Valuing Mortality Risk Reductions in Global Benefit-Cost Analysis

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October 2017 Review Draft

Guidelines for Benefit-Cost Analysis
Working Paper No. 7

Prepared for the Benefit-Cost Analysis Reference Case Guidance Project

Funded by the Bill and Melinda Gates Foundation

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Preface

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. It includes 11 basic principles supported by a series of methodological specifications and reporting standards to guide their implementation.

This draft 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. We thank Dean Jamison and Maureen Cropper for their many helpful comments on an earlier draft and for numerous useful discussions, as well as the other members of the project Leadership Team and Advisory Group who participated in related conversations. We are also grateful to the participants in the 2017 Society for Benefit-Cost Analysis Annual meeting and contributors to the 2017 *Journal of Benefit-Cost Analysis* symposium on valuing mortality risk reductions in low- and middle-income countries for their comments and substantial contributions to the work upon which this paper is based.

These papers will 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.

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

Executive Summary

Increasing life expectancy is a major policy goal of numerous 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 for estimating these values are also diverse, reflecting differing methodological choices as well as differences in the characteristics of those affected and the risks addressed.

In this paper, we review the literature and develop preliminary 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.

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.[1] 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 the term is often misinterpreted. The VSL is not the value that the individual, the society, or the government places on averting a death with certainty. Rather, it represents the amount of money an individual views as equivalent to a small change in his or her own mortality risk, which is demonstrated almost every day; for example, in deciding whether to spend money on protective equipment or safer products.

While there have been several efforts to change this terminology, none have yet been widely accepted and implemented. In this paper, we often use the phrase "value of mortality risk reduction" to clarify the concept. However, we also use the term "VSL" to link to the underlying concepts and literature. Research is now underway to explore the extent to which members of the general public understand alternative terms. We expect to review the results of that work when available to determine the implications for this project.

[1] The monetary value of a small change in mortality risk (in a specified period) is a rate of substitution; the units 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 10,000 or any other change in probability. (Analogously, speed can be measured in meters per second or kilometers per hour).

Basic Valuation Concepts and Methods

As indicated above, 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. 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. Presumably, this individual WTP 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). These values are likely to vary across individuals and also 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, estimates of individual WTP 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 risks of fatal injuries. These studies use statistical methods to separate the effects of risks on wages from the effects of other job and personal characteristics.

Conducting new primary research requires substantial time and expense; typically analysts rely on existing valuation studies instead. 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. 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. "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.

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.

Benefit-cost analysts interested in evaluating policies to be implemented in lower income countries generally 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. In the latter case, the starting point is often either values developed for use in U.S. regulatory analyses or for application by OECD member countries. While relying on high quality studies that are applicable to the population affected by the policy is generally preferable, our interest in this paper is on developing approaches that can be applied globally. Thus we focus on the second option. Given the gaps in the available research, our goal is to develop a standardized approach to sensitivity analysis that can be applied across countries, to promote comparability as well as to explore the effects of uncertainty.

In the U.S., values recommended for use by government agencies are typically derived by conducting a criteria-drive review of the literature. The central VSL estimates are generally between $9 million and $10 million (2013 U.S. dollars) and are based largely on wage-risk studies. OECD instead focuses on stated-preference studies and uses meta-analysis to combine the results. For policies that affect the OECD as a whole, the resulting values include a central VSL estimate of $3 million (2005 U.S. dollars). In each case, these central estimates are accompanied by reasonable high and low estimates that should be used to assess the effect of uncertainties. The recommended values are updated to reflect inflation and real income growth over time, and change periodically as new studies are completed and researchers develop new insights into best practices.[2]

Table ES.1 compares the range of U.S. and OECD values to gross national income (GNI) per capita (in the same year as each estimate), and also converts the VSL estimates to estimates of individual WTP for a 1 in 10,000 risk change (similar to the risk change considered in the underlying studies). As indicated by the table, the ratios differ substantially. This difference is in part attributable to the use of divergent analytic approaches: the organizations differ in the criteria used to select studies, the extent to which the estimates are derived from revealed- or stated-preference research, and the methods used to synthesize the results across studies. Generally, the results suggest that WTP is less than 2 percent of income in these high income countries, except at the high end of the U.S. values.

[2] Because these values are sensitive to choices about how to adjust for inflation and real income growth, we provide the values originally reported in each source here and focus on the ratio to income in that year, rather than adjusting all of the values to the same year.

Table ES.1. Comparison of selected VSL estimates to GNI per capita

Source (dollar year)	VSL estimate (range)	GNI per capita	Ratio of VSL to GNI per capita	WTP for 1 in 10,000 risk change	WTP as percent of GNI per capita
U.S. estimates[a] (2013 dollars)	$9.0 million ($4.2 million to $13.7 million)	$54,000	167 (78 to 254)	$900 ($420 to $137)	1.7 percent (0.8 percent to 2.5 percent)
OECD estimates[b] (2005 dollars)	$3.0 million ($1.5 million to $4.5 million)	$30,601	98 (49 to 147)	$300 ($150 to $450)	1.0 percent (0.5 percent to 1.5 percent)

Notes:
a. U.S. Department of Health and Human Services (2016) values taken from Robinson and Hammitt (2016); based on criteria-driven review of wage-risk and stated-preference studies.
b. OECD estimates recommended for benefit-transfer in OECD (2012); based on meta-analysis of stated-preference studies.

It is unclear whether the uncertainty in these 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.

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, as indicated by the table, 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 1.7 percent of U.S. GNI per capita, which was $54,000 in 2013.[3] 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 the need for spending on more basic 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 must select an estimate (or estimates) of the degree of change in the VSL associated with a change in income; i.e., the income elasticity. Often, researchers find that the change is less than proportional when extrapolating across high income groups (an income elasticity of less than one), but greater than one when extrapolating to groups with much lower incomes (an income elasticity of greater than one). This means that the ratio of the VSL to GNI per capita decreases when comparing high income to much lower income populations, as expected given the need to preserve income to cover more fundamental expenses. VSL is likely to differ across countries for many reasons in addition to income differences. For example, differences in life expectancy, health, economic and social support, religion, and culture across individuals as well as across countries are likely

[3] All GNI per capita estimates in this Executive Summary are expressed in current international dollars based on purchasing power parity, as reported in World Bank data accessed in October 2017 (https://data.worldbank.org/indicator/NY.GNP.PCAP.PP.CD?locations=US).

