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THE MORTALITY COST OF EXPENDITURES

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This paper updates the mortality cost of expenditures, which has relevance to a broad range of policies, including regulations, wars, and COVID-19 restrictions. Because changes in income lead to changes in mortality risk, health investments costing more per life saved than a threshold cost-per-life-saved cutoff level are expected to increase mortality risk. This article discusses the mechanisms driving this relationship and provides recent empirical support. The 2019 cost-per-life-saved cutoff level at which expenditures increase mortality risk has a lower bound of \$83.1 million and an upper bound of \$133.8 million, with a midpoint of \$108.5 million. (*JEL* D61, I18, J17, K32)

I. INTRODUCTION

Various government expenditures, voluntary private expenditures, and private expenditures mandated by government regulation seek to reduce mortality risk. While a reduction in risk is often the avowed objective of expenditures related to health, safety, security, and the environment, these efforts may also have unintended consequences that increase risks. The primary focus of this paper is on the increased mortality risk generated by government-mandated expenditures,[1] where the economic mechanism for this indirect effect primarily derives from the reduction in funds households have available for other health-enhancing expenditures. In particular, having more financial resources enables households to reduce their health risks in a variety of ways, such as by moving to a neighborhood with less crime or making greater investments in health care.

There are several roles for the mortality cost of expenditures in policy evaluation. First, sometimes mortality cost effects are of independent interest, particularly in situations where a comprehensive benefit–cost analysis (BCA) is not feasible. Social distancing policies in response to the recent COVID-19 pandemic entail economic costs to achieve reductions in illness risks. But these economic costs are not purely monetary, as economic dislocations also have health consequences. Using the mortality cost of expenditures estimates presented in this article, it is feasible to estimate the mortality costs associated with these economic dislocations. Similarly, Viscusi (2019) uses the mortality cost of expenditures to calculate the net mortality costs of the Vietnam War and all recent Middle East wars. While a net mortality cost impact analysis of wars or a pandemic is feasible, a comprehensive benefit–cost assessment of these events is much harder.

Second, within the context of a conventional BCA, proper calculation of risk effects will account for the net mortality benefits of the policy, including the ramifications that result from the mortality cost of the associated expenditures (Viscusi 1994a). Current practices that

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1. This paper focuses primarily on government-mandated expenditures and their effects on risks. While not discussed in detail here, governments also impose restrictions on output that indirectly affect income, and by extension expenditures on risk.

ABBREVIATIONS

BCA: Benefit–Cost Analysis
BLS: U.S. Bureau of Labor Statistics
GAO: U.S. General Accounting Office
HHA: Health–Health Analysis
MPSH: Marginal Propensity to Spend on Health
OMB: U.S. Office of Management and Budget
OSHA: Occupational Safety and Health Administration
PPP: Purchasing Power Parity
VSL: Value of a Statistical Life

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ignore these effects overstate the net mortality-related benefits of regulations. This omission is potentially influential since the U.S. Office of Management and Budget's (OMB) annual reports on regulation conclude that mortality effects constitute the largest measured component of all regulatory benefits.

Third, although executive branch agencies must prepare a BCA for significant rules, agencies may not be constrained by such analyses when their statutory mandate enables them to forgo balancing benefits and costs. Morrall (1986) provided the first comprehensive documentation of regulations with costs per life saved that greatly exceeded many estimates of the value of life at that time, with values of $100 million or more per expected life saved in some cases.

Even in the presence of restrictive statutory provisions that may exclude consideration of costs in setting regulatory standards, it would conceivably be feasible to base policies on whether on balance they are risk-reducing. For example, Viscusi (1994b) argues that legislation prohibiting consideration of costs contributed to increased interest in various forms of risk–risk analysis, suggesting forms of analysis focused on risks could be substitutes for BCA when agencies have restrictive statutory guidance. The assessment of the net mortality effects of regulations in a procedure that also accounts for the mortality cost of expenditures is known as health–health analysis (HHA). Application of HHA conceivably may demonstrate that a regulation on balance will increase, rather than decrease mortality risks, so that the policy should not be adopted even if decisions based on a BCA are not permitted.

The OMB periodically issues revised guidance for BCA of government regulations. Although the Trump administration is revisiting some criteria for evaluating regulatory policies, thus far neither the mortality cost of expenditures concept nor HHA has been adopted in official guidance documents. Two explanations seem most likely for the continued failure to adopt these concepts. First, the earliest uses of HHA by policymakers were not well understood by the public or policymakers and generated considerable controversy. In 1992, the OMB suspended review of a proposed regulation from the Occupational Safety and Health Administration (OSHA) on the grounds that OSHA's regulation might increase mortality risk because of the adverse mortality cost effect. In a return letter from the OMB to OSHA, OMB analysts produced a back-of-the-envelope HHA.[2] OMB's analysts suggested that the rule, which targeted air contaminants from construction and maritime activities, might increase mortality risk because of the mortality costs of the expenditures induced by the regulation. The letter generated a firestorm of criticism for making the counterintuitive claim that a regulation aiming to reduce risk might increase it instead. Two OMB analysts were called to testify before Congress, and the Chairman of the Committee on Government Affairs requested a U.S. General Accounting Office (GAO) study to explore the matter further. The GAO (1992) study, published later that year, was highly critical of OMB's use of HHA.

A second, perhaps more important, reason that HHA has not been integrated into policy evaluation practices is that BCA has gained greater acceptance over the past few decades. Nevertheless, the OMB benefit–cost requirements to analyze rules only pertain to new significant regulations, not policies in general.[3] Moreover, even those rules that are analyzed may not be subjected to a strict requirement that benefits exceed costs. Given these realities, application of HHA often can serve a constructive function.

