Final Contractor Report

Industrial Economics, Incorporated (IEc)

"Valuing Reductions in Fatal Risks to Children"

January 3, 2018

The report, *Valuing Reductions in Fatal Risks to Children,* presents the findings of a literature review conducted by Industrial Economics, Incorporated (IEc), under a contract with the U.S. Consumer Product Safety Commission (CPSC). IEc performed this work to address the value of fatal or nonfatal risk reductions that accrue to children.

IEc developed an approach for the literature review that included three phases: criteria development; literature search; and literature review. The report includes a discussion of the range of multipliers that may be used for determining a value per statistical life (VSL) for children, but also discusses the limitations of the results of the literature review. The report discusses potential next steps in developing a VSL for children.

This research was completed in support of CPSC staff's work on developing willingness to pay estimates that directly address the population and risks of interest to CPSC.

This report will be posted on CPSC's website to keep stakeholders informed of the progress of research related to the agency's VSL estimates.

IEc

Valuing Reductions in Fatal Risks to Children

Final Report | January 3, 2018

prepared for:

Consumer Product Safety Commission (CPSC)

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ACKNOWLEDGEMENTS

This final report was prepared by Industrial Economics, Incorporated (IEc) for the U.S. Consumer Product Safety Commission (CPSC) under Contract Number CPSC-D-15-0004, Task Order 12. The CPSC project manager is Charu Krishnan. Additional advice and helpful comments were provided by William Zamula, Gregory Rodgers, and Robert Franklin.

The IEc project manager is Jennifer Baxter, who coordinated the overall effort. The lead author of the report was William Raich, who was assisted by Lisa A. Robinson and James K. Hammitt of Harvard University (Center for Risk Analysis and Center for Health Decision Science). We thank Lucy O'Keeffe of the Harvard Center for Health Decision Science for sharing the results of her literature search.

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EXECUTIVE SUMMARY

The Consumer Product Safety Commission (CPSC) is an independent Federal agency that protects the public against unreasonable risk of injury or death from thousands of categories of consumer products. Thus the primary benefits of CPSC's regulations are reductions in these risks. To value fatal risk reductions, CPSC relies on estimates of the value per statistical life (VSL). Consistent with the conceptual framework for benefit-cost analysis, VSL estimates are derived from research on individual willingness to pay (WTP) for small changes in one's own risk within a defined time period. Currently, CPSC applies a VSL of $8.7 million (2014 dollars) in its analyses.

The VSL estimates used by CPSC and other Federal agencies reflect the value that adults place on reducing their own risk of fatality. Several studies have now been completed that address the value of fatal or nonfatal risk reductions that accrue to children. The results of these studies are diverse, but generally suggest that the value of reducing risks to children may be higher than adult values. However, these studies have not been carefully reviewed for quality and applicability to the types of risks and populations addressed by CPSC regulations. In this report, we review this literature and discuss its implications.

ANALYTIC APPROACH

Our analytic approach includes three phases: criteria development; literature search; and literature review. Our team began by developing two sets of criteria to guide our work. The first set was used to select studies of fatal or nonfatal risks to children for detailed review; the second set was used to evaluate these studies. As a starting point, we considered the criteria recently used to evaluate VSL studies of adult risk reductions for application in U.S. regulatory analyses (Robinson and Hammitt 2016, U.S. Department of Health and Human Services 2016), which in turn were based on criteria suggested by previous expert advisory groups. We adapt these criteria to reflect our focus on risks to children ages 0 through 17.

The two sets of criteria are summarized in Exhibit ES-1. The selection criteria are relatively straightforward, resulting in a simple "yes/no" determination. The evaluation criteria require more judgment, and focus on the quality and applicability of the studies.

EXHIBIT ES-1. SELECTION AND EVALUATION CRITERIA

SELECTION CRITERIA
1. Written in English. 2. Publicly available. 3. Data collected within the past 30 years. 4. Data collected in a high-income country. 5. Values a change in risk (not a change in life expectancy). 6. Estimates willingness to pay (not willingness to accept compensation).
EVALUATION CRITERIA
1. Addresses fatal rather than nonfatal risk reductions. 2. Data collected more recently. 3. Data collected in the United States. 4. Based on a sample of the general population (not a subgroup). 5. Based on a representative (probabilistic) sample (not a convenience sample). 6. Provides comparable values for children and adults within the study. 7. Provides evidence of validity.

The first two selection criteria (written in English, publicly available) reflect the purpose of regulatory analyses: to inform decision-makers and the public about potential policy impacts. To achieve this goal, the studies underlying the VSL estimates should be accessible to those reviewing the analyses. Under criterion 3, we limit our review to studies based on data collected within the past 30 years (between 1987 and the present). Older studies may not reflect the preferences of the current population or may not rely on methods that reflect the evolving understanding of best practices. Under criterion 4, we focus on studies conducted in countries with relatively high average incomes, given that residents of much poorer countries are likely to have substantially different preferences than the U.S. population. We select studies from countries with 2016 gross national income (GNI) per capita equal to 50 percent or more of U.S. GNI per capita in the same year; i.e., countries with GNI per capita greater than $28,090. Criteria 5 and 6 relate to the need for values that measure a reasonably consistent outcome. More specifically, criterion 5 focuses on studies that address a change in risk rather than a change in life expectancy. Under criterion 6, we select studies that address WTP rather than willingness to accept compensation (WTA). WTP is generally used to estimate the value of improvements from the status quo and is more frequently studied.

The first five evaluation criteria narrow the focus of the selection criteria to reflect our relative weighting of the studies based on their applicability in Federal regulatory analyses. In particular, criterion 1 indicates that we prefer studies of fatal risks to those focused on nonfatal outcomes. Similarly, because we are interested in preferences of the current U.S. population, criteria 2 and 3 indicate that we prefer more recent U.S. studies. Most major Federal regulations affect the population nationwide; thus criterion 4 addresses whether the study considers a narrower subgroup (e.g., children residing in a specific urban area) rather than the general population. The fifth evaluation criterion, relying on a probability sample rather than a convenience sample, reflects our interest in values that are representative of the population studied.

Criterion 6 expresses a preference for studies that estimate the value of reducing risks to both children and adults using the same approach. Such studies allow researchers to estimate the ratio of the two values, which may be more stable and well-estimated than the values of risk reduction. Comparing estimates of the value of reducing risk to a child from one study with estimates of the value of reducing risk to an adult from another study can be misleading. It is difficult to know whether any difference in the values is attributable to the focus on children versus adults or to other differences between the studies, such as the population sampled, question wording, or analytic approach.

Evaluation criterion 7 addresses evidence of validity. Applying this criterion requires considering the evidence that each study presents regarding the quality of the data, the appropriateness of the methods used, and the validity of the results. Thus it requires substantial professional judgment, and the factors we consider are tailored to the approach used in each study. For example, we consider whether stated preference studies provide evidence that estimated WTP varies with the magnitude of the risk change. Similarly, we consider how averting behavior studies account for individuals' understanding of the size of the risk change and whether and how they separately estimate the value of key inputs such as the time spent in the activity.

In many cases, we are able to easily determine whether papers satisfy our evaluation criteria (e.g., addresses fatal rather than nonfatal risk reductions). In other cases, the criteria require more detailed review of each study and the application of judgment. Few studies will meet all of these criteria; rather we use the criteria in weighing the advantages and limitations of each study. Whether each study meets each criterion is a matter of degree, and the criteria are not necessarily equal in importance.

RESULTS

We apply these two sets of criteria and identify 16 publications that satisfy all six selection criteria. Among these 16 publications, one paper satisfies our seven evaluation criteria and four satisfy many of the criteria. These studies suggest that VSL for children exceeds VSL for adults by a factor of 1.2 to 3.0, with a midpoint of roughly 2. Studies that estimate WTP for reductions in nonfatal risks lead to similar results. Although the available studies suggest that the divergence between child and adult values may decrease as the child ages, more work would be needed to determine the extent to which these multipliers vary across age groups.

These multipliers could be used directly to adjust adult values when estimating the value of risks to children. The implications of this review could also be explored further using other research synthesis methods. These methods include meta-analysis, which applies statistical techniques to combine the results of multiple studies and investigate sources of variation. Another method is structured expert elicitation, which provides a systematic framework for obtaining judgments about the value of specific parameters and is designed to avoid well-known heuristics and biases that can lead to poor judgment. In addition to providing further insights, these methods can be used individually or in combination to develop estimates tailored for application in particular contexts, such as risks that affect children of different ages or that stem from different causes.

Additional primary research may also be useful. CPSC previously explored options for conducting new research to value the types of nonfatal risks it regulates, using revealed and stated preference methods. That work provides a starting point for developing options for valuing fatal as well as nonfatal risks to children. The studies we identify and evaluate in this report typically address risks that differ in some respects from the types of risks CPSC regulates; for example, involving illnesses rather than injuries. Primary research could provide estimates that directly address the population and risks of interest to CPSC.

CHAPTER 1 | INTRODUCTION

The Consumer Product Safety Commission (CPSC) is an independent Federal agency that protects the public against unreasonable risk of injury or death from consumer products. It has jurisdiction over thousands of categories of consumer products, such as toys, cribs, power tools, cigarette lighters, and household chemicals.[1] The primary benefits of CPSC's regulations are reductions in the risk of injury or death associated with the use of these products, including risks to infants and children as well as adults.

To value fatal risk reductions, CPSC relies on estimates of the value per statistical life (VSL). Consistent with the conceptual framework for benefit-cost analysis, VSL estimates are derived from research on individual willingness to pay (WTP) for small changes in one's own risk within a defined time period. Currently, CPSC applies the U.S. Environmental Protection Agency's (EPA's) central VSL estimate of $8.7 million (2014 dollars) in its analyses.

The VSL estimates used by CPSC and EPA, as well as the estimates used by other Federal agencies, reflect the value that adults place on reducing their own risk of fatality.[2] While these agencies recognize that VSL may depend on the age of those affected, at present they apply the same values to children and adults of all ages. The number of studies that explore the value of reducing children's risks has increased substantially in recent years, providing an opportunity to review this literature and explore alternative approaches. The results of these studies are diverse, but generally suggest that the value individuals place on reducing risks to children is greater than the value of reducing risks to adults. This report reviews these studies for quality and applicability to the risks and populations addressed by CPSC regulations and policies.

Minimal guidance exists on such an adjustment. The U.S. Office of Management and Budget (OMB) provides general government-wide guidance for regulatory analysis in *Circular A-4* and suggests that monetary values for children should be at least as large as the values for adults (OMB 2003).[3] While guidance developed in other countries at times

[1] The laws that CPSC is responsible for implementing include the Consumer Product Safety Act, as amended by the Consumer Product Safety Improvement Act of 2008 and Public Law No. 112-28; the Federal Hazardous Substances Act; the Flammable Fabrics Act; the Poison Prevention Packaging Act; the Refrigerator Safety Act; the Virginia Graeme Baker Pool and Spa Safety Act; and the Children's Gasoline Burn Prevention Act.

[2] See EPA (2000), U.S. Department of Transportation (2016). U.S. Department of Health and Human Services (2016).

[3] As an independent agency, CPSC's regulations and supporting benefit-cost analyses are not subject to review by OMB. However, its major rules (i.e., those likely to have an effect on the economy of $100 million or more) are subject to Congressional review pursuant to the Congressional Review Act. CPSC generally prepares its analyses in accordance with the

considers higher values for children than for adults (e.g., Ministry of Finance (Norway) 2012, OECD 2012), the basis for these adjustments is not always clear and U.S. values may vary from the values held by other populations.[4]

Thus this report addresses a major gap in the currently available guidance. We conducted a criteria-driven review of the literature in three phases. First, we developed selection and evaluation criteria. Next, we searched the literature for potentially relevant studies. Finally, we evaluated the quality and applicability of these studies.