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.

To better understand the extent to which the approach for extrapolation may accurately characterize the preferences of the populations of low- and middle-income countries, we 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. 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. In addition, our review raises questions about the quality of several of these studies, suggesting that the results are highly uncertain.

Review of the income estimates reported in these studies suggests that the mean income level of the populations studied may differ significantly from mean national income and from estimates of GNI per capita. Thus the common practice of using GNI (or gross domestic product, 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 30 to about 1,300. We also calculate the income elasticity needed to extrapolate from the VSL to GNI per capita ratio of 170 (i.e., the U.S. ratio in Table ES.1) to the ratios calculated for each of these studies.[4] Excluding implausibly high and low ratios (greater than 170 or less than 20), the income elasticity implied by this comparison ranges from 1.2 to 2.6 with a median of 1.5. Extrapolating instead from the smaller U.S. VSL estimate ($4.2 million, or a ratio of 80) implies income elasticity between 0.4 and 1.8 with a median of 1.2.

Adjustments for Age and Life Expectancy

The studies that underlie the estimates described above generally address 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 values 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 for older adults 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.

[4] The formula for adjusting VSL for income is: $VSL_{target} = VSL_{base} * (Income_{target} / Income_{base})^{elasticity}$. It is often convenient to work with ratios of VSL to income rather than VSL itself, in which case the formula is: $(VSL_{target} / Income_{target}) = (VSL_{base} / Income_{base})^{(elasticity - 1)}$.

In applied work, analysts often make the simplifying assumption that the value of mortality risk reductions decreases linearly with life expectancy (or age). To implement this approach, typically 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. In other words, this value reflects the expected change in the years of life lived as a result of the policy. Assuming the value per life year 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.

In addition, benefit-cost analyses conducted in low- and middle-income countries must at times 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 in this case 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 would be derived from 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 other studies is often needed given the gaps in the available research. We recommend following the current practice of extrapolating from a VSL estimate using data on GNI per capita and income elasticity assumptions, to develop default estimates and to conduct a standardized sensitivity analysis so as to both examine related uncertainties and ease comparison of the results across analyses.

Figure ES.1. Near-term recommendations

1. Use context-specific values as the central estimates if available.
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. These estimates should include two VSL ratios (170 and 80) combined with two income elasticities (1.0 and 1.4) for a total of four values, as follows:
    a. VSL equal to 170 times GNI per capita.
    b. VSL equal to 80 times GNI per capita.
    c. VSL calculated from a ratio of 170 times GNI per capita using an income elasticity of 1.4.
    d. VSL calculated from a ratio of 80 times GNI per capita using an income elasticity of 1.4.
3. If the policy disproportionately affects the very young or the very old, conduct sensitivity analyses using VSLY estimates derived from the above VSL estimates.
    a. To calculate the VSLY, first estimate the VSL in the country of concern using the approaches under 1 and 2 above.
    b. Then divide VSL by an estimate of undiscounted future life expectancy for adults of average age in the country.
    c. Multiply the results by the discounted change in life expectancy attributable to the policy.
4. If the analysis addresses deaths around the age of birth, also assess the sensitivity of the results to alternative assumptions.
5. Address other sources of uncertainty.

More specifically, our near-term recommendations are as follows:

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. For high-income countries, such reviews are readily available and often incorporated into government guidance documents. For low- and middle-income countries, the review included in this paper provides a useful starting point and should be supplemented by consideration of more recent 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 default values should include the following:
    i. A ratio of VSL to GNI per capita of 170 (measured in international dollars using purchasing power parity). This estimate is based on the findings of stated- and revealed-preference studies conducted in the U.S., review of which indicates that best estimates of the VSL are generally about $9 million, or 170 times U.S. GNI per capita in the same year ($54,000). This ratio should then be applied to other countries. This approach assumes that the income elasticity is 1.0; i.e., that the change in the VSL is proportional to the change in income.
    ii. A ratio of VSL to GNI per capita of 80. This ratio is based on the low-end of the range of U.S. values ($4.2 million) and again assumes an income elasticity of 1.0. The range between these two base values encompasses the estimates used by several international organizations,

including the OECD and the World Bank. We use the low end of the range because we expect that the ratio of the VSL to GNI per capita will decrease as income decreases, given that the resources available are more constrained.

iii. A VSL calculated from the ratio of 170 times GNI per capita using an income elasticity of 1.4. This elasticity reflects the results of extrapolating from the U.S. ratio to the ratios found in the studies we reviewed, as well as the likelihood that income elasticity will exceed 1.0 when extrapolating from very high to very low income countries.

iv. A VSL calculated from the ratio of 80 times GNI per capita using an income elasticity of 1.4. This provides a low-end estimate of the VSL. It should not be allowed to drop below a ratio of VSL-to-GNI per capita of 20, given the expectation that VSL will exceed the value of consumption over the remaining life years – which are likely to be at least perhaps 20 years for an adult of average age in a very poor country.

These four 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 derived from the VSL 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. Future life years should not be discounted both because individuals may discount their own future years at a rate smaller than the rate at which they discount future consumption and other monetary values and because calculating VSLY using discounted future life years flattens the relationship between the value of reducing risk and age. For sensitivity analysis, it seems preferable to maintain the full effect of valuing life years equally rather than moderating the effect through choice of some positive discount rate.

4) ***If the analysis addresses deaths around the age of birth, also 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 (applying the VSLY estimate to life expectancy at birth), analysts should also explore the impact of assigning positive values to deaths that occur prior to birth. We know very little about parental WTP to avert the death of a fetus or newborn, and additional sensitivity analysis is likely to be desirable in this case.

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 affected by the analysis.

These differences should be addressed 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 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 methods that can be feasibly implemented in low- and middle-income settings, which will provide reasonably valid and reliable results. Such methods should be tailored to the likely resources available and take into account the characteristics of these populations as well as the risks they face.