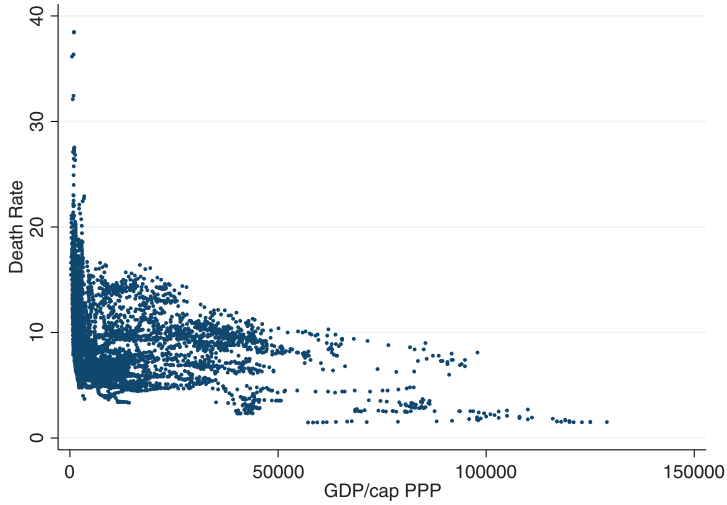
Now may be an opportune time to revisit the mortality costs of expenditures more generally. Many of the early criticisms leveled at HHA, such as those made by the GAO in its 1992 report, have turned out to be overblown. For example, one such criticism claimed that the income–mortality relationship, upon which HHA is based, is a correlation but that causation has not been established. However, as the sections below document, implementing HHA need not rely on statistical correlations between income and mortality. Furthermore, we are not suggesting that HHA replace benefit–cost tests, but rather that being able to assess the net mortality effects of policies may be instructive. Nothing here should be taken as an endorsement of HHA over BCA. But until BCA becomes more institutionalized throughout the federal government, we believe there is a constructive role for HHA in policymaking.

This paper is organized as follows. Section II discusses the channels by which income losses are likely to increase mortality risk. Mental health

2. See letter of James MacRae, Acting Administrator and Deputy Administrator, Office of Information and Regulatory Affairs, OMB, to Nancy Risque-Rohrbach, Assistant Secretary for Policy, Department of Labor, March 10, 1992.

3. See Section 3(f) of Exec. Order No. 12866, Regulatory Planning and Review, 58 Fed. Reg. 51,735 (October 4, 1993).

FIGURE 1
Income and Mortality, Select Countries (1990–2016): GDP Per Capita at Purchasing Power Parity and Deaths per 1,000 People per Year



Source: World Bank Development Indicators.

and the socioeconomic status of children are two of the most important channels by which income can affect mortality. Empirical evidence is also provided to support the general conclusion that expenditures on healthcare vary with income, and that these expenditures are effective, even if only modestly, at reducing mortality. Section III reviews estimates of the "cost-per-life-saved cutoff," which is a threshold cost-effectiveness level for life-saving expenditures. A direct approach based on correlations between income and mortality and an indirect approach based on economic theory both exist. Our preferred approach here is the indirect approach. Section IV provides an updated estimate of the cutoff using the indirect approach, estimating a cutoff range from \$83.1 million to \$133.8 million (2019 dollars), which is viewed as an upper bound on the cutoff. These estimates also provide a benchmark for assessing the mortality cost of expenditures more generally. Section V concludes by discussing the relative merits of analyzing the mortality cost of expenditures, both as a component of BCA and as a supplement to BCA.

II. LINKAGES BETWEEN INCOME AND MORTALITY

The mortality-cost-of-expenditures linkage derives from the strong correlation found between income and mortality. Figure 1 plots the relationship globally between GDP per capita and the death rate in countries. The negative relationship between income and mortality also holds for the United States (Dowd et al. 2011), and the positive association between income and life expectancy in the United States is well-documented (Chetty et al. 2016).

The oft-observed phenomenon that higher income is associated with reduced risk has come to be known as the "richer is safer" relationship, and it is often associated with Berkeley political scientist Aaron Wildavsky (Wildavsky 1981). All else equal, reductions in personal income will inevitably increase mortality risk, so long as some nonzero fraction of income is spent on risk reduction. Only in the extreme case where no income at all is spent on risk reduction, or when expenditures are completely ineffective, will government interventions have no countervailing cost with respect to mortality risk. While this general relationship is not controversial, because risk reduction is a normal good, that is, one that is demanded more as income rises, the magnitude of the effect remains in dispute.

Although a review of the causal mechanisms linking income and mortality is beyond the scope of this study, there are two mechanisms in particular that are worth highlighting: mental health and early childhood socioeconomic status. The psychological stress that often follows negative income shocks can lead to behavioral responses, such as increases in risky behavior. Similarly, prolonged periods of stress can lead to elevated use of the body's physiological systems, which leads to health problems (Smith 1999). There is also considerable evidence that supports the general conclusion that parental economic status influences child health as well as adult health (Almond and Currie 2011; Case, Lee, and Paxson 2008; Case, Lubotsky, and Paxson 2002; Currie 2009; Currie and Rossin-Slater 2015).

These drivers of the income–health relationship share some common characteristics. They are long run in nature, suggesting the health effects of income shocks are often not experienced immediately. The mechanisms are likely to be hard to identify in studies relying on relatively few years of data. Moreover, disentangling the effects of education and other confounders from the underlying circumstances of one's childhood upbringing is likely to be difficult. These empirical challenges lend support for a theoretical approach to estimating the cutoff, as is taken in this paper.

There is also considerable evidence that income and spending on mortality risk reduction are positively related. If the income elasticity of spending on mortality risk is positive, that will establish an economic mechanism by which decreases in income will adversely affect health-related expenditures by the individual. Indeed, the positive impact of income on the value of a statistical life (VSL) is well established, as estimates of the income elasticity of the VSL are consistently positive (Bellavance, Dionne, and Lebeau 2009; Costa and Kahn 2004; OECD 2012; Viscusi 2018).