The remainder of our report discusses the results of each phase, and includes the following.

- In Chapter 2, we discuss the general framework for valuing reductions in fatal risks, including the derivation of VSL for both adults and children.
- In Chapter 3, we summarize our analytic approach. We first discuss how we identified studies for review, including our selection criteria and search procedures. We then discuss how we evaluated these studies.
- In Chapter 4, we describe the results of our review. We first evaluate those studies that provide comparable estimates of the value of fatal risk reductions for both adults and children, and then describe the insights provided by those studies that instead address nonfatal risks or address risks to children without providing analogous estimates for adults.
- In Chapter 5, we summarize our results and discuss possible future research.

requirements applicable to other agencies, including Executive Orders 12866 and 13563 and the implementing guidance in OMB's Circular A-4 (OMB 2003).

[4] For policies targeting risks to children, Ministry of Finance (Norway) (2012) suggests multiplying the adult VSL by a factor of 2; OECD (2012) recommends multiplying the adult VSL by a factor of 1.5 to 2.

CHAPTER 2 | GENERAL FRAMEWORK

In benefit-cost analysis of regulations and other policies, the definition of value is derived from welfare economic theory. Two key assumptions are particularly important in this context. The first is the concept of "opportunity cost." Using resources (such as labor or raw materials) for one purpose means that they are not available for other productive uses. Thus the value of a resource is determined by its most productive or beneficial use. The second is "consumer sovereignty." Conventionally, benefit-cost analysis attempts to determine whether consumers in the aggregate judge themselves better off with a policy than without. Choosing to purchase a good or service presumably indicates that an individual values that item more than the other things he or she could have used that money to buy. Thus the amount of money individuals are willing to exchange for a good or service is used to estimate its value; i.e., the opportunity cost of not providing it.

Within this context, the value of fatal risk reduction is generally expressed as the value per statistical life (VSL). A "statistical life" involves aggregating many small risk changes across individuals, such as those resulting from rulemakings aimed at improving the safety of consumer products. The VSL represents the extent to which individuals are willing to trade off spending on other goods and services for small reductions in their own risk of death in a defined time period. In other words, it represents the individuals' marginal rate of substitution between money and mortality risk.[5]

To estimate the VSL, the value for a specified risk change is typically divided by the associated change in risk. For example, if an individual's WTP for a reduction in his or her own fatal risk of 1 in 10,000 in the current year is $900, then that individual's VSL is calculated as:

$$\$900 \div \left(\frac{1}{10{,}000}\right) = \$9{,}000{,}000$$

For risks that accrue throughout a population (e.g., hazards associated with a prevalent consumer product), 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, $90 million in a given year for a risk reduction that is expected to result in 10 fewer deaths in that year, the average VSL would be $9 million ($90 million divided by 10 cases).

[5] For a more formal derivation of the VSL, see Hammitt (2000b, 2017).

2.1 VALUATION METHODS

There are two common methods for estimating WTP for reductions in fatal risks: revealed preference and stated preference studies. Revealed preference studies use actual behaviors to infer how individuals trade off fatal risks and wealth. While risk reductions are not directly bought and sold in the marketplace, market decisions (e.g., choices of consumer products or types of employment) are associated with differing levels of safety (i.e., risk of injury or death). WTP for risk reductions can thus be inferred from the choices individuals make in these contexts.

Revealed preference research includes wage-risk and averting behavior studies. Wage-risk studies (often referred to as hedonic wage studies) estimate the VSL by modeling earnings as a function of job and personal characteristics, including the risk of death. Similarly, averting behavior studies infer WTP by studying defensive measures or consumer products used to protect against perceived risks, such as bicycle helmets or seat belts. Under either approach, researchers face the challenge of distinguishing the value of fatal risk reductions from the value of other, potentially confounding attributes, such as reductions in nonfatal risks, time costs, and comfort or convenience. One question that arises in this context is whether the risks associated with the marketed good or service are sufficiently similar to the risks associated with a regulation to provide suitable measures of value.

Stated preference studies instead rely on survey research techniques involving contingent valuation or discrete choice experiments. These methods are used to ask individuals to consider hypothetical scenarios in which they directly or indirectly value a change in risk. For example, respondents may be asked whether they would be willing to pay $50 annually to accrue a stated risk reduction associated with a hypothetical government project or medical treatment. Stated preference studies have the advantage that they can be designed to address the population and risk of interest. However, the hypothetical nature of the payment means that careful design and implementation is needed to ensure that the results are reasonably valid.

Both revealed preference and stated preference studies are routinely used by Federal agencies in estimating VSL for application in their regulatory analyses. Historically, agencies have relied more frequently on wage-risk studies than on stated preference studies, due largely to concerns about the quality and applicability of the latter. The EPA estimates currently used by CPSC are derived from literature reviews conducted in the early 1990s and are based on 26 studies, of which 21 are wage-risk studies (EPA 2010). EPA is currently working to update these estimates based on the results of recent research and advice from its Science Advisory Board (EPA 2016, Khanna et al. 2017).

Because the U.S. Department of Transportation (DOT) primarily addresses injury-related risks, it derives its VSL estimates exclusively from wage-risk studies, which also address injury-related risks (DOT 2016). In contrast, the U.S. Department of Health and Human Services (HHS) largely addresses illness-related risks. However, a review of related research (Robinson and Hammitt 2016) found that few U.S. studies of illness-related risks meet criteria for quality, and those that do yield similar values to studies of injury-related risks. Thus HHS bases its VSL estimates on six wage-risk studies and three stated

preference studies (HHS 2016). All of these agencies (EPA, DOT, and HHS) apply the same VSL to adults and children of all ages, and their estimates are relatively similar—generally in the range of $9 million to $10 million in recent years.

As indicated by these guidance documents, the research base for adult values is extensive and has been subject to substantial review, providing a much stronger basis for adult values than do the much smaller number of studies that also value risks to children. Thus we do not propose to use the results of the review summarized in this report to develop VSL estimates for adults as well as children. We instead use the results of our review to estimate adjustment factors that could potentially be applied to estimates of the adult VSL when valuing children's risks. While the studies we review include some discussion of the reasons why values may vary for adults and children, these reasons are not well-understood. They may, for example, include children's longer life expectancies and concerns about "fair innings;" i.e., that younger individuals have not yet had an opportunity to experience a full life.

2.2 APPROACHES FOR VALUING RISKS TO CHILDREN

The studies used by Federal agencies in developing their guidance consider how adults value reductions in their own risk of death rather than risks to friends, family, or other members of society. This approach is consistent with the general framework for benefit-cost analysis, which is based on the notion that each individual is the best (or the most legitimate) judge of his or her own wellbeing; i.e., the principal of consumer sovereignty. Thus the values used in policymaking—such as for reductions in fatal risks—should be based on the preferences of those affected by the policy; their individual WTP for changes in their own risks.[6] However, eliciting a child's WTP for his or her own risk reductions is problematic.

Generally, researchers expect that children may find it difficult to make informed, rational choices on the trade-offs between fatal or nonfatal risks and monetary wealth.[7] When very young, they are generally unable to communicate any preferences they may have or to comprehend related concepts. Understanding the concept of changes in risks is difficult for many adults, and likely to be even more difficult for children even as they reach their teens. In addition, children typically do not possess or control the financial resources to make these tradeoffs.

A few studies have investigated children's ability to comprehend these concepts and make these trade-offs. In particular, Guerriero et al. (2017) explore child and adult WTP to reduce asthma risks to children in a contingent valuation survey conducted in Naples, Italy. The respondents include 370 children ages 7 to 19 as well as their parents. While

[6] Because estimates of individual WTP for risk changes typically exclude costs or savings that accrue to others, changes in third party costs may be added to VSL estimates where appropriate to more fully capture the effects of the risk reductions on society (Robinson and Hammitt 2013, 2016). These third party costs may include, for example, medical or other costs paid by insurers and caregiving provided by friends or family members.

[7] For this report we define children as those age zero through 17.

the results pass several validity tests, WTP is not proportional to the size of the risk reduction – such proportionality is an important evaluation criterion, as discussed in the next chapter. In addition, although the authors focus on the child's own pocket money, the study does not address the question of children's lack of control over the allocation of their household's financial resources. Thus more work would be needed to further develop and apply this approach.

In lieu of eliciting WTP estimates from children for their own risk reductions, researchers commonly consider either the preferences of the general adult population for children in the population or the preferences of parents for their own children.[8] One issue that arises in this context is the distinction between pure and paternalistic altruism (Jones-Lee 1992, Bergstrom 1982, 2006). A pure altruist respects the preferences of others, placing the same relative weight on the costs and benefits others bear as they would themselves. In contrast, a paternalistic altruist places greater (or lesser) weight on some outcomes than would those affected. For example, if a regulation increases the safety of a toy but also increases its price, the pure altruist would place the same relative values as the individuals affected on both the lower risks faced by children and the increased prices parents pay for these products. In contrast, a paternalistic altruist might argue for more costly, and more protective, safety features than preferred by the affected households, or perhaps even banning a product that families would prefer to purchase despite its risks.

In benefit-cost analysis, counting the preferences of a pure altruist for outcomes that accrue to others, as well as the preferences of those affected for the outcomes they experience themselves, increases the magnitude of the net benefits but cannot change their sign. In effect, the altruist benefits or is harmed in proportion to the benefits or harms to the individuals who are affected directly. Because inclusion of pure altruism cannot change the sign of the net benefits, it does not affect the determination of whether the benefits exceed the costs. In contrast, counting the preferences of a paternalistic altruist could change the results, by placing a greater weight on some outcomes than would result if only the preferences of those affected were considered. Distinguishing between these two perspectives is very difficult, however, and altruism is generally not included in the values conventionally used in benefit-cost analysis.

For children whose preferences are not directly incorporated, the relevant question is whether society at large or parents are the best judge of the child's wellbeing.[9] Information provided by the general population indicates the values that individuals place on reducing the risks faced both by their own children and the children of others, and is at times described as the societal perspective. The parental perspective instead focuses on the allocation of the household's own resources across its members. An advantage of this

[8] A third approach is the adult-as-child approach, which asks adults to place themselves in the position of children. For example, an adult may be asked to refer to their childhood and the risks faced in those earlier years. For more information on this approach, see Dockins et al. (2002) and EPA (2003). We do not discuss this approach in detail because it is rarely used.

[9] For more discussion of these issues, see: Dockins et al. (2002), EPA (2003), Alberini et al. (2010), and Hammitt and Haninger (2017).

perspective is that parents have good information about their children's wellbeing and are generally interested in improving their welfare. They are also responsible for making safety decisions for children, such as which protective equipment to purchase and which activities to allow or prohibit.[10]

A related issue is how researchers model the household decision-making process for allocating resources between safety and other goods. The prevailing approach assumes that household decision-makers, generally parents or caretakers, maximize household wellbeing in accordance with a unified set of preferences and pooled financial resources. Thus, the practice of eliciting WTP from one parent may be justified by the notion of a parental consensus around such decision-making. Conversely, researchers have also modeled household decisions using a pluralistic approach in which preferences are allowed to differ across household members. In other words, this approach recognizes that parents may have different preferences for how the household allocates resources between safety and other goods. These preferences are then pooled to reach a collective decision.[11]

In sum, researchers generally use revealed or stated preference methods to estimate the value of reducing risks to children as well as to adults. In conducting these studies, they may focus on the perspective of the general population or of parents. The parental perspective is attractive because society largely delegates responsibility for child wellbeing to parents, making parents the legitimate decision-makers (within limits), and this approach focuses on those who are presumably most knowledgeable about and invested in the children's wellbeing. Such an approach also reflects models of household decision-making that assume that parents make these decisions so as to maximize the family's wellbeing. In the following chapters, we review the literature on the value of risks to children, considering studies that rely on the societal or the parental perspective.

