individual substitutes money for reductions in mortality risk within the current year or other short time period, the VSLY is the rate at which he or she substitutes money for gains in life expectancy -- essentially aggregating WTP for small risk reductions that may be distributed across time (Hammitt 2007, Jones-Lee et al. 2015).

Because relatively few primary research studies directly address changes in life expectancy, the VSLY is often estimated by dividing an estimate of VSL by the average (sometimes discounted) remaining life expectancy for the population studied.[36] To determine the value per statistical case, VSLY is multiplied by the (discounted) expected years of life extension for individuals affected by the policy. Under this approach, the per-case values of reducing current mortality risk are lower for older individuals than for younger individuals, because they have fewer years of expected life remaining.

---

[34] The four that find a positive relationship are Giergiczny (2008), Mofadal et al. (2015), Polat (2013), Rafiq and Shah (2010); the four that find a negative relationship are Chaturabong et al. (2011), Giergiczny (2010), Hammitt and Ibarrarán (2006), and Hoffmann et al. (2017).

[35] For example, World Bank and IHME (2016) include VSLY-based estimates in sensitivity analysis. USDHHS (2016) similarly suggests sensitivity analysis if policies disproportionately affect the very young or the very old. However, USDHHS recommends that analysts divide the VSL by expected quality-adjusted life years (QALYs) rather than life years in these calculations, to reflect the expected decrease in the quality of life that occurs with age.

[36] Often, expected discounted life years are approximated by the present value of a series of years with length equal to life expectancy; Jones Lee et al. (2015) discuss the size of the error resulting from this approximation.

This approach assumes that VSLY is constant and independent of the number of life years gained, implying that VSL is proportional to the individual's remaining (discounted) life expectancy. However, neither economic theory (Hammitt 2013, Jones Lee et al. 2015) nor the limited empirical research available support these assumptions. The rate at which an individual discounts his or her future life years need not correspond to the rate at which monetary benefits and costs are discounted. If life years are discounted at a smaller rate than monetary values (perhaps zero), that implies the monetary value of life years increases over time.

A few stated-preference studies, conducted primarily in high income countries, directly explore the value of changes in life expectancy with mixed results (e.g., Johannesson and Johansson 1996, 1997, Morris and Hammitt 2001, Desaigues et al. 2011).[37] It is difficult to compare the results across studies because they vary in the ways in which the change in life expectancy is expressed (e.g., as a current or future risk reduction) as well as in the age and other characteristics of the population and risks studied.[38] One problem is that, when questions are framed as life expectancy gains, they may be perceived as simply adding time at the end of life (when the quality of life is likely to be low), even if the life expectancy gain is the cumulative effect of reducing risk at each year of age.

Research by Nielson et al. (2010) and Hammitt and Tunçel (2015) suggests there is substantial heterogeneity in preferences for the timing of risk reductions. For example, some people may prefer a near-term to a continuing risk reduction that produces the same increase in life expectancy while others have the opposite preference. This implies that VSLY may depend on the time-path of risk reduction that produces the increase in life expectancy. While some studies suggest that respondents may comprehend gains in life expectancy better than reduced mortality risks, researchers need to carefully define the timing of these gains and control for expected quality of life.

Thus the empirical research on these values is not sufficiently consistent nor advanced to be used directly in policy analysis, for either high-income or low- and middle-income countries.

4.2 Estimating Values for Children

Because children generally lack the independent financial means as well as the cognitive ability needed to respond to WTP questions, related research often elicits parental WTP (see Dockins et al. 2002, EPA 2003, Alberini et al. 2010, Hammitt and Haninger 2017 for more discussion). Several studies, conducted in the U.S. and elsewhere and using varying methods, suggest that WTP for reduced current morbidity or mortality risks to children may be noticeably greater (perhaps by a factor of two) than adult WTP to reduce their own risks, although the magnitude of the difference varies across studies. Consistent with these findings, some government guidance documents and other reviews suggest that risks to children

[37] See Narain and Sall (2016) for more discussion. In addition, Ryen and Svensson (2015) review different approaches to estimating the value of a quality-adjusted life year (QALY), including the value of a full QALY which is equivalent to a year lived in full health.
[38] Some also rely on small, non-representative samples, and find that WTP does not change in proportion to the size of the change in life-expectancy, raising concerns about their quality.

be valued at 1.5 to 2 times the value used for adults (e.g., Ministry of Finance (Norway) 2012, OECD 2012).[39] Applying the VSLY approach described earlier also results in higher values for children, given that children have a larger number of expected life years remaining than older individuals.

As for adult risks, a key question is whether the relationships found in high-income countries are likely to hold in low- and middle-countries. Given the diversity of the latter countries, it seems unlikely that the ratio of the value of reducing health risks to children to the value for adults would be constant across countries with significantly different cultural and demographic characteristics.

For low- and middle-income countries, little empirical research is available. In the review discussed in Appendix A, we did not identify any studies that meet our selection criteria which addressed risks to both children and adults using a consistent approach.[40] Some (e.g., Jamison et al. 2013) suggest that the value of reducing mortality risks for young children may be less than for adults in these countries, but more work is needed.

4.3 Estimating Values for Deaths around the Time of Birth

Benefit-cost analyses conducted in low- and middle-income countries must at times address mortality risks around the time of birth, which raise difficult normative questions as well as empirical issues. Relatively little is known about parental or societal WTP to reduce neonatal or prenatal mortality risk in either high- or low- and middle-income countries. In the absence of better data, one approach (consistent with the above discussion) is to value these risks using the same estimates as applied elsewhere in the analysis – using a population-average VSL estimate or a VSLY estimate applied to life expectancy at birth. For fetuses, the probability of live birth (without and with the policy) could be incorporated into these calculations. However, given the controversy over when life begins, this approach is likely to be the subject of debate.

Jamison et al. (2006) discuss these issues within the context of estimating disability-adjusted life years (DALYs). They note that traditionally deaths that occurred prior to birth were provided zero weight in these calculations, whereas deaths that occur at birth were treated as many years of life lost. The authors explore the use of a function based on the concept of the acquisition of life potential (ALP) to instead gradually weight the estimates. This formulation is based on a normative framework which differs from the traditional focus of benefit-cost analysis on the preferences of those affected. The authors note that the “concept is that an infant (or fetus) only gradually acquires the full life potential

[39] Work currently underway by the authors and others confirms this finding. In a criteria-driven review of the research for high-income countries, our preliminary findings suggest that the VSL for children exceeds the VSL for adults by a factor of 1.2 to 3.0, with a midpoint of 2.1.

[40] Studies that solely address risks to children are less useful for this purpose that studies that address risks to both children and adults using a consistent approach. Comparing estimates of the value of reducing risk to a child with estimates from another study of the value of reducing risk to an adult can be misleading; it is difficult to know whether the difference is attributable to the age of those affected or to any of a large number of other possible differences between the studies (e.g., population sampled, question wording, analytic approach). The ratio of the two values also may be more stable and well-estimated than the values of risk reduction, and can be applied to the much larger body of research on adult values.

reflected in a stream of life years beginning at birth, that is, ALP can be gradual. The ethical understanding of the concept is based on two judgments: (a) an individual life acquires value only as it acquires self-awareness, and (b) an individual life acquires additional value as it develops bonds with others." (Jamison et al. 2006, p. 438).

Few other studies have explored these values.[41] Jamison (2016) conducted a survey using a convenience sample (Amazon's Mechanical Turk) to explore trade-offs among different life-saving programs. Respondents were presented with two programs which save the lives of individuals in different groups but are otherwise identical. The groups included 10-week-old fetuses, 39-week-old fetuses, 1-week-old infants, 1-year-old children, pregnant women with 10-week-old fetuses, pregnant women with 39-week-old fetuses, and adult women. The number of individuals whose lives were saved under the first program was specified. Respondents were then asked how many lives would need to be saved under a second program, that targets a different group, to equal the value of the lives saved under the first program. While this was not a valuation survey and was not administered to a representative sample, the results suggest that respondents held positive values to avert both fetal and neonatal losses, and that these values increased with age before and after birth with no discontinuity at birth.

4.4 Conclusions and Implications

The approach for estimating the VSL described in Chapter 4 provides population-average estimates; i.e., for middle-aged adults. Because the number of life years remaining for younger or older individuals may be much larger or smaller respectively, intuition suggests that different values may be applicable. However, both theory and empirical work indicate that the relationship is uncertain.

Research conducted largely in high-income countries suggests that values for children may exceed values for adults by as much as a factor of two, values for working-age adults may follow an inverse "U" pattern that peaks in middle-age, and values for older adults may remain constant, increase, or decrease. However, these results are inconsistent across studies, raising questions about the robustness of these findings. Given these uncertainties, adjustments for the age or life expectancy of adults are not recommended in the available guidance for benefit-cost analysis, most of which addresses high income settings (see Robinson et al. 2017a for review), although some suggest including such adjustments in sensitivity analysis using relatively simple assumptions (e.g., USDHHS 2016). Mortality risks around the time of birth raise even more difficult problems, including both a lack of directly relevant research and significant normative issues such as questions about when life begins.

For low- and middle-income countries, these relationships are even more uncertain. Little empirical research is available and it is unclear whether the same patterns are likely to hold as in high income

[41] One potentially-relevant valuation study is Ščasný and Zvěřinová (2014), who explore the value of increasing the likelihood of pregnancy. However, the resulting values appear small compared to the VSL estimates discussed in the previous chapter, suggesting that policies to increase the probability of conception are viewed very differently from decreasing the risk of death to an already conceived newborn (or fetus) or young child. More work is needed to better understand these values.

countries. Thus in the near-term, sensitivity analysis using relatively simple assumptions appears desirable. In the longer-term, more research is needed to better understand these values.

5.0 Summary and Recommendations

In this paper, we review the literature and develop recommendations for valuing mortality risk reductions in low- and middle-income countries, to support the development of reference case guidance for benefit-cost analysis. Although our recommendations apply to lower income countries, this work has implications for the values used globally.

We find that the value of mortality risk reductions is relatively well-studied, but that most of these studies address countries with relatively high incomes. The available literature addresses only a small proportion of low- and middle-income countries; the quality of these studies is uneven and their findings are diverse.

While we recommend that analysts use the results of high-quality studies that are applicable to the policy context where available, we recommend that these estimates be supplemented by a standardized sensitivity analysis to examine the effects of uncertainty about valuation and to facilitate comparison between studies. We also suggest priorities for future research.

5.1 Near Term Recommendations

In the near-term, we recommend that analysts proceed as follows, given available data and the results of related research.

