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Taking “All Men Are Created Equal” Seriously: Toward a Metric for the Intergroup Comparison of Utility Functions Through Life Values

David Courard-Hauri and Stephen A. Lauer

Abstract

The use of wage differential techniques to estimate the value of a statistical life (VSL) leads to the conclusion that willingness to pay for risk reduction increases with income. However, the use of this result in policy-relevant calculations, such as benefit-cost analysis, has led to criticism among ethicists and the lay public, at the same time as it has been defended in the economic literature. In this paper, we argue that differential valuation measures not a differential value that individuals place upon their own lives, but a differential value that they place upon marginal economic resources. Using two sets of VSL estimates from metastudies, we provide an initial estimate of the relative marginal value of income, allowing interpersonal comparison at the societal level. With these results, we propose an empirically determined, ethically justifiable social welfare function that can be easily incorporated into benefit-cost analysis and that has important implications for development economics, although more work is necessary to provide a robust estimate.

KEYWORDS: value of a statistical life, social welfare function, interpersonal comparison, marginal value of income

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1. Introduction

Over the past few decades, benefit-cost analysis (BCA) has increasingly been incorporated into the regulatory decisions of governments in the United States (US) and elsewhere (e.g., Graham, 2007; Harrington et al., 2009; Boardman et al., 2010). Traditional BCA focuses on economic efficiency, under the assumption that outcomes on the Pareto frontier will lead to the maximization of total resources for distribution. Analysts generally do not control the means of redistribution, and thus leave to politicians *post hoc* decisions about equity-enhancing compensation. Although Farrow (2011) argues that some actual compensation should take place, this distribution is rarely integrated into policies being analyzed, potentially leading to situations in which benefits accrue disproportionately, and suboptimally, to some groups and individuals at the expense of others. In fact, at times analysis appears to be in direct opposition to equity considerations. For example, in 1996, when the Intergovenmental Panel on Climate Change published its Second Assessment Report (IPCC, 1995), a firestorm of criticism erupted (e.g., Masood, 1995; Meyer, 1995; O'Riordan, 1995) over a technical detail included in the BCA: expected deaths in poor countries had lower value (worth only $100,000) than deaths in middle income ($300,000) and wealthy ($1,500,000) countries (IPCC, 1995, p. 73). Critics argued that differentiating in such a way was fundamentally unfair.

Even as BCA has become significantly more common in the past few decades, its efficiency focus has been called into question. Vining and Weimer (2010) write: "As distributional goals are often an explicit motivation for social policies, BCA may be an incomplete framework for public policy purposes unless analysts can find ways to incorporate people's willingness to pay for changes in the distribution of consumption across society." Executive Order 12898, signed in 1994, requires federal agencies to identify and address "disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low income populations." The consideration of distributional issues is thus required in US regulation, but methods for doing so are currently inconsistent and controversial. This is perhaps evidenced by the fact that the most recent US Environmental Protection Agency (EPA) guidance document on the construction of BCA, Guidelines for Performing Economic Analyses (USEPA, 2010) contains a chapter titled "Environmental Justice, Children, and Other Distributional Issues," but 2 years later (March 2012) that chapter is still only a paragraph long as the Agency prepares further guidance. Distributional analysis is also required in the UK, where the Green Book (Annex 5) suggests the use of an income-based weighting scheme, with the weighing scheme based loosely upon marginal utility of income from intertemporal substitution studies (Treasury, 2003). Cowell and Gardiner (1999) describe alternative methodologies for determining potential income weights, with different methods resulting in very different weights. In 1984, Robert Brent wrote "It is now almost accepted practice that distributional weights be incorporated into cost-benefit criteria" (Brent, 1984).