[10] Williams (2013) also notes that a parental WTP estimate is likely the closest approximation of the tradeoff between a child's safety and a child's wealth, as parents significantly contribute to the latter. In making a tradeoff between a parent's money and their child's safety, the parent is implicitly making a tradeoff between their child's safety and their child's future income.

[11] See Adamowicz et al. (2014) for an empirical application of different household decision-making models to the valuation of children's health.

CHAPTER 3 | ANALYTIC APPROACH

This chapter describes our approach for conducting a criteria-driven review of the literature on the value of risk reductions that accrue to children. Our approach includes three phases: criteria development; literature search; and literature review. We discuss the first two phases below, and report the results of the final phase in the next chapter.

3.1 CRITERIA DEVELOPMENT

Prior to identifying relevant primary research studies, our team developed two sets of criteria to guide our literature search and review. First, we developed selection criteria for identifying studies for detailed review. These selection criteria are straightforward, resulting in a simple "yes/no" determination. Second, we developed evaluation criteria for assessing the quality and applicability of studies. These criteria require detailed review of each study and often involve substantial professional judgment. We use these evaluation criteria to determine the relative strengths of each study. Applying these criteria aids us in exploring and documenting the strengths and limitations of the studies, and in discussing the implications of including or omitting them from our analysis.

As a starting point, we considered criteria recently used to evaluate adult VSL studies for application in U.S. regulatory analyses (Robinson and Hammitt 2016, HHS 2016), which in turn were based on advice provided by previous expert panels.[12] We adapt these criteria to reflect our focus on the risks to children ages 0 through 17. Some of the changes reflect the difference in context. For example, studies of risks to adults generally focus on individuals' WTP for changes in their own risks, whereas studies of risks to children require considering adult WTP for others. In addition, the valuation literature on adult risks is relatively large and well-developed, while the literature on children is much smaller. Thus we use somewhat less stringent criteria to avoid ignoring studies that may provide useful insights, given the more limited research available.

[12] The criteria used in this work were based on advice provided by the U.S. Environmental Protection Agency's (EPA's) Science Advisory Board (EPA 2010, Kling et al. 2011) and other experts; similar criteria were used in a study prepared for EPA on VSL income adjustments (Robinson and Hammitt 2015). EPA's Science Advisory Board recently provided additional advice on developing VSL estimates (EPA 2016, Khanna et al. 2017). This latter review focuses largely on estimating values for illness-related deaths (rather than for the deaths addressed by CPSC, which are largely injury-related) and on refining the approach used to conduct meta-analysis.

3.1.1 SELECTION CRITERIA

We are primarily interested in studies that use a consistent approach to estimate the value of fatal risks to children and to adults, to support development of an adjustment factor that can be applied to independently-derived adult VSL estimates.[13] However, in selecting studies, we also include those that address nonfatal risks or risks only to children, given that these studies may provide useful information. The selection criteria we used to identify these studies are presented in Exhibit 3-1 and discussed below.

EXHIBIT 3-1. SELECTION CRITERIA

1. Written in English.
2. Publicly available.
3. Data collected within the past 30 years.
4. Data collected in a high-income country.
5. Values a change in risk (not a change in life expectancy).
6. Estimates willingness to pay (not willingness to accept compensation).

Criteria 1 and 2 (written in English, publicly available) reflect the purpose of regulatory analyses: to inform decision-makers and the public about potential policy impacts. To achieve this goal, the studies underlying the VSL estimates should be accessible to those reviewing the analyses. Publicly available sources may include peer-reviewed journal articles, working papers, and government documents (e.g., guidance documents or expert panel reports). We do not focus exclusively on journal articles, because peer-reviewers may consider different factors than those of interest for regulatory analysis, such as the extent to which the methods are innovative rather than whether the methods follow generally-accepted best practices. We include publicly-accessible working papers because these studies are often close-to-final and may be published in the near future. We also include reports from government agencies and intergovernmental organizations, which typically involve substantial expert review.

Under criterion 3, we limit our review to studies based on data collected within the past 30 years (between 1987 and 2017).[14] Older studies are less likely to reflect current preferences for trading income for small risk changes. In addition, older studies do not reflect evolving standards for best practices. Under criterion 4, we focus on studies conducted in high income countries, given that residents of countries with much lower incomes than in the U.S. are likely to have substantially different preferences. Ideally, we would rely on studies of the general U.S population because cultural and other factors in

[13] As noted earlier, the research base for adult values is extensive and has been subject to substantial review, providing a much stronger basis for adult values than do the relatively few studies that include valuation of risks to children. Thus we do not propose to use the results of this review to develop VSL estimates for adults and children. We instead use the results to determine adjustment factors that can be applied to estimates of the adult VSL.

[14] Our search was conducted in July 2017. Given the time needed to collect and analyze the data and draft the resulting article or other document, the data collection in the studies we identified was generally completed several years in advance of this end date.

addition to income affect preferences across countries. However, we include studies from a wider range of countries in our initial selection since they may provide useful information and the overall number of studies is relatively small. We define high income countries as those with gross national income (GNI) per capita of 50 percent or more of U.S. GNI per capita, according to World Bank data.[15]

Criteria 5 and 6 aim to ensure that the outcomes valued are defined consistently. More specifically, criterion 5 focuses on studies that address a change in risk rather than a change in life expectancy or other outcome.[16] Valuation studies more frequently address changes in risk, and those few studies that consider changes in life expectancy generally address adults and face a number of problems. For example, respondents in stated preference studies may not understand that the risk reduction affects each year of life; it is not simply added to the end of one's lifespan when one's quality of life is likely to have declined.

Criterion 6 is primarily relevant to stated preference studies, and requires that they elicit WTP rather than WTA.[17] 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 large and variable differences between estimated WTP and WTA are not well understood (Horowitz and McConnell 2002, Tuncel and Hammitt 2014).

3.1.2 EVALUATION CRITERIA

We developed seven criteria to guide our evaluation of each study. These criteria are summarized in Exhibit 3-2 and described below.

EXHIBIT 3-2. EVALUATION CRITERIA

1. Addresses fatal rather than nonfatal risk reductions.
2. Data collected more recently.
3. Data collected in the United States.
4. Based on a sample of the general population (not a subgroup).
5. Based on a representative (probabilistic) sample (not a convenience sample).
6. Provides comparable values for children and adults within the study.
7. Provides evidence of validity.

[15] To estimate income, we rely on GNI per capita data from the World Bank. In 2016 (the most recent year for which data were available), U.S. GNI per capita was $56,180. We thus include studies conducted in countries with 2016 GNI per capita of $28,090 or higher (See: http://data.worldbank.org/indicator/NY.GNP.PCAP.CD). The World Bank derives these estimates using exchange rates following its Atlas method.

[16] Under this criterion, we exclude studies that elicit WTP for a change that occurs with certainty or for an entire policy or program without separating the value of the risk reduction from the value of other attributes.

[17] Revealed preference studies often address a market equilibrium rather than a change that can be easily characterized as WTP or WTA.

The first five evaluation criteria narrow the focus of the selection criteria to reflect our relative weighting of the studies based on their applicability in Federal regulatory analyses. Criterion 1 indicates that we prefer studies of fatal risks to those focused on nonfatal outcomes. Similarly, because we are interested in preferences of the current U.S. population, criteria 2 and 3 indicate that we prefer recent U.S. studies. Most CPSC and other major Federal regulations affect the population nationwide; thus criterion 4 addresses whether the study considers a narrower subgroup (e.g., children residing in a specific urban area) rather than the general population. The fifth criterion, relying on a probability sample rather than a convenience sample, reflects our interest in values that are representative of the population studied. However, we consider studies based on a convenience sample if they estimate values for children and adults among the same population and it seems reasonable to interpret the estimated differential as relevant to the general population.

Criterion 6 relates to the need for comparable values for children and adults, expressing a preference for studies that estimate the value of reducing risks to each using the same approach. Such studies allow researchers to derive the ratio of the two values, which may be more stable and well-estimated than the values of risk reduction. Comparing estimates of the value of reducing risk to a child with estimates of the value of reducing risk to an adult from another study can be misleading; it is difficult to know whether the difference is attributable to the focus on children versus adults or to any of a large number of other possible differences between the studies. For example, if a study estimates values for risks that differ in severity and duration depending on whether a child or an adult is affected, it becomes difficult to ascertain the extent to which the values reflect differences in the age of those affected rather than other factors. More generally, studies that apply the same approach to both children and adults avoid the difficulties inherent in separating out the effects of other factors, such as the methodology used, the types of risks addressed, and the population surveyed.

Criterion 7 addresses evidence of validity. Applying this criterion requires considering the evidence that each study presents regarding the quality of the data, the appropriateness of the methods used, and the validity of the results. Thus it requires substantial professional judgment and the factors we consider are tailored to the approach used in each study.

A major concern in stated preference studies is that respondents may not understand the size of small probabilities, reporting the same or similar WTP for risk reductions that vary in magnitude. Thus one factor we consider is the results of tests of the sensitivity of WTP to risk magnitude. Economic theory suggests that WTP should increase nearly proportionately to the size of the risk change, as long as WTP is a small fraction of income (see Hammitt 2000a, Corso et al. 2001, Alolayan et al. 2017). 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. In addition, the common practice of applying a constant VSL across differently-sized small risk changes rests on this assumption.[18]

Similarly, revealed preference studies that address risks to children are likely to consider averting behaviors; i.e., defensive measures or consumer products used to protect against perceived risks, such as seat belts or bicycle helmets. Issues to be considered in evaluating these studies include whether the researchers probe individuals' understanding of the size of the risk change and whether and how they separately estimate the value of key inputs such as the time spent in the activity.

In many cases, we are able to easily determine whether studies satisfy our evaluation criteria (e.g., address fatal rather than nonfatal risk reductions). In other cases, the criteria require more detailed review of each study and the application of judgment. The extent to which each study meets each criterion is a matter of degree, and the criteria are not necessarily equal in importance. Thus we use the evaluation criteria to weigh the advantages and limitations of each study rather than as firm dividing lines between studies of higher and lower quality.

3.2 LITERATURE SEARCH

Following criteria development, we began our search for primary research studies by reviewing other recent literature reviews on the valuation of fatal and nonfatal risk reductions for children (Alberini et al. 2010, Gerking and Dickie 2013).[19] The team followed an iterative process of (1) identifying studies cited within these reviews, (2) using the references cited in each study to identify additional studies, and (3) conducting forward searches for each study using the *cited by* feature in Google Scholar to identify newer work. Keyword searches using the phrase, "(children OR child) AND (WTP OR VSL)" in EconLit were also conducted.[20] Where the search led to unpublished conference papers and presentations or working papers, the team searched for published versions, writing to the authors to determine the status of the study if needed. We also wrote to leading researchers to identify any additional studies.

We then applied the selection criteria presented above in Exhibit 3-1 to the resulting studies. As illustrated in Exhibit 3-3, based on an initial screen, we identified 34 publications that appeared to meet the criteria. We then reviewed these 34 publications in more detail. Note that some of the stated preference surveys are discussed in more than one publication, and some publications discuss more than one stated preference survey, as described in Chapter 4.

