WORKING PAPERS

N° TSE –1018

June 2019

"Valuing Children's Fatality Risk Reductions"

Lisa A. Robinson, William Raich and James K. Hammitt

Toulouse School of Economics

Valuing Children's Fatality Risk Reductions

Lisa A. Robinson
Harvard University Center for Health Decision Science and Center for Risk Analysis

William Raich
Industrial Economics, Incorporated

James K. Hammitt
Harvard University Center for Health Decision Science and Center for Risk Analysis and
Toulouse School of Economics, University of Toulouse Capitole

January 2018

Abstract: The estimates used by U.S. Federal agencies and others to value reductions in fatality risks generally reflect adults' willingness to trade income for changes in their own risks. Several studies have now been completed that address the value of risk reductions to children. We review these studies for quality and applicability based on selection and evaluation criteria derived from recent discussions of best practices. To limit the effects of between-study variability, we searched for studies that estimate values for both adults and children using a consistent approach. We find seven studies that meet our selection criteria. The studies suggest that the value for children exceeds the value for adults by a factor of 1.2 to 3.0, with a midpoint of 2.1. Studies that estimate the value of reductions in nonfatal risks lead to similar results. Although some studies suggest that the divergence between child and adult values may decrease as the child ages, more work is needed to determine the extent to which these multipliers vary across age groups.

Keywords: benefit-cost analysis, value per statistical life, willingness to pay, health risk valuation, regulation

1.0 Introduction

To value fatal risk reductions in benefit-cost analysis, U.S. Federal regulatory agencies generally apply the same values for children and adults (EPA 2000, DOT 2016, HHS 2016).[1] While each agency developed its estimates at different times based on different reviews of the literature, the values were all derived from studies of adult willingness to pay for changes in their own risks. As of 2016, the central value per statistical life (VSL) estimates used by these agencies were generally between $9 million and $10 million.

The number of studies that investigate the value of reducing risks to children has increased substantially in recent years, providing an opportunity to explore whether different values should be used.[2] While the results are diverse, they generally suggest that individuals place a higher value on reducing risks to children than to adults. Some guidance now recommends this approach. For example, for risk reductions that accrue to children, the Norwegian Ministry of Finance (2012) suggests multiplying adult values by a factor of 2.0 and the Organisation of Economic Cooperation and Development (OECD 2012) suggests multiplying adult values by a factor of 1.5 to 2.0. However, the underlying research has not been subject to detailed review for quality and applicability. This article fills that gap, focusing on values for use in U.S. regulatory analysis.

The research base for adult values is extensive and has been subject to substantial review, providing a strong foundation for these values. In contrast, while growing, the research base for children is much smaller. Thus our review focuses on developing factors to adjust adult VSL estimates when valuing risks to children, rather than on developing independent VSL estimates.

We begin by discussing the conceptual framework for valuing fatal risk reductions. We then describe the approach we used to conduct our review of the literature and the results, concluding with a summary of the implications.

[1] The U.S. Environmental Protection Agency (EPA) is now updating its recommendations to reflect the results of recent research and advice from its Science Advisory Board (EPA 2016, Khanna et al. 2017).
[2] We define children as those under age 18 (i.e., age zero through 17).

2.0 Conceptual framework

In benefit-cost analysis, 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 use that money to buy. Thus the amount of money individuals are willing to exchange for a good or service provides an estimate of its value; i.e., the opportunity cost of not providing it.

Within this context, the value of fatal risk reduction is generally expressed as a population-average VSL. VSL represents an individual's willingness to trade off spending on other goods and services for a small reduction in his or her own risk of death. It is the individuals' marginal rate of substitution between money and fatality risk (Hammitt 2000, 2017). VSL can be estimated as the value of a specified risk change divided by the risk change. For example, if an individual's willingness to pay (WTP) for a 1 in 10,000 reduction in his or her own fatal risk in the current year is $900, then that individual's estimated VSL is $9 million ($900 divided by 1 in 10,000).