1) *Use context-specific values as the central estimates if available.*

Ideally, the values used in benefit-cost analysis should be derived from a criteria-driven review of the WTP literature. This review should follow the benefit transfer framework to identify high-quality studies that are suitable for the context, taking into account the characteristics of the risks and of the affected population. The review may be supplemented by the use of meta-analysis or formal, structured expert elicitation to aid in synthesizing the estimates.[42] For high-income countries, such reviews are readily available and often incorporated into government guidance documents. The recommendations in this paper are designed to be implemented in low- and middle-income countries, and the reviews we cite provide useful starting points for identifying and evaluating relevant studies.

2) *Apply default values: (a) if context-specific values are not available, and (b) in a standardized sensitivity analysis even if context-specific values are used as the primary estimates.*

The sensitivity analysis should follow the current practice of extrapolating from a VSL estimate using data on GNI per capita (measured in international dollars using purchasing power parity) and an assumed income elasticity. GNI per capita should be used because it is an easily accessible and reasonably comprehensive measure that is consistently calculated (e.g., by the World Bank) for a large number of countries. Analysts should recognize, however, that there are a large variety of income measures and it is uncertain which is most appropriate for this purpose.

[42] See Robinson and Hammitt (2015) for discussion of the use of expert elicitation to estimate VSL.

The sensitivity analysis should use the following:

a. VSL = 160 * GNI per capita in the target country.
b. VSL = 100 * GNI per capita in the target country.
c. VSL extrapolated from a U.S. estimate to the target country using an elasticity of 1.5.

The first estimate is derived from recommended U.S. values, and is consistent with the finding that other estimates may reflect significant publication bias. The second estimate is derived from the OECD meta-analysis of stated preference studies conducted globally. The use of a constant VSL-to-GNI per capita ratio under options (a) and (b) is equivalent to assuming that income elasticity is 1.0 when extrapolating from these base values to another country. The third option reflects our review of studies from low- and middle-income countries, and is the mean elasticity estimate (1.5) found when extrapolating from this U.S. value to the values found in those studies (the median, 1.4, is similar). Estimates using each of these three approaches for all countries categorized as low- or middle-income (based on 2015 GNI per capita) are provided in Appendix D. The range of estimates widens as income levels become lower, reflecting the substantial uncertainty regarding these values.

It often requires several years for policy impacts to fully manifest. Analysts should also project the change in real income (measured as GNI per capita) that occurs over this time period and adjust the VSL estimates accordingly, using the same approaches as above. The underlying assumption is that income elasticities are the same over time as across different income groups at the same point in time.

These values should be used in sensitivity analysis even if context-specific values are featured, to allow comparison to the primary results and across analyses.

3) *If the policy disproportionately affects the very young or the very old, conduct sensitivity analyses using VSLY estimates.*

The approaches discussed above yield population-average estimates, whereas some policies disproportionately affect the very young or the very old. In such cases, analysts should, at minimum, conduct sensitivity analysis using a constant VSLY derived from the VSL estimates that result from recommendations 1 and 2; i.e., the context-specific estimates (if any) and the estimates that result from the standardized sensitivity analysis.

This constant VSLY should be calculated by first estimating the population-average VSL for the country affected by the policy, then dividing the VSL by undiscounted future life expectancy at the average age of the adult population in that country. This calculation should not discount future years for two reasons. First, individuals may discount their own future years at a rate smaller than the rate at which they discount future consumption or other monetary values. Second, calculating VSLY using discounted future life years flattens the relationship between the value of reducing risk and age, making it more similar to the alternative of using the same VSL for all ages. For sensitivity analysis, it seems preferable to maintain the full effect of valuing life years equally rather than moderating the effect through the choice of some positive discount rate.

4) ***If the analysis addresses deaths around the age of birth, assess the sensitivity of the results to alternative assumptions.***

When the analysis addresses mortality risks near birth, determining the appropriate approach is very difficult and raises a number of normative issues. We know very little about parental WTP to reduce neonatal or prenatal mortality risk in either high-income or lower income countries. One option is to apply the VSL and VSLY estimates described above to risks that occur at or subsequent to birth and to value deaths that occur prior to birth at zero. Additional sensitivity analysis is likely to be desirable in this case that tests the effects of assigning positive values to risks incurred prior to birth. As always, related uncertainties and their implications should be discussed when presenting the results.

5) ***Address other sources of uncertainty*****:**

While recommendations 1 through 4 address uncertainties related to the effects of income and age or life expectancy, they do not address other differences between the risks and populations studied and the risks and populations addressed by the analysis. These differences should be explored both qualitatively and quantitatively. Analysts should also indicate the implications for decision-making; i.e., the extent to which the uncertainties affect the estimated net benefits of a policy or the ranking of alternative policies.

5.2 Long Term Recommendations

Over the long term, more research is needed that explicitly addresses the value of mortality risk reductions in low- and middle-income countries. To support and encourage such studies, research methods tailored to this context should be further developed.

1) ***Conduct additional research on WTP for mortality risk reductions in low- and middle-income countries:*** Substantial additional research is needed on the value of mortality risk reductions in low- and middle-income countries, given the importance of these estimates in policy analysis and the likely differences in preferences across members of different populations. Such research should address population-average values as well as the extent to which values vary by age and life-expectancy; more work on the extent to which other risk and population characteristics affect these values should also be pursued.

2) ***Develop protocols for the conduct of these studies that are tailored to low- and middle-income settings.*** To encourage additional research and ease its implementation, more work is needed on developing approaches for data collection and analysis that can be feasibly implemented in low- and middle-income settings, which will provide reasonably valid and reliable results. Such approaches should be tailored to the likely resources available and take into account the characteristics of these populations as well as the risks they face.[43]

3) ***Develop an easily accessible repository for these studies*****,** that includes primary research as well as studies that synthesize the results. While the research discussed in this paper provides a reasonably up-to-date summary of the currently available literature as well as criteria for benefit transfer, it will quickly become outdated as new work is conducted. In addition, many researchers in low- and middle-income countries may not have easy access to these studies, so will find it difficult to conduct the type of careful review that is needed to determine whether studies are applicable in particular settings and to form the foundation for new research.

Such additional research will help analysts, decision-makers, and other stakeholders better understand the preferences of those affected, which can aid in policy implementation as well as evaluation. It also moves away from focusing largely on the effects of income differences, and encourages greater attention to other sources of variation such as differences in cultural norms and other context-specific factors.

[43] For example, Hoffmann et al. (2017) find that the approaches recommended for eliciting payments in higher income countries do not necessarily work well when stated-preference studies are conducted in other settings.

References

(Includes links for publications that are freely available online.)

Alberini, A., M. Scasny, B. Kohlová, and J. Melichar. 2006. The Value of a Statistical Life in the Czech Republic: Evidence from a Contingent Valuation Study. In: *Climate Change and Adaptation Strategies for Human Health*. (Bettine, M. and L.E. Kristie eds). World Health Organization.

Alberini, A., I. Bateman, G. Loomes, and M. Ščasný. 2010. V*aluation of Environment-Related Health Risks for Children*. OECD Publishing. http://www.oecd-ilibrary.org/environment/valuation-of-environment-related-health-risks-for-children_9789264038042-en

Aldy, J.E. and W.K. Viscusi. 2008. "Adjusting the Value of a Statistical Life for Age and Cohort Effects." *Review of Economics and Statistics* 90(3): 573–581.

Alolayan, M.A., J.S. Evans, and J.K. Hammitt. 2017. "Valuing Mortality Risk in Kuwait: Stated-Preference with a New Consistency Test." *Environmental and Resource Economics* 66: 629–646.

Arias, E., M. Heron, J. Xu. 2017. United States Life Tables, 2013. National Vital Statistics Reports 66(3). https://www.cdc.gov/nchs/data/nvsr/nvsr66/nvsr66_03.pdf

Benkhalifa, A., M. Ayadi, and P. Lanoie. 2013. "Estimated Hedonic Wage Function and Value of Life in an African Country" *Economics Bulletin*. 33(4): 3023-3031.

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

Bhattacharya, S., A. Alberini, and M. Cropper. 2007. "The Value of Mortality Risk Reductions in Delhi, India." *Journal of Risk and Uncertainty* 34(1): 21-47.

Bosworth, R., T.A. Cameron, and J.R. DeShazo. 2010. "Is an Ounce of Prevention Worth a Pound of Cure? Comparing Demand for Public Prevention and Treatment Policies." *Medical Decision Making* 30(4): E40-E56.

Cameron, T.A., J. R. Deshazo, and P.S Tiffler. 2010. "Demand for Health Risk Reductions: A Cross-National Comparison between the U.S. and Canada." *Journal of Risk and Uncertainty* 41: 245-273. https://link.springer.com/article/10.1007/s11166-010-9106-9

Chaturabong, P., K. Kanitpong, and P. Jiwattanakulpaisarn. 2011. "Analysis of Costs of Motorcycle Accidents in Thailand by Willingness-to-Pay Method." *Transportation Research Record* 2239: 56-63.

Claxton, K., J. Ochalek, P. Revill, A. Rollinger and D. Walker. 2016. "Informing Decisions in Global Health: Cost Per DALY Thresholds and Health Opportunity Costs." Policy and Research Briefing, Centre for Health Economics, University of York.
https://www.york.ac.uk/media/che/documents/policybriefing/Cost%20per%20DALY%20thresholds.pdf

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.

Cropper, M., J.K. Hammitt, and L.A. Robinson. 2011. "Valuing Mortality Risk Reductions: Progress and Challenges," *Annual Review of Resource Economics* (G. Rausser, ed.) 3: 313-336.

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

Desaigues, B., D. Ami, A. Bartczak, M. Braun-Kohlová, S. Chilton, M. Czajkowski, V. Farreras, A. Hunt, M. Hutchison, C. Jeanrenaud, and P. Kaderjak. 2011. "Economic Valuation of Air Pollution Mortality: A 9-Country Contingent Valuation Survey of Value of a Life Year (VOLY)." *Ecological Indicators* 11(3): 902-910.

Dockins, C., R.R. Jenkins, N. Owens, N.B. Simon, and L.B. Wiggins. 2002. "Valuation of Childhood Risk Reduction: The Importance of Age, Risk Preferences, and Perspective." *Risk Analysis* 22(2): 335-346.

Evans, M.F. and V.K. Smith. 2006. "Do We Really Understand the Age-VSL Relationship? *Resource and Energy Economics* 28(3): 242–261.

Faudzi, M.Y., N.A. Mohamad, N.Z. Abidin, M.N. Ghani, and H. Salleh. 2013. *The Value of Statistical Life in Fatal Injury Among Drivers and Riders in Malaysia: Conjoint Analysis Method.* MIROS Internal Report No. 130.

Faudzi, M.Y., M.N Ghani, R.S. Umar, and H.A. Hariza. 2004. "The Value of Life and Accident Costing." *Applied Health Economics and Health Policy* 3(1): 5-8.