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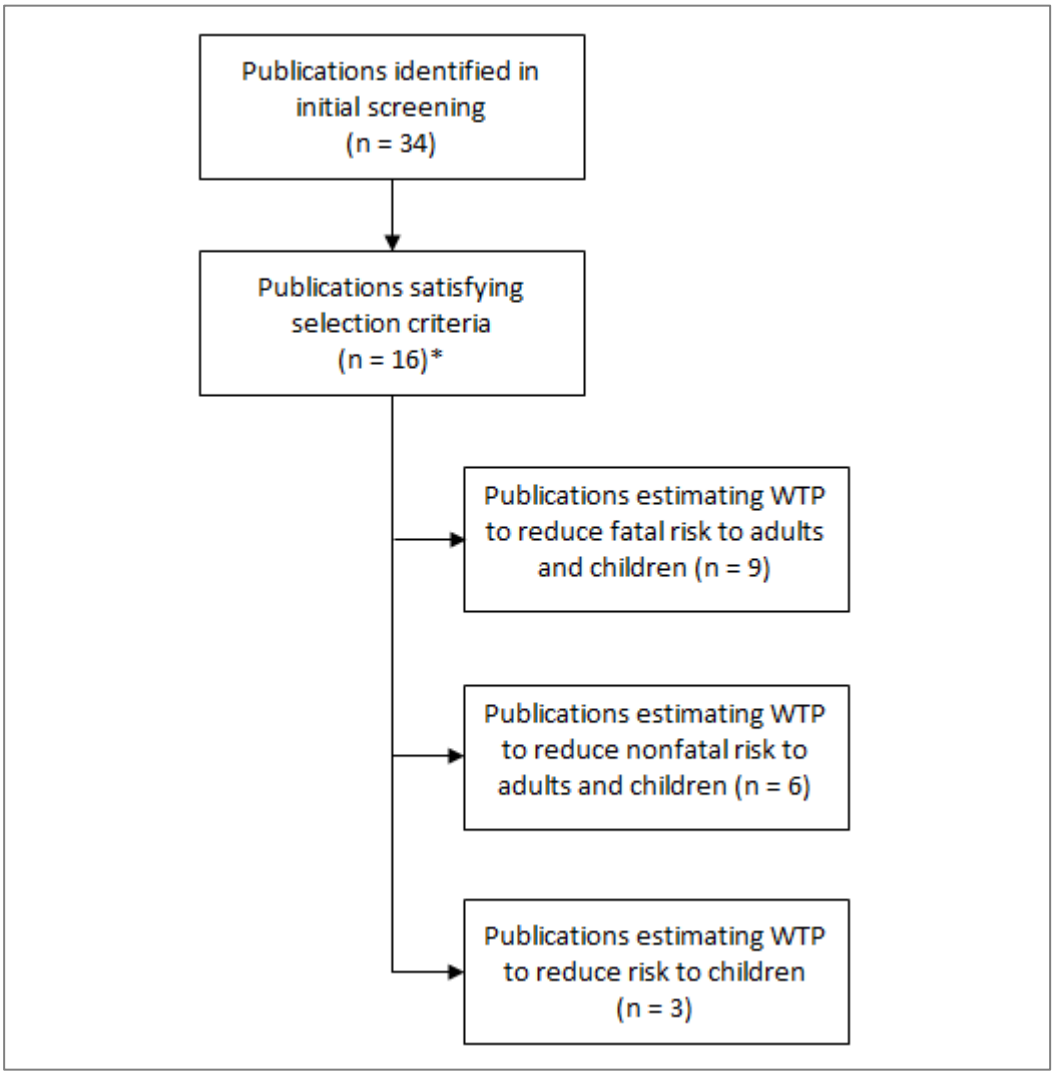
[18] For example, if WTP is $900 for a 1 in 10,000 risk change and $4,500 for a 5 in 10,000 risk change, then the VSL (WTP divided by risk change) is $9 million in both cases. If the changes are not proportional, then the VSL differs and it is not clear what VSL is appropriate for small risk changes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

[19] We thank Lucy O'Keeffe of the Harvard Center for Health Decision Science for providing the results of her search for valuation studies conducted globally, which provided the starting point for this work.

[20] EconLit is a comprehensive database of economics publications maintained by the American Economics Association. For more information, see https://www.aeaweb.org/econlit/.

EXHIBIT 3-3. LITERATURE SEARCH RESULTS



Note: *Two publications provide WTP estimates for both fatal and nonfatal risk reductions accruing to adults and children (Blomquist, Dickie, and O'Conor 2010; Gerking, Dickie, and Veronesi 2014). Thus, the number of publications satisfying our selection criteria (16) is less than the sum of the publications in each of the three subcategories (18).

In this more detailed review, we found that 18 of the 34 publications do not meet our selection criteria. For example, several explored structural models rather than reporting the results of new primary research, valued an outcome other than a specified risk change to a particular individual, or relied on data collected prior to our cutoff date.[21] Thus the

[21] Three papers published within the past 30 years relied upon data collected prior to 1987 (Agee and Crocker 1994, 1996; Carlin and Sandy 1991). Structural models generally combine theoretical expectations with parameter estimates from existing data sources, rather than reporting the results of new primary research on individual WTP for risk reduction. We exclude five such publications: Agee and Crocker (2007, 2008), Birchenall and Soares (2009), Cordoba and Ripoll (2014), and Dickie (2005). We also drop ten publications that do not directly value a change risk to a specified individual; e.g., that estimate the value of a product or intervention without separating the value of a specified fatal or nonfatal risk reduction

selection criteria led us to identify 16 publications for more detailed evaluation. These 16 publications include three that only address risks to children; the remainder address fatal and/or nonfatal risks to both adults and children. We further assess the quality and applicability of these studies in the next chapter and highlight those that best satisfy our selection criteria.

from its other attributes. These include Barron et al. (2004); Brandt, Lavin, and Hanemann (2012); Carlsson, Daruvala, and Jaldell (2010); Cawley (2008); Dickie and Messman (2004); Leung and Guria (2006); Mansfield, Johnson, and Van Houtven (2006); Niens, Strack, and Marggraf (2014); Prosser et al. (2013); and Takeuchi, Kishimoto, and Tsuge (2008).

CHAPTER 4 | RESULTS

This chapter discusses the results of our evaluation of the 16 primary research publications that meet the six selection criteria presented in Exhibit 3-1 of Chapter 3.[22,23] In addition to being accessible to a general U.S. audience (i.e., written in English and publicly available), these publications address studies that rely on data collected in a high-income country in the past three decades and provide WTP estimates for changes in fatal or nonfatal risks. We begin by evaluating the studies that provide estimates for fatal risk reductions for both children and adults. We supplement the findings with evidence from studies focused on reductions in nonfatal risks as well as those that only address risks to children. We conclude by describing possible adjustment factors as well as the implications of these studies for valuing risks to children of different ages.

4.1 STUDIES OF FATAL RISKS TO ADULTS AND CHILDREN

Of the 16 publications, nine provide WTP estimates for fatal risks to both children and adults. In this section, we first evaluate these studies using the seven criteria discussed in the prior chapter, then discuss the strongest of these studies in more detail. Some stated preference surveys are discussed in more than one publication and some publications discuss more than one stated preference survey, so there is not a one-to-one match between the publications and the studies. However, these nine publications address a total of seven stated preference surveys and two revealed preference studies, yielding nine studies that address fatal risks to both adults and children.

4.1.1 APPLICATION OF EVALUATION CRITERIA

Exhibit 4-1 summarizes the nine publications that provide WTP estimates for reductions in fatal risks to both adults and children. These publications satisfy evaluation criteria 1 (addresses fatal risks) and 6 (provide values for adults and children).

[22] Of these 16 publications, 12 are journal articles, three are book chapters or reports (Dickie and Gerking 2003, Dickie and Gerking 2006, Ščasný and Zverinova 2014), and one is an unpublished working paper (Mount et al. 2000).

[23] We review two publications that include surveys conducted in the Czech Republic as well as in higher income countries (Alberini and Ščasný 2011, Ščasný and Zverinova 2014). In our discussion, we only include the results from the surveys that meet selection criterion 4 (data from a high income country) and exclude the Czech results.

EXHIBIT 4-1. EVALUATION OF STUDIES OF FATAL RISKS TO ADULTS AND CHILDREN

STATED PREFERENCE STUDIES					
STUDY	**DATA COLLECTION**	**RISK TYPE**	**LOCATION**	**POPULATION**	**SAMPLE**
Alberini and Ščasný (2011)	2008	Respiratory health, cancer, and road safety	Milan, Italy	Parents	Probabilistic
Blomquist, Dickie, and O'Conor (2010)	2001	Asthma	Nine U.S. states	Parents of asthmatic children	Convenience
			Kentucky	General population	Probabilistic
Dickie and Gerking (2006)*	2002	Skin cancer	Hattiesburg, MS	Parents	Probabilistic
Dickie and Gerking (2007)*	2002	Skin cancer	Hattiesburg, MS	Parents	Probabilistic
Gerking, Dickie, and Veronesi (2014)*	2002	Skin cancer	Hattiesburg, MS	Parents	Probabilistic
	2008-2009	Leukemia	Orlando, FL	Parents	Probabilistic
Hammitt and Haninger (2010)	2007	Food-borne illness and motor vehicle accidents	U.S.	General population	Probabilistic (over-sampled parents)
Hammitt and Herrera (2017)	2012	Food-borne illness	France	General population	Probabilistic
REVEALED PREFERENCE STUDIES					
STUDY	**DATA COLLECTION**	**RISK TYPE**	**LOCATION**	**POPULATION**	**SAMPLE**
Jenkins, Owens, and Wiggins (2001)	1994-1997	Bicycle accidents (helmets)	U.S.	Bicycle helmet purchases	N/A
Mount et al. (2000)	1995-1997	Motor vehicle accidents	U.S.	Automobile purchases	N/A

Notes: N/A = not applicable. * These studies include data from the same survey on skin cancer. All studies are based on adult samples; samples of parents include parents of children under 18 years old, the exact ages vary across studies (see section 4.2.2 for more discussion). All listed studies meet evaluation criteria 1 and 6; the exhibit summarizes results for evaluation criteria 2, 3, 4, and 5; criterion 7 is discussed in the subsequent text.

As indicated by the exhibit, the Hattiesburg skin cancer survey is discussed in three publications (Dickie and Gerking 2006, Dickie and Gerking 2007, Gerking, Dickie, and Veronesi 2014) while the Blomquist, Dickie, and O'Conor (2010) article discusses two surveys.[24] In the discussion that follows, we focus on the count of studies rather than the count of publications, including seven unique stated preference surveys and two revealed preference studies.

The date of data collection varies by study design: the stated preference studies use datasets from 2001 to 2012, while the two revealed preference studies use datasets from 1994 to 1997. Thus the stated preference studies come closer to satisfying evaluation criteria 2 (data collected more recently).

Three of the nine studies (including one stated preference study and the two revealed preference studies) address the national U.S. population, as discussed under evaluation criteria 3 and 4 (data collected in the U.S., sample of the general population). However, only one is based on a probabilistic national sample (Hammitt and Haninger 2010); the other national studies address purchases of specific products (bicycle helmets and automobiles). Of the remaining six studies, two were conducted outside the U.S. and four use data from selected U.S. cities or states.

Four of the seven stated preference surveys sample parents and three sample the general population; all but one of the surveys rely on probabilistic sampling techniques. Unlike the other surveys, the Blomquist, Dickie, and O'Conor (2010) study elicits child and adult values from two distinct samples, raising questions about comparability.[25] The revealed preference studies match data on purchases with data from other sources on accident rates and attributes of those using these products.[26]

In addition, we evaluate the extent to which each study provides evidence of validity under evaluation criterion 7. As discussed previously, applying this criterion requires considering the evidence that each study presents regarding the quality of the data, the appropriateness of the methods used, and the validity of the results.