Despite Brent's claim, the algorithmic consideration of distributional impacts remains controversial in the literature and in application. One reason is that the methodology for incorporating these impacts into BCA is commonly assumed to be a normative issue. Starrett (1988) suggests weighting costs and benefits accruing to each group by their marginal utility of income. As Loomis (2010) points out, however, this devolves into value judgments, because it requires comparing utility functions between individuals. William Stanley Jeavons first argued for the impossibility of interpersonal utility comparison by observing: "Every mind is inscrutable to every other mind [so] no common denominator of feeling is possible." (Jeavons, 1911 as cited in Aldred, 2009). Nicholas Kaldor agreed, concluding that economists must concern themselves only with producing outcomes that maximize total resources, and politicians could then redistribute these resources if so desired. For Kaldor, redistribution was a topic upon which an economist "could hardly pronounce an opinion" (Kaldor, 1939). If there is no objective way to determine how much utility is obtained from various levels of income, then there is no objective way to weigh various outcomes beyond their efficiency outcomes. Even according to Kaldor and Jeavons, this does not mean that we cannot compare outcomes for their distributional impacts, but it does mean that our choice of optimal result will necessarily be socially constructed and outside of the purview of economics.

Loomis (2010) argues that we may simply need to accept this observation, and focus on constructing a normative system for assigning value. Following Adler (2008), he suggests that tax policy may be a place to look for socially determined weights to apply to equity effects of different outcomes. These would clearly be normative, but at least would incorporate democratic processes in their determination. Zerbe (2007) argues that the consideration of the value of moral harm, identified through contingent valuation studies, could improve the distributional effects of BCA because people generally prefer policies that do not exacerbate inequality. Sen and others have attempted to come up with more fair social welfare functions that privilege distribution to the less fortunate (Sen, 1974; Sen and Foster, 1997), but the choice of any of these social welfare functions still requires a value judgment that many analysts are unwilling to make, and we are unaware of instances in which government policy utilizes this methodology.

The literature on new welfare economics has generally explored the question of whether it is possible to arrive at meaningful conclusions about resource distribution within a framework of ordinal utility functions and noncomparability across individuals. Although this field has made significant progress, it still relies upon normative choices such as the no envy criterion (Foley, 1967). Moreover, a major weakness of the fair allocation methodology in application is that it requires more information than is generally available to policy makers. For example, the construction of a social welfare function may require knowledge of the shape of individual utility functions (Fleurbaey, 2008).

For a social welfare function to be usable for policy analysis, it must allow for the comparison of outcomes using a metric that is relatively easily applied, and for which the collection of data is not necessary at the individual level. Both Sen and Weymark have argued convincingly that a cardinal representation of utility is required for the normative assessment that such policy application attempts (Sen, 1976; Weymark, 2005). Moreover, Sen (1979) has shown that if an appropriate cardinal representation can be found, it would not be subject to the Arrow impossibility theorem. This leads analysts to look beyond the ordinalist revolution (discussed with clarity in Mandler, 1999), including von Neumann-Morgenstern type lotteries proposed by Harsanyi and others (Harsanyi, 1977), which indeed Adler and Posner have pointed out are unusable as a decision procedure and really meant instead to "illuminate the notion of well-being" (Adler and Posner, 2006, p. 52).

We believe that one can move in the direction of a rational and ethically sound weighting scheme by assuming human lives[1] to be of equal value and allowing the marginal utility of money to vary accordingly. The use of life (or, more precisely, mortality risk aversion) as a common value metric avoids the ethically indefensible outcome of valuing some lives over others merely based on income, and expands BCA to include an explicit measure of the declining marginal utility of wealth. Setting the value of human lives as equal conforms to an ethical precept so fundamental that it was taken as axiomatic by the authors of the Declaration of Independence of the United States, as well as modern ethicists (e.g., Shrader-Frechette, 2002; Singer, 2009). Shrader-Frechette encapsulates the mainstream ethical understanding in arguments for a Principle of Prima-Facie Political Equality, which places the burden of justification on those seeking less

[1] We will actually be using the Value of a Statistical Life (VSL) as a proxy for the "value" of a life. The VSL, commonly used in BCA, allows analysts to determine the social cost of lives expected to be lost prematurely under a particular policy. In reality, the VSL measures the cost of a small change in mortality risk, not the value of a particular individual life, and has certain advantages and shortcomings that will be discussed.