Ghani, M.N, and M.Y. Faudzi. 2003. "Value of Life Malaysian Motorists: Estimates from Nationwide Survey." *Journal of the Eastern Asia Society for Transportation Studies* 4: 275-284.

Gibson, J., S. Barns, M. Cameron, S. Lim, F. Scrimgeour, and J. Tressler. 2007. "The Value of Statistical Life and the Economics of Landmine Clearance in Developing Countries." *World Development* 35(3): 512-531.

Giergiczny, M. 2008. "Value of a Statistical Life—the Case of Poland." *Environmental and Resource Economics* 41(2): 209-221.

Giergiczny, M. 2010. *Testing Sensitivity of Willingness to Pay for Mortality Risk Reduction.* University of Warsaw Faculty of Economic Sciences, Working Paper No. 10/2010(33).

Grosse, S.D., K.V. Krueger, and M. Mvundura. 2009. "Economic Productivity by Age and Sex: 2007 Estimates for the United States." *Medical Care* 47(7): S94-S103.

Guo, X. and J. Hammitt. 2009. "Compensating Wage Differentials with Unemployment: Evidence from China." *Environmental and Resource Economics* 42(2): 187-209.

Guo, X., T. Haab and J. Hammitt. 2006. *Contingent Valuation and the Economic Value of Air-Pollution-Related Health Risks in China*. RePEc IDEAS Working Paper.

Hammitt, J. K. 2007. "Valuing Changes in Mortality Risk: Lives Saved versus Life Years Saved." *Review of Environmental Economics and Policy* 1(2): 228-240.

Hammitt, J.K. 2013. "Admissible Utility Functions for Health, Longevity, and Wealth: Integrating Monetary and Life-Year Measures." *Journal of Risk and Uncertainty* 47: 311-325

Hammitt, J.K. 2015. "Implications of the WTP–WTA Disparity for Benefit–Cost Analysis." *Journal of Benefit-Cost Analysis* 6(1): 207-216.

Hammitt, J.K. 2017. "Extrapolating the Value per Statistical Life Between Populations: Theoretical Implications." *Journal of Benefit-Cost Analysis* 8(2): 215-225.

Hammitt, J.K. and K. Haninger. 2017. "Valuing Nonfatal Health Risk as a Function of Illness Severity and Duration: Benefit Transfer using QALYs." *Journal of Environmental Economics and Management* 82: 17-38.

Hammitt, J.K. and M.E. Ibarrarán. 2006. "The Economic Value of Fatal and Non-Fatal Occupational Risks in Mexico City using Actuarial- and Perceived-Risk Estimates." *Health Economics* 15(12): 1329-1335

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(6): 468-478.

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(1): Art. 1. https://www.cambridge.org/core/journals/journal-of-benefit-cost-analysis/article/the-income-elasticity-of-the-value-per-statistical-life-transferring-estimates-between-high-and-low-income-populations/3AE5B0BB1034B7D898E2C9B3C1507794

Hammitt, J.K. and T. Tunçel. 2015. "Preferences for Life-Expectancy Gains: Sooner or Later?" *Journal of Risk and Uncertainty* 51(1): 79-101.

Hammitt, J.K. and K. Zhou. 2006. “The Economic Value of Air-Pollution-Related Health Risks in China: A Contingent Valuation Study.” *Environmental and Resource Economics* 33(3): 399-423.

Hoffmann, S., P. Qin, A. Krupnick, B. Badrakh, S. Batbaatar, E. Altangerel, and L. Sereeter. 2012. “The Willingness to Pay for Mortality Risk Reductions in Mongolia.” *Resource and Energy Economics* 34(4): 493-513.

Hoffmann, S., A. Krupnick, and P. Qin. 2017. “Building a Set of Internationally Comparable VSL Studies: Estimates of Chinese Willingness to Pay to Reduce Mortality Risk.” *Journal of Benefit-Cost Analysis* 8(2): 251-289.

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

Jamison D.T., S. Shahid-Salles, J. Jamison, J. Lawn, and J. Zupan. 2006. Incorporating Deaths Near the Time of Birth into Estimates of the Global Burden of Disease. In: *Global Burden of Disease and Risk Factors* (A.D. Lopez, C.D. Mathers, M. Ezzati, D.T. Jamison, and C.J.L. Murray CJL, eds.) New York: Oxford University and the World Bank. https://www.ncbi.nlm.nih.gov/books/NBK11805/

Jamison, D.T. et al. 2013. “Global Health 2035: A World Converging within a Generation.” *The Lancet* 382: 1898-1955. http://www.thelancet.com/journals/lancet/article/PIIS0140-6736(13)62105-4/fulltext

Johnston, R.J., K.J. Boyle, W. Adamowicz, J. Bennett, R. Brouwer, T.A. Cameron, W.M. Hanemann, N. Hanley, M. Ryan, R. Scarpa, R. Tourangeau, and C.A. Vossler. 2017. “Contemporary Guidance for Stated Preference Studies.” *Journal of the Association of Environmental and Resource Economists* 4(2): 319-405.

Johannesson, M., and P-O. Johansson. 1996. “To Be, or Not to Be, That is the Question: An Empirical Study of the WTP for an Increased Life Expectancy at an Advanced Age.” *Journal of Risk and Uncertainty* 13: 163-174.

Johannesson, M. and P-O. Johansson. 1997. “The Value of Life Extension and the Marginal Rate of Time Preference: A Pilot Study.” *Applied Economic Letters* 4: 53-55.

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

Jones-Lee, M., S. Chilton, H. Metcalf, J.S. Nielson. 2015. “Valuing Gains in Life Expectancy: Clarifying Some Ambiguities.” *Journal of Risk and Uncertainty* 51: 1–21.

Khanna, M. et al. 2017. *SAB Review of EPA’s Proposed Methodology for Updating Mortality Risk Valuation Estimates for Policy Analysis.* Memorandum to E. Scott Pruitt, EPA Administrator, from the

EPA Science Advisory Board and Environmental Economics Advisory Committee. EPA-SAB-17-005. https://yosemite.epa.gov/sab/sabproduct.nsf/LookupWebReportsLastMonthBOARD/436C15984A487E1F852580D0004429CF/$File/EPA-SAB+2017-005+Unsigned.pdf

Kling, C.L. et al. 2011. *Review of Valuing Mortality Risk Reductions for Environmental Policy: A White Paper (December 10, 2010)*. Prepared by the U.S. Environmental Protection Agency's Science Advisory Board, Environmental Economics Advisory Committee. EPA-SAB-11-011. https://yosemite.epa.gov/sab/sabproduct.nsf/298E1F50F844BC23852578DC0059A616/$File/EPA-SAB-11-011-unsigned.pdf

Knetsch, J.L. 2015. "The Curiously Continuing Saga of Choosing the Measure of Welfare Changes." *Journal of Benefit-Cost Analysis* 6(1): 217-225.

Kniesner, T., W.K. Viscusi, and J. Ziliak. 2006. "Life-Cycle Consumption and the Age-Adjusted Value of Life." *Contributions to Economic Analysis and Policy* 5 (1): 1–36.

Krupnick, A. 2007. "Mortality-risk Valuation and Age: Stated-preference Evidence." *Review of Environmental Economics and Policy* 1(2): 261-282.

Landrigan, P.J. et al. 2018. The Lancet Commission on Pollution and Health (and supplementary appendix). *The Lancet* 391: 462-512.

Lindhjem, H., S. Navrud, N.A. Braathen, and V. Biausque. 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.

Madheswaran, S. 2007. "Measuring the Value of Statistical Life: Estimating Compensating Wage Differentials among Workers in India." *Social Indicators Research* 84(1): 83-96.

Mahmud, M. 2009. "On the Contingent Valuation of Mortality Risk Reduction in Developing Countries." *Applied Economics* 41(2): 171-181.

Masterman, C. and W.K. Viscusi. 2018. "The Income Elasticity of Global Values of a Statistical Life: Stated Preference Evidence." Vanderbilt Law Research Paper No. 18-12. https://ssrn.com/abstract=3127641.

Mofadal, A., K. Kanitpong, and P. Jiwattanakulpaisarn. 2015. "Analysis of Pedestrian Accident Costs in Sudan using the Willingness-to-Pay Method." *Accident Analysis and Prevention* 78: 201-211.

Ministry of Finance. 2012. *Cost-Benefit Analysis*. Official Norwegian Reports. https://www.regjeringen.no/contentassets/5fce956d51364811b8547eebdbcde52c/en-gb/pdfs/nou201220120016000en_pdfs.pdf

Narain, U. and C. Sall. 2016. *Methodology for Valuing the Health Impacts of Air Pollution: Discussion of Challenges and Proposed Solutions*. Washington, DC: World Bank Group. http://documents.worldbank.org/curated/en/832141466999681767/Methodology-for-valuing-the-health-impacts-of-air-pollution-discussion-of-challenges-and-proposed-solutions

Nielson, J. S. et al. 2010. "How Would You Like Your Gain in Life Expectancy To Be Provided? An Experimental Approach." *Journal of Risk and Uncertainty* 41(3): 195–218.

OECD. 2012. *Mortality Risk Valuation in Environment, Health and Transport Policies*. Paris: OECD Publishing. http://www.oecd.org/env/tools-evaluation/env-value-statistical-life.htm

OECD. 2016. *The Economic Consequences of Outdoor Air Pollution*. Paris: OECD Publishing. http://www.oecd.org/env/the-economic-consequences-of-outdoor-air-pollution-9789264257474-en.htm

Ortiz, R.A., A. Markandya, and A. Hunt. 2009. "Willingness to Pay for Mortality Risk Reduction Associated with Air Pollution in São Paulo." *Revista Brasileira De Economia* 63(1): 3-22.

Parada-Contzen, M., A. Riquelme-Won, and F. Vasquez-Lavin. 2013. "The Value of a Statistical Life in Chile." *Empirical Economics* 45(3): 1073-1087

Polat, S. 2014. "Wage Compensation for Risk: The Case of Turkey." *Safety Science* 70: 153-160.

Rafiq, M. and M.K. Shah.2010. "The Value of Reduced Risk of Injury and Deaths in Pakistan—Using Actual and Perceived Risk Estimates." *The Pakistan Development Review* 49(4): 823-837. https://www.jstor.org/stable/41428692

Robinson, L.A. and J.K. Hammitt. 2009. *The Value of Reducing Air Pollution Risks in Sub-Saharan Africa.* Prepared for the World Bank under subcontract to ICF Incorporated.