For stated preference studies, we evaluate whether the authors implement tests of scope sensitivity (i.e., the sensitivity of WTP to the magnitude of risk changes) and assess the results of these tests. In particular, we consider whether the results are consistent with economic theory on two dimensions: (1) WTP should be higher for larger risk reductions,

[24] More specifically, Dickie and Gerking (2006) and Dickie and Gerking (2007) both rely on the same skin cancer survey but focus on somewhat different issues. Gerking, Dickie, and Veronesi (2014) also include the same skin cancer survey, but supplement it with the results of an additional survey on leukemia.

[25] The child values are taken from a small convenience sample of parents with asthmatic children in nine states while the adult values are taken from a probabilistic sample in Kentucky that includes both those who are and are not familiar with asthma.

[26] Mount et al. (2000) primarily draw from the National Highway Traffic Safety Administration's Fatality Analysis Reporting System for years 1995-1997 and the 1995 National Personal Transportation Survey. Jenkins, Owens, and Wiggins (2001) use a national survey conducted by Consumer Reports in 1997 as well as nationwide datasets for population, bicycle ridership, and helmet usage.

and (2) WTP should increase nearly proportionally to the size of the risk change for small changes in risks. The second (proportionality) test is less frequently satisfied but nonetheless provides important evidence of validity (Hammitt and Graham 1999, Alolayan et al. 2017), as discussed in the prior chapter.[27] Exhibit 4-2 summarizes the results of these tests.

EXHIBIT 4-2. SENSITIVITY OF WTP TO RISK MAGNITUDE FOR STATED PREFERENCE SURVEYS

SURVEY	INCLUDES SCOPE TEST?	CLOSE-TO-PROPORTIONAL?
Alberini and Ščasný (2011)	Yes	Sensitive, but not proportional
Blomquist, Dickie, and O'Conor (2010) (nine states)	Yes	Sensitive, but ratio not reported
Blomquist, Dickie, and O'Conor (2010) (Kentucky)	Yes	Sensitive, but ratio not reported
Dickie and Gerking (2006, 2007), Gerking, Dickie, and Veronesi (2014) (skin cancer)*	Yes	Sensitive, but ratio not reported**
Gerking, Dickie, and Veronesi (2014) (leukemia)	Yes	Sensitive, but ratio not reported
Hammitt and Haninger (2010)	Yes	Yes
Hammitt and Herrera (2017)	Yes	Yes

Note: *These studies rely on data from the same survey on skin cancer. ** Dickie and Gerking (2007) indicate that the results are not proportional for some models.

All of the stated preference surveys provide evidence that WTP is higher for larger risk reductions, as indicated in Exhibit 4-2. However, the results are close to proportional in only two cases (Hammitt and Haninger 2010, Hammitt and Herrera 2017).[28] Several studies also provide additional evidence of validity. For example, Hammitt and Herrera (2017) use an innovative latent class design that allows for the derivation of a VSL drawn primarily from responses that satisfy four validity tests.

We also evaluate the validity of results presented in the two revealed preference studies. These studies consider averting behaviors; i.e., defensive measures or consumer products

[27] It is possible that the ratio of values for children to values for adults is valid for respondents who are insensitive to the size of the risk change. However, the lack of scope tests suggests that the researchers may not be aware of the importance of this concern, and the lack of sensitivity where these tests are administered may suggest that respondents do not understand the valuation task. Thus these results can be viewed as indicators of the overall quality and validity of the survey.

[28] Hammitt and Herrera (2017) find that responses to their second and third valuation questions diverge from economic theory. The authors cite respondent fatigue and lack of motivation for this divergence after the first set of valuation questions. Thus, they primarily rely on the responses to the initial set of valuation questions.

used to protect against perceived risks, including bicycle helmets (Jenkins, Owens, and Wiggins 2001) and vehicle safety features (Mount et al. 2000). In these studies, the value of the risk reduction is implicit in the behavior rather than explicitly addressed in survey questions, and researchers must develop statistical models to explore the relationship and control for other influencing factors, an inherently difficult task.

As noted earlier, wage-risk studies are often used to estimate VSL among working age adults. Many such studies have been conducted globally and researchers have explored a number of issues related to the data sources and model specifications used (see, for example, Viscusi 2013 and Viscusi 2017). In contrast, as suggested by the results of this review, relatively few studies have explored these issues in the context of valuing risks to children. The authors of both the papers we review indicate that more work is needed to validate the results and refine the methods and models. For example, Jenkins et al. note that their approach is novel and suggest that their results not be used in policy analysis. The Mount et al. study is a working paper and the authors describe their analysis as "preliminary."[29] We explore some related issues below.

We first consider whether the researchers investigate individuals' understanding of the size of the risk change. Neither publication makes clear whether individuals are likely to be aware of the magnitude of the risk reductions afforded by the products.[30,31] Second, we consider how the authors separately estimate the value of key inputs. Jenkins, Owens, and Wiggins (2001) assume that time and disutility costs (such as the degree of comfort) associated with using a bicycle helmet are zero, potentially underestimating the VSL for children and adults. However, the impact on the ratio between the VSLs for adults and children is unclear. Mount et al. (2000) also assume zero time costs associated with owning and operating a safer vehicle. This appears reasonable, as features such as airbags, vehicle design, and vehicle size—characteristics strongly linked to safety—require little or no additional input from drivers and passengers. The authors do account for the added fuel costs for larger vehicles.

The authors of both revealed preference studies note that their results are sensitive to key assumptions. The VSLs estimated by Jenkins, Owens, and Wiggins (2001) are sensitive to the assumed lifespan of a helmet and the rate of helmet usage. Their finding that the VSL is higher for adults than children—based upon the assumption that all helmets last four years—is reversed when assuming that children's helmets only last two years and adults' helmets last eight years. Similarly, the results presented by Mount et al. (2000) are highly sensitive to the assumed income elasticity of the VSL. The authors find that the average VSL for children is the same as the VSL for adults when income elasticity is

[29] Because the Mount et al. (2000) study has only been published as a working paper, it is not likely to have undergone as stringent review as the other studies.

[30] Generally, survey results are needed to test respondent understanding of the outcome they are asked to value. Thus it is difficult to evaluate this understanding in revealed preference studies unless they are supplemented by survey data.

[31] Jenkins, Owens, and Wiggins (2001) note that the assumption "that purchasers would continue to be willing to buy bicycle helmets after having been informed of the actual risk reduction seems plausible." While likely true, improved information on risks could plausibly shift the demand for bicycle helmets, affecting their prices and the implied VSL.

0.65. At larger elasticities, the value for children is greater than the value for adults; this finding is reversed at lower elasticities, where the adult VSL becomes higher than the value for children. More generally, Mount et al. develop a theoretical model of household decision-making so as to estimate the relationship of vehicle attributes to the value of risk reductions at different ages; further exploration and validation of this model seems warranted.[32]

Based on the evaluation criteria, we conclude that five publications are relatively weak and do not warrant further consideration. The Blomquist, Dickie, and O'Conor (2010) paper elicits child and adult values from two distinct samples, raising questions about comparability. The two revealed preference studies rely on older data sets and rely on novel approaches that require further investigation of validity (Jenkins, Owens, and Wiggins 2001, Mount et al. 2000). Of the remaining publications, we drop Dickie and Gerking (2006, 2007) from further discussion because they draw upon the same dataset for skin cancer risks as Gerking, Dickie, and Veronesi (2014). The latter publication also includes a survey addressing leukemia risks. In the following section, we provide more information on the four remaining publications.

4.1.2 DETAILED DISCUSSION OF HIGHER QUALITY STUDIES

As discussed above, four of the publications appear to satisfy many or all of our evaluation criteria. In this section, we discuss these publications in more detail, in the same order that they are presented in the preceding exhibits, and summarize their results. Some of these studies address both fatal and nonfatal risks; in these cases we discuss the results for both types of risks. We report the ratio of child and adult values based on the preferred or central estimates highlighted by the study authors.

Alberini and Ščasný (2011) develop a conjoint choice experiment to estimate parents' WTP to reduce fatal risks to themselves or to one of their children. The self-administered computer survey was completed by 1,906 parents of children less than 18 years old in Milan, Italy. The authors study three causes of death (respiratory illness, cancer, road traffic accidents) and present risk reductions from either general government programs or individual preventative actions randomized between either 2, 3, 5, or 7 deaths per 10,000 over a five-year period. One-time costs for the risk reductions range between €200 and €2,000. Across the three causes of death, the authors estimate a VSL of €4.7 million for children and €4.0 million for adults. The ratio of these estimates, 1.2, implies higher VSL for children; however, these VSLs are not found to be statistically different.[33]

Gerking, Dickie, and Veronesi (2014) address parents' WTP to reduce risks to themselves and one of their children from two sets of survey data. In both surveys, individuals consider the risk of illness and the conditional risk of death after becoming ill. First, the researchers present results from a 2002 contingent valuation survey of 610

[32] In this respect, the Mount et al. study is similar to the structural models that we exclude from this review, as discussed previously.

[33] P-value = 0.105.

parents in Hattiesburg, MS. Parents are asked to consider hypothetical sun lotions aimed at reducing the risk of getting skin cancer or the conditional risk of death from this disease. The costs of the products were randomly varied ($20 to $125 annually) as was their effectiveness across the two dimensions of risk. Risk reductions of 10 percent and 50 percent were offered to respondents in relation to their self-assessed skin cancer risks.

Second, Gerking, Dickie, and Veronesi (2014) estimate parents' WTP to reduce leukemia risks to themselves and to one of their children. The survey was distributed in 2008 and 2009 to a sample of 815 parents in Orlando, FL. The survey instrument is similar to the skin cancer survey instrument, but respondents were presented with vaccination options rather than sun lotions. The vaccinations are said to reduce the risk of getting leukemia or the conditional risk of dying from leukemia. Costs for the vaccines are randomly selected from among five values between $150 and $2,400, and risk reductions are again expressed as percentage reductions (10 percent or 90 percent) from self-assessed risks for both the parent and the child.

Determining the implications of the results for this report is complicated by the different models and assumptions used by the authors to address the issues of concern in their work. In particular, they are interested in exploring whether risk of morbidity and conditional mortality risk are perfect substitutes (i.e., the morbidity associated with a non-fatal case is negligible). If this is the case, then the total benefit of the risk reduction is captured by the value of reducing the mortality risk.

For skin cancer, they find that morbidity risk and conditional mortality are perfect substitutes; i.e., marginal WTP does not vary across the two conditions. They note that this finding is plausible given that skin cancers "generally can be cured by excision, particularly if diagnosed at an early stage" (p. 33). Parental marginal WTP for a one percentage point decrease in their own risk of skin cancer is $0.70 for morbidity and for conditional mortality; for their child, the value is $1.05 – a ratio of 1.5 (see Gerking et al. Table 6).

For leukemia, the results (also reported in Table 6) are less straightforward. The authors find that parental marginal WTP for a one percentage point decrease in their own risk is $7.61 for morbidity and less than zero (-$2.16) for conditional mortality; however, the latter is not statistically different from zero. For children, the conditions appear to be perfect substitutes: $8.11 for morbidity and for conditional mortality. The reasons for these findings and their implications are unclear. The authors note that respondents may have misunderstood the probabilities. Leukemia symptoms can be debilitating and involve significant suffering, and, although five-year mortality rates are relatively low, treatment results in remission rather than a cure. The ratio of the values of reducing risk of illness for children and adults in this case is about 1.1, suggesting slightly larger WTP to reduce morbidity risk to a child than to oneself.