equal distributions of social costs. Shrader-Frechette argues that differences in compensating wage differentials do not meet the burden of justification required for preferring policies that reduce mortality among the wealthy over those that would lead to equal or greater reductions in mortality among the poor. Sen (1973) suggests that human mortality be used as an indicator of social progress alongside GDP (gross domestic product), rather than determining the value of lives lost based on GDP. From the standpoints of both ethics and revealed preferences, differential valuation appears problematic at best (as Abram Bergson saw when he introduced the social welfare function in 1938). As an empirical matter, there is also little evidence that individuals who are wealthy value their own lives more than individuals who are poor, at least if we look at non-monetary measures. Bengston et al. (1977) found no evidence that attitudes towards death were dependent upon social stratum, race, or ethnicity, suggesting that the poor do not fear death any less than the wealthy. Moreover, when the former Soviet republics (with very high suicide rates, but unique history) are analyzed separately from other countries, suicide rates increase significantly with GDP (Virén, 1999), indicating that the poor are not more willing to end their lives than the rich (see also Kalist et al., 2007).

It can be argued that differential valuation of life is reasonable because it preserves consumer sovereignty and rationality on the local scale. People with greater wealth are likely, *ceteris paribus*, to require greater compensation to accept a risk than people with less wealth. In the US, for example, a large literature has demonstrated that people are willing to pay millions of dollars to avoid the loss of a statistical life. If economists used such high values in developing countries, however, they would run the serious risk of overvaluing risk reduction. If unrepresentatively high values for the loss of a statistical life were used in policy making, this could lead to outcomes that might devote too many resources to pollution control, reducing economic activity and increasing poverty, for example; a perverse result given the relative dangers of poverty (very high risk) and outdoor air pollution (relatively low risk). This is a similar argument to that underpinning the conclusion that it makes economic sense to locate polluting industries in developing nations if doing so leads to a reduction in poverty (Johnson et al., 2007). In this sense, differential valuation appears to emerge naturally from differential risk exposure.

We are left, then, with a problem: economic argument leads logically to differential valuation, but ethical argument is incompatible with this finding. Thus, we find that attempts to produce an objective comparison of economic outcomes lead, paradoxically, to clearly unethical conclusions. This suggests that ethical choices have, in fact, been included within the axioms of the assessment.

Put another way, an error must lie either with the ethical presuppositions that lead us to reject the conclusion that human value is related to income, or with the assumptions upon which the economic result derives.

We argue that the error appears with the unwillingness to compare interpersonal utility, and in particular the interpersonal utility of money: the counterintuitive results appear when instead we compare the interpersonal monetary valuations of people with vastly different resource allocations.

Doing away with the assumption of incomparability of personal utility values, at least within income classes, allows us to work directly with the idea that the marginal utility of money declines with wealth. While some authors are skeptical (Lawsky, 2011), declining marginal utility is widely used to explain behaviors such as risk aversion (Nicholson, 1995), plays a fundamental role in the intergenerational discount rate (Ramsey, 1928; Nordhaus, 2007), and is the basis for an array of social welfare functions (e.g., Sen, 1973; Blackorby and Donaldson, 1978; Bossert et al., 2009). Weber (2005) shows that the ordinally defined marginal value of income falls as income rises, and subjective well-being clearly does not rise linearly with income (although researchers argue whether it plateaus or rises logarithmically; see Frey and Stutzer, 2002; Clark et al., 2008; Deaton, 2008; Stevenson and Wolfers, 2008). The ability to empirically determine the magnitude of declining marginal utility to wealth is significant for BCA, and setting as equal the value of human lives allows analysts to use the existing data on the value of statistical life to develop an empirical measure of the declining marginal utility of wealth. An accurate measure of the declining marginal utility of wealth is critical to accurately weighing the trade-offs between, for instance, economic growth and redistribution.

Farrow (2011) suggests attaching weights to income classes when performing BCA, where weights are derived from inequality aversion. Several researchers have attempted to calculate the marginal value of income directly from subjective well-being studies (see, e.g., Layard et al., 2008; Dolan et al., 2011). Our analysis is similar, but we assume that the value of life is more defensible as a common unit of comparison than well-being.

If we assume that all human lives are of equal value *a priori*, then any differences between the measured value of life for different groups of people would be attributable to differences in the marginal utility of income to those groups rather than to differences in the marginal utility of life. The value of life itself can be considered a single, fundamental metric through which all other values can be compared.

