Equity and the Value per Statistical Life

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Abstract:

The value of mortality risk reductions, conventionally expressed as the value per statistical life (VSL), often drives the benefits of environmental and other policies and regulations. While both theory and empirical evidence suggest that VSL varies depending on the characteristics of the individuals and the risks affected, it is often treated as a constant. Equity is the main justification for using a common VSL as it seemingly avoids making any judgement about how VSL should vary by individual characteristics. In particular, a uniform VSL is tantamount to attaching relatively larger weight to survival benefits for the poor and lower weight to survival benefits for the wealthy. Thus, a uniform VSL mimics the use of weighting for the marginal utility of income and other indicators of relative disadvantage, while avoiding the challenges of explicitly computing the weights. The paper investigates the bias in policy ranking by using a uniform VSL instead of heterogeneous VSLs and equity weights. Focusing on the relationship between VSL and income, we find that the uniform VSL tends to over-estimate the utilitarian value of a policy because it neglects the distribution of costs and the welfare burden of policies on low-income individuals. A numerical application based on U.S. data suggests that the bias is sizable, especially when the policy costs are regressive and the survival benefits are progressive.

Keywords: benefit-cost analysis, value per statistical life (VSL), equity, distribution, marginal utility of income

JEL codes: D61, D63, I31, Q51, Q52, Q58

1. Introduction

The value of mortality risk reductions, conventionally expressed as the value per statistical life (VSL), is a major determinant of the benefits of environmental, health, and safety policies and regulations. Theory and empirical evidence suggest that VSL varies depending on the characteristics of the individuals and the risks, yet estimates of the population-average VSL are often uniformly applied across all those affected. Equity is the main justification for using a common VSL. For example, empirical VSL estimates are typically increasing in wealth, because they are derived from the trade-offs individuals are willing to make between their income and their mortality risk. A uniform VSL avoids the appearance that society values saving the life of a wealthy person more than saving the life of a less wealthy person.

An alternative is to rely on equity weights, as advocated for decades by many welfare economists. Using such in benefit-cost analysis (BCA) more fully accounts for the distributional impacts of a policy and for differences in the value of money across individuals (e.g., Arrow 1963, Dasgupta and Pierce 1972, Drèze and Stern 1987, Blackorby and Donaldson 1990, Johansson-Stenman 2005, Boadway 2016, Adler 2012). According to this approach, the social value of a policy is equal to the weighted sum of individuals' willingness to pay, where the weights depend on the social marginal value of each individual's income and are derived by an agreed-upon social welfare function. Equity-weighted BCA respects the plurality of individuals' valuations and incorporates equity considerations through the weights.

The goal of this paper is to better understand the ethical assumptions and policy implications of these two alternative methods for addressing equity concerns: the uniform VSL approach and equity-weighted BCA. Through a simple theoretical model and numerical application, we show that the uniform VSL approach tends to over-estimate the value of a policy compared to utilitarian equity-weighted BCA because it neglects the distribution of policy costs and the associated welfare burden on low-income individuals. The more regressive the policy costs and the more progressive the survival benefits, the greater the bias induced by the use of a uniform VSL. Thus, applying a uniform value could lead to policy decisions that are the opposite of what many intended, leading to inequitable treatment of groups of concern.

1.1. Rationale for uniform values: Misunderstanding of the concept

There are three main rationale that underlie the practice of using a uniform VSL. The first is substantial public misinterpretation of the VSL concept, which has been amplified by the media (Robinson 2007, Viscusi 2009, Robinson 2009, Cameron 2010, Simon et al. 2019). VSL is often described as the value the government places on an individual's life, rather than as derived from individuals' willingness to exchange their own income for a small change in their own risk in a defined time period (Hammitt 2000). This conflation of VSL estimates, based on individual's own preferences, with the value the government places on saving their life, has led to strong public opposition to the use of different values for different individuals.

Note that, perhaps anticipating such opposition, VSL is rarely if ever adjusted for income differences within a population, although it is common practice to adjust a population-average VSL for inflation and real income growth over time (HHS 2016, 2019, 2024, DOT 2022, EPA 2024).[1] The debates have instead focused on adjustments for age, particularly in EPA analyses of air pollution policies. Most of the expected deaths averted by these policies are among the elderly. In some older assessments, EPA adjusted VSL downwards in sensitivity analysis, based on empirical research on the differences in values held by older and younger individuals (Robinson 2007). This practice, often referred as the "senior discount," led to significant outcry and was discontinued.