The authors also translate the skin cancer results into WTP estimates for a 1 in 10,000 change in unconditional mortality risk. The results for unconditional risks appear more comparable to the adult VSLs used by Federal agencies; the agency values are generally derived from studies that do not involve significant morbidity prior to death, although death is not always immediate (for more discussion, see Gentry and Viscusi 2016,

Robinson and Hammitt 2016). For skin cancer, the authors find values of $19.63 for the parent and $31.61 for the child; a ratio of 1.6.[34] They note, however, that this estimate is not adjusted for the perceived latency of the risk; i.e., the fact that use of sun lotion in the current period reduces the risk of skin cancer in the future. They use estimates of the implicit discount rate to translate these values into estimates for the current period. The results are $28.04 for parents and $81.05 for children, or a ratio of 2.9.

For leukemia, the authors report that mean WTP to reduce a child's unconditional mortality risk is $1,659 but the distribution is highly skewed; the median value is $32. They do not report a separate estimate for unconditional mortality for parents, for whom risk of morbidity and conditional mortality were not found to be perfect substitutes. Instead, they sum the value of reducing morbidity and conditional mortality risks. The resulting median is $11.63; thus the median value for children ($32) is about 2.8 times the value for adults. The authors are unable to adjust these values for perceived latency, however, because related data were not collected in this survey. We therefore exclude this result when summarizing the findings, because it differs in significant respects from the other results for fatal risks.

Thus for fatal risks, we report the ratios for unconditional mortality from the skin cancer survey; 1.6 for latent risks and 2.9 if adjusted to reflect risks that occur in the current period. In section 4.2.1, we discuss the results of studies that address nonfatal risks and use the ratios discussed above (from Table 6) to illustrate the ratios between morbidity values for children and adults; i.e., 1.5 for skin cancer and 1.1 for leukemia.

Hammitt and Haninger (2010) estimate the VSL for children and adults in the United States using a nationally representative sample of 2,018 adults. The sample, drawn from the Knowledge Networks, Incorporated online panel, includes 967 parents of children aged 2-18 years. The risk reductions specified in the survey are either 1 or 2 cases per 10,000 per year, with starting bids for the safer food (due to changes in pesticide use) ranging from $10 to $5,000 per year. In addition, the authors include follow-up questions to elicit WTP to reduce the risk of a fatal motor-vehicle crash. VSL estimates in the study range from $12 million to $15 million for children and $6 million to $10 million for adults. They estimate that WTP to reduce risk to one's child is 1.8 times larger than to reduce risk to oneself.[35]

[34] These payments are annual; the authors convert these to a VSL by calculating the discounting present value of the payments over a 50 year life expectancy. The results are a VSL of $6.3 million for the parent and of $10.1 million for the child, or a ratio of 1.6.

[35] As noted earlier, in this and other studies, Hammitt and co-authors also elicit values for reducing risk to another adult. In this study, they estimate that WTP to reduce risk to another adult in the household is 1.2 times larger than WTP to reduce risk to oneself, though this estimate is not statistically significantly different from 1. If WTP to reduce risk to a child rather than to oneself is composed of two effects, child vs. adult and other person vs. self, then comparing WTP to reduce risk to a child with WTP to reduce risk to another adult implies that the difference in WTP associated with a child rather than an adult is a factor of 1.6. However, given that the adult VSL estimates used by Federal agencies usually address risks to oneself, we focus on the ratio between own risks and risk to the child in reporting the results of this and other studies.

Hammitt and Herrera (2017) examine the differences in adults' WTP to reduce fatal risks to themselves, to another household adult, and to their children, using a translation of the survey instrument in Hammitt and Haninger (2010). The authors administer a double-bounded binary choice elicitation instrument to a representative sample of 1,000 French adults over the internet. Fifty-one percent of adults in the sample have at least one child under 18 years old. For the questions that address reduced risks of fatality associated with pesticide residues on food, the authors present risk changes of either 1 or 2 cases per 10,000 per year and randomized initial bids ranging from €10 to €6,000 per year.

The authors use four key assumptions derived from economic theory as validity criteria: (1) WTP estimates should be close to proportional to the size of the risk reduction; (2) WTP estimates should be insensitive to small differences in the baseline risk; (3) income elasticity of WTP should be non-negative; and (4) WTP should not exceed respondent income. They use latent class analysis to subdivide respondents into groups giving relatively homogenous responses. Each group represents a weighted average of respondents and each respondent has a positive probability of membership in each class. Of the three latent classes, one gives responses consistent with the four key assumptions. The results indicate a higher VSL for children than for adults using the preferred latent class model, as well as using a conventional approach to estimating VSL. Their preferred model indicates a VSL of €6 million for children and €2 million for adults.[36] The ratio between these values is 3.0.

In Exhibit 4-3, we summarize the results of the above studies that best satisfy most or all of our evaluation criteria, focusing on the findings for fatal risks. The ratio between the VSL for children and the VSL for adults spans a relatively narrow range, from 1.2 to 3.0.

EXHIBIT 4-3. RATIO OF CHILD TO ADULT VSL FROM STUDIES THAT BEST SATISFY EVALUATION CRITERIA

STUDY	RATIO
Alberini and Ščasný (2011)	1.2[+]
Gerking, Dickie, and Veronesi (2014)	1.6, 2.9*
Hammitt and Haninger (2010)	1.8
Hammitt and Herrera (2017)	3.0

Notes: Includes those studies that best satisfy most or all of the evaluation criteria; + denotes ratio not statistically significantly different from 1. * Based on results of skin cancer survey.

[36] Deriving estimates using a conventional approach (i.e., no latent class analysis), the authors estimate a VSL of €10 million for children and €4 million for adults (ratio = 2.5). The authors find no significant difference between the values for an adult's own risk and risk to another adult.

4.2 SUPPLEMENTAL RESEARCH

We identified six publications that address nonfatal risks to both adults and children, including two publications that also address fatal risks and were discussed above.[37] We compare these publications to our evaluation criteria to gain additional insights into the relationship between the VSL for adults and children. Because fatal and nonfatal risks differ in significant respects, we do not necessarily expect to find the same relationships between child and adult values for nonfatal as for fatal risks.

We also explore the extent to which the studies we review address the variation in values by age of the child. In this discussion, we add three studies that address only children without providing comparable adult values.

4.2.1 STUDIES OF NONFATAL RISKS TO ADULTS AND CHILDREN

Exhibit 4-4 summarizes six publications that provide WTP estimates for reductions in nonfatal risks to both adults and children. While these estimates do not satisfy evaluation criterion 1 (addresses fatal risks), the publications meet criterion 6 (provides values for adults and children). Among these publications are two that also provide WTP estimates for fatal risk reductions and were discussed previously (Blomquist, Dickie, and O'Conor 2010, Gerking, Dickie, and Veronesi 2014).

All six publications are based on stated preference research. They include the results of eight surveys, since two publications address more than one survey (Blomquist, Dickie, and O'Conor 2010, Gerking, Dickie, and Veronesi 2014). Dickie and Gerking (2003) reports the results of a separate pilot study; the full study results are discussed in Gerking, Dickie, and Veronesi 2014).

Data collection for these studies spanned the years 2000 to 2014, and thus is relatively recent as specified under evaluation criterion 2. All of the studies meet criterion 3 (data collected in the U.S.); however, only three are national samples (criterion 4). The remainder address selected cities or states. All studies sampled either the general adult population or parents of children under 18 years old. Sampling was probabilistic in all but one case, consistent with evaluation criterion 5. As noted earlier, Blomquist, Dickie, and O'Conor (2010) compare adult and child values from different samples, one of which is a convenience sample, so the results are not as comparable as those where both values are derived from the same sample.

We also consider whether these articles provide evidence of validity under criterion 7. Two studies provide evidence that WTP is unambiguously higher for larger risk reductions as expected (Adamowicz et al. 2014, Hammitt and Haninger 2007), as do three of four models presented by Hammitt and Haninger (2017). Only one of four models presented by Dickie and Gerking (2003) is consistent with this expectation. As discussed

[37] Some of these studies do not explicitly state that the illness is not fatal, but review of the studies suggests that the results primarily reflect morbidity rather than mortality. We include Hammitt and Haninger (2007) in this section because although it includes conditional mortality risks, the fatal risks were very small and the authors find they are not a significant predictor of WTP.

in the previous section, Blomquist, Dickie, and O'Conor (2010) and Gerking, Dickie, and Veronesi (2014) find that WTP is sensitive to the size of the risk change but do not test if it is proportional. Hammitt and Haninger (2007) find that WTP is significantly less sensitive to the risk change than required by conventional theory. However, Hammitt and Haninger (2017) find that WTP is nearly proportional to the specified risk change. The authors' 2017 results further satisfy the theoretical prediction that WTP is insensitive to small changes in baseline risk, providing additional evidence of validity. Thus among the studies of nonfatal risks to adults and children, Hammitt and Haninger (2017) provides the strongest evidence of validity, in addition to largely satisfying the remaining evaluation criteria.

Of these six publications, two are described in section 4.1.2 (Blomquist, Dickie, and O'Conor 2010, Gerking, Dickie, and Veronesi 2014). Below, we discuss three of the remaining four. While Dickie and Gerking (2003) satisfies several of our evaluation criteria, it is a pilot study; we do not discuss that study in detail and instead focus on the full scale study discussed in Gerking, Dickie, and Veronesi (2014). As in the previous section, we report the ratio of child and adult values based on the preferred or central estimates reported by the authors of each study.

EXHIBIT 4-4. EVALUATION OF STUDIES OF NONFATAL RISKS TO ADULTS AND CHILDREN

STUDY	DATA COLLECTION	RISK TYPE	LOCATION	POPULATION	SAMPLE
Adamowicz et al. (2014)	2014	Heart disease	U.S.	Parents	Probabilistic
Blomquist, Dickie, and O'Conor (2010)	2001	Asthma treatment	Nine U.S. states	Parents of asthmatic children	Convenience
			Kentucky	General population	Probabilistic
Dickie and Gerking (2003)*	2000	Skin cancer	Hattiesburg, MS	Parents	Probabilistic
Gerking, Dickie, and Veronesi (2014)*	2002	Skin cancer	Hattiesburg, MS	Parents	Probabilistic
	2008-2009	Leukemia	Orlando, FL	Parents	Probabilistic
Hammitt and Haninger (2007)	2004	Food-borne illness	U.S.	General population	Probabilistic
Hammitt and Haninger (2017)	2008	Exposure to environmental contaminants	U.S.	General population	Probabilistic

Notes: *Dickie and Gerking (2003) is a pilot for the skin cancer study discussed in Gerking, Dickie, and Veronesi (2014). All studies are stated preference surveys based on adult samples; samples of parents include parents of children under 18 years old, the exact ages vary across studies (see section 4.2.2 for more discussion). The estimates discussed in this section do not meet evaluation criterion 1 (address fatal risks) but meet criterion 6 (provide values for adults and children. The exhibit summarizes results for evaluation criteria 2, 3, 4, and 5; criterion 7 is discussed in the subsequent text.

Adamowicz et al. (2014) empirically examine different household decision-making models for estimating parents' WTP to reduce health risks to themselves and their children. Using an online U.S. sample of 432 pairs of married parents with at least one child between the ages of 6 and 16, the authors estimate WTP to reduce risks of heart disease using a contingent valuation instrument.[38] Respondents are asked whether they would purchase vaccines that provide risk reductions of 10 or 70 percent of the respondents' self-assessed heart disease risks or 20 or 80 percent of the risks they assess for their child.[39] Risk reductions are randomly selected, as are the first-year costs ranging between $10 and $160. Despite finding that parents' WTP to reduce their child's risk of heart disease is 1.5 times greater than WTP to reduce their own risks, the difference in estimated WTP to reduce risk to child or self is not significant at the 5 percent level.[40]

Hammitt and Haninger (2007) designed and administered a contingent valuation survey to elicit WTP to reduce risks of food-borne illness. Using a nationally representative sample of 3,766 respondents in 2004, the authors estimate parents' WTP to reduce risks of illness to themselves and to a child in their household (if present). Roughly one-third of sample households have children between two and 18 years old. Similar to Hammitt and Haninger (2010), summarized in section 4.1.2, risk reductions are described as produced by a stringent government safety program aimed at reducing the probability of food-borne illness (in this case from microbial contamination). Initial bids range from $0.04 to $4.00 per meal for a risk reduction of 1 case per 10,000. The results show that the value per statistical case ranges from $23,600 to $30,500 for children and $8,300 to $16,400 for adults. After controlling for severity and duration of illness, the value per statistical case is estimated to be 2.2 times greater for a child than for an adult.