Such 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.

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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. As a result, it is not surprising that the value of reduced mortality risks has been extensively studied; these values often account for a substantial share of the benefits of environmental, public health, safety, and other policies. To guide the assessment of these policies, several organizations have developed recommendations for estimating the values of mortality risk reductions in benefit-cost analysis.

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, available research is limited. Values are usually extrapolated from estimates for high-income countries by applying relatively simple assumptions. The results can vary substantially due to differing choices regarding the estimate used as a starting point and the assumptions used in the extrapolation.

These approaches raise a number of important issues, which we explore in this paper. We discuss current practices and review studies conducted in low- and middle-income countries to provide insights and develop recommendations. While we focus on estimating the value of mortality risk reductions in lower income settings, this work also has implications for analyses that address higher income countries.[5]

Before proceeding, one note on 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 her (or his) own mortality risk within a defined time period. Specifically, an individual's VSL is the ratio of the amount of money she would give up in exchange for a small reduction in mortality risk, such that she is no better and no worse off with the reductions in mortality risk and money remaining for other spending than without the exchange. VSL is not the value of a "life," nor the value that the government, the analyst, or the individual places on preventing certain death. It represents the value we each place on small changes in our own risks, which we demonstrate almost every day -- for example, in deciding whether to buy protective equipment, to drive more safely, or to use less polluting fuels.

The VSL is typically calculated by taking an estimate of an individual's willingness to pay (WTP) for a change in his or her own risks (such as $300 for the current year) and dividing it by the risk change (such

[5] 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, Hammitt, Chang, and Resch (2017) for more discussion.

as a 1 in 10,000 reduction in the chance of dying this year), which yields a $3 million VSL for this individual ($300 divided by 1 in 10,000). This translation of the amount an individual is willing to pay into a VSL estimate can obscure the fundamental concept; i.e., that the values used in benefit-cost analysis should reflect individual preferences – the $300 in this case.

Over the years, many alternative terms have been suggested, but none have been widely accepted or used. 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) 2010) to refer to an individual's willingness to exchange income for a 1 in 10,000 mortality risk reduction ($300 in the example above) or a 1 in 1,000,000 mortality risk reduction ($3 in using the numbers from the example). 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 is now underway to explore the extent to which members of the general public understand alternative terms.[6] We expect to review the results of that work when available to determine the implications for this project.

The remainder of this paper consists of the following:

- Chapter 2 discusses the basic concepts and methods used for valuation.
- Chapter 3 explores the primary research from low- and middle-income countries and compares the results to the findings in higher income settings.
- Chapter 4 investigates the relationships between these values and age and life expectancy.
- Chapter 5 summarizes the discussion and the recommendations, and suggests priorities for future research.

The appendices provide more detailed data on the topics discussed in the main text.

[6] This work is being conducted by the U.S. Environmental Protection Agency (USEPA), following the recommendations of its independent Science Advisory Board (Kling et al. 2011). Email communication from Nathalie Simon, National Center for Environmental Economics, USEPA, October 6, 2017.

2.0 Basic Concepts and Methods

The starting point for valuation involves defining the outcomes to be valued, then determining how to best estimate the values. We briefly introduce related concepts and methods in this chapter, building on the discussion in our scoping report (Robinson et al. 2017) 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 these affected rather than reducing the likelihood that they will die over the longer run. 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, it is not unusual for a policy to decrease the risk of dying by perhaps 1 in 10,000 or 1 in 100,000 per year. If 10,000 individuals 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" 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 generally based on individuals' willingness to trade-off spending on other goods and services for reductions in their own risks.[7] VSL is an individual's marginal rate of substitution between wealth and the risk of dying in a defined time period.[8] Presumably, individual willingness to pay (WTP) for a reduction in mortality

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[7] The 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 well-being, such as young children, those with cognitive impairments, or those dealing with addiction.

[8] 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 10,000 or any other change in probability. Analogously, speed can be measured in meters per second or kilometers per hour.

risk accounts for both the pecuniary effects of the risk change (including avoided out-of-pocket medical 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). 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, as in the example provided in the previous chapter. [9] In that case, the individual was willing to pay $300 for a 1 in 10,000 reduction in his or her risk of dying in the current year, yielding 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, the 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.[10] 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 affected people. 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. 2017) as well as in our separate methods paper on distributional concerns (Robinson, Hammitt, and Adler 2017).

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, 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

[9] 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.

[10] Some VSL studies (conducted largely in high-income settings) address risk reductions to the community at-large, but some of the results seem nonsensical. For example, 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.

"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.[11] 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.[12]

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

[11] 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.

[12] 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 for individuals of about the same age (in the same dollar year), which are around $8 million (see, for example, USEPA 2010a). On a global level, 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 million per year using the human capital approach and $5.11 trillion per year using VSL estimates.

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 for more discussion of the use of these research synthesis methods in estimating the VSL).

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 general approach for extrapolating values from high-income countries to lower income settings. We then review the literature on values in low- and middle-income countries and discuss the implications for this extrapolation.

3.1 Extrapolating Values from High-Income to Lower-Income Settings

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 (see Robinson et al. 2017). For low- and middle-income countries, values are often extrapolated from the estimates used by either U.S. regulatory agencies or the OECD (see Robinson 2017).[13]

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). The resulting central estimates are between $9 million and $10 million (2015 U.S. dollars) and rely largely on U.S. wage-risk studies.[14] 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 gross national income (GNI) per capita for the same year and the same countries.[15] For the U.S., we rely on the most

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[13] Narain and Sall (2016) provide a comprehensive recent review of the available research and current practices in both high and lower income countries.
[14] Caution is needed when comparing values across sources; the same approach may result in estimates that vary because they are reported for different years. We do not adjust the estimates reported in this section to a common year because such an adjustment requires an assumption about the effects of real income growth as well as inflation, as discussed later.
[15] Unless otherwise noted, all GNI per capita estimates are expressed in current international dollars based on purchasing power parity (PPP), as reported by the World Bank

recent review adopted by a government agency for use in its regulatory analyses (Robinson and Hammitt 2016), since this review considers both the stated- and revealed-preference literature and applies criteria derived from recent expert-panel advisories. The values that result are similar, however, to the results from the older reviews used by other U.S. agencies, which rely on different sets of studies. For the OECD, we report the estimates recommended for use in benefit transfer for those analyses that address all OECD countries (OECD 2012). 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. In addition, researchers are now updating the database and meta-analysis that underlies the OECD estimates.[16]