Viscusi (2009) suggests that this opposition may in part reflect loss aversion. Interestingly, a recent U.S. Consumer Product Safety Commission (CPSC) (2024) proposal to increase the VSL for children garnered little opposition, although it was based on weak empirical evidence (Robinson, Raich, Hammitt, and O'Keeffe 2019). While differing responses to upwards adjustments for children compared to downwards adjustments for the elderly may in part reflect differing attitudes towards gains versus losses, other influencing factors may be more important. The lack of opposition likely reflects a general (normative) consensus that averting risks to children should be valued more highly than averting risks to adults, regardless of the conceptual framework that underlies BCA or the empirical research findings. It may also reflect the relatively low visibility of the CPSC proposal compared to EPA regulations.

[1] Income adjustments are also often made when applying VSL across countries with different income levels, without adjustment for within-country income differences (Robinson, Hammitt, and O'Keefe 2019, Rennert et al. 2022).

1.2. Rationale for uniform values: Gaps and inconsistencies in the empirical research

A second rationale for the use of a uniform VSL is gaps and inconsistencies in empirical research. Theory suggests that VSL is likely sensitive to attributes of the individual, such as income, age, and health status, and to attributes of the risk, such as whether it is viewed as voluntarily incurred, under the individual's control, or preceded by significant morbidity. However, theory provides little or no guidance on the magnitude of these effects, or even the direction in many cases. While close to 300 VSL studies have been conducted globally (OECD forthcoming), they vary greatly in quality and applicability (Robinson and Hammitt 2016, Robinson, Hammitt, O'Keeffe 2019), and many influencing factors have not been sufficiently explored. As a result, the extent to which their impact is counterbalancing is uncertain (Robinson, Eber, Hammitt 2019).

The two attributes that have received the most attention are the effects of income and age. Both theory and empirical research suggest that VSL increases with income, although the rate of increase (the VSL income elasticity) is uncertain. This relationship is unsurprising. VSL is typically derived from estimates of individual willingness to pay (WTP) per unit of risk reduction, which is bounded by income.[2] If an individual spends more on mortality risk reductions, he or she will have less to spend on other things. Thus we expect WTP per unit of risk reduction to decrease as income decreases. In the U.S., it is common to use a VSL income elasticity of 1.0 (e.g., HHS 2016, DOT 2022), although empirical research suggests that elasticities roughly between 0.8 and 1.2 may be reasonable.[3]

It seems intuitive to assume that VSL decreases with age, given that an older individual has fewer years of life remaining, however, this assumption is not necessarily consistent with theory and empirical research.[4] While the evidence is weak, it appears that values for children are larger

[2] While willingness to accept compensation (WTA) estimates are also consistent with the underlying conceptual framework, WTP estimates are more frequently used in practice. Policies and regulations typically involve expenditures for improvements from the status quo rather than compensation for damages, which leads many to consider WTP conceptually the more appropriate measure. WTP is also more frequently studied and the estimates are considered more reliable. The large and variable differences between estimated WTP and WTA are poorly understood (Horowitz and McConnell 2002, Robinson and Hammitt 2011, Tuncel and Hammitt 2014).

[3] The formula is: $VSL_{target} = VSL_{reference} * (Income_{target} / Income_{reference})^{elasticity}$.

[4] Unlike the U.S. Environmental Protection Agency (2024), the U.S. Department of Health and Human Services (2016, 2019, 2024) supports adjustment for age or life expectancy in sensitivity analysis, assuming that VSL declines with age.

than for middle-aged adults (Robinson, Raich, Hammitt and O'Keeffe 2019), increase then decrease with age over the typical working years, following an inverse "U" pattern (e.g., Murphy and Topel 2006, Aldy and Viscusi 2008), and may increase, decrease, or remain the same among the elderly (e.g., Evans and Smith 2006, Krupnick 2007).

1.3.Rationale for uniform values: Equitable treatment

In this paper, we explore a third rationale: that applying a uniform VSL across all members of the population is more equitable. This claim has been made by many scholars and commenters over the years, and has been bolstered more recently by official U.S. guidance. Evaluating this claim provides insights into the relative validity and importance of equity considerations in decisions to apply uniform values. It also illustrates the application of alternative approach for estimating income-sensitive VSLs in distributional analysis.