Of course, we cannot actually measure the value that a person places on their own life. We might expect that, for many individuals, willingness to pay would be nearly identical to available resources. Worse, people might deviate from this value if they have a high-quality family life and would like to leave resources for loved ones, but it hardly seems likely that such people would actually value their lives less than those without such ties. Marginal analysis loses its meaning when we ask questions about what a person would require in exchange for surrendering existence. However, economists estimate something similar in calculating the value of a statistical life (VSL), which is essentially the same as a shadow price for risk reduction times the reciprocal of the risk of death. This is not the same as the value of life, for several reasons. First, and most obviously, one cannot currently "save" a life, one can only postpone death. Thus, VSL estimates really measure the amount that an average person values avoiding one of many risk factors, knowing that another risk factor will eventually lead to death.[2] Also, it applies only to expected mortality in a population. Analysts do not determine which particular individual would be expected to die, but only how many people are likely to die in a large population; that is, it addresses statistical versus identifiable risk (for a discussion of these issues, see Hammitt and Treich, 2007). That said, it certainly appears reasonable to imagine that the value that a person places on the risk of losing their life should be correlated with the value that they place upon their life itself. *Our goal, after all, is not to determine the actual value of life, but to use a value that we may assume is constant across incomes as a way of estimating the marginal utility of income*. Inasmuch as using the VSL to estimate the marginal utility of income allows us to avoid a result that is both counterintuitive and morally indefensible, we believe that a reassessment of the data would lead to a conclusion that is more consistent, rational, and ethically defensible than current practice.

As we will see, this idea is easy to state in theory but difficult to apply in practice for reasons that are not entirely limited to data quality. Cameron (2010) addresses this issue in arguing that economists should do away with the term VSL altogether, and instead use a phrase like "willingness to swap for a microrisk reduction." Her basic argument is that we are not actually measuring the "value" of a life in layman's terms, but the market price of goods and services that a person is willing to do without in exchange for a very small increment of reduced mortality risk. Moreover, and this will become a key challenge in our subsequent analysis, not all mortality risks are valued equivalently by an individual. People may be significantly more willing to pay to reduce their risk of death by 1 in 10,000 from terrorism than from auto accidents, for example, or from cancer versus heart disease.

[2] Although some authors, such as Kurzweil (2005), argue that postponing death currently will allow individuals to live to a point where technology makes death no longer inevitable.

We believe that there are two separate issues here. The first is that, whatever the scale of the measurement, equivalency between the utility value of a small additional risk of death for average individuals from two income classes is significantly more defensible than assumed equivalency of actual dollars, which clearly provides differential utility. The fact that individuals are not internally consistent may bring up more of a measurement issue than a conceptual one: ideally, we need to ensure that we use the same instrument for the estimation of value across income classes, whether we translate it into VSL, microrisk, or something else. Current surveys from across a large distribution of incomes are not sufficiently consistent to produce an accurate weighting scheme, but here we provide an initial estimate, with the hope of encouraging further work in the area.

2. Estimates for the Value of a Statistical Life

Taking as axiomatic the assumption that all humans value their lives similarly (when addressing similar risks), and that all are of equal weight, we can use the value of life as a metric to determine the marginal value of money as a function of income. From this perspective, the increasing demand for compensation with income reflects the lower per unit value of money to those with higher incomes, rather than a change in the absolute value of their lives.

To construct a welfare function based on this assumption, we used two metastudies that compiled life values using different methodologies. The first was Kip Viscusi's comprehensive 2003 study, The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World (Viscusi and Aldy, 2003), and the second was a 2011 analysis that grew out of an OECD (Organization for Economic Co-operation and Development) study, Valuing Mortality Risk Reductions from Environmental, Transport and Health Policies: A Meta-Analysis of Stated Preference Studies (Lindhjem et al., 2011).

Both metastudies compiled estimates of the VSL for populations with varying incomes. We can use this information to estimate a factor that would allow us to compare the value of money between individuals in a way that would make the VSL, in terms of calculated "value," constant from an individual in one income class to another. We will draw upon work from each metastudy separately, as they focus upon different methodologies.