Table 3.1. Comparison of Selected VSL estimates to GNI per capita

Source (dollar year)	VSL estimate (range)	GNI per capita	Ratio of VSL to GNI per capita	WTP for 1 in 10,000 risk change	WTP as percent of GNI per capita
U.S. estimates[a] (2013 dollars)	$9.0 million ($4.2 million to $13.7 million)	$54,000	167 (78 to 254)	$900 ($420 to $137)	1.7 percent (0.8 percent to 2.5 percent)
OECD estimates[b] (2005 dollars)	$3.0 million ($1.5 million to $4.5 million)	$30,601	98 (49 to 147)	$300 ($150 to $450)	1.0 percent (0.5 percent to 1.5 percent)

Notes:
a. U.S. Department of Health and Human Services (2016) values taken from Robinson and Hammitt (2016); based on criteria-driven review of wage-risk and stated-preference studies.
b. OECD estimates recommended for benefit-transfer in OECD (2012); based on meta-analysis of stated-preference studies.

As indicated by the exhibit, the relationship of these values to income differs substantially. This difference is largely attributable to the use of divergent analytic approaches; the effects of income alone are likely to be much smaller, as discussed below. The estimates reflect significant differences in the criteria used to select studies, the extent to which they are derived from revealed- or stated-preference research, and the methods used to synthesize the results across studies.

(https://data.worldbank.org/indicator/NY.GNP.PCAP.PP.CD?locations=US). We rely on GNI because it is a broader measure than gross domestic product (GDP); we rely on PPP because it is likely to better represent the resources available to the individuals affected by the policy than the use of market exchange rates. (PPP is an index designed to represent purchasing power in different economies and is usually measured in international dollars. In the country of concern, an international dollar would buy a comparable amount of goods and services as a U.S. dollar would buy in the United States.) However, the results of the analysis may need to be converted into the local currency and into U.S. dollars for comparison to costs, which are often estimated using market exchange rates. Where needed, we use the consumer price index for the country that is the source of the estimates to inflate values to a common year in the original currency, prior to converting the values to another currency. See Robinson, Hammitt, and O'Keeffe (2017) for more discussion.

[16] Email communication with Ståle Navrud, October 7, 2017.

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 (see Hammitt 2017). 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.[17]

As introduced earlier, these values reflect 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, Table 3.1 suggests that the average U.S. resident is willing to pay $900 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.

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. The relationship can be derived from the formula above; it is:

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

(equation 2)

Table 3.2 illustrates the sensitivity of the extrapolation to the value of the income elasticity. To construct the table, we begin with a U.S. VSL of $9 million and extrapolate to the values for an income level of

[17] The approach described in this section is typically used to estimate the effects of population-average real income growth over time or of 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.

$1,025, using different elasticities. We use $1,025 as the target income level because the World Bank uses this value as the dividing line between low- and middle-income countries.[18]

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	$9.0 million	8,800	$900	88 percent
Elasticity = 0.5	$1.2 million	1,200	$120	12 percent
Elasticity = 1.0	$171,000	170	$17	1.7 percent[c]
Elasticity = 1.5	$24,000	23	$2.40	0.2 percent
Elasticity = 2.0	$3,200	3.2	$0.32	0.03 percent

Notes:
a. Estimates are for illustration only; see text for more discussion.
b. Extrapolated from a U.S. VSL of $9 million and U.S. GNI per capita of $54,000.
c. An income elasticity of 1.0 means the ratio is constant; e.g., the starting point (U.S. VSL = $9 million) yields a WTP estimate of $900 for a 1 in 10,000 risk change, or 1.7 percent of U.S. GNI per capita.

As illustrated by Table 3.2, changes in the income elasticity can change the results by orders of magnitude. Hammitt and Robinson (2011) report that the then-existing studies found income elasticities of VSL ranging from as low as 0.1 to greater than 2.0. More recent reviews seem to be coalescing on estimates around 1.0, combining the results of related research with various reasonableness checks. Recent work by the World Bank (Narain and Sall 2016, World Bank and IHME 2016) uses the OECD estimates as a starting point, and applies an elasticity of 0.8 to transfer the estimates to high-income countries and an elasticity of 1.2 to transfer estimates to low- and middle-income countries. Similarly, the OECD (Roy and Braathan 2017) uses an elasticity of 0.8 for OECD countries and an elasticity of 1.0 for the BRIICS countries (Brazil, Russia, India, Indonesia, China and South Africa). Others (e.g., Viscusi and Masterman 2017b) suggest starting with the U.S. VSL from wage-risk studies rather than the OECD estimates, which results in higher values (see Robinson 2017). In the following section, we review studies from low- and middle-income countries and examine the implications for such extrapolation.

3.2 Review of Studies Conducted in Low- and Middle-Income Countries

As discussed above, 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 these countries has increased substantially in recent years. In this section, 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 studied and discuss the implications.

[18] As noted earlier, all calculations are based on values reported using purchasing power parity rather than market exchange rates for currency conversions. However, the World Bank instead uses market exchange rates (calculated using its Atlas method) when categorizing countries by income level; the $1,025 value is based on the World Bank's 2015 data.

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 A, these include 172 countries.[19] 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.[20] 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.

3.2.1 Selection Criteria

In our review of the valuation research conducted in low- and middle-income countries, we used the following criteria to select studies for more detailed review.

Figure 3.1. 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 probabilistic samples, not convenience samples.
6. Estimate willingness to pay, not willingness to accept compensation.
7. Address 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-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 attention to papers published in peer-reviewed journals because papers that report estimates of VSL

[19] 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. As noted earlier, these classifications are based on GNI per capita estimates using the World Bank's Atlas method, which relies on market exchange rates instead of PPP.