In updating its best practice guidelines for benefit-cost analysis of U.S. regulations, the Office of Management and Budget (2023a, 2023b) proposed to weight benefits and costs by the marginal utility of income, to reflect the greater value of a dollar to a poor person than a wealthy person. OMB noted, however, that when a uniform population-average VSL is used, it is already implicitly weighted by the marginal utility of income, and hence the weights applied elsewhere in the analysis should not be applied to VSL. However, the empirical estimates that underlie the population-average estimates are based on differing subsets of the U.S. population at differing points in time, and hence may not reflect the same relationship to income as indicated by the utility weights applied elsewhere in the analysis. An alternative, for example, would be to calculate VSL for each income group affected by the regulations, using generally accepted income elasticities, then weight by the same estimate of marginal utility throughout the analysis. Note that this discussion assumes that income is the only indicator of disadvantage of concern, reflecting a relatively narrow conception of equity.[5]

A closely related problem is the need to compare benefits to costs to assess whether the distribution of net benefits across income groups is equitable (Robinson, Hammitt, and Zeckhauser 2016). A population-average VSL will overestimate the values held by poorer populations and underestimate the values held by wealthier populations. Using a uniform value

[5] For more discussion of this issue and alternative approaches, see Baker et al. (2008, 2009), Adler, Hammitt, and Treich (2014), Kneisner and Viscusi (2023), and Sunstein (2023).

to compare the value of the risk reductions that poor individuals would accrue to the costs they would bear would ultimately lead to inequitable decisions, overstating the net benefits they receive.[6]

In the sections that follow, we discuss the theoretical model that underlies this discussion in more technical detail, describe our approach to the economic modeling and simulations, and report the results. We explore the assumptions, ethical choices, and policy implications of the common practice of using a single, population-average value for mortality risk reductions across all individuals and risks nationally in a given year. The application refers to the U.S. economy.

2. Theoretical framework

2.1. A simple model

We focus on the extent to which the use of a uniform VSL may lead to biased conclusions when benefits and costs are compared. We explore a simple model to theoretically investigate this bias. In this model, we assume the benefit of the policy is a decrease in mortality risk; the costs are the investments needed to implement the policy and may include some offsetting savings or other monetary benefits.

There are N individuals in the economy, $i = 1, .., N$. Individual i has income y_i and survival probability $p_i \in (0,1)$. The lifetime expected utility of individual i is:

$$p_i u(y_i) + (1 - p_i) v(y_i)$$

The terms $u(\cdot)$ and $v(\cdot)$ represent, respectively, the utility of income conditional on being alive and dead, with $u > v$. The utility functions are increasing, twice differentiable and concave, and the marginal utility of income is larger when the individual is alive, i.e., $u' > v' \geq 0$. We also assume that all individuals have the same preferences (i.e., utilities u and v). Although restrictive, assuming homogeneous preferences is common in the literature and allows for interpersonal comparability.

[6] For some policies, the costs and benefits will accrue to the same individuals; for other policies the distribution of costs will differ from the distribution of the benefits. For example, industry may pass on the costs of air pollution regulations to its shareholders, employees, and/or consumers, while the benefits may be concentrated among the elderly, who are more vulnerable to the associated health effects.

The individual's VSL is defined as the willingness to pay (or accept) for an infinitesimal increase in survival probability and it is equal to:

$$vsl_i \equiv -\frac{dy_i}{dp_i} = \frac{u(y_i) - v(y_i)}{p_i u'(y_i) + (1 - p_i)v'(y_i)}$$

The VSL is increasing in baseline mortality risk $(1 - p_i)$ and in income y_i. The dependence on baseline risk denotes the so-called dead-anyway effect (Pratt and Zeckhauser 1996), i.e., the intuition that individuals with a high probability of dying have little incentive to limit their spending on risk reduction since they are unlikely to survive. The positive relation between VSL and income is the combination of two effects: i) the utility of being alive is larger for wealthier individuals (i.e., the numerator increases in y_i); ii) the marginal value of money is smaller for wealthier individuals since the utility is concave (i.e., the denominator decreases in y_i).