A final question relates to the overall effectiveness of expenditures at reducing mortality risk. While the effect of healthcare spending on health outcomes found in the literature is typically modest, the relationship nonetheless tends to be positive (Gallet and Doucouliagos 2017). A number of recent studies of the effectiveness of government healthcare expenditures have found that such expenditures can generate significant reductions in mortality specifically (Sommers 2017; Sommers, Baicker, and Epstein 2012; Sommers, Long, and Baicker 2014). Furthermore, other expenditures beyond health expenditures are also likely to impact mortality risk.

Thus, the empirical evidence indicate a positive correlation between income and mortality. One explanation for this relationship is the positive income elasticity of the VSL, which explains that higher income earners spend more on mortality risk reduction. Combined with the evidence that negative shocks to income have harmful effects on health, especially in early childhood, and that expenditures on healthcare have a significant, even if modest, effect on health and, specifically, mortality, the economic mechanisms connecting income and mortality become more clear.

III. THE MORTALITY COST OF EXPENDITURES

The cost-per-life-saved cutoff (the "cutoff") is a threshold cost-effectiveness level beyond which life-saving expenditures will be counterproductive in that they can be expected to induce more fatalities than they prevent. This cutoff will vary over time and across different populations, and it also establishes the rate at which expenditures lead to mortality risks, thus making it possible to estimate fatalities induced by expenditures as a component of any BCA.

Decision scientist Ralph Keeney developed the first formal model for estimating fatalities induced by income losses, finding that for every \$7.25 million (1980 dollars) in costs, one statistical fatality can be expected to be induced (Keeney 1990). Chapman and Hariharan (1994) develop a similar empirical model but controls for initial health status as a means to account for reverse causality (i.e., poor health causing lower income). The study's authors estimate the cutoff at \$12.2 million (1990 dollars). Keeney updated his model in 1997, estimating the cutoff at between \$5 million and \$14 million (1991 dollars), depending on the distribution of costs, noting that the cutoff is likely to be lower for low-income individuals and for African Americans (Keeney 1997). This emphasis on distributional impacts would show up in other studies. Chapman and Hariharan (1996) estimate that the cutoff is about twice as high for the richest 20% of the population as for the poorest 20%.

Kuchler et al. (1999) attempt an original analysis of the net mortality consequences of a regulation, exploring the repercussions of a potential oyster harvesting ban in the Gulf of Mexico. Using Keeney's (1997) estimate of the cutoff, and combining this figure with projections of income losses to fishermen that would result from a ban, these authors estimated that the ban, if implemented, would induce 8–12 fatalities annually, while preventing roughly 17 premature deaths annually from food poisoning. However, application of mortality risk analysis to other policies finds that the risk reduction balance is often less favorable. Hahn, Lutter, and Viscusi (2000) analyzed 24 federal regulations, finding that a majority of the regulations in the sample increase mortality risk, though aggregate mortality risk was estimated to fall for all regulations together.

Interestingly, a burgeoning literature began to emerge from Scandinavians around the turn of the century. Elvik (1999) estimates the cutoff in Norway at between 25 million and 317 million NOK (1995 prices), which translates to \$3.8 million to \$47.5 million (1995 U.S. dollars). Gerdtham and Johannesson (2002) use longitudinal data (tracking individuals for between 10 and 17 years) for a sample of randomly selected Swedes. After controlling for initial health status, they estimated the cutoff at between \$6.8 million and \$9.8 million (1996 U.S. dollars), depending on how costs are distributed.

More recently, Ashe, de Oliveira, and McAneney (2012) examined fire prevention regulations in Australia. These authors estimate the cutoff at between AU\$20 million and AU\$50 million (\$13.3 million to \$33.3 million 2010 U.S. dollars at purchasing power parity [PPP]), again depending on how costs are distributed across the population. The authors did not conduct a formal analysis of the net mortality effects of fire prevention efforts. However, they did compare estimates of induced deaths (90–225 fatalities per year) to the 114 lives lost on average to fires each year in Australia, suggesting the costs incurred by fire prevention efforts may be excessive. Because the effectiveness of fire prevention efforts in Australia is unknown, it is unclear whether these efforts pass a mortality risk test.

These studies just mentioned are similar in that they use correlations between income and mortality to estimate the cost-per-life-saved cutoff, and attempt to resolve potential problems of endogeneity by controlling for variables such as initial health status and education. We refer to this general approach as the "direct" approach to estimating the cutoff. The models and data used to estimate the cutoff under the direct approach have been subjected to a number of criticisms. Among the first to criticize these models was Sinsheimer (1991), which criticized the original Keeney (1990) model on two grounds: ecological fallacy and confounding bias. Ecological fallacy refers to making inferences about individual phenomena on the basis of the observations of groups. The Keeney study used census tract data but inferred a causal relationship between individual income and mortality based on these group data. This issue would later be accounted for in Keeney (1997), which used individual-level data rather than census tract data.

Confounding bias, on the other hand, also known as omitted variables bias, refers to the possibility that an unobserved variable or variables influence both income and mortality, leading either to a spurious correlation or to an overestimation of the impact of income on mortality. A similar issue relates to the degree to which the correlation between income and health can be explained by the causal effect of health on income (i.e., reverse causality). GAO (1992), among other studies, would make similar criticisms.

It is the direct approach that has led to misunderstandings about whether correlation is being confused with causation. Criticisms of the direct approach have merit in that studies employing the direct approach to estimating the cost-per-life-saved cutoff have likely misestimated the cutoff value (which implies a misestimation of the number of fatalities induced by expenditures). However, such criticisms do not justify abandoning the analysis of mortality risks or imply that the cutoff level is infinite. Another approach, which we call the "indirect" approach, is our preferred method here, and it relies on a theoretical model of the income–mortality relationship that is calibrated using data on the VSL and the marginal propensity to spend on health (MPSH). The indirect approach infers the cutoff value from individual preferences and is not subject to the same criticisms related to correlation and causation.