Robinson, L.A. and J.K. Hammitt. 2013. "Skills of the Trade: Valuing Health Risk Reductions in Benefit-Cost Analysis." *Journal of Benefit-Cost Analysis* 4(1): 107-130. https://www.cambridge.org/core/journals/journal-of-benefit-cost-analysis/article/skills-of-the-trade-valuing-health-risk-reductions-in-benefit-cost-analysis/69DC1C4F8DD9430A99701CA729351167

Robinson, L.A. and J.K. Hammitt. 2015. "Research Synthesis and the Value per Statistical Life." *Risk Analysis* 35(6): 1086-1100.

Robinson, L.A. and J.K. Hammitt. 2016. "Valuing Reductions in Fatal Illness Risks: Implications of Recent Research." *Health Economics* 25: 1039–1052.

Robinson, L.A., J.K. Hammitt, and M.D. Adler. 2018. *Assessing the Distribution of Impacts in Global Benefit-Cost Analysis*. https://sites.sph.harvard.edu/bcaguidelines/methods-and-cases/

Robinson, L.A., J.K. Hammitt, L. O'Keeffe, C. Munk, B. Patenaude, and F. Geng. 2017a. *Benefit-Cost Analysis in Global Health and Development: Current Practices and Opportunities for Improvement (Scoping Report).* https://sites.sph.harvard.edu/bcaguidelines/scoping/

Robinson, L.A., J.K. Hammitt, A.Y. Chang, and S. Resch. 2017b. "Understanding and Improving the One and Three Times GDP per Capita Cost-Effectiveness Thresholds." *Health Policy and Planning* 32: 141-145. https://academic.oup.com/heapol/article/32/1/141/2555408

Ryen, L. and M. Svensson. 2015. "The Willingness to Pay for a Quality Adjusted Life Year: A Review of the Empirical Literature." *Health Economics* 24: 1289-1301.

Ščasný, M. and I. Zvěřinová. 2014. *Stated-preference Study to Examine the Economic Value of Benefits of Avoiding Selected Adverse Human Health Outcomes Due to Exposure to Chemicals in the European Union*. Report for the European Chemicals Agency.

Shepard, D.S. and R.J. Zeckhauser. 1982. "Life Cycle Consumption and Willingness to Pay for Increased Survival." *The Value of Life and Safety.* (M.W. Jones-Lee, ed.) Amsterdam: North-Holland. pp. 95-141.

Shepard, D.S. and R.J. Zeckhauser. 1984. "Survival versus Consumption." *Management Science* 30(4): 423-439.

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.

Tekeşin, C. and S. Ara. 2014. "Measuring the Value of Mortality Risk Reductions in Turkey." *International Journal of Environmental Research and Public Health* 11(7): 6890-6922.

Tunçel, 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 Health and Human Services. 2016. *Guidelines for Regulatory Impact Analysis*. https://aspe.hhs.gov/pdf-report/guidelines-regulatory-impact-analysis

U.S. Department of Transportation. 2016. "Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Transportation Analyses – 2016 Adjustment." Memorandum to Secretarial Officers and Modal Administrators from M.J. Moran, Acting General Counsel, and Carlos Monje Assistant Secretary for Transportation Policy. https://www.transportation.gov/regulations/economic-values-used-in-analysis

U.S. Environmental Protection Agency. 2003. *Children's Health Valuation Handbook.* https://www.epa.gov/environmental-economics/handbook-valuing-childrens-health

U.S. Environmental Protection Agency. 2010a (with 2014 update). *Guidelines for Preparing Economic Analyses.* https://www.epa.gov/environmental-economics/guidelines-preparing-economic-analyses

U.S. Environmental Protection Agency. 2010b. *Valuing Mortality Risk Reductions for Environmental Policy: A White Paper*. Prepared by the U.S. Environmental Protection Agency's National Center for Environmental Economics, for review by the EPA's Science Advisory Board, Environmental Economics Advisory Committee. https://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0563-1.pdf/$file/EE-0563-1.pdf

U.S. Environmental Protection Agency. 2016. *Valuing Mortality Risk Reductions for Policy: A Meta-Analytic Approach*. Prepared by the U.S. Environmental Protection Agency's Office of Policy, National Center for Environmental Economics, for review by the EPA's Science Advisory Board, Environmental Economics Advisory Committee. https://yosemite.epa.gov/sab/SABPRODUCT.NSF/81e39f4c09954fcb85256ead006be86e/0CA9E925C9A702F285257F380050C842/$File/VSL+white+paper_final_020516.pdf

Vassanadumrongdee, S. and S. Matsuoka. 2005. "Risk Perceptions and Value of a Statistical Life for Air Pollution and Traffic Accidents: Evidence from Bangkok, Thailand." *Journal of Risk and Uncertainty* 30(3): 261-287.

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. https://www.bls.gov/opub/mlr/2013/article/using-data-from-the-census-of-fatal-occupational-injuries-to-estimate-the.htm

Viscusi, W.K. 2015a. "Reference-Dependence Effects in Benefit Assessment: Beyond the WTA–WTP Dichotomy and WTA–WTP Ratios." *Journal of Benefit-Cost Analysis* 6(1): 187-206.

Viscusi, W.K. 2015b. "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 C.J. Masterman. 2017a. Anchoring Biases in International Estimates of the Value of a Statistical Life. *Journal of Risk and Uncertainty* 54(2): 103–128.

Viscusi, W.K. and C.J. Masterman. 2017b. "Income Elasticities and Global Values of a Statistical Life." *Journal of Benefit-Cost Analysis* 8(2): 226-250. https://www.cambridge.org/core/journals/journal-of-benefit-cost-analysis/article/income-elasticities-and-global-values-of-a-statistical-life/5AE299883F668DCC265C41A377E1E063

World Bank and Institute for Health Metrics and Evaluation. 2016. *The Cost of Air Pollution: Strengthening the Economic Case for Action.* Washington, D.C.: World Bank. http://documents.worldbank.org/curated/en/781521473177013155/pdf/108141-REVISED-Cost-of-PollutionWebCORRECTEDfile.pdf

Appendix A: Review of Studies Conducted in Low- and Middle-Income Countries

As discussed in the main text, researchers often extrapolate from research conducted largely in higher income countries to estimate values in low- and middle-income countries. However, the number of studies conducted in the latter countries has increased substantially in recent years. In this appendix, we review the literature and evaluate its quality and its findings. We then assess the relationship of the results to the income level of those included in each study and discuss the implications.

Because the status of individual countries changes over time, determining how to best categorize studies is not straightforward. In the discussion that follows, we include studies conducted in countries that were categorized by the World Bank as low- or middle-income at any time during the past 20 years (1997 through 2017). As indicated in Appendix B, these include 172 countries.[44] As of June 2017, of the 218 countries identified by the World Bank, 31 were classified as low-income and 108 were middle-income for a total of 139.[45] The remaining 79 are now high-income.

We focus on studies that estimate values for adults; studies that estimate the value of changes in life expectancy (often expressed as the value per statistical life year - VSLY) or the value of risk reductions for children are discussed in Chapter 4. More information on the individual studies is provided in Appendix B.

A.1 Selection Criteria

In our review, we used the following criteria to select studies for detailed review and evaluation.

Figure A.1. Selection Criteria

1. Written in English.
2. Publicly available.
3. Data collected within the past 20 years (1997-2017).
4. Conducted in a low- or middle-income country.
5. Based on a probabilistic sample, not a convenience sample.
6. Estimates willingness to pay, not willingness to accept compensation.
7. Addresses the values adults place on changes in their own risks.

Criteria 1 and 2 (written in English, publicly available) align with the goals of this project: to develop methodological recommendations for application in benefit-cost analysis globally. To achieve this goal, the underlying studies should be accessible to those conducting and reviewing the analyses. While English is not necessarily the first language of those involved, it is often used in academic discourse and publications and is the language most likely to be understood by a wide-range of researchers. Publicly-

[44] Detailed information on how these categories are determined and on the historical classification of each country is available here: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups. We rely on the version of that spreadsheet that was available for download when we conducted our review in June 2017.

[45] As of 2017, the World Bank defined low-income economies as those with 2015 GNI per capita of $1,025 or less; lower middle-income economies as those with GNI per capita between $1,026 and $4,035; upper middle-income economies as those with GNI per capita between $4,036 and $12,475; high-income economies as those with GNI per capita of $12,476 or more, measured in U.S. dollars based on market exchange rates (Atlas method).

available sources may include peer-reviewed journal articles, working paper series maintained by academic and other institutions, and reports from government agencies and international organizations. We include publicly-accessible working papers and reports as well as journal articles. We do not restrict our search to papers published in peer-reviewed journals; papers that report estimates of VSL using generally-accepted best practices (that are useful for our analysis) are not necessarily published in journals, either because the authors or funders do not put high priority on journal publication or because journals' publication criteria emphasize factors other than adherence to best practices, such as methodological innovation.

Criteria 3, 4, and 5 (data collected within the past 20 years in low- or middle-income countries using a probabilistic sample) reflect our interest in understanding the preferences of these populations. Older studies are less likely to reflect the preferences of those affected by current or future policies, and do not reflect researchers' evolving understanding of how to best conduct these studies. As noted earlier, we use the World Bank classifications to identify countries categorized as low- or middle-income countries at any point over the past 20 years (1997-2017); the countries included in this group are listed in Appendix B. We consider studies that rely on probability samples due to our desire for values that are representative of the population studied.

Criteria 6 and 7 relate to the need for values that measure a reasonably consistent outcome. Criterion 6 is primarily relevant to stated-preference studies, and requires that they elicit WTP rather than WTA.[46] WTP is more often used in benefit-cost analyses because policy options typically involve expenditures for improvements from the status quo rather than compensation for damages. WTP is also more frequently studied and the estimates are generally considered more reliable; the reasons for the large and variable differences between estimated WTP and WTA are not well understood (Horowitz and McConnell 2002, Tunçel and Hammitt 2014).

Criterion 7 focuses on changes in an adult's own risk.[47] In this Appendix, we consider risk changes rather than changes in life expectancy; studies that consider the latter are discussed in Chapter 4, which also addresses values for children.[48] We review studies that address changes in one's own risk rather than risks to others (or to the community of which one is a part) for consistency with the conceptual framework for benefit-cost analyses, which assumes that the individual is the best or most legitimate judge of his or her own welfare. This criterion also reflects concerns about the limitations of the available research on risks to others, as discussed in Chapter 2. Note that Criterion 7 relates to the framing of the WTP questions, not to 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

[46] 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.
[47] We exclude studies that address outcomes that occur with certainty or that address particular programs or interventions without separating the value of mortality risk reductions from the value of other outcomes.
[48] The age ranges considered in the adult VSL studies vary; we discuss the effects of age on VSL in Chapter 4.

whether the respondent is instructed to only consider his or her own risks in answering the valuation questions.