2.1 Valuation methods

Because these risk reductions are not directly bought and sold in the marketplace, two methods are commonly used to estimate VSL: revealed preferences and stated preferences.[3] Revealed preference studies use data on actual behaviors and market decisions to infer how individuals trade off risks and wealth, such as decisions to purchase protective equipment or to select a safer

[3] 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.

job. Stated preference studies instead rely on survey research techniques to elicit values from respondents.

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 occupational fatality. 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 reduction from the value of potentially confounding attributes, such as reductions in nonfatal risks, time costs, and comfort or convenience. One question that arises when using these studies is whether the risks associated with the marketed good or service are sufficiently similar to the risks associated with a regulation to provide a suitable measure of value.

Stated-preference studies rely on survey research involving contingent valuation or discrete choice experiments. Researchers ask individuals to consider hypothetical scenarios and directly or indirectly value a change in risk. For example, they may ask respondents whether they would be willing to pay $900 annually for 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 U.S. Federal agencies in estimating VSL for application in their regulatory analyses. Historically, agencies have relied more frequently on wage-risk studies than on studies of averting behavior or stated preferences, due in part to the availability of studies of each type and in part to concerns about quality and applicability (EPA 2000, DOT 2016, HHS 2016). However, wage-risk studies include only employed individuals and do not address the value of risks to young children. Thus valuing risks to children requires relying on studies of averting behavior and stated preference research.

2.2 Approaches for valuing risks to children

The studies used by Federal agencies in developing their guidance generally 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 notion of consumer sovereignty; i.e., that each individual is the best (or the most legitimate) judge of his or her own wellbeing. However, eliciting a child's WTP for his or her own risk reduction is problematic.

Researchers typically expect that children will find it difficult to make informed, rational choices on the trade-offs between fatal risks and monetary wealth, especially at very young ages. Understanding the concept of risk 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.[4]

Instead, 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.[5] In benefit-cost analysis, counting preferences both for oneself and for others raises issues related to distinguishing 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. While including pure altruism does not affect the determination of whether the benefits of a policy exceed its costs, counting the preferences of a paternalistic altruist may do so by placing a greater weight on some outcomes. Because distinguishing between pure and paternalistic altruism is very difficult, altruism is generally not included in the values conventionally used in benefit-cost analysis.

[4] A few studies have investigated children's ability to comprehend these concepts and make these trade-offs, such as Guerriero et al. (2017). However, more work is needed to address issues such as children's lack of control over the allocation of their household's financial resources.

[5] A third approach is the adult-as-child approach, which asks adults to place themselves in the position of children (Dockins et al. 2002, EPA 2003). However, this approach is rarely used in part because it is difficult to implement effectively.

For children whose preferences are not directly incorporated into the analysis, the relevant question is whether society at large or parents are the best judge of the child's wellbeing.[6] Studies that elicit values from the general population indicate 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 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.[7]

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. The practice of eliciting WTP from one parent may be justified by the notion of a parental consensus around such decision-making. Researchers have also modeled household decisions using a pluralistic approach in which preferences are allowed to differ across household members. These preferences are then pooled to reach a collective decision.

While researchers have explored some 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.

3.0 Analytic approach

Our goal is to estimate an adjustment factor that can be applied to independently-derived adult VSL estimates to estimate VSL for children in the U.S. The research base for adults is extensive

[6] For more discussion, see: Dockins et al. (2002), EPA (2003), and Alberini et al. (2010).
[7] Williams (2013) also notes that parental WTP 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 the child's safety, the parent is implicitly making a tradeoff between the child's safety and the child's future income.

and has been subject to substantial review, providing a strong basis for estimating adult values. The research base for children is limited and does not provide as strong a foundation for developing monetary values. Thus, in our review, we focus on studies that indicate the ratio of adult and child values, since this ratio may be more stable and well-estimated than the monetary values. In other words, we consider only studies that use a consistent approach to estimate values for both groups; i.e., that use the same study design to evaluate a substantially similar outcome for both children and adults within the same population.[8] Our approach includes three phases: criteria development, literature search, and literature review. We discuss the first two phases below, then discuss the results in the next section.