Viscusi (1994a) developed the first theoretical model to estimate the cutoff without relying on correlations between income and mortality. Viscusi begins with an individual who chooses the level of health-enhancing expenditures and the level of job risk (for which the individual is paid a compensating differential), but the analysis generalizes to product risks as well.

$$(1) \quad EU(s,h) = q(s,h)U(A + w(s) - h) + (1 - q(s,h)V(A + w(s) - h).$$

Here the worker maximizes expected utility, which is a weighted average of two world states. In one case, the worker survives and receives utility of $U(A + w(s) - h)$. In the other state, the worker dies and leaves a bequest value of $V(A + w(s) - h)$. Let $q(s, h)$ be the worker's probability of survival, which is a function of expenditures on safety, s, and expenditures on health, h; $w(s)$ is the wage rate, which is a function of the safety conditions of a job, and A represents other sources of worker income.

Taking the partial derivatives with respect to the optimal healthcare expenditure, h, and safety expenditures, s, respectively, yields first order conditions of

$$\frac{1}{q_h} = \frac{U - V}{qU' + (1 - q)V'} \tag{2}$$

and

$$\frac{-w_s}{q_s} = \frac{U - V}{qU' + (1 - q)V'}, \tag{3}$$

which, when combined, yield

$$\frac{1}{q_h} = \frac{-w_s}{q_s} = \frac{U - V}{qU' + (1 - q)V'}. \tag{4}$$

Equation (4) states that, when the agent is maximizing expected utility, the marginal value of life for health expenditures will equal the marginal value of statistical life for job safety expenditures, which in turn will equal the utility difference been life and death, $U - V$, divided by the expected marginal utility of income.

If we assume that the responsibility to set safety levels is a function of government regulation, then a binding government regulation that affects risk levels will produce two effects. First, because health expenditures and job safety levels are substitutes, regulation will decrease the private incentive to invest in health. Second, because the individual bears regulatory costs, there will be decreased investment in health.

Whether a regulation reduces risks on balance depends on the sum of three components: the direct effect of the regulation on safety, the indirect effect on risk through a substitution toward safety achieved through regulation and away from personal health expenditures, and the indirect effect on risk as personal health expenditures fall from reduced income as a result of compliance with regulations. This relationship is described in Equation (5):

$$\Delta q = \frac{\partial q}{\partial s}\Delta s + \frac{\partial q}{\partial h}\frac{\partial h}{\partial s}\Delta s + \frac{\partial q}{\partial h}\frac{\partial h}{\partial y}\Delta y, \tag{5}$$

which states that the worker's probability of survival is the sum of three components. The first term on the right-hand side of Equation (5) is the direct effect that changing safety standards has on mortality risk. The second term is a substitution effect term that describes how health expenditures and the probability of survival change as a result of changing the safety level. Again, this effect follows from the fact that health expenditures and safety standards set by government policy are close substitutes.[4] The final term is an income effect term that describes how health expenditures and the probability of survival change as income changes. If a policy, or more generally an expenditure, passes a mortality risk test, then $\Delta q > 0$. In other words, the sum of the three terms on the right-hand side of Equation (5) is positive.

At first glance, it may seem odd that healthcare spending is the primary means in the model by which the worker invests in mortality risk reduction. Many other forms of spending also address mortality risk, including spending on food, housing, and transportation. While there is no doubt that these kinds of expenditures do influence health to some extent, healthcare spending may nonetheless be a useful proxy for spending on mortality risk more generally in that the primary aim of health expenditures is to improve health. As already mentioned, the academic literature finds a significant, albeit modest, relationship between healthcare expenditures and mortality. Furthermore, it will be difficult to identify what fraction of other forms of spending relate specifically to risk reduction, whereas almost all health spending is presumably aimed at achieving better health.

After some algebra, Viscusi (1994a) derives the cost-per-life-saved cutoff value as equal to the ratio VSL/MPSH.[5] His analysis estimated a value for the MPSH of 0.1, so that the cutoff is 10 times the VSL. Several studies follow the indirect approach developed by Viscusi (1994a), but modify the core model (and hence the final ratio) in one manner or another, for example by incorporating elasticities of risky behavior. Lutter, Morrall, and Viscusi (1999) supplement the model with income elasticities for cigarette smoking, activity-related illnesses and alcohol

4. In theory, it is possible that public health expenditures could increase the effectiveness of private spending on risk reduction, making public and private expenditures on risk reduction complements, rather than substitutes. To account for this possibility, one could add an additional term to Equation (5) to account for a positive interaction effect between public and private risk mitigation efforts.

5. This ratio may be counterintuitive in its interpretation. For a more intuitive explanation for why the cutoff equals this ratio, see James Broughel, "How Much of an Income Drop Will Take a Life?" *The Regulatory Review*, February 13, 2018. https://www.theregreview.org/2018/02/13/broughel-income-drop-life/.

abuse, which had the effect of lowering their estimate of the cutoff, in this case to roughly $15 million (1990 dollars). van Kippersluis and Galama (2014) develop a theoretical model (one different from the Viscusi model) that allows wealth shocks to influence health in either positive or negative directions.

We chose to forgo including elasticities of risky behaviors in our model for several reasons. First, the effect of income on risk clearly varies depending on the particular individuals involved and on the particular risks. Second, leaving out such elasticities is likely to result in an overestimate of the cutoff. Having the cutoff represent an upper bound may be desirable if HHA is used as a form of screening analysis to weed out the most ineffective programs.[6] Third, it is feasible for others to take the estimate of the cutoff produced in this paper and modify it with their own preferred income elasticities for risky behavior.

Oddly, there are only two estimates of the cutoff we are aware of that use the indirect approach but do not supplement the model with elasticities of various types. One is Viscusi (1994a), which estimates the cutoff to be $50 million (1990 dollars). The other is Hjalte et al. (2003), which uses Swedish survey data and estimates the cutoff to be 116 million (1999 SEK), which translates to $13.3 million (1999 U.S. dollars).