A.2 Search Results

To identify studies conducted in low- and middle-income countries, we began with those listed in previous reviews, including Robinson and Hammitt (2009), OECD (2012), Narain and Sall (2016), Viscusi and Masterman (2017a, 2017b), and World Bank and IHME (2016). Some of the identified studies were conference presentations or working papers, for which we substituted the versions published as journal articles or report or book chapters if available. We also contacted the authors of these reviews and other researchers and searched EconLit to identify additional studies.[49,50]

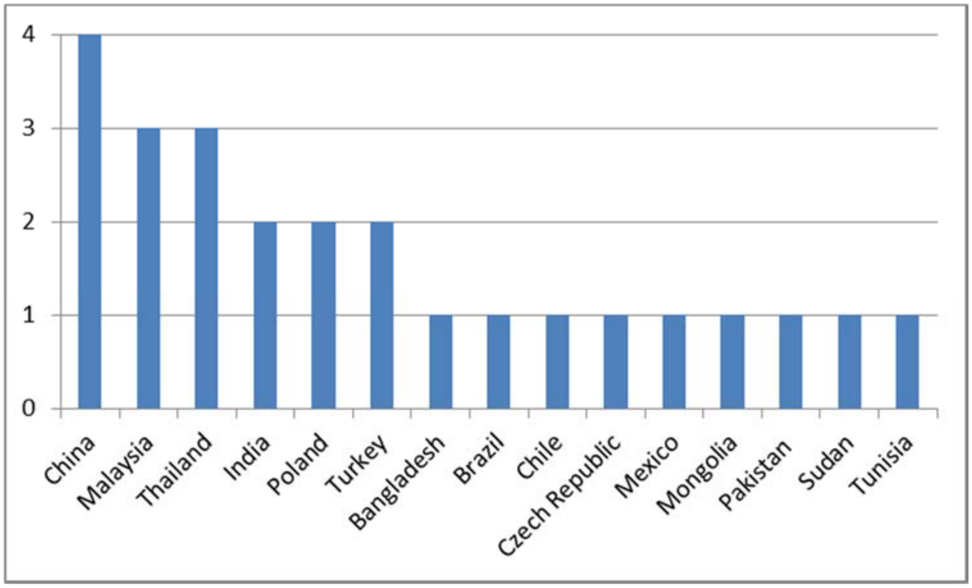
We found 17 stated-preference studies (which include 18 surveys) and eight wage-risk studies that meet the criteria listed in Figure A.1; a complete listing of these 25 studies is provided in Appendix C. These studies are clustered in a small subset (15) of the 172 countries that were classified as low- or middle-income over the past 20 years, as shown in Figure A.2. Of the countries in which these studies were conducted, as of 2017 (based on 2015 GNI per capita) the World Bank now classifies six as lower middle-income (Bangladesh, India, Mongolia, Pakistan, Sudan, and Tunisia), six as upper middle-income (Brazil, China, Malaysia, Mexico, Thailand, and Turkey), and three as high-income (Chile, Czech Republic, and Poland). Of the 17 stated-preference studies, 15 elicit values from the population of particular cities or regions rather than the country as a whole. Of the eight wage-risk studies, two focus on particular cities or regions while the remainder address the national population. All studies address adults, although the age ranges considered vary.

---

[49] Additional references provided via email by Maureen Cropper, Sandra Hoffmann, and Christopher Sall, June 21, 2017. For revealed-preference studies, we focus on research that considers the trade-off between wages and mortality risks, due to the concerns about other methods (such as studies of averting behavior) noted in Chapter 3.

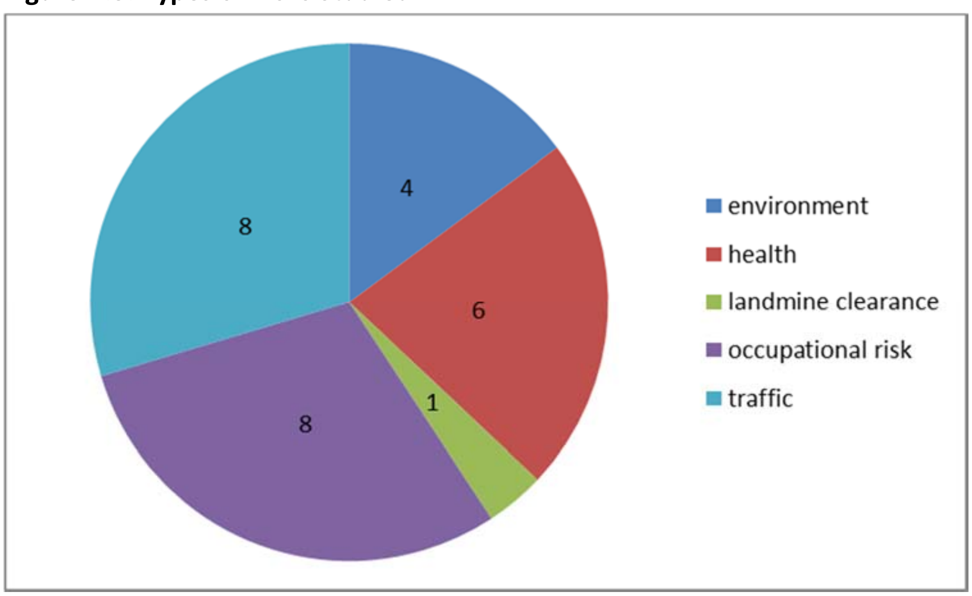
[50] Search terms included WTP OR VSL; WTP AND VSL; (VSL OR WTP) AND "low income;" (VSL OR WTP) AND "middle income."

Figure A.2. Number of Studies by Country



These studies vary in the types of mortality risks they consider. As indicated in Figure A.3, eight consider risks associated with transportation or traffic safety, four consider risks from environmental causes, six consider health risks (such as cancer or respiratory or cardiovascular diseases) from unspecified causes, eight consider occupational risks (one stated-preference study plus the seven wage-risk studies), and one considers landmine clearance. The count of studies in this figure exceeds the count of studies in the previous figure because two studies consider risks from more than one cause.[51]

Figure A.3. Types of Risks Studied



[51] In one of these two studies (Vassanadumrondgee and Matsuoka 2005) the authors discuss two separate surveys and report separate VSLs.

A.3 Evaluating Study Quality

Further evaluating the quality of these studies is difficult, in part because they vary in the extent to which they document the data sources and methods used and in part because there are few studies that address similar populations – which makes it difficult to determine whether differences in results are due to differences in populations or other study characteristics.

For the stated-preference studies, one indicator of validity is whether estimates of WTP are sensitive to scope; i.e., whether WTP for different magnitudes of risk reduction are statistically significantly different. Theory suggests that WTP should be larger for a larger risk reduction, and close to proportional to the risk change as long as WTP is small relative to income (see Corso et al. 2001, Alolayan et al. 2017). The common practice of applying a constant VSL across differently-sized risk changes rests on this assumption of proportionality; if WTP is not proportional to the risk change, then estimated VSL (WTP divided by the risk change) depends on the magnitude of the risk change.[52,53]

The 17 studies we identify include 18 surveys, of which ten test for whether WTP differs between different-sized risk reductions.[54] Six find that WTP is significantly different for different risk reductions, but it is often less than proportional to the risk change.[55] The lack of scope tests in many of these studies is troubling, suggesting that researchers may not fully understand some of the challenges associated with conducting stated-preference research. These tests help validate whether respondents comprehend the outcome to be valued, and can be seen more generally as an indicator of whether the researchers are conscientiously adhering to standards for high quality work.[56]

The finding that, when scope tests are included, WTP is often relatively insensitive to risk magnitude is common in research conducted in high-income countries as well (see, for example, USEPA 2010b, Robinson and Hammitt 2016). It suggests, for example, that the value of a 1 in 10,000 risk reduction is similar to the value of a 5 in 10,000 risk reduction. Using the same value for differently-sized risk reductions in policy analysis would suggest that investing in policies that provide smaller risk reductions may be preferable (assuming the costs of implementing the policy increase with the size of the risk reduction), which seems nonsensical. It is more likely that individuals are misinterpreting the

---

[52] For example, if WTP is $900 for a 1 in 10,000 risk change and $4,500 for a 5 in 10,000 risk change, then the VSL (WTP divided by risk change) is $9 million in both cases. If the changes are not proportional, then the VSL differs and it is not clear what VSL is appropriate for small risk changes.

[53] While some studies report whether WTP is statistically significantly different for risk reductions of different magnitude (e.g., OECD 2012), a significant difference does not necessarily mean that WTP is close-to-proportional.

[54] Vassanadumrondgee and Matsuoka (2005) provides results separately from two surveys.

[55] We rely on the authors' tests of scope sensitivity and their judgements about whether the results are sensitive to scope or close to proportional (see Appendix C). Bhattacharya et al. (2007) find that WTP is approximately proportional to risk reduction for a subsample of respondents (those with college education).

[56] Johnston et al. (2017) provide recent, comprehensive guidance on conducting stated-preference studies to value environmental and health outcomes. We do not apply this guidance in our review, both because these studies were conducted before it was issued and because that guidance is not tailored to this particular context. More work is needed to develop guidance that is appropriate for valuing mortality risk reductions in low- and middle-income countries, which addresses how to best conduct these studies given resource limitations as well as cultural differences and other issues.

probabilities.[57] This misunderstanding can be reduced by including educational materials in the survey then querying respondents to determine whether they comprehend the differences in probabilities. Using visual aids to illustrate the change in risk (such as a grid in which an area proportional to the risk reduction is colored) has been found to reduce this misunderstanding in several studies, but is not always effective.

For the wage-risk studies, work conducted in the U.S. suggests that the results of these studies may be very sensitive to the quality of the risk and other data and to the controls included in the statistical models (see, for example, Viscusi 2013). Inspection of the information reported in the studies themselves suggests that several have significant drawbacks. For example, because job-related deaths may be somewhat infrequent, it is usually desirable to combine data from more than one year. However, two studies (Parada-Contzen et al. 2013, Benkhalifa et al. 2013) are based on a single year. In addition, typically multiple data sources are used in these studies; often one that reports job-related deaths, and a second that reports worker characteristics (such as income) by industry and/or occupation. If these sources address different populations (e.g., one is national and another is regional) the results may be biased. In at least two studies (Rafiq and Shah 2010, Benkhalifa et al. 2013), the articles do not provide sufficient information to explore the match between the data sources used. While the remaining articles suggest that the match may be reasonable, more investigation of the underlying data sources would be needed to confirm this finding.

As discussed in the main text, Viscusi and Masterman (2017a, 2017b) and Masterman and Viscusi (2018) explore the effects of publication-selection bias on these estimates. Their meta-analysis of wage-risk studies includes some of the studies we review; their analysis of stated preference studies include all 17 of the studies we identify. They find that U.S. studies that rely on Census of Fatal Occupational Injuries data appear less subject to this bias than other research. Their results suggest that selection bias is likely a concern in the studies we review.