3.1 Criteria development

Prior to identifying relevant primary research studies, we established two sets of criteria to guide our work. First, we developed selection criteria to identify 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 some 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. We adapted these criteria to reflect our focus on the risks to children ages 0 through 17. Some 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, because the valuation literature on adult risks is relatively large and well-developed,

[8] If we were to instead compare VSL estimates across studies that address adults and studies that address children, the results could be misleading. Such an approach would require separating the effects of factors such as the methodology used, the types of risks addressed, and the population sampled, which can substantially influence the monetary values. It would be difficult to know whether any differences in the results were attributable to the focus on adults versus children or to other differences between the studies.

while the literature on children is much smaller, we use somewhat less stringent criteria to avoid ignoring studies that may provide useful insights.

3.1.1 Selection criteria

The selection criteria we used to identify these studies are presented in Table 1 and described below.[9]

Table 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 impacts. To achieve this goal, the studies underlying the VSL estimates should be accessible to those reviewing the analyses. We considered publicly available sources including peer-reviewed journal articles, papers published as part of a working paper series, and government documents (e.g., guidance documents or expert panel reports).

Under criterion 3, we limit our review to studies based on data collected within the past 30 years (between 1987 and 2017).[10] 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.

Criterion 4 addresses the country in which the research was conducted. Ideally, for analyses of U.S. policies, we would rely on studies of the U.S population because cultural and numerous

[9] In our original work, we also reviewed studies of nonfatal risks. In this article, we focus on studies that address reductions in fatal risks and adapt our discussion of the criteria to reflect this narrower focus. We summarize the additional insights provided by the studies that address nonfatal risks when discussing our results.

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

other factors affect preferences across countries (Hammitt 2017). However, we include studies from a wider range of countries in our initial selection because they may provide useful information and the overall number of studies is relatively small. We use population-average income as a rough proxy for differences in preferences across countries. We select studies from high income countries defined 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.[11]

Criteria 5 and 6 aim to ensure that the outcomes valued are similar to the outcomes addressed in the adult VSL studies to which adjustment factors might be applied (EPA 2010, DOT 2016, HHS 2016). More specifically, criterion 5 focuses on studies that expressly address specified risk changes, consistent with the studies that are typically used to estimate the adult VSL. We exclude studies that instead estimate the value of a change in life expectancy or an outcome that occurs with certainty. We also exclude studies that consider the value of a policy or other intervention more holistically, without separating the value of the risk reduction from the value of other attributes.

Criterion 6 is primarily relevant to stated preference studies and requires that they elicit WTP rather than willingness to accept compensation (WTA).[12] 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).

[11] To estimate income, we relied on 2016 GNI per capita data from the World Bank (http://data.worldbank.org/indicator/NY.GNP.PCAP.CD, as viewed July 2017). At that time, GNI per capita was $56,180 for the U.S., which means that we included studies conducted in countries with 2016 GNI per capita of $28,090 or higher. The World Bank derives these estimates using exchange rates following its Atlas method.
[12] Revealed preference studies often address a market equilibrium rather than a change that can be easily characterized as WTP or WTA.

3.1.2 Evaluation criteria

We developed five criteria to guide our evaluation of each study that met our selection criteria, as summarized in Table 2 and described below.

Table 2. Evaluation Criteria

1. Data collected more recently.
2. Data collected in the United States.
3. Based on a national sample.
4. Based on a probabilistic sample (not a convenience sample).
5. Provides evidence of validity.

The first four evaluation criteria narrow the focus of the selection criteria to reflect our relative weighting of the studies based on their applicability. Because we are interested in preferences of the current U.S. population, and the ratio of child-to-adult values may vary over time and across countries, criteria 1 and 2 indicate that we prefer recent U.S. studies. Most major Federal regulations affect the population nationwide; thus criterion 3 addresses whether the study considers a narrower subgroup (e.g., a specific city or region) rather than the general population. The fourth 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 5 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 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 (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.[13]

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 several cases, we are able to easily determine whether studies satisfy our evaluation criteria (e.g., whether they address the U.S. population). 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 exploring other recent reviews (e.g., Alberini et al. 2010, Gerking and Dickie 2013).[14] We 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. We also searched for studies using the keywords "(children OR child) AND (WTP OR VSL)" in the EconLit bibliographic database. When we found unpublished conference papers and presentations or

[13] 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 VSL differs and it is not clear what VSL is appropriate for small risk changes of different magnitudes.