The population-average VSL is thus equal to:

$$\overline{vsl} = \frac{1}{N}\sum_i vsl_i$$

Let us consider a policy that increases the survival probability of individual i by ϵ_i and causes a reduction in income by c_i. The income change represents the policy cost borne by individual i and any potential offsetting savings or other monetary benefit associated with the policy (i.e., c_i could in principle be negative, thereby denoting an income gain). The lifetime expected utility after the policy is implemented is equal to: $(p_i + \epsilon_i)u(y_i - c_i) + (1 - p_i - \epsilon_i)v(y_i - c_i)$.

First of all, we can derive the individual's willingness to pay wtp_i for the policy, defined as the reduction in income such that the individual is indifferent between the no policy status quo and a policy scenario with a reduced income:

$$p_i u(y_i) + (1 - p_i)v(y_i) = (p_i + \epsilon_i)u(y_i - c_i - wtp_i) + (1 - p_i - \epsilon_i)v(y_i - c_i - wtp_i)$$

or:

$$\epsilon_i[u(y_i - c_i - wtp_i) - v(y_i - c_i - wtp_i)] = p_i[u(y_i) - u(y_i - c_i - wtp_i)] + (1 - p_i)[v(y_i) - v(y_i - c_i - wtp_i)]$$

Taking a first order Taylor approximation around $\epsilon_i = 0$ and $c_i + wtp_i = 0$ (i.e., the change in risk is relatively small and the change in income is negligible compared to the individual's income), we get:

$$wtp_i = \epsilon_i \frac{u(y_i) - v(y_i)}{p_i u'(y_i) + (1 - p_i)v'(y_i)} - c_i \equiv \epsilon_i vsl_i - c_i$$

The policy is beneficial for the individual (i.e., it increases the individuals' expected utility) if and only if $wtp_i > 0$. The individual willingness to pay for the policy increases with the size of the mortality risk reduction and decreases with the policy cost. Moreover, for a given risk change ϵ_i, individuals with a high VSL (i.e., individuals that care more about improvements in survival) have a larger willingness to pay for the policy. Since VSL is increasing in income, wealthy individuals express a larger willingness to pay for the policy compared to less wealthy individuals that face the same risk reduction ϵ and the same policy cost c.

2.2. Conventional BCA

According to "textbook" BCA,[7] costs and benefits are estimated for each individual then summed, reflecting each individual's circumstances – consistent with the Kaldor-Hicks potential compensation test. Thus, the net value of the policy is equal to the sum of individuals' willingness to pay:

$$W^{BCA} = \sum_i wtp_i = \sum_i \epsilon_i vsl_i - \sum_i c_i$$

As a consequence, "textbook" BCA is indifferent to the distribution of policy costs (only the total costs matter) and it attaches more value to increasing the survival of wealthy individuals than to delivering similar reductions in mortality among less wealthy individuals (since VSL is increasing in income).

However, as discussed in the introduction, practitioners typically neglect the potential heterogeneity of VSL across the population and adopt a population average VSL for all affected individuals:

[7] We make a distinction between the standard definition of BCA (unweighted sum of individuals' willingness to pay) and what is instead done in practice (replacing the heterogeneity in willingness to pay with a uniform value). We call the first approach the "textbook" BCA.

$$W^{unif} = \overline{vsl} \sum_i \epsilon_i - \sum_i c_i$$

The rule W^{unif} is still indifferent to the distribution of policy costs, but it values all changes in mortality risk equally, independently of who experiences them. Note that W^{BCA} and W^{unif} lead to the same ranking of policies only when ϵ_i and vsl_i are independently distributed, i.e., $\frac{1}{N}\sum_i \epsilon_i vsl_i = \frac{1}{N}\sum_i vsl_i \frac{1}{N}\sum_i \epsilon_i$.[8] For example, if all individuals were experiencing the same reduction in mortality risk or if there were no recognizable statistical correlation between the change in risk and the individuals' characteristics affecting the VSL (e.g., income). If, instead, the policy benefits mostly those with low VSL (ϵ_i and vsl_i are negatively correlated), then $W^{unif} > W^{BCA}$, i.e., the adoption of a uniform VSL leads to larger net benefits than what "textbook" BCA would recommend. The opposite occurs when the policy primarily benefits those with high VSL, i.e., ϵ_i and vsl_i are positively correlated. Intuitively, the uniform VSL prevents discrimination against those with a low VSL (e.g., the poor), and, as a result, it is more likely to recommend policies that primarily affect the disadvantaged (who typically have low VSL).