Hammitt and Haninger (2017) estimate WTP for reductions in the risks of several illnesses, including influenza, migraines, skin and lung cancer, and Parkinson's disease. In total, 2,184 respondents provide separate WTP estimates for risk reductions that accrue to themselves, to a child in their household (if present), and to another adult in their household (if present). Thirty-three percent of respondents provide WTP estimates for a child and 77 percent provide responses for another adult. Risk reductions of either 1 or 2 cases per 10,000 per year are attributed to government screening tests and preventative medicine to reduce risks from exposure to environmental contaminants. Initial cost levels are randomly varied across respondents and range between $10 and $2,000. The authors

[38] Although heart disease is often fatal, this study appears to focus on morbidity. It is framed as WTP to reduce the risk of coronary artery disease and describes related symptoms. It is not clear whether the survey includes information on the risk of death and a separate VSL is not reported.

[39] As is the case with the Gerking and Dickie studies, a concern with this design is that the risk reduction is endogenous to the respondent; it is an exogenous fraction of an endogenous baseline. That could bias the estimate of the rate of substitution; e.g., someone who places a high value on risk reduction might overestimate their baseline risk, which means the calculated rate of substitution could be biased downward.

[40] Mothers are willing to pay $5.62 to reduce their child's risk of heart disease by 1 in 100 and $5.48 to reduce their own risk of heart disease by the same amount (ratio = 1.0). Fathers are willing to pay $4.08 to reduce their child's risk of heart disease by 1 in 100 and $2.14 to reduce their own risk of heart disease by the same amount (ratio = 1.9). The average of these ratios is roughly 1.5.

find that WTP to reduce risks to a child are three times greater than WTP to reduce one's own risks.[41]

In Exhibit 4-5, we summarize the results for nonfatal risks, including those from the studies discussed in the prior section and the three studies discussed above. Similar to the results for fatal risks, these ratios range from 1.1 to 3.0, providing additional evidence that values for risks to children are likely to be greater than or equal to the value of risks to adults.

EXHIBIT 4-5. RATIO OF CHILD TO ADULT VALUES FOR NONFATAL RISKS FROM STUDIES THAT BEST SATISFY EVALUATION CRITERIA*

STUDY	RATIO
Adamowicz et al. (2014)	1.5+
Gerking, Dickie, and Veronesi (2014)	1.1, 1.5
Hammitt and Haninger (2007)	2.2
Hammitt and Haninger (2017)	3.0

Notes: Includes those studies that best satisfy most of the evaluation criteria; + denotes ratio not statistically significantly different from 1. In several of these studies, the estimated ratio may include some consideration of the risk of fatality.

4.2.2 VARIATION BY AGE OF CHILD

The studies reviewed above address children at a variety of ages. The age ranges considered are summarized in Exhibit 4-6 for those eight publications that largely satisfy our evaluation criteria, including both those that address fatal risks and those that address nonfatal risks (listed in Exhibits 4-3 and 4-5). While most studies include children ages 16 and below, only three studies include infants. Exhibit 4-6 also reports whether studies provide evidence that WTP declines with children's age.

[41] However, the authors note that WTP to reduce risk to another adult is 2.5 times larger than for a risk to oneself, which implies that WTP to reduce risk to a child is only 1.2 times larger than WTP to reduce risk to an adult.

EXHIBIT 4-6. RELATIONSHIP TO AGE OF CHILD

STUDIES OF FATAL RISKS TO ADULTS AND CHILDREN		
STUDY	AGE RANGE OF CHILDREN	DOES WTP DECLINE WITH CHILD'S AGE?
Alberini and Ščasný (2011)	0 – 17	No
Gerking, Dickie, and Veronesi (2014)	2 – 12 (skin cancer survey)	Yes
	1 – 16 (leukemia survey)	No
Hammitt and Haninger (2010)	2 – 18	Yes
Hammitt and Herrera (2017)	0 – 17	N/R
STUDIES OF NONFATAL RISKS TO ADULTS AND CHILDREN		
STUDY	AGE RANGE OF CHILDREN	DOES WTP DECLINE WITH CHILD'S AGE?
Adamowicz et al. (2014)	6 - 16	N/R
Gerking, Dickie, and Veronesi (2014)	2 – 12 (skin cancer survey)	Yes
	1 – 16 (leukemia survey)	No
Hammitt and Haninger (2007)	2 - 18	Yes
Hammitt and Haninger (2017)	0 – 17	No

As indicated by the exhibit, only some of these studies provide evidence that WTP may vary by the age of the child. For fatal risk reductions, two surveys suggest that estimated WTP declines with the age of the child (Gerking, Dickie, and Veronesi 2014, skin cancer survey; Hammitt and Haninger 2010); but two surveys find no significant impact (Alberini and Ščasný 2011; Gerking, Dickie, and Veronesi 2014, leukemia survey). Hammitt and Herrera (2017) do not report whether WTP differs by children's age.

The evidence from studies of nonfatal risk reductions is similarly mixed. While two surveys find that WTP may decline with children's age (Gerking, Dickie, and Veronesi 2014, skin cancer survey; Hammitt and Haninger 2007), results from two other surveys find no significant relationship (Gerking, Dickie, and Veronesi 2014, leukemia survey; Hammitt and Haninger 2017). Adamowicz et al. (2014) do not report whether WTP may differ by children's age. We are not aware of any study that finds that WTP increases with children's age.

In addition to the studies presented above, we identify three that estimate WTP for changes in risks that accrue only to children and meet our selection criteria. We do not discuss these studies in detail because they do not provide consistently-derived estimates

for risks to adults and children and are less useful for deriving adjustment factors. We do, however, review these studies for further evidence of whether WTP estimates differ across children's age groups. These three studies are summarized in Exhibit 4-7.

EXHIBIT 4-7. EVALUATION OF STUDIES THAT ONLY ADDRESS RISKS TO CHILDREN

STUDIES OF FATAL RISKS TO CHILDREN					
STUDY	DATA COLLECTION	RISK TYPE	LOCATION	POPULATION	SAMPLE
Loomis et al. (2009)	N/R	Drinking water risks	Colorado, U.S.	Parents of infants	Convenience
STUDIES OF NONFATAL RISKS TO CHILDREN					
STUDY	DATA COLLECTION	RISK TYPE	LOCATION	POPULATION	SAMPLE
Guerriero et al. (2017)	2013	Asthma treatment	Naples, Italy	School children (age 7- 19) and their parents	Convenience
Ščasný and Zvěřinová (2014)	2014	Chemicals in consumer products	Italy, Netherlands, United Kingdom	Potential parents; general population	Probabilistic

Notes: N/R = no reported. All studies are stated preference surveys. "Potential parents" refers to adults aged 18 to 65 who would like to have children in the future.

All three studies use stated preference methods. Loomis et al. (2009) estimates WTP for fatal risk reductions, focusing on the effects of nitrates in drinking water on infants. The other two studies focus largely on nonfatal risks. Ščasný and Zvěřinová (2014) provide WTP estimates for the effects of chemicals on specific birth outcomes (e.g., low birth weight, birth defects). The Guerriero et al. (2017) study addresses asthma; as noted earlier, it is unusual because it queries children as well as adults. Each of the three studies provides evidence that WTP increases for larger risk reductions. However, only Guerriero et al. (2017) report whether the WTP estimates change in proportion to the size of the risk change; they find that the changes are not proportional.

Of the three studies, only one reports age-specific WTP estimates (Guerriero et al. 2017). The researchers find that estimated WTP declines with children's age, based on their sample of both parents and children.

In sum, the studies we review address differing age ranges and their findings on the relationship between the age of the child and WTP for fatal or nonfatal risk reductions vary. Some find that WTP decreases as the child's age increases. Others do not find a statistically significant relationship. Thus more work would be needed to determine the extent to which the ratio of adult values to the values for children varies depending on the age of the child.

CHAPTER 5 | CONCLUSIONS AND NEXT STEPS

In the previous chapters, we discuss the conceptual framework for valuing risks to children and describe our analytic approach and findings in detail. In this chapter, we summarize our findings and discuss their implications. We also describe the limitations of this work and suggest possible next steps.

5.1 SUMMARY OF FINDINGS

Our criteria-driven literature review provides evidence that the VSL for children may be higher than the VSL for adults. Among the four publications that satisfy many of our evaluation criteria, we find that the VSL for children exceeds the VSL for adults by a factor of 1.2 to 3, with a midpoint of roughly 2. In particular, the one study that comes closest to satisfying all of our evaluation criteria (Hammitt and Haninger 2010) finds that VSL for children is higher than VSL for adults by a factor of about 1.7. Although fatal and nonfatal risks vary in many important respects, the results of studies evaluating nonfatal risks are generally consistent with those evaluating fatal risks. Some studies suggest that WTP may decrease as the child's age increases; however, the rate of decrease varies and only a minority of the studies support this conclusion.

As indicated by our review, the number of studies that provide comparable estimates of the value of fatal risk reductions for adults and children, while growing, remains relatively small, and the validity of the results is unclear in many cases. Most of these studies use stated preference methods; more work is needed to improve the approaches for estimating these values using revealed preference methods. The finding that the values for children are equal to or greater than the values for adults is consistent across studies. However, the size of the difference and the extent to which it varies by age of the child is uncertain.

5.2 FUTURE RESEARCH NEEDS

To build on this review, several types of additional research may be useful. First, CPSC may wish to further explore the implications of the studies we identify through the use of meta-analysis. Meta-analysis uses statistical methods to combine the results of multiple studies and to investigate sources of variation.[42] It can be viewed as a way to develop "best" or "central" estimates; to explore the extent to which values are affected by

[42] One advantage of meta-analysis is that it allows the analyst to more easily include all of the estimates provided in each article, rather than relying on the authors' judgement of which estimate is best. See, for example, Viscusi (2017) for more discussion of this issue in the context of adult VSL estimates.

variation in the analytic approach and the study context; or to predict how values changes in response to changes in the characteristics of the risk or of those affected.

In addition, or alternatively, structured expert elicitation could be used to provide more insights into these results and perhaps develop valuation functions that vary by the age of the child. This approach is often used in risk analysis and provides a systematic framework for obtaining judgments about the value of specific parameters. Carefully selected experts are asked to provide their judgments in the form of a probability distributions that characterizes their beliefs about the value of the parameter (e.g., that the parameter is equally likely to be larger or smaller than the median of the expert's distribution). The experts are typically asked to explain how they used evidence to support these judgments. This type of elicitation is designed to avoid well-known heuristics and biases that can lead to poor judgment.

Structured expert elicitation has been used in a pilot study to estimate the VSL for adults (Roman et al. 2012). Using three experts, the study also elicited an adjustment factor for children; based on the then-available evidence, one expert judged there should be no adjustment, one judged it should be positive and the third judged it more plausible to be positive than negative. That approach could be refined and updated to recruit additional experts familiar with the literature on valuing risk reductions to children, which has evolved considerably since the 2008 elicitations. Structured expert elicitation can be used to develop "best" or "central" estimates and characterize the uncertainty surrounding these values.