[14] 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.

working papers, we 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 additional studies.

We then applied the selection criteria presented in Table 1 to the resulting studies. We found eight publications that used a consistent approach to value fatal risks to adults and children and meet these criteria. These eight publications cover seven unique studies as discussed below.[15]

4.0 Results

In this section, we discuss the results of our review of the studies that meet the selection criteria presented in Table 1, applying the evaluation criteria in Table 2. We then discuss supplemental evidence provided by studies of nonfatal risks.

4.1 Evaluation of studies of fatal risks

As summarized in Table 3, the eight publications that address fatal risks include a total of five stated preference surveys and two revealed preference studies, for a total of seven unique studies.[16]

Table 3. Study Descriptions

Study	Data Collection Date	Risk Type	Location	Population Surveyed	Age of Children	Sampling Method
Stated Preference Studies						
Alberini and Ščasný (2011)	2008	Respiratory health, cancer, road safety	Milan, Italy	Parents	0 - 17	Probabilistic
Dickie and Gerking (2006)†	2002	Skin cancer	Hattiesburg, MS	Parents	2 - 12	Probabilistic
Dickie and Gerking (2007) †	2002	Skin cancer	Hattiesburg, MS	Parents	2 - 12	Probabilistic
Gerking, Dickie, and Veronesi (2014) †	2002	Skin cancer	Hattiesburg, MS	Parents	2 - 12	Probabilistic
	2008-2009	Leukemia	Orlando, FL	Parents	1 – 16	Probabilistic
Hammitt and Haninger (2010)	2007	Foodborne illness, motor vehicle accidents	U.S.	General population	2 – 18	Probabilistic

[15] One publication includes a survey conducted in the Czech Republic as well as in Italy (Alberini and Ščasný 2011). We only include results from surveys that meet selection criterion 4 (data from a high income country) and exclude the Czech results.

[16] Of these eight publications, six are journal articles, one is a book chapter (Dickie and Gerking 2006), and one is an unpublished working paper (Mount et al. 2000).

Hammitt and Herrera (2018) ††	2012	Foodborne illness	France	General population	0 - 17	Probabilistic
Revealed Preference Studies						
Jenkins, Owens, and Wiggins (2001)	1994-1997	Bicycle accidents (helmets)	U.S.	Bicycle helmet purchasers	5 - 14	N/A
Mount et al. (2000)	1995-1997	Motor vehicle accidents	U.S.	Automobile purchasers	0 - 15	N/A

Notes: N/A = not applicable. †These three publications include data from the same survey on skin cancer. ††This article was available on early view at the point when our search was conducted, but has since been published.

As indicated by the table, the Hattiesburg skin cancer survey is discussed in three publications (Dickie and Gerking 2006, Dickie and Gerking 2007, Gerking, Dickie, and Veronesi 2014), the third of which also discusses a separate leukemia survey. In the discussion that follows, we focus on the count of studies rather than the count of publications, including five 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 2002 to 2012, while the revealed preference studies use datasets from 1994 to 1997. Thus the stated preference studies come closer to satisfying evaluation criterion 1 (data collected more recently).

Three studies (one stated preference study and the two revealed preference studies) address members of the U.S. population, as discussed under evaluation criteria 2 and 3 (data collected in the U.S., national sample). However, only one represents the general population (Hammitt and Haninger 2010); the other national studies address purchasers of specific products (bicycle helmets and automobiles). Of the remaining four studies, two were conducted outside the U.S. and two use data from specific U.S. cities.