[20] 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).

using generally-accepted best practices (that are useful for our analysis) may not be published in journals, either because the authors do not put high priority on journal publication or because journals' criteria for which papers they publish may 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 A. 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.[21] 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, Tuncel and Hammitt 2014).

Criterion 7 focuses on changes in an adult's own risk.[22] In this chapter, 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.[23] 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. Criterion 7 relates to the framing of the WTP questions, not the characteristics of the risk-reducing program described in the survey. The risk reduction may result from a government program or a private good; what matters is whether the respondent is instructed to only consider his or her own risks in answering the valuation questions.

3.2.1 Search Results

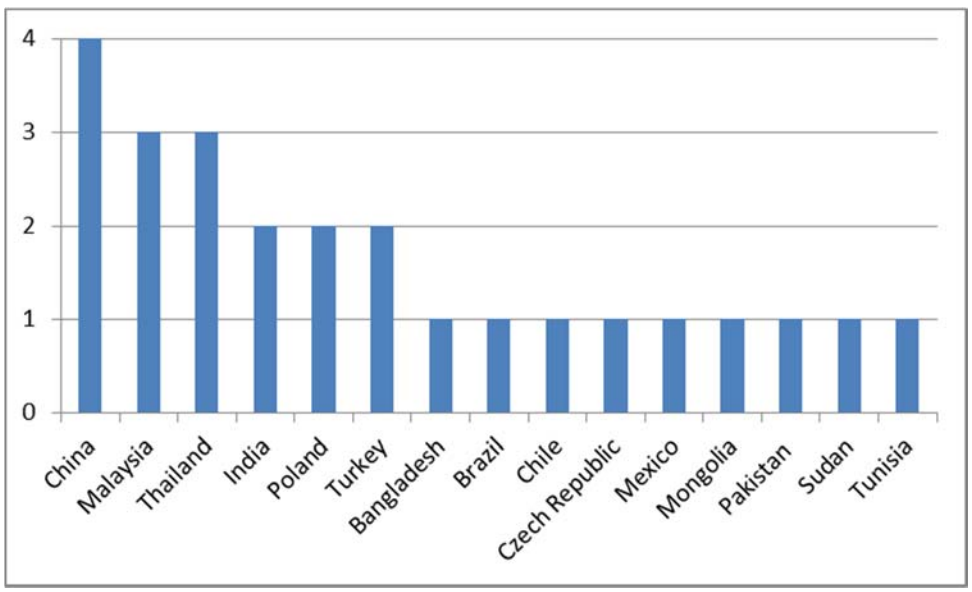
To identify studies conducted in low- and middle-income countries, we began with those listed in previous reviews, including Robinson and Hammitt (2009), OECD (2012), Narain and Sall (2016), Viscusi

[21] 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.
[22] 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.
[23] The age ranges considered in the adult VSL studies vary; we discuss the effects of age on VSL in Chapter 4.

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.[24,25]

We found 17 stated-preference studies and eight wage-risk studies that meet the criteria listed in Figure 3.1; a complete listing of these 25 studies is provided in Appendix B. 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 3.2. 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.

Figure 3.2. Number of Studies by Country

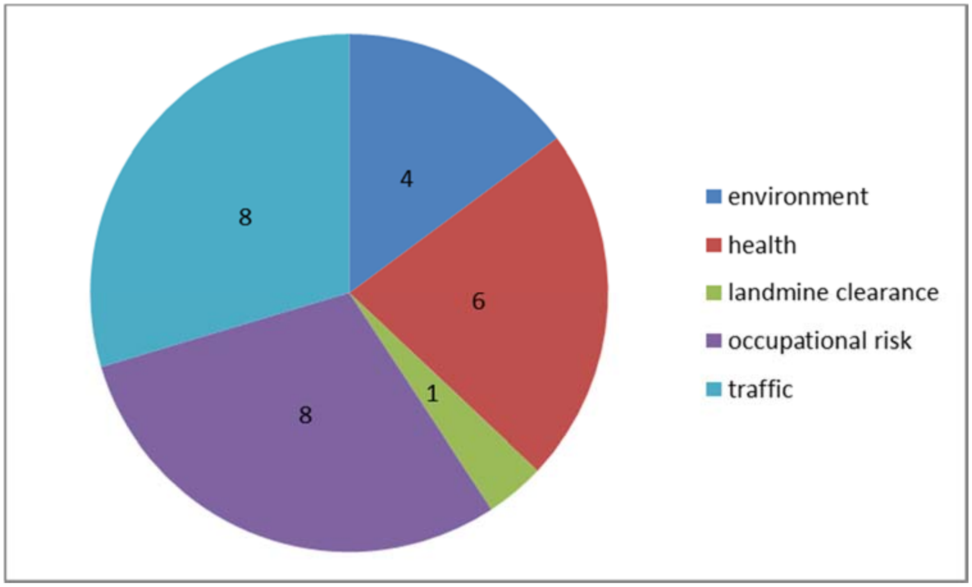


These studies vary in the types of mortality risks they consider. As indicated in Figure 3.3, eight consider risks associated with transportation or traffic safety, four consider risks from environmental causes, six

[24] 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 the previous chapter.
[25] Search terms included WTP OR VSL; WTP AND VSL; (VSL OR WTP) AND “low income;” (VSL OR WTP) AND “middle income.”

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.[26]

Figure 3.3. Types of Risks Studied



3.2.2 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.[27,28]) We find that nine of the 18 studies test for whether WTP differs

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

[27] 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.

[28] While statistical significance is often used to address scope sensitivity (e.g., OECD 2012), it does not necessarily mean that the results are close-to-proportional.

between different-sized risk reductions; of these, five find that WTP is significantly different for different risk reductions, but it is less than proportional to the risk change.[29]

The lack of scope tests in the majority 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.[30]

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 address 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 probabilities.[31] 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, it is difficult to determine their quality without further exploring the data sources used as well as the effects of alternative model specifications. However, 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). In addition, Viscusi and Masterman (2017a, 2017b) explore the results of wage-risk studies conducted globally for evidence of publication or selection bias. Such bias occurs when researchers or journals are unwilling to report or publish estimates that appear inconsistent with expectations. They find that U.S. studies that rely on Census of Fatal Occupational Injuries data appear less subject to this bias than other research. However, their research did not specifically address the individual studies referenced in this section.