Table 1 lists the estimates of the cutoff from the studies reviewed here. The majority of studies rely on the direct approach. Two studies employ the indirect approach, and two studies employ a modified indirect approach. These latter studies adapt the indirect approach to include elasticities from micro- or macroeconomic correlations between income and health or income and risky behavior.[7] Since the studies in Table 1 were conducted across many years, estimates of the cutoff have been adjusted for inflation and presented in 2019 U.S. dollars, using PPP currency conversions where necessary.

Estimates fall in the range of $6.1–$90.9 million (2019 dollars). If one excludes estimates from outside the United States, the range is $8.7–$90.9 million. The only study that strictly employs the indirect approach for the United States, without further modifications, is Viscusi (1994a), with a cutoff estimate of $90.9 million (2019 dollars). The next highest estimate is $28 million for the United States, which is the high end in the range of estimates found in Chapman and Hariharan (1996). The Viscusi estimate is notably higher than any of the other estimates appearing in Table 1. While this makes the estimate an outlier, we believe this higher cutoff value avoids the simultaneity concerns involved in estimating the income–mortality relationship with the direct approach. A higher cutoff value is consistent with the reasonable possibility that some, but not all, of the observed correlation between income and mortality is due to reverse causality and omitted variables and is also consistent with the relatively modest empirical findings of the effects of health expenditures on health.

IV. UPDATING THE COST-PER-LIFE-SAVED CUTOFF

Only two values are required to calibrate the model described in Section III: the VSL and the MPSH. For the VSL, we use a recent estimate from the US Department of Transportation (2016). The department's internal guidance recommended a VSL of $9.6 million in 2015 dollars based on labor market estimates of the VSL. Updating for inflation yields a value of $10.3 million in 2019 dollars. Similar values are used by other agencies, such as the US Environmental Protection Agency (2016), which recommends a VSL of $9.7 million (2013 dollars) and the US Department of Health and Human Services (2016), which recommends a figure of $9.6 million (2014 dollars). The estimate reported in Viscusi (2018) adjusts for publication selection effects and is $10 million (2017 dollars).

The MPSH, dh/dy, is equal to the fraction of income spent on healthcare, h/y, multiplied by the income elasticity of the demand for healthcare, which is denoted η in Equation (6),

$$\frac{dh}{dy} = \frac{h}{y}\eta. \tag{6}$$

One way to estimate the fraction of income spent on healthcare is using national data. According to the Centers for Medicaid and Medicare Services, national health expenditures in the United States amounted to $3.6 trillion

6. A cutoff estimated using revealed preferences is also likely to underestimate risk increases if individuals place less weight on future risks, due to discounting.

7. One example of a study employing macroeconomic correlations is Lutter and Morrall (1994), which employs a version of the indirect approach but which also relies on cross-country correlations between GDP per capita and mortality. The study estimates the cutoff value at between $9 million and $12 million for the United States (1991 dollars).

TABLE 1
Studies Estimating the Cost-per-Life-Saved Cutoff

Study	Cost-Per-Life-Saved Cutoff (Millions of U.S. Dollars)	Dollar Year	Direct or Indirect Approach	MPSH	Inflation-Adjusted Cutoff (Adjusted to Millions of 2019 U.S. Dollars)	Comments
Keeney (1990)	3.14–7.25	1980	Direct	N/A	8.7–20.2	First model to formally estimate the cutoff; mortality risk is a function of income with no additional controls used; cutoff varies depending on distribution of regulatory costs; study is open to critiques of ecological bias and confounding bias.
Chapman and Hariharan (1994)	12.2	1990	Direct	N/A	22.2	Controls for initial health status to account for possibility of reverse causation; Social Security data are used for males around retirement-age.
Chapman and Hariharan (1996)	6.7–15.4	1990	Direct	N/A	12.2–28.0	Controls for initial health, marital status, age, a quadratic income variable, assets (a measure of patience), and time varying (fixed) effects.
Keeney (1997)	5–14	1991	Direct	N/A	8.8–24.7	Uses individual-level data rather than census-tract data to correct for ecological bias but does not control for other confounding variables; study finds little difference in fatalities from concentrated versus dispersed costs; estimates of fatalities vary significantly across income and racial groups.
Elvik (1999)	3.8–47.5	1995	Direct	N/A	6.1–75.9	Uses Norwegian data; cutoff varies depending on controls used in regression analysis; controls include healthcare spending, age, and sex.
Gerdtham and Johannes-son (2002)	6.8–9.8	1996	Direct	N/A	10.6–15.3	Uses Swedish data; controls for initial health status and various personal characteristics.
Ashe, de Oliveira, and McAneney (2012)	13.3–33.3[a]	2010	Direct	N/A	15.6–39.0[a]	Builds on Keeney (1997) model; assumes American correlations between income and mortality hold for Australia, which may be incorrect.
Viscusi (1994a)	50	1990	Indirect	0.10	90.9	First study to employ the indirect approach; builds a structural model of the income/mortality risk relationship; incorporates the VSL and MPSH; avoids problems of endogeneity and reverse causation found in direct approaches.
Hjalte et al. (2003)	13.3	1999	Indirect	0.179	19.7	Calibrates Viscusi (1994a) model with Swedish data; estimates MPSH based on surveys; finds MPSH varies by income level (MPSH is 0.20 for individuals in lowest quintile of household income and 0.14 for individuals in top quartile for household income).
Lutter and Morrall (1994)	9–12	1991	Modified Indirect	0.275	15.9–21.1	Coined the term "health-health analysis"; uses the Viscusi (1994a) model but incorporates income elasticities of various health measures from cross-country studies; these adjustments introduce the possibility of confounding and ecological bias.
Lutter, Morrall, and Viscusi (1999)	15	1990	Modified Indirect	0.10 (same as Vis-cusi 1994a)	27.3	Begins from Viscusi (1994a) model; incorporates income elasticities of various risky behaviors into the model, which could lead to confounding and reverse causation biases and a misestimation of the cutoff.