Viscusi (whose metastudy we will refer to as Viscusi03) surveyed over 60 studies published between 1974 and 2001 that determined the value of statistical life. Of the studies surveyed, 56 included both mean income and estimated VSL. Of these, two studies provided what we considered to be unworkable ranges for their estimate of the VSL (approximately \$5–70 million in both). Two studies looked at particularly high risk occupations, thus potentially sampling individuals with significantly lower levels of risk aversion than the average individual. Indeed, both studies calculate anomalously low VSLs. Two studies used data from before the 1930s, which we deemed too old. We removed these studies for our sample.

From this sample, we only selected results based on compensating wage or wage differential methodologies. In the studies we used, the wage equation is assumed to take the form:

$$w_i = \alpha + H_i'\beta_1 + X_i'\beta_2 + \gamma p_i + \varepsilon_i \qquad (1)$$

where w_i is the wage required for an individual to enter the labor market, H_i' is a vector of personal characteristics (such as gender, education level, age, etc.), X_i' is a vector of characteristics of the specific job (industry type, white collar vs. blue collar, physical exertion required, hierarchical level, etc.), p_i is the fatality risk associated with the job, and ε_i is an error term representing stochasticity or unmeasured factors. α, β_i, and γ are parameters estimated through regression analysis (Viscusi and Aldy, 2003). Many studies also include terms for the risk of non-fatal injury, expected worker's compensation if injury is non-fatal, union bargaining power, time preferences, and so on. Some authors include a squared term in p_i term as well.

We ended up with 31 estimates from studies with relatively uniform, although not identical, methodologies. These are given in Table 1. The authors converted values from various studies into year 2000 US dollars on a purchasing power parity (PPP) basis (see source for methods). We converted these values into year 2005 dollars using the CPI-U (Consumer Price Index for all Urban consumers) deflator series to simplify comparison between our two data sets.

Table 1: Estimates of the Value of a Statistical Life from various comparative risk studies reported in Viscusi and Aldy (2003).

Paper	Year of data	Country	Mean income level ($)	VSL (million $)
Simon et al. (1999)	1990	Taiwan	696	0.38
Shanmugam (1996)	1990	India	882	0.86
Shanmugam (2001)	1990	India	882	0.85
Shanmugam (2000)	1990	India	884	1.1
Liu et al. (1997)	1982–1986	Taiwan	6292	0.62
Siebert and Wei (1998)	1991	Hong Kong	13,233	1.9
Weiss et al. (1986)	1981	Austria	13,622	5.9
Marin and Psacharopoulos (1982)	1975	UK	16,413	4.8
Meng (1989)	1986	Canada	22,640	5.9
Arabsheibani and Marin (2000)	1980	UK	22,868	22.6
Viscusi (1981)	1976	US	25,652	9.4
Kniesner and Leeth (1991)	1984–1985	Australia	26,434	4.8
Moore and Viscusi (1988a)	1972–1985	US	28,275	7.1
Dilingham (1985)	1977	US	30,317	5.7
Miller et al. (1997)	1991	Australia	31,303	17.2
Smith (1974)	1960–1967	US	32,923	10.4
Leigh and Folsom (1984)	1974	US	32,933	10.4
Leigh (1995)	1977–1981	US	33,556	14.1
Meng and Smith (1991)	1984	Canada	33,623	9.5
Cousineau et al. (1992)	1979	Canada	33,645	5.2
Smith (1976)	1967, 1973	US	35,189	6.7
Moore and Viscusi (1988b)	1980–1985	US	35,263	11.0
Viscusi (1978)	1969–1970	US	36,114	6.0
Leigh (1991)	1972–1981	US	37,383	12.7
Kniesner and Leeth (1991)	1978	US	38,138	8.7
Olson (1981)	1976	US	41,001	7.6
Leigh and Folsom (1984)	1974	US	41,902	15.1
Berger and Gabriel (1991)	1980	US	50,881	11.0
Berger and Gabriel (1991)	1980	US	53,152	9.8
Baranzini and Luzzi (2001)	1994–1995	Switzerland	53,759	8.4
Herzog and Schlottmann (1990)	1970	US	54,852	13.3
Brown (1980)	1966–1971	US	55,595	2.2

All values reported as year 2005 US dollars.