Additional primary research may also be useful. CPSC has previously explored approaches to developing WTP studies that focus specifically on the types of nonfatal risks it regulates, including both revealed and stated preference methods (IEc 2017). That work provides a starting point for developing options for valuing fatal as well as nonfatal risks to children. Such research could also be used to further assess the extent to which values vary depending on the age of the child. In addition, the studies we identify and evaluate in this report typically address risks that differ significantly from the types of risks CPSC regulates; for example, involving illnesses rather than injuries. Primary research could provide further insights into how to best tailor the values to these injury-related risks.

REFERENCES

Adamowicz, W., M. Dickie, S. Gerking, et al. 2014. Household Decision-Making and Valuation of Environmental Health Risks to Parents and Their Children. *Journal of the Association of Environmental and Resource Economists*, 1(5): 481-519.

Agee, M.D. and T.D. Crocker. 1994. Parental and Social Valuations of Child Health Information. *Journal of Public Economics*, 55(1): 89-105.

Agee, M.D. and T.D. Crocker. 1996. Parental and Child Lead Exposure: Inferences from the Demand for Chelation Therapy. *Journal of Human Resources*, 33(3): 677-691.

Agee, M.D. and T.D. Crocker. 2007. Children's Health Benefits of Reducing Environmental Tobacco Smoke Exposure: Evidence from Parents who Smoke. *Empirical Economics*, 32(1): 217-237.

Agee, M.D. and T.D. Crocker. 2008. Does Parents' Valuation of Children's Health Mimic their Valuation of Own Health. *Journal of Population Economics*, 21(1): 231-249.

Alberini, A., I. Bateman, G. Loomes, and M. Ščasný. 2010. *Valuation of Environment-Related Health Risks for Children.* OECD Publishing.

Alberini, A. and M. Ščasný. 2011. Context and the VSL: Evidence from a Stated Preference Study in Italy and Czech Republic. *Environmental and Resource Economics*, 49(4): 511-538.

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

Barron, A.C., T. Lee, J. Taylor, T. Moore, M.H. Passo, T.B. Graham, T.A. Griffin, A.A. Grom, D.J. Lovell, and H.I. Brunner. 2004. Feasibility and Construct Validity of the Parent Willingness-To-Pay Technique for Children with Juvenile Idiopathic Arthritis. *Arthritis and Rheumatism*, 51(6): 899-908.

Bergstrom, T. 1982. *When Is a Man's Life Worth More than His Human Capital*? In: Jones-Lee, M. (Ed.), The Value of Life and Safety, Amsterdam.

Bergstrom, T. 2006. Benefit-cost Analysis in a Benevolent Society. *American Economic Review*, 96: 339-351.

Birchenall, J.A. and R.R. Soares. 2009. Altruism, Fertility, and the Value of Children: Health Policy Evaluation and Intergenerational Welfare. *Journal of Public Economics*, 93(1-2): 280-295.

Blomquist, G.C., M. Dickie, and R.M. O'Conor. 2010. Willingness to Pay for Improving Fatality Rates and Asthma Symptoms: Values for Children and Adults of All Ages. *Resource and Energy Economics*, 33(2); 410-425.

Brandt, S., F.V. Lavin, and M. Hanemann. 2012. Contingent Valuation Scenarios for Chronic Illnesses: the Case of Childhood Asthma. *Value in Health*, 15(8): 1077-1083.

Carlin, P.S. and R. Sandy. 1991. Estimating the Implicit Value of a Young Child's Life. *Southern Economic Journal*, 58(1): 186-202.

Carlsson, F, D. Daruvala, and H. Jaldell. 2010. Preferences for Lives, Injuries, and Age: A Stated Preference Survey. *Accident Analysis and Prevention*, 42(6): 1814-1821.

Cawley, J. 2008. Contingent Valuation Analysis of Willingness to Pay to Reduce Childhood Obesity. *Economics and Human Biology*, 6(2): 281-292.

Cordoba, J.C. and M. Ripoll. 2014. The Elasticity of Intergenerational Substitution, Parental Altruism, and Fertility Choice. Iowa State University Economic Working Paper.

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

Dickie, M. 2005. Parental Behavior and the Value of Children's Health: A Health Production Approach. *Southern Economic Journal*, 17(4): 855-872.

Dickie, M. and S. Gerking. 2003. Parents' Valuation of Latent Health Risks to their Children. *Risk and Uncertainty in Natural Resource and Environmental Economics*, Ch. 4: 251-278.

Dickie, M. and S. Gerking. 2006. Valuing Children's Health: Parental Perspectives. *Economic Valuation of Environmental Health Risks to Children*, OECD, Ch. 3.

Dickie, M. and S. Gerking. 2007. Altruism and Environmental Risks to Health of Parents and their Children. *Journal of Environmental Economics and Management*, 53: 323-341.

Dickie, M. and V.L. Messman. 2004. Parental Altruism and the Value of Avoiding Acute Illness: Are Kids Worth More than Parents? *Journal of Environmental Economics and Management*, 48(3): 1146-1174.

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

Gentry, E.P. and W.K. Viscusi. 2016. The Fatality and Morbidity Components of the Value of Statistical Life. *Journal of Health Economics*, 46: 90-99.

Gerking, S. and M. Dickie. 2013. Valuing reductions in environmental risks to children's health. *Annual Review of Resource Economics*, 5(1), 245-260.

Gerking, S., M. Dickie, and M. Veronesi. 2014. Valuation of Human Health: An Integrated Model of WTP for Mortality and Morbidity Risk Reductions. *Journal of Environmental Economics and Management*, 68(1): 20-45.

Guerriero, C., J. Cairnes, F. Bianchi, and L. Cori. 2017. Are Children Rational Decision Makers When They are Asked to Value Their Own Health? A Contingent Valuation Study Conducted with Children and their Parents. *Health Economics*, 1-14.

Hammitt, J.K. 2000a. Estimating Contingent Valuation of Environmental Health Risks: The Proportionality Test. *Association of Environmental and Resource Economists Newsletter*, 20(1): 14-19.

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

Hammitt, J. K. 2017. Extrapolating the Value per Statistical Life Between Populations: Theoretical Implications. *Journal of Benefit-Cost Analysis*, 8(2), 1-11.

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

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

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

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

Hammitt, J.K. and D. Herrera. 2017. Peeling Back the Onion: Using Latent Class Analysis to Uncover Heterogeneous Responses to Stated Preference Surveys. *Journal of Environmental Economics and Management*, in press.

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

Industrial Economics, Incorporated. 2017. *Improving Estimates of the Value of Nonfatal Injury Risk Reductions: Summary of Research Options*. Prepared for the U.S. Consumer Product Safety Commission by J. Baxter, R.W. Paterson, W. Raich and S. Ramakrishna in collaboration with L.A. Robinson and J.K. Hammitt.

Jenkins, R.R., N. Owens, and L.B. Wiggins. 2001. Valuing Reduced Risks to Children: The Case of Bicycle Safety Helmets. *Contemporary Economic Policy*, 19(4): 397-408.

Jones-Lee, M.W. 1992. Paternalistic Altruism and the Value of a Statistical Life. *Economic Journal*, 102: 80-90.

Khanna, M., et al. 2017. *SAB Review of EPA's Proposed Methodology for Updating Mortality Risk Valuation Estimates for Policy Analysis*. Memorandum to E. Scott Pruitt, EPA Administrator, from the EPA Science Advisory Board and Environmental Economics Advisory Committee. EPA-SAB-17-005.

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

Leung, J. and J. Guria. 2006. Value of Statistical Life: Adults Versus Children. *Accident Analysis and Prevention*, 38(6): 1208-1217.

Loomis, J., P. Bell, H. Cooney, and C. Asmus. 2009. A Comparison of Actual and Hypothetical Willingness to Pay of Parents and Non-Parents for Protecting Infant Health: The Case of Nitrates in Drinking Water. *Journal of Agricultural and Applied Economics*, 41(3): 697-712.

Mansfield, C., F.R. Johnson, and G. Van Houtven. 2006. The Missing Piece: Valuing Averting Behavior for Children's Ozone Exposures. *Resource and Energy Economics*, 28(3): 215-228.

Ministry of Finance. 2012. Official Norwegian Reports. Cost-Benefit Analysis.

Mount, T.D., W. Weng, W. Schulze, and L. Chestnut. 2000. Automobile Safety and the Value of Statistical Life in the Family: Valuing Reduced Risks for Children, Adults and the Elderly. US EPA NCEE Economic Report.

Niens, C., M. Strack, and R. Marggraf. 2014. Parental Risk Perception of Mycotoxins and Risk Reduction Behaviour. *British Food Journal*, 116(6): 1014-1030.

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

Prosser, L.A., K. Payne, D. Rusinak, P. Shi, and M. Messonnier. 2013. Using a Discrete Choice Experiment to Elicit Time Trade-off and Willingness-to-Pay Amounts for Influenza Health-Related Quality of Life at Different Ages. *PharmacoEconomics*, 31(4): 305-315.

Robinson, L.A. and J.K. Hammitt. 2013. Skills of the Trade: Valuing Health Risk Reductions in Benefit-Cost Analysis. *Journal of Benefit-Cost Analysis*. 4(1): 107–130.

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

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

Roman, H.A., J.K. Hammitt, T.L. Walsh, and D.M. Stieb. 2012. Expert Elicitation of the Value per Statistical Life in an Air Pollution Context. *Risk Analysis*, 32: 2133-2151.

Ščasný, M. and I. Zvěřinová. 2014. *Stated-preference Study to Examine the Economic Value of Benefits of Avoiding Selected Adverse Human Health Outcomes Due to*

Exposure to Chemicals in the European Union. Report for the European Chemicals Agency.

Takeuchi, K., A. Kishimoto, and T. Tsuge. 2008. Altruism and Willingness to Pay for Reducing Child Mortality. Kobe University. Working Paper.

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

U.S. Department of Health and Human Services 2016. *Guidelines for Regulatory Impact Analysis: U.S. Department of Health and Human Services*. Prepared by L.A. Robinson, J.K. Hammitt, and J. Baxter under subcontract to Industrial Economics, Incorporated and Mathematica Policy Research.

U.S. Department of Transportation. 2016. "Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Transportation Analyses—2016 Adjustment." Memorandum to Secretarial Officers and Modal Administrators from M. Moran, Acting General Counsel, and C. Monje, Assistant Secretary for Transportation Policy.

U.S. Environmental Protection Agency. 2000. *Guidelines for Preparing Economic Analyses*. EPA-240-R-00-003.

U.S. Environmental Protection Agency. 2003. *Children's Health Valuation Handbook*. EPA-100-R-03-003.

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

U.S. Environmental Protection Agency. 2016. *Valuing Mortality Risk Reductions for Policy: A Meta-Analytic Approach*. Prepared by the U.S. Environmental Protection Agency's Office of Policy, National Center for Environmental Economics, for review by the EPA's Science Advisory Board, Environmental Economics Advisory Committee.

U.S. Office of Management and Budget. 2003. *Circular A-4: Regulatory Analysis.*

Viscusi, W.K. 2013. Using Data from the Census of Fatal Occupational Injuries (CFOI) to Estimate the 'Value of a Statistical Life'. *Monthly Labor Review*. Bureau of Labor Statistics. https://www.bls.gov/opub/mlr/2013/article/using-data-from-the-census-of-fatal-occupational-injuries-to-estimate-the.htm

Viscusi, W,K. 2017. Best Estimate Selection Bias in the Value of a Statistical Life. *Journal of Benefit-Cost Analysis*, FirstView.

Williams, S.H. 2013. Statistical Children. *Yale Journal on Regulation*, 30(1): 63-124.