A.4 Relationship to Income

As introduced earlier, estimates of VSL reflect individuals' willingness to trade income for their own mortality risk reductions rather than spending on other things that money could buy. Given this framing, it seems unlikely that these values would be the same in populations with substantially different incomes. In the main text, we discuss the elasticity estimates used in several recent studies. In this section, we discuss the relationship of the values reported in the studies we reviewed to the income levels of respondents and of the country as a whole. We then discuss the implications for transferring estimates between countries with differing income levels.

The studies we reviewed each provide multiple VSL estimates, both because many consider more than one scenario and because most researchers consider several model specifications when analyzing the data. In the discussion that follows, we focus on the estimate that the authors identify as their "best"

[57] An alternative explanation is that respondents engage in a form of mental accounting that limits the share of income they are willing to spend on reducing mortality risks.

estimate or feature in their abstract or conclusions. If there is no featured estimate, we rely on the mid-point of the range of reported values.[58] More information on these estimates is provided in Appendix C.

Comparing the resulting monetary values requires converting them to the same currency and year. Because we are interested in transferring these values across countries with different income levels, we simplify the comparisons by instead reporting the ratio of the VSL to income in the year for which the results were reported.

One complicating factor is the need for consistently-derived and easily accessible estimates of income that can be used to transfer values across countries. VSL studies often rely on per household or per worker estimates of income, but estimates of GNI per capita or GDP per capita are more widely available and hence more often used in benefit transfer. As noted earlier, we rely on GNI per capita in this paper (based on purchasing power parity) because it is the broader measure. In addition to conceptual differences between GNI per capita and estimates of household or individual income, we face the challenge that many of the studies we review are not based on national samples. Thus the income of the people studied may differ significantly from the national average, affecting the resulting WTP estimates and rendering comparison to national income estimates flawed. Even studies based on national samples may find mean income levels that differ significantly from estimates of GNI per capita, given the differences in how these measures are defined.

More specifically, of the 25 studies, 20 report the mean income levels for the sample. Of these, seven report household income, seven report individual income, two report both household and individual income, and four do not indicate whether the income level is for the individual or the household. Where mean individual income is reported, in six studies it is within +50 percent of GNI per capita for the country. In the remainder, mean individual income for the sample varies from about 160 percent of GNI per capita to about 290 percent. These differences result in part because of the area studied. For example, the 290 percent difference is for Bhattacharya et al. (2007), which is based on a sample of commuters in Delhi, and hence not representative of the national population of India. The remaining studies do not provide income data. Three are based on national samples; the remainder address residents of particular cities or regions which may have income levels that diverge significantly from the national average. These data raise serious questions about comparing VSL estimates to GNI per capita, given that differences in income can significantly affect these estimates.

As an additional plausibility check, we compare the ratio of VSL to GNI per capita in each of these studies to ratios that seem reasonable based on the discussion in the main text. Several of these studies report VSLs that result in implausibly high or low ratios (see Appendix C). These include those where the ratio is above the U.S. ratio (160); it seems highly unlikely that the ratio in substantially poorer countries

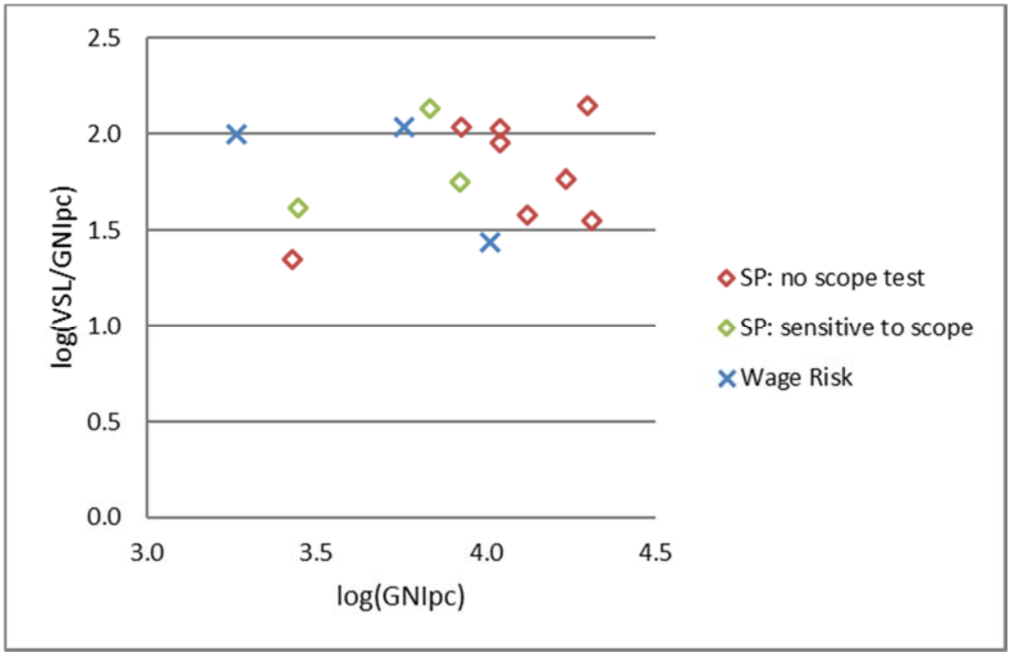
[58] Ideally, we would prefer to rely on the predicted value for the mean or median individual in the study population, derived from the “best” statistical model. However, this value may not be reported by the authors and determining which model is “best” is difficult. The Masterman and Viscusi (2018) study discussed in the main text uses all of the estimates from these studies in their meta-analysis, controlling for bias that may result from the criteria used to select these studies and estimates.

would exceed the ratio for the U.S. Exactly where this upper bound is set makes little difference, given the distribution of the ratios reported in Appendix C, Table C.3. We also exclude those where the ratio is less than 20.[59] This lower bound reflects the expectation that the VSL would exceed the future earnings (and consumption) of the average individual; we assume that an adult of average age would have at least 20 years of life remaining in the countries of concern. The results from seven of the 18 stated preference surveys are outside of these upper and lower bounds; as are the results from five of the eight wage-risk studies. Thus in the analysis that follows, we exclude the results of these 12 studies, focusing on the 14 remaining estimates

The differences between the income levels of the study populations and GNI per capita means that any comparisons as part of the benefit transfer process are fraught with problems. For the moment, we ignore these problems and in Figure A.5 display the ratios of estimated VSL to GNI per capita (in the same year as the VSL estimate). These comparisons exclude the 12 studies that include implausibly high or low estimates; focusing on the results from the remaining 11 stated preference surveys and three wage-risk studies. Note that the scales are logarithmic (base 10). Overall, there is substantial variability in the ratio of VSL to GNI per capita, with most falling between roughly 39 (log ratio = 1.6) and 107 (log ratio = 2.0). The ratios appear to be similar for the three wage-risk studies (log ratios = 1.4 or 2.0), and the 11 stated-preference studies (log-ratios = 1.4 to 2.2), regardless whether the latter test for sensitivity to scope. Note that, of the studies in our review that fell within the plausible range of VSL-to-GNI per capita ratios (and hence are included in Figure A.5), all that conducted a scope test found that WTP was sensitive to scope.

[59] The value of living a year seems likely to exceed the monetary value of consumption, because life is about much more than consumption of goods and services. This logic is consistent with the view that the human-capital approach to valuing life-saving provides a lower-bound estimate (see Chapter 2 for more discussion). Hammitt and Robinson (2011) use this approach to set a lower bound on estimates of VSL extrapolated from high- to low-income countries. Although this argument is appealing, standard economic models do not imply that VSL must exceed the expected value of future consumption (see Hammitt 2017).

Figure A.5. Ratio of VSL to GNI per Capita (GNIpc)



Notes: The term "scope test" is used to refer to the different categories of stated-preference (SP) studies: those that do not test the sensitivity of WTP to the size of the risk reduction ("no scope test") and those that conduct a test and find that WTP is sensitive to scope ("sensitive to scope"). None of the studies that remain after excluding those with implausible results conduct a scope test and find that WTP is insensitive to scope. As noted earlier, scope tests generally cannot be conducted for wage-risk studies.

An alternative way of viewing the implications of these results is to estimate the income elasticity that would be needed to extrapolate from a VSL estimate for a high-income country to each of these VSL estimates. The U.S. VSL estimates discussed in the main text results in a VSL-to-GNI per capita ratio of about 160. Again excluding implausibly high and low ratios, the income elasticity implied by comparing the remaining ratios with the U.S. estimate ($9.4 million) ranges from 1.1 to 2.5 with a mean of 1.5 and a median of 1.4.[60]

The ratio of estimated VSL to GNI per capita in the studies we reviewed varies widely. The variation likely reflects several issues. One is that VSL depends on the disposable income of the sampled population, which may differ from GNI per capita in studies that do not rely on nationally-representative samples. These estimates may also diverge in studies that are nationally representative because income is a different measure than GNI per capita. A second issue is that the variation likely reflects differences in the quality of these studies. Finally, the ratios and elasticities calculated above do not control for other factors that may influence the relationship between the VSL and income, such as cultural norms, quality of the health care system, or age and life expectancy (see Hammitt 2017).

[60] The formula used in this extrapolation is elasticity = $1+(\ln(ratio_{target}/ratio_{base})/(\ln(income_{target}/income_{base})))$ where "ratio" is the VSL-to-GNI per capita ratio in that country. The base values are the US DHHS VSL of $9.4 million and GNI per capita of $57,900, which results in a ratio of 162 (rounded to 160 in the text and recommendations). The target values are reported for each study in in Table C.3.

Appendix B: Countries Categorized as Low- or Middle-Income, 1997 to 2017

The countries categorized by the World Bank as low- or middle-income during any one year from 1997 to 2017 are listed below. These included 172 out of the 218 countries the World Bank identifies. Detailed information on how these categories are determined and on the historical classification of each country is available here: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups. We rely on the version of that spreadsheet that was available for download in June 2017.