Note: Figures converted to 2019 dollars using the Trimmed Mean PCE Inflation Rate available from the Federal Reserve Bank of Dallas.

[a]Converted to 2010 U.S. dollars using the World Bank PPP conversion factor for Australia in 2010 and then adjusted for inflation from 2010 U.S. dollars to 2019 U.S. dollars. World Bank, "PPP Conversion Factor, GDP," International Comparison Program database, http://data.worldbank.org/indicator/PA.NUS.PPP?page=1.

Sources: Authors' calculations, based on work by Ashe, de Oliveira, and McAneney (2012); Chapman and Hariharan (1994, 1996), Elvik (1999), Gerdtham and Johannesson (2002), Hjalte et al. (2003), Keeney (1990, 1997), Lutter and Morrall (1994), Lutter, Morrall, and Viscusi (1999), and Viscusi (1994a).

in 2018, or 17.7% of GDP.[8] These expenditures include both public and private spending on healthcare. If public spending is less effective in enhancing health than private expenditures, use of the total expenditure value will overstate the healthcare share of income that is pertinent to this calculation.

To establish a floor on the healthcare share of income, we examine expenditures on healthcare at the consumer level. According to the 2018 Consumer Expenditure Survey from the U.S. Bureau of Labor Statistics (BLS), average pre-tax income for a consumer unit that year was \$78,635, while spending on healthcare was \$4,968 on average.[9] This represents 6.3% of consumer income.[10] This number includes \$3,405 in spending on health insurance but excludes employer spending on premiums as part of employer-provided health insurance. According to the BLS, in March of 2019, the average share of premiums paid by the employer varied from 79% to 86% for single coverage and 66% to 71% for family coverage, depending on whether employment was in the civilian sector, private industry, or state and local government (BLS 2019). A Kaiser Family Foundation survey finds a similar breakdown. For family coverage, the average annual health insurance premium for employer-based coverage in 2019 was \$20,576, of which \$6,015 (29%) was paid by the worker on average, meaning \$14,561 (71%) was paid by the employer (Claxton et al. 2019).

Since a BLS consumer unit contains 2.5 people on average, we use the ratio for family coverage; assuming a split where 70% is paid by the employer and 30% is paid by the employee.[11] Assuming the \$3,405 spent on health insurance is all spent on premiums, then \$11,350 would be spent in total (\$7,945 by the employer and \$3,405 by the employee). If we add the \$7,945 paid by the employer as a contribution to a consumer unit's total compensation, then total income rises to \$86,580 in 2018. Spending on healthcare would then represent 14.9% of total income ([4,968 + 7,945]/86,580).

However, according to the BLS, 52% of civilian and 49% of private industry workers participated in employer-provided health insurance (BLS 2019). These numbers likely underestimate participation generally since many individuals participate through a spouse, and higher participation rates are observed in the public sector. Nonetheless, the 2019 Current Population Survey from the U.S. Census Bureau estimates that 55.1% of individuals in the United States were covered by employment-based health plans for all or part of 2018 (Berchick, Barnett, and Upton 2019), which is only slightly higher. We assume 45% of the population spends the unadjusted fraction of income spent on healthcare for a consumer unit (6.2%), and the other 55% spends the higher fraction estimated for consumer units covered by employer-provided health insurance (14.9%). The weighted average of these values, 11.0%, is our lower bound value used for h/y in Equation (6).

There is considerable debate surrounding the income elasticity η of health spending. At the high end is Fogel (2009), which uses an elasticity of 1.6. Most elasticity estimates come from aggregated data, which may not be appropriate for making inferences about individuals. Studies using national data tend to find an elasticity over 1, while those using regional data typically estimate the elasticity as below 1 (Costa-Font, Gemmill, and Rubert 2011). This is further complicated by the fact that much of public health expenditures in the United States show up at the national level rather than the individual level or regional level.

We believe the estimates in the lower range may be more accurate since these include studies that attempt to correct for problems related to endogeneity and publication bias. A recent meta-regression analysis found the income elasticity for health expenditures to be in the range of 0.4–0.8 (Costa-Font, Gemmill, and Rubert 2011). Research by Acemoglu, Finkelstein, and Notowidigdo (2012) uses oil shocks as an instrument for exogenous income increases, estimating the income elasticity of health spending to be around 0.72. We choose to use 0.7, which lies in the range estimated in the recent meta-regression analysis and is also close to the value estimated by Acemoglu and coauthors.

If healthcare expenditures range from 11.0% to 17.7% of income and the income elasticity

8. NHE Fact Sheet, available at https://www.cms.gov/research-statistics-data-and-systems/statistics-trends-and-reports/nationalhealthexpenddata/nhe-fact-sheet.html, accessed April 20, 2020.

9. US Bureau of Labor Statistics, "Consumer Expenditures—2018," released September 10, 2019, accessed April 20, 2020, https://www.bls.gov/news.release/pdf/cesan.pdf.

10. A consumer unit contains 2.5 people on average, and 0.6 of these people are children under the age of 18 on average, those for whom spending may be most effective.

11. These proportions fall in the range of the BLS breakdown and roughly correspond with the breakdown in the Kaiser Family Foundation report.

of healthcare spending is 0.7, this implies a MPSH of about 0.0770–0.1239. With the Department of Transportation VSL of $10.3 million (2019 dollars), the cutoff estimate range is from $83.1 million to $133.8 million (2019 dollars) with a midpoint of $108.5 million, which clearly exceeds all of the estimates in Table 1. The cutoff is also likely to vary by subpopulations. In a cross-country study, Di Matteo (2003) notes that national income elasticities are higher at low-income levels and lower at high income levels. The same may hold for low-income individuals. Use of higher elasticities would raise the MPSH, which in turn would lower the cost-per-life-saved cutoff. This is consistent with the findings of a Swedish study, which estimated that the lowest income quintile had an average MPSH of 0.20, while the highest quintile had an average MPSH of 0.14 (Hjalte et al. 2003).