Three of the five stated preference surveys sample parents and two sample the general adult population; all rely on probabilistic sampling techniques consistent with criterion 4. The revealed

preference studies match data on purchases with data from other sources on accident rates and on attributes of those using these products.[17]

Determining the extent to which each study provides evidence of validity under evaluation criterion 7 is more complicated. Applying this criterion requires considering the evidence that the researchers provide 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., examine the sensitivity of WTP to the magnitude of the risk change) 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, 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 as discussed previously. All of the stated preference surveys provide evidence that WTP is higher for larger risk reductions. However, the authors report that the results are close to proportional in only two cases (Hammitt and Haninger 2010, Hammitt and Herrera 2018).[18,19] Several studies provide additional evidence of validity.

Interpreting the results of two of the five stated preference studies is difficult, however. The skin cancer study reported in Dickie and Gerking (2006, 2007) and Gerking, Dickie, and Veronesi (2014), and the leukemia study reported in Gerking, Dickie, and Veronesi (2014), address the risk of illness and the conditional risk of death after becoming ill. Determining the implications

[17] 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.

[18] Hammitt and Herrera (2018) find that responses to their second and third valuation questions diverge from economic theory. The authors suggest respondent fatigue and lack of motivation may account for this divergence after the first set of valuation questions. Thus, they primarily rely on the responses to the initial set of valuation questions.

[19] Hammitt and co-authors also elicit values for reducing risk to another adult. 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.

of the results for the ratio between adult and child values for fatal risks requires sorting out the effects of nonfatal risks on these estimates.

In the 2014 article, the researchers translate the skin cancer results into WTP estimates for a 1 in 10,000 change in unconditional mortality risk, which is more comparable to the adult VSLs used by Federal agencies than the conditional estimates. Agency values are generally derived from studies that do not involve significant morbidity prior to death, although death is not always immediate (Gentry and Viscusi 2016, Robinson and Hammitt 2016). For skin cancer, the findings depend on whether the values are adjusted for the perceived latency of the risk; i.e., that undertaking protective measures in the current period reduces the risk of skin cancer in the future. For leukemia, the authors report estimates for mean WTP to reduce a child's unconditional mortality risk, but do not provide a comparable estimate for parents due to challenges related to interpreting the results. Thus we include the ratios for unconditional mortality from the skin cancer survey but exclude the leukemia survey from our findings.

We also evaluate the validity of the results of the two revealed preference studies. These studies consider averting behaviors; i.e., defensive measures or consumer products used to protect against perceived risks, including bicycle helmets (Jenkins, Owens, and Wiggins 2001) and vehicle safety features (Mount et al. 2000). The validity of these studies is difficult to assess, in part because we did not find other studies that use similar methods to which the results could be compared. However, the authors of both studies indicate that more work is needed to validate the results and refine the methods and models.[20] 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."

In both studies, the results are sensitive to assumptions. 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 VSL for children and adults with an

[20] In contrast, as noted earlier, wage-risk studies are often used to estimate VSL among working age adults. Around 200 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) -- leading to refinement of the approaches used and improved understanding of related uncertainties.

uncertain impact on the ratio of these values. Their finding that VSL is higher for adults than children is based upon the assumption that all helmets last four years; it is reversed if the authors instead assume that children's helmets last two years and adults' helmets last eight years. Similarly, the Mount et al. (2000) results are sensitive to the assumed income elasticity of the VSL. They find that average VSL for children is the same as average VSL for adults if income elasticity is 0.65. At larger elasticities, the value for children is greater than the value for adults; the reverse is true at lower elasticities. In addition, neither publication makes clear whether individuals are likely to be aware of the magnitude of the risk reductions afforded by the products.[21,22]

In Table 4, we report the ratio of child and adult values based on the preferred or central estimates highlighted by the study authors. We exclude Dickie and Gerking (2006, 2007) because they report the results of the same skin cancer survey as Gerking, Dickie, and Veronesi (2014), and exclude the results for leukemia from the latter study because of the lack of an adult value for unconditional mortality risks. All studies find ratios greater than 1.0, except for the two revealed preference studies.