2.3. Equity-weighted BCA

Let us suppose that the social welfare criterion is the utilitarian one, which corresponds to the sum of individuals' expected utilities. According to the utilitarian framework, the policy should be adopted if and only if total welfare with the policy is larger than total welfare without the policy:

$$\sum_i [(p_i + \epsilon_i)u(y_i - c_i) + (1 - p_i - \epsilon_i)v(y_i - c_i)] - \sum_i [p_i u(y_i) + (1 - p_i)v(y_i)] \geq 0$$

Taking a first order Taylor approximation around $\epsilon_i = 0$ and $c_i = 0$, we get:

$$\sum_i \{\epsilon_i [u(y_i) - v(y_i)] - c_i [p_i u'(y_i) + (1 - p_i)v'(y_i)]\} \geq 0$$

After rearranging terms, the utilitarian criterion can be rewritten as:

[8] From the covariance rule: $Cov(\epsilon, vsl) = \frac{1}{N}\sum_i \epsilon_i vsl_i - \frac{1}{N}\sum_i vsl_i \frac{1}{N}\sum_i \epsilon_i$.

$$W^U = \sum_i \omega_i(\epsilon_i vsl_i - c_i)$$

where individual i's net monetary benefits are weighted by the factor $\omega_i = p_i u'(y_i) + (1 - p_i)v'(y_i)$. The equity-weight ω_i represents the moral value attached to monetary net benefits experienced by individual i. The equity weight is increasing in survival probability p_i (since $u' > v'$ by assumption) and decreasing in income y_i due to the concavity of the utility functions. Since VSL is typically increasing in income, there is a negative correlation between the weight and the VSL.

There are two differences compared to the uniform criterion W^{unif}. First, in W^{unif} individual mortality risk reductions ϵ_i are evaluated at $\overline{vsl}$ rather than $\omega_i vsl_i$. Second, in W^U the weights mean that the distribution of costs matters as well, while in W^{unif} it does not. If the uniform VSL is chosen such that $\overline{vsl} \simeq \omega_i vsl_i$ for all i and the policy were costless (i.e., $c_i = 0 \ \forall i$), then the two criteria would lead to the same ranking of policies. Thus, in this case we can conclude that using a uniform VSL is a simple and pragmatic approximation of a more complicated equity-weighted BCA.

However, once we consider the distribution of policy costs, the policy recommendation made by W^{unif} may substantially differ from the overall assessment of W^U. For example, let us consider a society with only two individuals, A and B. Individual A is poor and individual B is rich. Suppose that A does not gain from the policy, i.e., $vsl_A\epsilon_A - c_A < 0$, while B does, $vsl_B\epsilon_B - c_B > 0$, and that $vsl_B\epsilon_B - c_B > -(vsl_A\epsilon_A - c_A)$. "Textbook" BCA W^{BCA} would recommend the policy because the rich could potentially compensate the poor. Equity-weighted BCA W^U does not recommend the policy if it attaches a sufficiently large moral weight to avoiding harming the poor, i.e., $\omega_B(vsl_B\epsilon_B - c_B) < -\omega_A(vsl_A\epsilon_A - c_A)$. BCA with uniform VSL W^{unif} may recommend the policy even if W^U does not if the uniform VSL is such that $\overline{vsl}\epsilon_A - c_A + \overline{vsl}\epsilon_B - c_B > 0$. In particular, the uniform VSL may inflate the net benefits to the poor to the point that $\overline{vsl}\epsilon_A - c_A > 0$ even though the poor is actually losing from the policy. Thus, W^{unif} may lead to inequitable results even if it used for equity reasons.

2.4. Theoretical predictions

To better understand under which conditions W^{unif} may lead to a biased ranking of policies compared to W^U, let us rewrite the utilitarian criterion as follows:

$$W^U = \sum_i \frac{\omega_i}{\sum_i \omega_i \sigma_i} \delta_i vsl_i \sum_i \epsilon_i - \sum_i c_i$$

The term $\sigma_i = \frac{c_i}{\sum_i c_i} \in [0,1]$ represents the share of the total policy costs borne by individual i, with $\sum_i \sigma_i = 1$. If all individuals pay the same dollar amount, then $\sigma_i = \frac{1}{N}$. The term $\delta_i = \frac{\epsilon_i}{\sum_i \epsilon_i} \in [0,1]$ represents the share of the total survival benefits enjoyed by individual i, with $\sum_i \delta_i = 1$.