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

[30] 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 the 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.

[31] 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.

3.2.3 Relationship to Income

As introduced earlier, estimates of VSL reflect individuals' willingness to trade income for mortality risk reductions rather than spending on the other things that money could buy. Given this framing, it seems unlikely that these values would remain constant across populations with substantially different incomes. In this section, we discuss the relationship of the values reported in the above studies 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" 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.[32] More information on these estimates is provided in Appendix B.

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 reporting the ratio of the VSL to income in the same year. 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.[33] As noted earlier, we rely on GNI per capita in this paper (based on PPP) because it is the broader measure.[34] In addition to conceptual differences between GNI per capita and estimates of household or individual income, we face the challenge that may 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.

More specifically, of the 25 studies, only 16 report the mean income levels for the sample. Of these 16, four report household income, four report individual income, two report both household and individual income, and six do not indicate whether the income level is for the individual or the household. Where mean individual income is reported, in three studies it is within ±50 percent of GNI per capita for the country; In the remainder, it varies from about 30 percent of GNI per capita to about 500 percent. Of the remaining nine, four 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. (Even

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[32] 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.

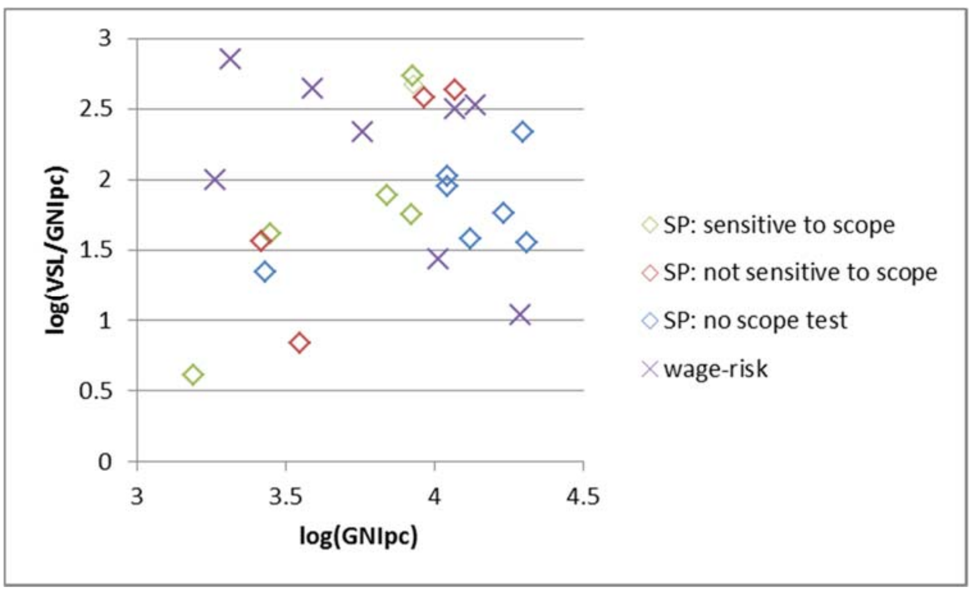
[33] The World Bank provides consistently-measured estimates of these values for many years and most countries. For 2015, if measured using PPP, it provides estimates of GDP per capita for 185 countries, and of GNI per capita for 182 countries. The number of countries covered varies by year. For GNI 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.

[34] GDP represents net domestic production, while GNI also includes monetary inflows and outflows from abroad.

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). These data raise serious questions about comparing VSL estimates to GNI per capita, given that differences in income can significantly affect these estimates.

These issues mean that any comparison of these estimates to GNI per capita as part of the benefit transfer process is fraught with problems. For the moment, we ignore these problems and in Figure 3.5 display the ratios of estimated VSL to GNI per capita (in the same year as the VSL estimate).[35] Note that both scales are logarithmic (base 10). Overall, there is substantial variability in the ratio of VSL to GNI per capita, with most falling between roughly 30 (log ratio = 1.5) and 300 (log ratio = 2.5). There seems to be little difference in the distributions of the ratios between the revealed- and stated-preference studies, nor are there strong differences between the ratios from stated-preference studies that do or do not report sensitivity to scope. The stated-preference estimates suggest that the ratio is larger for populations with higher GNI per capita, but the revealed-preference estimates suggest the opposite trend.

Figure 3.5. Ratio of VSL to GNI per Capita (GNIpc)



Notes: The term "scope test" is used to refer to the different categories of stated-preference studies: those that do not test the sensitivity of WTP to the size of the risk reduction ("no scope test"); those that conduct a test and find that WTP is sensitive to scope ("sensitive"); and those that conduct a test and find that WTP is insensitive to scope ("not sensitive"). As noted earlier, such 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 estimate of $9 million discussed earlier is based on representative samples of the U.S. population, and results in a VSL-to-GNI per capita ratio of 170. Excluding implausibly high and

[35] Figure 3.5 includes 26 ratios because one of the 25 studies (Vassanadumrondgee and Matsuoka 2005) reports values separately for two surveys, one which addresses air pollution and one which addresses traffic safety.

low ratios, the income elasticity implied by comparing the remaining ratios with the U.S. ratio ranges from 1.2 to 2.6 with a median of 1.5.[36] Extrapolating from the smaller U.S. VSL estimate ($4.2 million) implies income elasticity between 0.4 and 1.8 with a median of 1.2.

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 is different than GNI per capita. Moreover, average incomes in the studies that do not rely on nationally-representative samples may differ from the national average. 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).

Several reviews have focused more explicitly on the income elasticities found in research that directly addresses the relationship between the VSL and income (e.g., Cropper and Sahin 2009, Hammitt and Robinson 2011, Robinson and Hammitt 2015, Narain and Sall 2016). These suggest that elasticities greater than one may be appropriate when extrapolating from high- to lower-income settings, consistent with the thought experiment illustrated in Table 2.2. However, it is difficult to validate these estimates without more high-quality estimates 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.