Table 4. Ratio of Child to Adult VSL

Study	Ratio
Stated preference studies	
Alberini and Ščasný (2011)	1.2†
Gerking, Dickie, and Veronesi (2014) (skin cancer)	1.6, 2.9††
Hammitt and Haninger (2010)	1.8
Hammitt and Herrera (2018)	3.0
Revealed preference studies	
Jenkins, Owens, and Wiggins (2001)	0.7
Mount et al. (2000)	1.0

Notes: †Ratio not statistically significantly different from 1. ††Ratios reflect results with and without adjustment for latency.

[21] 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.

[22] 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.

We find that the two revealed preference studies are relatively weak in terms of applicability and quality. They rely on older data sets and on novel approaches that require further investigation of validity. Although the stated preference studies vary in the extent to which they meet our evaluation criteria, they generally appear better suited for application. Thus our review suggests that the ratio of child-to-adult VSL estimates is likely in the range of 1.2 to 3.0, with a mid-point of 2.1.

4.2 Supplemental evidence

In addition to the above studies, we identified four publications that address nonfatal risks to both adults and children, and otherwise meet our selection criteria. These include three publications not discussed previously (Adamowicz et al. 2014, Hammitt and Haninger 2007, Hammitt and Haninger 2017), as well as one that also addresses fatal risks and was discussed above (Gerking, Dickie, and Veronesi 2014).[23,24] Because the latter study includes two surveys, the total count of studies across these four publications is five. We review these studies to gain more insights. However, because fatal and nonfatal risks differ in significant respects, we do not necessarily expect to find the same relationships between child and adult values.

All five studies are based on stated preference research conducted in the U.S. between 2000 to 2014 and were probabilistic samples of either the general adult population or of parents. All but Gerking, Dickie, and Veronesi (2014) were based on national samples. These studies generally provide evidence that WTP is higher for larger risk reductions as expected, but some do not report the extent to which the estimates change proportionately. In their study of foodborne illness, Hammitt and Haninger (2007) find that WTP is significantly less sensitive to the risk

[23] Although it meets our selection criteria, we exclude Dickie and Gerking (2003) from this list, because it is a pilot for the skin cancer study that we discuss in detail.

[24] Some of these publications do not explicitly state that the illness is not fatal, but the results appear to primarily reflect morbidity rather than mortality, with the exception of the Gerking, Dickie, and Veronesi (2014) study discussed earlier. We also 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.

change than required by conventional theory. In their study of environmental exposures, Hammitt and Haninger (2017) finds that WTP is nearly proportional to the specified risk change.

The ratio of child-to-adult values found in these five surveys is reported in Table 5, based on the preferred or central estimates highlighted by the study authors. Similar to the results for fatal risks, these ratios range from 1.1 to 3.0, providing additional evidence that the value of reducing risks to children is likely to be greater than or equal to the value for adults.[25]

Table 5. Ratio of Child to Adult Values for Morbidity

Study	Ratio
Adamowicz et al. (2014)	1.5 †
Gerking, Dickie, and Veronesi (2014) (skin cancer)	1.5
Gerking, Dickie, and Veronesi (2014) (leukemia)	1.1
Hammitt and Haninger (2007)	2.2
Hammitt and Haninger (2017)	3.0

Notes: †Ratio not statistically significantly different from 1. In several of these studies, the estimated ratio includes some consideration of the risk of fatality.

The studies reviewed above address children at a variety of ages, which raises questions about the extent to which the results may vary depending on 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 (2018) 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

[25] Other studies find similar results. For example, Blomquist et al. (2011) compare the results for children and adults across separate samples and find that the ratio of child to adult values is about 1.7 for VSL and 1.5 for asthma control when evaluated at the mean age for each group. They also find that the relationship between VSL and age is nonlinear, rising and falling at different points in the lifecycle.

2017). Adamowicz et al. (2014) do not report whether WTP may differ by children's age. 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.

5.0 Conclusion

Our review indicates that the number of studies on the value of reducing risks to children, while small, is increasing. We select and evaluate six studies that provide VSL estimates for both children and adults, focusing on those that address outcomes that are reasonably similar to the outcomes addressed in studies used by Federal agencies to estimate VSL for adults.[26] These include four stated preference studies and two revealed preference studies. However, the quality and applicability of the revealed preference studies is comparatively weak. The four stated preference studies suggest that the VSL for children exceeds the VSL for adults by a factor of 1.2 to 3, with a midpoint of 2.1.