Recently, many researchers in the field of environmental valuation have moved away from the wage risk methodology for two reasons. First, environmental pollution tends to affect the very young and the very old most adversely, but wage risk studies draw disproportionately from men in their prime working years, and these groups may not have similar levels of risk aversion. Also, wage risk studies most directly measure the risk of accidental death and morbidity, whereas environmental pollutants are more likely to lead to mortality from chronic conditions and exacerbation of pre-existing medical conditions or susceptibilities, and individuals may treat these types of risks in different ways. Finally, it is not obvious that workers always have access to complete morbidity and mortality data, and perceived risks may differ from observed risks used by econometricians. For these reasons, the stated preference study (which we will refer to as Lindhjem11) focused on stated preference methods, including contingent valuation and choice modeling (Lindhjem et al., 2011).

Lindhjem et al. (2011) compiled a massive data set of 900 different estimates for the VSL. The authors looked for consistent methodologies and recommended only a subset of the studies for inclusion in the metastudy. Selecting only recommended estimates from studies that included both VSL and mean household income left us with 42 VSL estimates from 24 different studies (Table 2). Some authors broke populations up into age groups or other subdivisions, but we only used estimates based on the full population sampled. By contrast, some authors asked multiple questions, for example, having respondents think about high cancer risk, low cancer risk, high/low heart attack risk, and so on. Different types of risks elicited very different life valuations in some cases. When surveys reported different VSLs for the same population, we used the mean of the responses. However, when different groups of respondents were asked different questions within the same study, we treated them as independent studies and included all of the responses given. Comparing VSLs estimated based on responses to different risk scenarios increased the spread of points significantly, but there was no subset of more closely related methodologies that was large enough to use for our purposes.

Both Viscusi03 and Lindhjem11 suffer from the important drawbacks of limited sampling at very low levels of income and an overrepresentation of particular countries where more studies have been done. This distributional bias reduces the generalizability of our results, as cultural factors are likely to have an impact on stated risk aversion (Lindhjem et al., 2011). Still, the strongest outliers at a given income level, both with high and low estimated VSL, all come from OECD nations, suggesting that between study variation may be more important in the current data sets than cultural factors. The underrepresentation of low income countries becomes especially important when we attempt to estimate the variable elasticity case.

Table 2: Estimates of the Value of a Statistical Life from various stated preference studies reported in Lindhjem et al. (2011).

Paper	Year of data	Country	Mean income level ($)	VSL (million $)
Hammitt and Zhou (2006)	1999	China	1097	0.123
Hammitt and Zhou (2006)	1999	China	2040	0.025
Hammitt and Zhou (2006)	1999	China	3302	0.062
Bhattacharya et al. (2007)	2005	India	5012	0.023
Guo et al. (2006)	2003	China	5136	0.022
Dziegielewska and Mendelsohn (2005)	2000	Poland	12,775	0.287
Ortiz et al. (2009)	2003	Brazil	12,786	3.59
Liu et al. (2005)	2003	Taiwan	16,260	4.31
Alberini and Chiabai (2006)	2004	Italy	16,671	1.06
Alberini et al. (2005)	2004	Czech Rep.	17,815	2.66
Alberini et al. (2005)	2004	Czech Rep.	18,677	1.37
Hammitt and Liu (2004)	2001	China	19,485	1.57
Alberini et al. (2005)	2004	Czech Rep.	20,517	1.49
Alberini and Chiabai (2006)	2004	Italy	24,785	5.64
Alberini et al. (2005)	2004	Czech Rep.	25,823	1.98
Alberini et al. (2007)	2005	Italy	30,631	6.34
Guria et al. (2005)	1998	New Zealand	31,072	15.38
Alberini and Chiabai (2006)	2004	Italy	32,297	1.83
Guria et al. (2005)	1998	New Zealand	32,385	9.73
Guria et al. (2005)	1998	New Zealand	32,427	2.58
Johannesson et al. (1996)	1995	Sweden	32,854	7.02
Johannesson et al. (1996)	1995	Sweden	32,854	5.83
Guria et al. (2005)	1998	New Zealand	33,071	1.99
Guria et al. (2005)	1998	New Zealand	33,681	2.24
Strand (2009)	1995	Norway	33,867	6.41
Johannesson et al. (1997)	1996	Sweden	34,101	4.47
Guria et al. (2005)	1998	New Zealand	34189	3.19
Tonin et al. (2008)	2007	Italy	35,252	4.08
Desaigues et al. (2007)	2002	France	36,535	2.63
Itaoka et al. (2007)	1999	Japan	47,881	1.67
Chestnut et al. (2011)	2003	Canada	49,862	2.68
Svensson (2009)	2006	Sweden	50,285	2.99
Corso et al. (2001)	1999	US	53,227	3.76
Corso et al. (2001)	1999	US	54,516	4.28
Krupnick et al. (2002)	1999	Canada	54,698	3.58
Chestnut et al. (2011)	2002	US	54,720	4.92
Tsuge et al. (2005)	2002	Japan	55,584	2.69
Corso et al. (2001)	1999	US	55,806	2.86
Krupnick et al. (2002)	1999	Canada	56,079	1.14
Svensson (2009)	2006	Sweden	56,145	8.22
Alberini et al. (2004)	2000	US	60,107	1.42