Table B.1. Countries Classified and Low- or Middle-Income, 1997-2017

Country				
Afghanistan	Congo, Rep.	Iraq	Myanmar	South Africa
Albania	Costa Rica	Isle of Man	Namibia	South Sudan
Algeria	Côte d'Ivoire	Jamaica	Nauru	Sri Lanka
American Samoa	Croatia	Jordan	Nepal Nicaragua	St. Kitts and Nevis
Angola	Cuba	Kazakhstan	Niger	St. Lucia
Antigua and Barbuda	Curaçao	Kenya	Nigeria	St. Martin (French part)
Argentina	Czech Republic	Kiribati	Northern Mariana Islands	St. Vincent and the Grenadines
Armenia	Djibouti	Korea, Dem. Rep.	Oman	Sudan
Azerbaijan	Dominica	Korea, Rep.	Pakistan	Suriname
Bahrain	Dominican Republic	Kosovo	Palau	Swaziland
Bangladesh	Ecuador	Kyrgyz Republic	Panama	Syrian Arab Republic
Barbados	Egypt, Arab Rep.	Lao PDR	Papua New Guinea	Tajikistan
Belarus	El Salvador	Latvia	Paraguay	Tanzania
Belize	Equatorial Guinea	Lebanon	Peru	Thailand
Benin	Eritrea	Lesotho	Philippines	Timor-Leste
Bhutan	Estonia	Liberia	Poland	Togo
Bolivia	Ethiopia	Libya	Puerto Rico	Tonga
Bosnia and Herzegovina	Fiji	Lithuania	Romania	Trinidad and Tobago
Botswana	Gabon	Macedonia, FYR	Russian Federation	Tunisia
Brazil	Gambia, The	Madagascar	Rwanda	Turkey
British Virgin Islands	Georgia	Malawi	Samoa	Turkmenistan
Bulgaria	Ghana	Malaysia	San Marino	Turks and Caicos Islands
Burkina Faso	Gibraltar	Maldives	São Tomé and Principe	Tuvalu
Burundi	Greece	Mali	Saudi Arabia	Uganda
Cabo Verde	Grenada	Malta	Senegal	Ukraine
Cambodia	Guatemala	Marshall Islands	Serbia	Uruguay
Cameroon	Guinea	Mauritania	Seychelles	Uzbekistan
Central African Republic	Guinea-Bissau	Mauritius	Sierra Leone	Vanuatu
Chad	Guyana	Mexico	Sint Maarten (Dutch part)	Venezuela, RB
Chile	Haiti	Micronesia, Fed. Sts.	Slovak Republic	Vietnam
China	Honduras	Moldova	Slovenia	West Bank and Gaza
Colombia	Hungary	Mongolia	Solomon Islands	Yemen, Rep.
Comoros	India	Montenegro	Somalia	Zambia
Congo, Dem. Rep.	Indonesia	Morocco		Zimbabwe
	Iran, Islamic Rep.	Mozambique		

Appendix C: Adult VSL Studies Conducted in Low- and Middle-Income Countries

In this appendix, we first list the VSL studies (discussed in Appendix A) which meet our selection criteria. We then summarize the scope test results for the stated-preference studies. Finally, we provide the VSL estimates, income estimates, and gross national income (GNI) per capita estimates used in the analysis. The studies are listed in alphabetical order by the country within which they were conducted, as indicated in Table C.1.

Table C.1. List of VSL Studies

Author, date	Country (current World Bank classification)[a]	Year of Data Collection
Stated-Preference Studies		
Mahmud, 2009	Bangladesh (lower-middle)	2003
Ortiz et al., 2009	Brazil (upper-middle)	2003
Guo et al., 2006	China (upper-middle)	2002
Hammitt and Zhou, 2006	China (upper-middle)	1999
Hoffmann et al., 2017	China (upper-middle)	2006
Alberini et al., 2006	Czech Republic (high)	2004
Bhattacharya et al., 2007	India (lower-middle)	2005
Faudzi et al., 2004	Malaysia (upper-middle)	1999
Faudzi et al., 2013	Malaysia (upper-middle)	2006
Ghani and Faudzi, 2003	Malaysia (upper-middle)	1999
Hoffmann et al., 2012	Mongolia (lower-middle)	2010
Giergiczny, 2010[b]	Poland (high)	2005
Mofadal et al., 2015	Sudan (lower-middle)	2013
Chaturabong et al., 2011	Thailand (upper-middle)	2011
Gibson et al., 2007	Thailand (upper-middle)	2003
Vassanadumrondgee and Matsuoka, 2005	Thailand (upper-middle)	2003
Tekeşin and Ara, 2014	Turkey (upper-middle)	2012
Revealed-Preference Studies		
Parada-Contzen et al., 2013	Chile (high)	2006
Giergiczny, 2008	Poland (high)	2002
Guo and Hammitt, 2009	China (upper-middle)	1995
Madheswaran, 2007	India (lower-middle)	2001
Hammitt and Ibarrarán, 2006	Mexico (upper-middle)	2002
Rafiq and Shah, 2010	Pakistan (lower-middle)	2006
Benkhalifa et al., 2013	Tunisia (lower-middle)	2002[b]
Polat, 2013	Turkey (upper-middle)	2011

Notes: See Appendix A for discussion of selection criteria and search process.
a. Indicates status of country based on World Bank 2017 categories (based on 2015 GNI per capita using market exchange rates and the Atlas method). All studies were conducted in countries classified as low- or middle-income at the time the data were collected.
b. Data were collected in 2002; results are reported at 2000 price levels.

Table C.2 Stated-Preference Study Scope Test Results

Author, date	Scope Test Results
Mahmud, 2009	sensitive
Ortiz et al., 2009	insensitive
Guo et al., 2006	insensitive
Hammitt and Zhou, 2006	insensitive
Hoffmann et al., 2017	sensitive
Alberini et al., 2006	none reported
Bhattacharya et al., 2007	sensitive
Faudzi et al., 2004	none reported
Faudzi et al., 2013	none reported
Ghani and Faudzi., 2003	none reported
Hoffmann et al., 2012	sensitive
Giergiczny, 2010	insensitive
Mofadal et al., 2015	none reported
Chaturabong et al., 2011	none reported
Gibson et al., 2007	none reported
Vassanadumrondgee and Matsuoka, 2005	sensitive
Tekeşin and Ara, 2014	none reported
Notes: Scope test refers to whether the authors examine the sensitivity of WTP to changes in risk magnitude. We rely on the authors' reports of whether a scope test was performed and whether the WTP estimates were sensitive to changes in scope. "Insensitive" includes studies where the values varied with the risk change but the difference was not statistically significant.	

Table C.3 Relationship of VSL to Income

Author, date	VSL estimate[a]	GNIpc	VSL/GNIpc	Reported income[b]	VSL/income
Stated Preference Studies					
Mahmud, 2009	$6,273	$1,550	4.0	$1,345*	4.7
Ortiz et al, 2009	$3,536,000	$9,280	381.0	$10,200	346.7
Guo et al, 2006[c]	$24,000	$3,520	6.8	$2,888*	8.3
Hammitt and Zhou, 2006	$10,500	$2,630	4.0	$5,147[d]	2.0
Hoffmann et al., 2017	$474,194	$8,360	56.7	15,968*	29.7
Alberini et al., 2006	$2,788,889	$19,820	140.7	$17,188*	162.3
Bhattacharya et al., 2007	$117,117	$2,810	41.7	$8,125	14.4
Faudzi et al., 2004	$1,000,000	$11,060	90.4	NR	---
Faudzi et al., 2013	$1,000,000	$17,160	58.3	NR	---
Ghani and Faudzi, 2003	$1,181,818	$11,060	106.9	NR	---

Author, date	VSL estimate[a]	GNIpc	VSL/GNIpc	Reported income[b]	VSL/income
Hoffmann et al, 2012	$921,167	$6,830	134.9	$3,573	257.8
Giergiczny, 2010	$5,035,556	$11,740	428.9	$12,458**	404.2
Mofadal et al, 2015[c]	$60,000	$2,700	22.2	NR	---
Chaturabong et al., 2011	$504,032	$13,210	38.2	NR	---
Gibson et al., 2007	$914,414	$8,490	107.7	$2,315**	395.1
Vassanadumrondgee and Matsuoka, 2005 (air pollution)	$4,007,896	$8,490	472.1	$32,712**	122.5
Vassanadumrondgee and Matsuoka, 2005 (traffic safety)	$4,572,114	$ 8,490	538.5	$36,437**	125.5
Tekeşin and Ara, 2014	$726,414	$ 20,480	35.5	$2,742	256.0
Revealed Preference Studies					
Parada-Contzen et al., 2013	$4,625,958	$13,850	334.0	$6,957[d]	665.0
Guo and Hammitt, 2009	$184,366	$1,840	100.2	$2,049**	90.0
Madheswaran, 2007	$1,480,392	$2,070	715.2	$3,959[e]	373.9
Hammitt and Ibarrarán, 2006	$280,000	$10,290	27.2	$4,200**	66.7
Rafiq and Shah, 2010	$1,728,978	$3,900	443.3	$6,161	280.7
Benkhalifa et al., 2013	$617,700	$5,740	107.6	$4,514	136.8
Giergiczny, 2008	$3,658,333	$11,740	311.6	$ 11,997	304.9
Polat, 2014	$211,737	$19,490	10.9	$10,996	19.3

Notes:
NR=not reported, GNIpc= gross national income per capita.
VSL estimates are the "best" or "central" estimates highlighted by the authors or the mid-point of their highlighted range. All estimates are reported in international dollars based on purchasing power parity for the year in which the data were reported by the authors; monetary estimates have not been updated for inflation and reflect different base years (see Table C.1 for year of data collection), so are not directly comparable.
a. Multiple VSL estimates are reported in some studies. In four cases (Faudzi et al. 2013, Madheswaran 2007, Rafiq and Shah 2010, and Polat 2014), we use the midpoint of the reported values. Vassanadumrondgee and Matsuoka (2005) conducted two separate CV surveys, one for air pollution and one for traffic safety, and report two VSL estimates as indicated in the table.
b. An asterisk (*) indicates that the authors reported average income only at the household level; a double asterisk (**) indicates the authors did not indicate whether the income measure was per household or for the individual. If the authors report income at both the individual and household level, we include individual income in this table.
c. The VSL estimate(s) are reported in U.S. dollars; the authors do not report the exchange rate applied in the analysis.
d. Parada-Contzen et al. (2013) report that ln(mean monthly wage)=$12.19, which seems implausibly high, suggesting that annual income averages $197,000. We instead use the income level back-calculated by Viscusi and Masterman from the regression results. Email from Clayton Masterman, March 14, 2018.
e. Annual income calculated as a weighted average of the cities studied, based on the number of respondents from each area.

Appendix D: Population-Average VSL Estimates by Country

In this appendix, we provide VSL estimates for the countries categorized as low- or middle-income by the World Bank, based on their 2015 income levels. All estimates are reported in international dollars based on purchasing power parity. The countries are listed in order of GNI per capita, from highest to lowest.