Although fatal and nonfatal risks vary in many important respects, we also review five studies that address nonfatal risks, and find the results are generally consistent with those evaluating fatal risks – suggesting that values for children equal or exceed adult values. More work is needed, however, to explore the extent to which the values for fatal and nonfatal risks vary by the age of the child.

Acknowledgements: This article builds on work conducted for the U.S. Consumer Product Safety Commission (CPSC) under contract to Industrial Economics, Incorporated (IEc). The CPSC project manager was Charu Krishnan; the IEc project manager was Jennifer Baxter. We thank them both as well as William Zamula, Gregory Rodgers, and Robert Franklin of CPSC for their very helpful comments on our earlier work. The views expressed in this article are our own and do not reflect the views nor the endorsement of CPSC.

[26] We exclude a seventh study, the Gerking, Dickie, and Veronesi (2014) leukemia research, from these summary counts, because it does not report a ratio of values for unconditional fatality risks for children and adults.

References

Adamowicz, Wiktor, Mark Dickie, Shelby 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.

Alberini, Anna, Ian Bateman, Graham Loomes, and Milan Ščasný. 2010. *Valuation of Environment-Related Health Risks for Children.* OECD Publishing.

Alberini, Anna and Milan 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, Mohammad A., John S. Evans, and James K. Hammitt. 2017. Valuing Mortality Risk in Kuwait: Stated-Preference with a New Consistency Test. *Environmental and Resource Economics* 66: 629–646.

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

Blomquist, Glenn C., Mark Dickie, and Richard 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.

Corso, Phaedra S., James K. Hammitt, and John 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, Mark and Shelby Gerking. 2003. Parents' Valuation of Latent Health Risks to their Children. *Risk and Uncertainty in Natural Resource and Environmental Economics* (J. Wesseler, H-P. Weikard, R.D. Weaver, eds.) Edward Elgar.

Dickie, Mark and Shelby Gerking. 2006. Valuing Children's Health: Parental Perspectives. *Economic Valuation of Environmental Health Risks to Children*. OECD Publishing.

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

Dockins, Chris, Robin R. Jenkins, Nichole Owens, Nathalie B. Simon, and Lanelle B. Wiggins. 2002. Valuation of Childhood Risk Reduction: The Importance of Age, Risk Preferences, and Perspective. *Risk Analysis* 22(2): 335-346.

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

Gerking, Shelby and Mark Dickie. 2013. Valuing Reductions in Environmental Risks to Children's Health. *Annual Review of Resource Economics* 5(1): 245-260.

Gerking, Shelby, Mark Dickie, and Marcella 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, Carla, John Cairnes, Fabrozio Bianchi, and Liliana 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* Early View.

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

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

Hammitt, James K. and Kevin 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, James K. and Kevin 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, James K. and Kevin 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, James K. and Daniel Herrera. 2018. Peeling Back the Onion: Using Latent Class Analysis to Uncover Heterogeneous Responses to Stated Preference Surveys. *Journal of Environmental Economics and Management* 87: 165-189.

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

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

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

Khanna, Madhu 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, Catherine 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.

Ministry of Finance (Norway). 2012. Cost-Benefit Analysis. Official Norwegian Reports NOU 2012: 16.

Mount, Timothy D., Weifeng Weng, William Schulze, and Laurie Chestnut. 2000. Automobile Safety and the Value of Statistical Life in the Family: Valuing Reduced Risks for Children, Adults and the Elderly. U.S. Environmental Protection Agency, National Center National Center for Environmental Economics Economic Report (draft).

OECD. 2012. *Mortality Risk Valuation in Environment, Health and Transport Policies*. Paris: OECD Publishing.

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

Tuncel, Tuba and James 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*. Washington, D.C.: Office of the Assistant Secretary for Planning and Evaluation.

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.

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

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

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