V. CONCLUSION

This paper estimates a cost-per-life-saved cutoff range from $83.1 million to $133.8 million (2019 dollars). A reasonable rule of thumb might be to assume that health investments costing more than $100 million per life saved will be counterproductive in that they can be expected to increase mortality risks on net. The $133.8 million figure is almost certainly an upper bound on the cutoff since spending on risk reduction is not limited only to expenditures on healthcare, and this figure does not take into account changes in the propensity to engage in risk behaviors as income rises, among other factors.

This cutoff is also likely to rise over time. An income elasticity of the VSL in the range of 0.5–1.0 for the United States would imply the VSL rises at a rate of roughly 0.5%–2.0% a year on average, given labor productivity growth averaging 1%–2% a year in recent years. If the MPSH remains relatively constant,[12] the cutoff is likely to grow at the same rate as the VSL.

While current use of the cost-per-life-saved cutoff remains quite limited, especially relative to analytical tools like BCA, we believe now there is an opportunity to revisit the potential usefulness of ascertaining the net mortality effects of policies, which can serve as an input in BCA or be a matter of independent interest. The COVID-19 pandemic has raised concerns about whether the adverse economic dislocations associated with government restrictions could also produce harms to health, just as does the disease. While we do not attempt an HHA of the ongoing social distancing measures taken to address the pandemic, future such analyses could easily be conducted utilizing the $108.5 million cutoff value calculated in this paper. Each loss of $1 trillion in income will lead to about 9,200 expected deaths.

More generally, any regulatory or other health-related expenditure costing more per life saved than the cutoff value should receive extra attention, including more careful BCA. Currently, very few existing regulations or other policies ever receive the scrutiny of a BCA, likely because a full-fledged BCA takes considerable time and resources to produce. Mortality risk analysis, by contrast, is relatively simple and less effort-intensive.

The Trump administration's reporting under Executive Order 13771 also creates an opportunity for mortality risk analysis. Annual reporting from OMB calculates the difference between costs and cost savings for a variety of the administration's regulations. These estimates of the net financial impact of regulations can be easily converted into estimates of mortality risk, since they account for both positive and negative expenditures resulting from government mandates.[13]

Given the limitations of HHA, recognition of the income–mortality relationship is perhaps best suited to a "mortality risk analysis" of policies, which asks: What are the net mortality consequences of policies after taking into account the mortality losses generated by government-mandated expenditures? All expenditures are subject to tradeoffs related to mortality risk. Mortality risk analysis can bring these tradeoffs into the open, both within and outside of government. Future research that incorporates the mortality cost of expenditures can help cast

12. And apparently it has. Viscusi (1994a) estimated an MPSH of about 0.1. According to our updated estimates, this remains a reasonable rule of thumb. The midpoint of our range for the MPSH is 0.10045.

13. For HHA to be conducted properly, expenditure-affecting costs must be estimated comprehensively. Regulations can impost such costs directly on individuals in the form of compliance costs or fees, etc., but can also impost them indirectly, for example by restricting output, such that incomes would be higher in absence of the regulation. Examples of such output restrictions would be the FDA's premarket approval process for drugs or an environmental permitting process for development projects. In absence of an output restriction, incomes would be higher and by extension health-enhancing expenditures. Proper measurement of costs will account for these indirect effects. Importantly, private restrictions on output have similar effects.

light on when and where counterproductive expenditures are likely to arise.

REFERENCES

Acemoglu, D., A. Finkelstein, and M. J. Notowidigdo. "Income and Health Spending: Evidence from Oil Price Shocks." *Review of Economics and Statistics*, 95(4), 2012, 1079–95.

Almond, D., and J. Currie. "Killing Me Softly: The Fetal Origins Hypothesis." *Journal of Economic Perspectives*, 25(3), 2011, 153–72.

Ashe, B., F. D. deOliveira, and J. McAneney. "Investments in Fire Management: Does Saving Lives Cost Lives?" *Agenda: A Journal of Policy Analysis and Reform*, 19(2), 2012, 89–103.

Bellavance, F., G. Dionne, and M. Lebeau. "The Value of a Statistical Life: A Meta-analysis with a Mixed Effects Regression Model." *Journal of Health Economics*, 28(2), 2009, 444–64.

Berchick, E., J. Barnett, and R. Upton. "Health Insurance Coverage in the United States: 2018." *Current Population Reports*. US Census Bureau, 2019.

Case, A., D. Lee, and C. Paxson. "The Income Gradient in Children's Health: A Comment on Currie, Shields and Wheatley Price." *Journal of Health Economics*, 27(3), 2008, 801–7.

Case, A., D. Lubotsky, and C. Paxson. "Economic Status and Health in Childhood: The Origins of the Gradient." *American Economic Review*, 92(5), 2002, 1308–34.

Chapman, K., and G. Hariharan. "Controlling for Causality in the Link from Income to Mortality." *Journal of Risk and Uncertainty*, 8(1), 1994, 85–93.

———. "Do Poor People Have a Stronger Relationship between Income and Mortality Than the Rich? Implications of Panel Data for Health-Health Analysis." *Journal of Risk and Uncertainty*, 12(1), 1996, 51–63.

Chetty, R., M. Stepner, S. Abraham, S. Lin, B. Scuderi, N. Turner, A. Bergeron, and D. Cutler. "The Association between Income and Life Expectancy in the United States, 2001–2014." *JAMA: The Journal of the American Medical Association*, 315(16), 2016, 1750–66.

Claxton, G., M. Rae, A. Damico, G. Young, and D. McDermott. *Employer Health Benefits 2019 Annual Survey*. Menlo Park, CA: Henry J. Kaiser Family Foundation, 2019.

Costa, D., and M. Kahn. "Changes in the Value of Life, 1940–1980." *Journal of Risk and Uncertainty*, 29(2), 2004, 159–80.

Costa-Font, J., M. Gemmill, and G. Rubert. "Biases in the Healthcare Luxury Good Hypothesis? A Meta-regression Analysis." *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 174(1), 2011, 95–107.