3.3 Conclusions and Implications

Although an increasing number of studies have been conducted in low- and middle-income countries, we find that this research covers relatively few such countries. We searched for studies conducted in any of the 172 countries categorized as low- or middle-income in any of the past 20 years. The 17 stated-preference studies and eight wage-risk studies that meet our selection criteria were conducted in only 15 countries, all of which are now middle- or high-income. Hence the available studies represent the preferences of only a small fraction of those who may be affected by policies targeted on these countries. In addition, our review raises issues regarding the quality of several of these studies, suggesting that the results are highly uncertain. For example, only five of the 17 stated-preference studies provide evidence that WTP is sensitive to the size of the risk reduction.

While ideally the value of mortality risk reductions would be derived from high-quality studies of the population affected by the policy, these findings suggest that extrapolation from studies conducted in high-income countries will continue to be necessary in the near future. Such extrapolation requires selecting a base VSL estimate, a measure of income (e.g., GNI per capita), and an income elasticity. To acknowledge the substantial uncertainty in estimation of VSL, we recommend two alternative base

[36] As described below, we conclude that ratios greater than the U.S. ratio (170) and smaller than 20 are implausible.

values and two income elasticities. Because we find it more convenient to work with ratios of VSL to income rather than the VSL itself, this implies choosing two values of the base ratio.

We recommend using base ratios of VSL to income of 170 and 80, consistent with the central value and lower estimate of VSL from U.S. Department of Health and Human Services (USHHS) 2016 guidance, and two values of the income elasticity of VSL, 1.0 and 1.4. The justification for these recommendations is as follows.

For the base ratio of VSL to income, the USHHS estimates are preferred to the base value from the OECD meta-analysis for two reasons. First, they include evidence from both revealed-preference and stated-preference studies. Given that each method has advantages and limitations, combining the results provides a stronger foundation for the estimates. Second, the review that underlies the USHHS estimates (Robinson and Hammitt 2016) finds that the stated-preference studies that provide the strongest evidence of validity yield estimates that are reasonably close to the results from the wage-risk studies. The lower estimates found in the OECD meta-analysis of stated-preference studies may reflect the less-stringent screening criteria used and other factors. For example, that 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 earlier) can be viewed as indicating the extent to which respondents understand the outcome they are being asked to value.

The central estimate in Robinson and Hammitt (2016) is $9 million in 2013 dollars, or about 170 times U.S. GNI per capita ($54,000) in that year. This estimate is very close to the estimates used by other U.S. agencies. The U.S. Department of Transportation (USDOT), which considers only wage-risk studies because it primarily regulates risks from injuries rather than illnesses, recommended a value of $9.2 million in the same year (DOT 2014).[37] The USEPA, which relies on the results of a review of the revealed- and stated-preference literature conducted in the early 1990s, used a value of $9.7 million in that year (EPA 2016). In each case, the agencies also provide reasonable high and low estimates for use in sensitivity analysis.

As an alternative, we recommend a smaller base VSL equal to $4.2 million from the same study, or about 80 times U.S. GNI per capita. We do not include a larger alternative because estimates of VSL relative to income are higher for the U.S. than for other high-income countries. Note that the range of ratios (80 to 170) includes the ratio derived from the OECD estimates (about 100) in Table 3.1.

As suggested by our review, estimates of income elasticity vary widely. Our recommendation of low and high values of 1.0 and 1.4 is based on the following considerations:

1) It seems very plausible that the ratio of VSL to income increases with income, as the share of income required to provide basic necessities decreases. This suggests the appropriate income elasticity for

[37] Viscusi and Masterman (2017b) similarly recommend a value of $9.6 million (2015 dollars) based on recent assessment of U.S. wage-risk studies.

extrapolating between countries is greater than 1.0; hence 1.0 provides a reasonable lower estimate. This implies the ratio of VSL to income should not exceed the U.S. ratio (170) for low- and middle-income countries.

2) 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). Taking GNI per capita as a rough estimate of average consumption suggests a minimum ratio of VSL to income equal to remaining life expectancy (possibly discounted), which at minimum is perhaps 20 years for an adult of average age in a very poor country.[38]
3) Our review of estimates of VSL in low- and middle-income countries yields a wide range of ratios. Excluding values that are implausibly high (greater than 170) and implausibly low (less than 20) yields a set of 14 ratios that range from 22 to 140.[39] Half are between 37 and 98, and the median and mean are 57 and 67, respectively. The GNI per capita corresponding to these estimates ranges from about $2,000 to $20,000 with a median and mean of $9,400 and $9,800, respectively.[40]

We select the higher income elasticity value of 1.4 because it yields extrapolated ratios of VSL to GNI per capita that are reasonably consistent with these three considerations. Extrapolating from the higher and lower base ratios (170 and 80) it yields a ratio at a GNI per capita of $10,000 of 87 and 41, roughly consistent with the interquartile range of the estimates reviewed above, for which average GNI per capita is near $10,000. At a GNI per capita of $1,000, extrapolation yields ratios of 34 and 16, near the minimum plausible value of 20. Because extrapolation using any elasticity greater than one can lead to implausibly small ratios at sufficiently low income, we recommend replacing any extrapolation-based ratio smaller than 20 with 20, treating this value as a reasonable lower bound.

We summarize these recommendations in Figure 3.2 below. These estimates should be used in a standardized sensitivity analysis to reflect the uncertainty in these values, and to test the effects of the results on these differing assumptions.

Table 3.6. Recommended Values for Standard Sensitivity Analysis

1. Base VSL = 170 * GNI per capita, income elasticity = 1.0
2. Base VSL = 80 * GNI per capita, income elasticity = 1.0
3. Base VSL = 170 * GNI per capita, income elasticity = 1.4
4. Base VSL = 80 * GNI per capita, income elasticity = 1.4

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[38] 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).

[39] Nine ratios exceed 170; the two smallest of these are 215 and 312. Three ratios are less than 20 (11, 7, and 4).

[40] Note that these income estimates are for the year in which the data were collected and have not been adjusted for inflation. Although they are not necessarily equivalent, they provide an indication of the income levels considered.