Therefore, the uniform VSL criterion over-estimates the utilitarian value of the policy if and only if:

$$W^{unif} \geq W^U \Leftrightarrow \overline{vsl} \geq \sum_i \frac{\omega_i}{\sum_i \omega_i \sigma_i} \delta_i vsl_i$$

Let us first suppose that all individuals experience the same change in survival probabilities and bear the same policy costs, i.e., $\epsilon_i = \epsilon$ and $c_i = c$ (which implies that $\sigma_i = \frac{1}{N}$ and $\delta_i = \frac{1}{N}$). However, individuals differ in underlying characteristics such as income and survival probability, and the equity weights ω_i are such that individuals with low VSL are assigned a larger weight, i.e., ω_i and vsl_i are negatively correlated. In this scenario, the use of a uniform VSL overestimates the social value of the policy. Indeed, we get $\overline{vsl} \geq \frac{\sum_i \omega_i vsl_i}{\sum_i \omega_i}$, or $\frac{1}{N}\sum_i \omega_i \frac{1}{N}\sum_i vsl_i \geq \frac{1}{N} \sum_i \omega_i vsl_i$, and the latter is true if and only if ω_i and vsl_i are negatively correlated. In other words, the equity weighted VSL when policy costs are uniformly distributed is lower than the population average VSL.

Let us now suppose that the mortality risk change is identical across individuals, but low-income people bear the brunt of the policy costs, i.e., σ_i is decreasing in income. As a result, σ_i and ω_i are positively correlated: those that suffer high costs are also those who are assigned a larger weight. Once again, the uniform VSL criterion over-estimates the social value of the policy: $\overline{vsl} \geq \frac{\sum_i \omega_i vsl_i}{\sum_i \omega_i} \geq \sum_i \frac{\omega_i}{\sum_i \omega_i \sigma_i} vsl_i$. The first inequality derives from the negative correlation between

ω_i and vsl_i, while the second inequality derives from the positive correlation between σ_i and ω_i (which implies that $\sum_i \omega_i \sigma_i > \sum_i \omega_i$). The uniform VSL criterion underestimates the burden of the policy costs on low-income individuals and may recommend policies that have a negative social value.

If, in contrast, the mortality risk change was identical across individuals and the policy costs were progressive, then it is ambiguous whether W^{unif} under- or over-estimates the value of the policy. On the one hand, W^{unif} now over-estimates the burden of the policy costs because it neglects that the costs are paid mostly by the better-off. On the other hand, it also over-estimates the policy benefits since, as we saw earlier, the equity-weighted VSL tends to be lower than the average VSL.

Let us now consider the opposite case. Costs are equally distributed, representing a larger share of a poor person's income than a wealthy person's (i.e., the policy costs are regressive), and the poor benefit the most from the reduction in mortality risk (i.e., δ_i and vsl_i are negatively correlated). The uniform VSL rule still over-estimates the social value of the policy if $\delta_i vsl_i$ is larger for high-income individuals. Indeed, we have that $\frac{\sum_i \omega_i \delta_i vsl_i}{\frac{1}{N}\sum_i \omega_i} \leq \sum_i \delta_i vsl_i \leq \overline{vsl}$. The first inequality derives from the covariance rule[9] and holds if and only if $\delta_i vsl_i$ is increasing in income. The second inequality derives from the assumed negative correlation between δ_i and vsl_i. In other words, even though the poor benefit the most from the policy, the fact that they are paying a substantial fraction of the costs makes the uniform VSL rule (which neglects the distribution of costs) over-estimate the social value of the policy. Similar results hold when the poor benefit the most but also pay a more than equal share of the policy costs. Indeed, we have that $\frac{\sum_i \omega_i \delta_i vsl_i}{\sum_i \omega_i \sigma_i} \leq \frac{1}{N}\sum_i \frac{\delta_i}{\sigma_i} vsl_i$ if and only if $\frac{\delta_i}{\sigma_i} vsl_i$ is increasing in income and $\frac{1}{N}\sum_i \frac{\delta_i}{\sigma_i} vsl_i \leq \overline{vsl}$ as long as $\frac{1}{N}\sum_i \frac{\delta_i}{\sigma_i} \leq 1$ (or the poor pay more than they benefit). Instead, when the wealthy bear most of the costs, the comparison is ambiguous, independently on the distribution of benefits. Similarly, when the wealthy benefit the most.