Currie, J. "Healthy, Wealthy, and Wise: Socioeconomic Status, Poor Health in Childhood, and Human Capital Development." *Journal of Economic Literature*, 47(1), 2009, 87–122.

Currie, J., and M. Rossin-Slater. "Early-Life Origins of Life-Cycle Well-Being: Research and Policy Implications." *Journal of Policy Analysis and Management*, 34(1), 2015, 208–42.

Di Matteo, L. "The Income Elasticity of Health Care Spending: A Comparison of Parametric and Nonparametric Approaches." *European Journal of Health Economics*, 4(1), 2003, 20–9.

Dowd, J. B., J. Albright, T. E. Raghunathan, R. F. Schoeni, F. Leclere, and G. A. Kaplan. "Deeper and Wider: Income and Mortality in the USA over Three Decades." *International Journal of Epidemiology*, 40(1), 2011, 183–8.

Elvik, R. "Can Injury Prevention Efforts Go Too Far? Reflections on Some Possible Implications of Vision Zero for Road Accident Fatalities." *Accident Analysis and Prevention*, 31(3), 1999, 265–86.

Fogel, R. W. "Forecasting the Cost of US Health Care in 2040." *Journal of Policy Modeling*, 31(4), 2009, 482–8.

Gallet, C., and H. Doucouliagos. "The Impact of Healthcare Spending on Health Outcomes: A Metaregression Analysis." *Social Science & Medicine*, 179, 2017, 9–17.

Gerdtham, U., and M. Johannesson. "Do Life-Saving Regulations Save Lives?" *Journal of Risk and Uncertainty*, 24(3), 2002, 231–49.

Hahn, R., R. Lutter, and W. Kip Viscusi. *Do Federal Regulations Induce Mortality?* Washington, DC: AEI-Brookings Joint Center for Regulatory Studies, 2000.

Hjalte, K., A. Norinder, U. Persson, and P. Maraste. "Health-Health Analysis—An Alternative Method for Economic Appraisal of Health Policy and Safety Regulation: Some Empirical Swedish Estimates." *Accident Analysis and Prevention*, 35(1), 2003, 37–46.

Keeney, R. L. "Mortality Risks Induced by Economic Expenditures." *Risk Analysis*, 10(1), 1990, 147–59.

———. "Estimating Fatalities Induced by the Economic Costs of Regulations." *Journal of Risk and Uncertainty*, 14(1), 1997, 5–23.

van Kippersluis, H., and T. J. Galama. "Wealth and Health Behavior: Testing the Concept of a Health Cost." *European Economic Review*, 72, 2014, 197–220.

Kuchler, F., J. L. Teague, R. A. Williams, and D. W. Anderson. "Health Transfers: An Application of Health-Health Analysis to Assess Food Safety Regulations." *Risk: Health, Safety and Environment*, 10(4), 1999, 315–32.

Lutter, R., and J. F. Morrall. "Health-Health Analysis: A New Way to Evaluate Health and Safety Regulation." *Journal of Risk and Uncertainty*, 8(1), 1994, 43–66.

Lutter, R., J. F. Morrall III. , and W. K. Viscusi. "The Cost-per-Life-Saved Cutoff for Safety-Enhancing Regulations." *Economic Inquiry*, 37(4), 1999, 599–608.

Morrall, J. F. III. "A Review of the Record." *Regulation*, 10(2), 1986, 13–24 30-34.

OECD (Organisation for Economic Co-operation and Development). *Mortality Risk Valuation in Environment, Health and Transport Policies*. OECD Publishing, 2012.

Sinsheimer, P. "The Risks of Economic Modeling before Establishing the Causal Inference." *Risk Analysis*, 11(2), 1991, 187–8.

Smith, J. P. "Healthy Bodies and Thick Wallets: The Dual Relation between Health and Economic Status." *Journal of Economic Perspectives*, 13(2), 1999, 145–66.

Sommers, B. D. "State Medicaid Expansions and Reduced Mortality, Revisited: A Cost–Benefit Analysis." *American Journal of Health Economics*, 3(3), 2017, 392–421.

Sommers, B. D., K. Baicker, and A. Epstein. "Mortality and Access to Care among Adults after State Medicaid Expansions." *New England Journal of Medicine*, 367(11), 2012, 1025–34.

Sommers, B. D., S. Long, and K. Baicker. "Changes in Mortality after Massachusetts Health Care Reform: A Quasi-experimental Study." *Annals of Internal Medicine*, 160(9), 2014, 585–93.

U.S. Bureau of Labor Statistics. *Employee Benefits in the United States—March 2019*. US Bureau of Labor Statistics, 2019.

U.S. Department of Health and Human Services. *Guidelines for Regulatory Impact Analysis*. US Department of Health and Human Services, 2016.

U.S. Department of Transportation. *Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in US*

Department of Transportaiton Analyses – 2016 Adjustment. US Department of Transportation, 2016.

U.S. Environmental Protection Agency. *Valuing Mortality Risk Reductions for Policy: A Meta-analytic Approach*. US Environmental Protection Agency, 2016.

U.S. General Accounting Office. *Risk-Risk Analysis: OMB's Review of a Proposed OSHA Rule*. US General Accounting Office, 1992.

Viscusi, W. K. "Mortality Effects of Regulatory Costs and Policy Evaluation Criteria." *RAND Journal of Economics*, 25(1), 1994a, 94–109.

———. "Risk-Risk Analysis." *Journal of Risk and Uncertainty*, 8, 1994b, 5–17.

———. *Pricing Lives: Guideposts for a Safer Society*. Princeton, NJ: Princeton University Press, 2018.

——— "The Mortality Cost Metric for the Costs of War." *Peace Economics, Peace Science and Public Policy*, 25(3), 2019, 1–10.

Wildavsky, A. "Richer Is Safer." *Financial Analysts Journal*, 37(2), 1981, 19–22.