Table D.1 VSL Estimates for Standardized Sensitivity Analysis (2015 international dollars)

Country Name	GNI per capita[a]	Value per Statistical Life		
		GNI per capita *160	GNI per capita *100	Extrapolated from U.S. VSL with elasticity = 1.5[b]
Malaysia	$25,880	$4,140,800	$2,588,000	$2,809,030
Turkey	$24,570	$3,931,200	$2,457,000	$2,598,470
Russian Federation	$24,030	$3,844,800	$2,403,000	$2,513,279
Kazakhstan	$23,530	$3,764,800	$2,353,000	$2,435,246
Romania	$21,060	$3,369,600	$2,106,000	$2,062,042
Panama	$20,210	$3,233,600	$2,021,000	$1,938,472
Argentina	$19,950	$3,192,000	$1,995,000	$1,901,185
Mauritius	$19,940	$3,190,400	$1,994,000	$1,899,756
Equatorial Guinea	$19,920	$3,187,200	$1,992,000	$1,896,898
Bulgaria	$17,750	$2,840,000	$1,775,000	$1,595,539
Iran, Islamic Rep.	$17,620	$2,819,200	$1,762,000	$1,578,043
Belarus	$17,550	$2,808,000	$1,755,000	$1,568,649
Azerbaijan	$17,100	$2,736,000	$1,710,000	$1,508,704
Mexico	$16,860	$2,697,600	$1,686,000	$1,477,054
Montenegro	$16,690	$2,670,400	$1,669,000	$1,454,771
Gabon	$16,430	$2,628,800	$1,643,000	$1,420,909
Botswana	$16,090	$2,574,400	$1,609,000	$1,377,032
Iraq	$15,780	$2,524,800	$1,578,000	$1,337,428
Maldives	$15,780	$2,524,800	$1,578,000	$1,337,428
Suriname	$15,640	$2,502,400	$1,564,000	$1,319,669
Thailand	$15,380	$2,460,800	$1,538,000	$1,286,899
Brazil	$15,280	$2,444,800	$1,528,000	$1,274,369
Turkmenistan	$15,220	$2,435,200	$1,522,000	$1,266,870
Costa Rica	$15,180	$2,428,800	$1,518,000	$1,261,879
China	$14,400	$2,304,000	$1,440,000	$1,165,880
Palau	$14,230	$2,276,800	$1,423,000	$1,145,295
Algeria	$14,140	$2,262,400	$1,414,000	$1,134,447
Lebanon	$14,060	$2,249,600	$1,406,000	$1,124,833

Country Name	GNI per capita[a]	Value per Statistical Life		
		GNI per capita *160	GNI per capita *100	Extrapolated from U.S. VSL with elasticity = 1.5[b]
Dominican Republic	$13,610	$2,177,600	$1,361,000	$1,071,266
Colombia	$13,560	$2,169,600	$1,356,000	$1,065,368
Macedonia, FYR	$13,330	$2,132,800	$1,333,000	$1,038,377
Serbia	$13,210	$2,113,600	$1,321,000	$1,024,387
Grenada	$13,130	$2,100,800	$1,313,000	$1,015,096
South Africa	$12,840	$2,054,400	$1,284,000	$981,652
Peru	$12,100	$1,936,000	$1,210,000	$898,024
St. Lucia	$11,870	$1,899,200	$1,187,000	$872,541
Sri Lanka	$11,620	$1,859,200	$1,162,000	$845,122
Bosnia and Herzegovina	$11,600	$1,856,000	$1,160,000	$842,941
Ecuador	$11,250	$1,800,000	$1,125,000	$805,080
Albania	$11,170	$1,787,200	$1,117,000	$796,507
Mongolia	$11,160	$1,785,600	$1,116,000	$795,438
Tunisia	$11,090	$1,774,400	$1,109,000	$787,966
St. Vincent and the Grenadines	$11,080	$1,772,800	$1,108,000	$786,900
Indonesia	$10,680	$1,708,800	$1,068,000	$744,675
Egypt, Arab Rep.	$10,570	$1,691,200	$1,057,000	$733,200
Namibia	$10,560	$1,689,600	$1,056,000	$732,160
Dominica	$10,240	$1,638,400	$1,024,000	$699,133
Kosovo	$9,840	$1,574,400	$984,000	$658,571
Georgia	$9,350	$1,496,000	$935,000	$609,997
Armenia	$9,090	$1,454,400	$909,000	$584,731
Jordan	$8,940	$1,430,400	$894,000	$570,317
Philippines	$8,850	$1,416,000	$885,000	$561,727
Paraguay	$8,690	$1,390,400	$869,000	$546,562
Fiji	$8,610	$1,377,600	$861,000	$539,032
Jamaica	$8,350	$1,336,000	$835,000	$514,801
Swaziland	$8,340	$1,334,400	$834,000	$513,877
Belize	$8,120	$1,299,200	$812,000	$493,678
El Salvador	$8,000	$1,280,000	$800,000	$482,775
Ukraine	$7,850	$1,256,000	$785,000	$469,261
Morocco	$7,620	$1,219,200	$762,000	$448,789
Guatemala	$7,570	$1,211,200	$757,000	$444,379

Country Name	GNI per capita[a]	Value per Statistical Life		
		GNI per capita *160	GNI per capita *100	Extrapolated from U.S. VSL with elasticity = 1.5[b]
Bhutan	$7,520	$1,203,200	$752,000	$439,984
Guyana	$7,470	$1,195,200	$747,000	$435,603
Bolivia	$6,720	$1,075,200	$672,000	$371,675
Angola	$6,250	$1,000,000	$625,000	$333,373
Uzbekistan	$6,200	$992,000	$620,000	$329,380
Cabo Verde	$6,070	$971,200	$607,000	$319,075
India	$6,060	$969,600	$606,000	$318,287
Tuvalu	$6,030	$964,800	$603,000	$315,926
Nigeria	$5,880	$940,800	$588,000	$304,212
Lao PDR	$5,860	$937,600	$586,000	$302,661
Congo, Rep.	$5,840	$934,400	$584,000	$301,113
Samoa	$5,800	$928,000	$580,000	$298,025
West Bank and Gaza	$5,700	$912,000	$570,000	$290,350
Vietnam	$5,610	$897,600	$561,000	$283,501
Tonga	$5,580	$892,800	$558,000	$281,230
Moldova	$5,410	$865,600	$541,000	$268,476
Marshall Islands	$5,400	$864,000	$540,000	$267,732
Pakistan	$5,310	$849,600	$531,000	$261,067
Nicaragua	$5,280	$844,800	$528,000	$258,858
Myanmar	$5,160	$825,600	$516,000	$250,083
Honduras	$4,280	$684,800	$428,000	$188,919
Kiribati	$4,200	$672,000	$420,000	$183,647
Sudan	$4,150	$664,000	$415,000	$180,377
Micronesia, Fed. Sts.	$4,140	$662,400	$414,000	$179,726
Ghana	$4,060	$649,600	$406,000	$174,542
Papua New Guinea	$4,040	$646,400	$404,000	$173,254
Zambia	$3,800	$608,000	$380,000	$158,047
Mauritania	$3,690	$590,400	$369,000	$151,234
Timor-Leste	$3,690	$590,400	$369,000	$151,234
Bangladesh	$3,550	$568,000	$355,000	$142,709
Cameroon	$3,450	$552,000	$345,000	$136,722
Tajikistan	$3,360	$537,600	$336,000	$131,407
Côte d'Ivoire	$3,350	$536,000	$335,000	$130,821

Country Name	GNI per capita[a]	Value per Statistical Life		
		GNI per capita *160	GNI per capita *100	Extrapolated from U.S. VSL with elasticity = 1.5[b]
Kyrgyz Republic	$3,310	$529,600	$331,000	$128,485
Cambodia	$3,290	$526,400	$329,000	$127,322
Lesotho	$3,210	$513,600	$321,000	$122,706
São Tomé and Principe	$3,130	$500,800	$313,000	$118,148
Kenya	$2,990	$478,400	$299,000	$110,310
Yemen, Rep.	$2,710	$433,600	$271,000	$95,184
Tanzania	$2,610	$417,600	$261,000	$89,964
Nepal	$2,500	$400,000	$250,000	$84,337
Senegal	$2,370	$379,200	$237,000	$77,845
Solomon Islands	$2,170	$347,200	$217,000	$68,202
Benin	$2,110	$337,600	$211,000	$65,393
Chad	$2,110	$337,600	$211,000	$65,393
Mali	$1,980	$316,800	$198,000	$59,444
Afghanistan	$1,940	$310,400	$194,000	$57,652
Zimbabwe	$1,790	$286,400	$179,000	$51,096
Rwanda	$1,780	$284,800	$178,000	$50,669
Guinea	$1,770	$283,200	$177,000	$50,242
Haiti	$1,770	$283,200	$177,000	$50,242
Uganda	$1,740	$278,400	$174,000	$48,970
South Sudan	$1,700	$272,000	$170,000	$47,292
Burkina Faso	$1,630	$260,800	$163,000	$44,401
Ethiopia	$1,630	$260,800	$163,000	$44,401
Gambia, The	$1,620	$259,200	$162,000	$43,993
Guinea-Bissau	$1,570	$251,200	$157,000	$41,972
Comoros	$1,510	$241,600	$151,000	$39,589
Madagascar	$1,410	$225,600	$141,000	$35,722
Sierra Leone	$1,380	$220,800	$138,000	$34,588
Togo	$1,300	$208,000	$130,000	$31,625
Mozambique	$1,170	$187,200	$117,000	$27,002
Malawi	$1,120	$179,200	$112,000	$25,289
Niger	$940	$150,400	$94,000	$19,445
Burundi	$800	$128,000	$80,000	$15,267
Congo, Dem. Rep.	$740	$118,400	$74,000	$13,582

Country Name	GNI per capita[a]	Value per Statistical Life		
		GNI per capita *160	GNI per capita *100	Extrapolated from U.S. VSL with elasticity = 1.5[b]
Liberia	$720	$115,200	$72,000	$13,035
Central African Republic	$670	$107,200	$67,000	$11,701
American Samoa	NR	NR	NR	NR
Cuba	NR	NR	NR	NR
Djibouti	NR	NR	NR	NR
Eritrea	NR	NR	NR	NR
Korea, Dem. Rep.	NR	NR	NR	NR
Libya	NR	NR	NR	NR
Somalia	NR	NR	NR	NR
Syrian Arab Republic	NR	NR	NR	NR
Vanuatu	NR	NR	NR	NR
Venezuela, RB	NR	NR	NR	NR

Notes:
NR = GNI per capita (2015 international dollars) not reported by the World Bank.
a. The World Bank uses GNI per capita calculated using exchange rates and its Atlas method to classify countries by income level; this table includes the same list of countries but instead reports GNI per capita using purchasing power parity.
b. Derived from U.S. VSL = $9.4 million, U.S. GNI per capita = $57,900, income elasticity = 1.5. See main text for discussion.