Under the first two options, the ratio is constant across countries, and the 170 and 80 multipliers can be applied direction to the GNI per capita of the population affected by the policy. Under the second two options, equation 2 in section 3.1 must be used to calculate the ratio in the target country, given its GNI per capita and the income elasticity.

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 (Hammitt 2007) and empirical work indicate that the relationship is more complex and uncertain.

In particular, 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 (Robinson et al. 2017), although some suggest including such adjustments in sensitivity analysis using relatively simple assumptions (e.g., USDHHS 2016). 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 countries.

Because age and life expectancy are highly correlated, the two terms are often used interchangeably in discussing the valuation of mortality risk reductions. 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.[41] 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., 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.

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[41] 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.

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 often have relatively high costs but even higher benefits and 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.

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 Shephard 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.[42]

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 then multiplied by the change in expected years of life

[42] 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 Hoffman et al. (2017).

remaining.[43] 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 gains that sum to one year (Hammitt 2007, Jones-Lee et al. 2015). Note that the same gain in life expectancy can be produced by many different time patterns of decreases in mortality risk.

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 (discounted) remaining life expectancy for the population studied.[44] 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.

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 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, Hammitt and Morris 2001, Desaigues et al. 2011).[45] It is difficult to compare the results across studies because they vary in the ways in which the change 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.[46] 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 decline), 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 Tuncel (2015) suggests there is substantial heterogeneity in preferences for the timing of risk reductions. For example, some people may prefer a

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[43] 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.
[44] Often, discounted expected 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.
[45] 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.
[46] 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 concern about their quality.

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 populations 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 be valued at 1.5 to 2 times the value used for adults (e.g., Ministry of Finance (Norway) 2012, OECD 2012).[47] 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 this value would be constant across countries with significantly different cultural and demographic characteristics.

For low- and middle-income countries, little empirical research is available and it is unclear whether the same patterns are likely to hold. In the review discussed in the previous chapter, we did not identify any studies that addressed risks to both children and adults using a consistent approach, that otherwise met our selection criteria (see Figure 3.1).[48] 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 research is needed.

[47] 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.

[48] 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.

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 deaths around the time of birth, which raise difficult normative questions as well as empirical issues. Relatively little is known about parental or societal WTP for averting these deaths 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 deaths 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 the time of 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 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.[49] 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

[49] 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.

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. 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.

More specifically, if the policy disproportionately affects the very young or the very old, analysts should, at minimum, conduct sensitivity analysis using a constant VSLY derived from the VSL estimates that result from the recommendations discussed in the prior chapter. 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 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 other monetary values. Second, calculating VSLY using discounted future life years has the effect of flattening 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 choice of some positive discount rate.

If the analysis addresses deaths around the age of birth, determining the appropriate approach is very difficult and raises a number of normative issues. We know very little about parental WTP to avert the death of a fetus or a stillbirth. 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 in this case that tests the effects of assigning positive values to deaths prior to births. As always, related uncertainties and their implications should be discussed when presenting the results.

5.0 Summary and Recommendations

In this paper, we review the literature and develop preliminary 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. 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 also 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. This 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. This analysis should include two estimates of the base VSL (a high estimate of 170 times GNI per capita and a low estimate of 80 times GNI per capita) and two estimates of the income elasticity (1.0 and 1.4). This range of base estimates (80 to 170) encompasses the range of values used by several international organizations, including the OECD and the World Bank. Extrapolating using the income elasticity of 1.0 applies this range to countries of all income levels; extrapolating using the income elasticity of 1.4 yields smaller ratios of VSL to income in lower-income countries, consistent with the greater share of income required for necessities.

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 the above recommendations. 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. If the analysis addresses deaths around the age of birth, analysts should also assess the sensitivity of the results to different values, and explicitly note the difficult normative issues raised.

While these recommendations 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 affected by the analysis. These differences should be addressed 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 longer term, more research seems desirable. This research may need to focus on stated-preference studies, given that the data needed to support wage-risk studies is not available in many countries. Although stated-preference research poses many challenges, it has the advantage of allowing researchers to investigate the values placed on risks of different types that affect different population groups. Such 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 focuses more attention on other sources of variation such as differences in cultural norms and other context-specific factors. To encourage the completion of such studies, developing protocols for their conduct in low- and middle-income settings would be useful. The guidance currently available tends to focus on higher income settings, and does not take into account resource constraints or cultural and other differences.[50]

[50] 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.

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Appendix A: 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 identified by the World Bank. 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.

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

In this appendix, we first list the VSL studies (discussed in Chapter 3) 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.

Table B.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	Poland (high)	2002
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[c]	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 main text 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 B.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.	

Table B.3 Relationship of VSL to Income

Author, date	VSL estimate[a]	GNIpc	VSL/GNIpc	Reported income[b]	VSL/income
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	NR	---
Hammitt and Zhou, 2006	$96,450	$2,630	36.7	$1,800**	53.6
Hoffmann et al., 2017	$474,194	$8,360	56.7	15711.93*	30.2
Alberini et al., 2006	$2,788,889	$19,820	102.8	$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	---
Hoffmann et al, 2012	$536,315	$6,920	77.5	$2,080	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	---

Author, date	VSL estimate[a]	GNIpc	VSL/GNIpc	Reported income[b]	VSL/income
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;	$32,686**	122.6
Vassanadumrondgee and Matsuoka, 2005 (traffic safety)	$4,572,114	$ 8,490	538.5	$36,577**	125.0
Tekeşin and Ara, 2014	$726,414	$ 20,480	35.5	$ 2,742*	265.0
Parada-Contzen et al., 2013	$4,625,958	$13,710	337.4	NR	---
Guo and Hammitt, 2009	$184,366	$1,840	100.2	$2,049**	90.0
Madheswaran, 2007	$1,480,392	$2,070	715.2	NR	---
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	$1,235,400	$5,740	215.2	NR	---
Giergiczny, 2008	$3,658,333	$11,740	311.6	$ 11,997	304.9
Polat, 2013	$211,737	$19,490	10.9	$96,599	2.2

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 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 B.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 2013), 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.