[9] Let $g(x)$ be a decreasing function. $\frac{\sum_i f(x_i)}{\sum_i g(x_i)} \leq \frac{1}{N}\sum_i \frac{f(x_i)}{g(x_i)}$ if and only if f/g is increasing.

Table 1 summarizes the comparison between W^U and W^{unif}. A + sign identifies the conditions under which the uniform VSL rule over-estimates the social value of the policy.

Table 1. Comparison between conventional BCA and equity-weighted BCA.

	Poor benefit the most	Equal benefits	Wealthy benefit the most
Poor pay most of the costs	+ whenever $\frac{\delta_i}{\sigma_i} vsl_i$ is increasing in income and $\frac{1}{N}\sum_i \frac{\delta_i}{\sigma_i} \leq 1$	+	+/-
Equal costs	+ whenever $\delta_i vsl_i$ is increasing in income	+	+/-
Wealthy pay most of the costs	+/-	+/-	+/-

3. Simulation exercise

To quantitatively assess the size of the bias, we build a numerical exercise based on U.S. data. Our approach has two parts. First, we estimate VSLs that vary by income, based on an assumed income elasticity. Second, we aggregate the results using a utilitarian social welfare function, that accounts for the marginal utility of income.

Throughout, we assume that the only source of heterogeneity in the population is income. Based on 2023 data from the U.S. Census Bureau Current Population Survey, we assume that income has a lognormal distribution with mean $63,500 and standard deviation $71,700. The lognormal distribution fits the data relatively well, although it tends to overestimate the income of the poor. To estimate the income distribution of VSL, we adopt the following formula:

$$vsl_i = vsl_{ref}\left(\frac{y_i}{y_{ref}}\right)^{elast}$$

where $elast$ is the elasticity of VSL to income, and vsl_{ref} and y_{ref} are the VSL and the income of the reference individual. We use mean income as the reference income level and, based on VSL values in 2023 from HHS, we assume that the VSL of the average person is about 170

times the average income. Based on recent reviews of the income elasticity of VSL, we assume that $elast = 1$. To compute the utilitarian weight ω, we normalize the utility when dead v to zero and assume that u has a constant relative risk aversion functional form with coefficient γ. Thus, $\omega_i = y_i^{-\gamma}$. Following guidance from OMB (2023a), we set $\gamma = 1.4$.

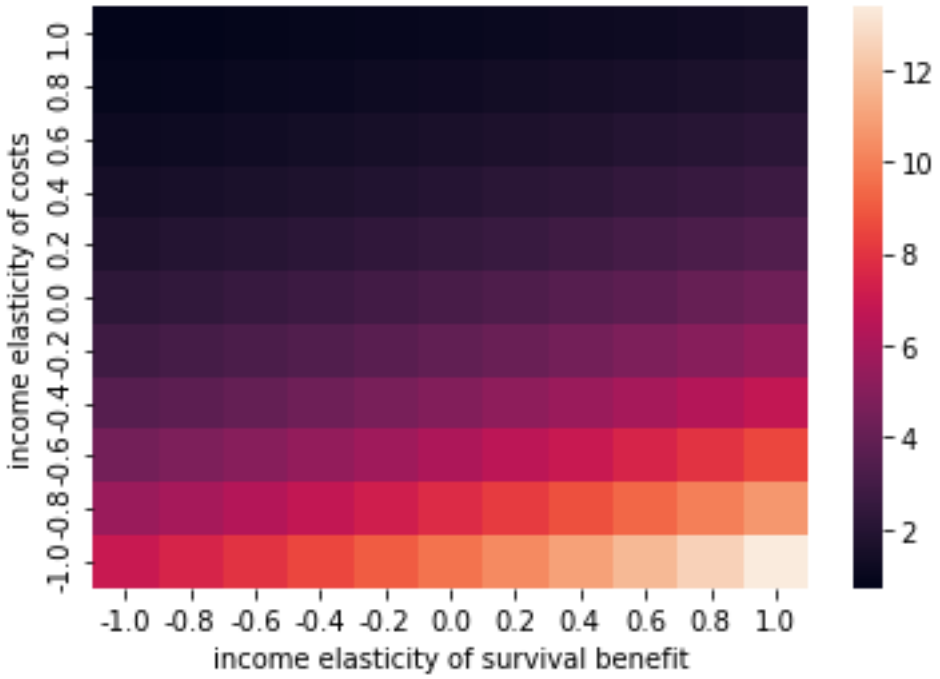
Finally, to explore the potential correlation between policy costs, survival benefits, and income, we assume the following:

$$\delta_i = \frac{y_i^{\alpha}}{\sum_i y_i^{\alpha}} \quad \text{and} \quad \sigma_i = \frac{y_i^{\beta}}{\sum_i y_i^{\beta}}$$

The coefficients α and β represent, respectively, the income elasticity of survival benefits and the income elasticity of policy costs. If $\alpha = 0$ and $\beta = 0$, then both costs and benefits are equally distributed across the population. If $\alpha = 1$ and $\beta = 1$, then both costs and benefits are proportion to income, i.e., the rich benefits the most from the policy and bear the brunt of policy costs. If $\alpha = -1$ and $\beta = -1$, then both costs and benefits are inversely proportion to income, i.e., the poor benefits the most from the policy and bear the brunt of policy costs.

We randomly select 100,000 draws from the lognormal distribution of income and estimate the quantity $\sum_i \frac{\omega_i}{\sum_i \omega_i \sigma_i} \delta_i vsl_i$, i.e., the equity-weighted value of a small aggregate reduction in mortality risk given that mortality changes are distributed according to δ_i and policy costs are distributed according to σ_i. We then compute the ratio $\frac{\overline{vsl}}{\sum_i \frac{\omega_i}{\sum_i \omega_i \sigma_i} \delta_i vsl_i}$. If the ratio is larger than 1, than the use of a uniform VSL over-estimates the social value of the policy. If the ratio is smaller than 1, a uniform VSL under-estimates the social value. Figure 1 depicts the results. The more costs are regressive (income elasticity of costs close to -1) and the more the survival benefits are progressive (income elasticity of benefits close to 1), the larger the over-estimation.

Figure 1. Relative bias due to using a uniform VSL. A value larger than 1 means that the use of a uniform VSL over-estimates the utilitarian value of the policy.



4. Conclusions and extensions

This paper investigates the differing conclusions that result when relying on conventional BCA (with a uniform VSL) versus equity-weighted BCA. Assuming that the latter is the normatively appropriate approach, but that the former may be a convenient proxy, we analyze the direction and the size of the bias, and find that the use of a uniform VSL often over-estimates the social value of policies. It neglects the distribution of policy costs and the larger burden that the policy may impose on lower-income individuals. Preliminary estimates indicate that the bias is substantial. Moreover, the more regressive the policy costs and the more progressive the survival benefits, the greater the resulting bias.

This conclusion suggests that using a uniform VSL could lead to less equitable, rather than more equitable, policy decisions. The benefits of this common approach, in terms of ease of application, may be outweighed by the costs, in terms of the distributional consequences of the resulting regulations or other policies.

The analysis has several limitations, most of which will be addressed in the next iteration of the paper. First of all, to assess the robustness of the numerical results, we are performing more sensitivity analyses around the main model assumptions, including the VSL income elasticity, the reference VSL, the coefficient of relative risk aversion, the population-average VSL, and the income distribution. Second, we plan to explore the use of empirical estimates of VSL by income group rather than applying a single income elasticity across the population. Some research (e.g., Kniesner et al. 2010), suggests that these elasticities may vary greatly across income groups. Such a comparison would provide an external validation of our VSL estimates and separate the question of what values people actually hold from the assumptions and normative judgements of analysts. Third, we plan to explore important characteristics in additional to income that affect VSL, such as age and baseline health.

Fourth, we focused exclusively on a utilitarian social welfare criterion, and expect to explore competing normative frameworks, such as prioritarianism or egalitarianism. Finally, we will further investigate the normative framework underlying the use of a uniform VSL and which social welfare functions it most closely approximates.

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