All values reported as year 2005 US dollars.

Another important weakness in the data sets is that it was impossible to obtain a sufficiently large set of estimates using a consistent methodology to do our analysis. Thus, we had to accept some variation in methodological approach, meaning that the estimates for VSL may not all represent the same underlying value. We do not control for some variables that influence the relationship between income and VSL, such as degree of risk, whether the risk is voluntary, respondent age, and so on. Although we attempted to identify studies that were as similar as possible (as explained previously), and we do not retain obvious biases between income groups, the remaining lack of uniformity increases the uncertainty in our estimates.

3. Elasticity and the Value of Money

We estimate elasticity in two ways, in both cases using maximum likelihood estimation (MLE) to fit the VSL estimates from our survey. First, we use a fixed elasticity assumption to estimate the parameters a and elasticity (ε) in the equation:

$$L = a\,Y^{\varepsilon} \tag{2}$$

where L is the calculated VSL and Y is annual income in year 2005 US dollars. Hammitt and Robinson (2011) argue that the assumption of a constant income elasticity for the VSL leads to large errors when comparing groups with widely divergent incomes, both due to difficulties in elasticity estimation and the possibility that elasticity is income-dependent. We allow for the latter by using the equation:

$$\varepsilon = \frac{\mathrm{a}}{Y+h}; Y, a > 0 \tag{3}$$

where a and h are empirically determined constants. We find that h actually approaches zero when fit empirically, however, so we used a simplified version of the equation:

$$\varepsilon = \frac{\mathrm{a}}{Y}; Y, a > 0 \tag{4}$$

Using the definition of elasticity, and letting L = VSL, we can write:

$$\frac{a}{Y} = \frac{dL}{dY}\frac{Y}{L} \tag{5}$$

(5)

which we can rearrange and integrate:

$$\int \frac{a}{Y^2}\, dY = \int \frac{dL}{L} \tag{6}$$

$$-aY^{-1} + c = \ln L \tag{7}$$

$$L = be^{-\left(\frac{a}{Y}\right)} \tag{8}$$

where c is a constant of integration, and is incorporated into the parameter b.

We use MLE to fit our model function to the available data. We assume a double-exponential distribution function for error, which results in an algorithm that minimizes absolute error, rather than the square of the error as in ordinary least squares analysis. Because the estimates of the VSL in the literature rely on several different methodologies, some of which would be expected to result in different estimates even if applied to the same data, least squares analysis runs the risk of providing undue weights to expected outliers.

We can calculate the "true" value of a statistical life by multiplying the number of dollars that a person would deem equivalent to their statistical life by the marginal value of those dollars (m) in utils:

$$A_i = m_i L_i \tag{9}$$

where A_i is the value of a statistical life for person i in utils rather than dollars. If we take as axiomatic that A_i is constant – that all people value risk reduction equally[3], regardless of income – and if we assume that L is only a function of income, then we have:

$$m_i = \frac{A}{L(Y_i)} \tag{10}$$

Arbitrarily setting the units of utils such that $A = 1$, the marginal value of money is simply L^{-1}.

[3] Of course, individuals actually have very different levels of risk aversion. Our work here deals only with groups of people at different income levels, and we assume that risk aversion, i.e., the level of desire to avoid death, is uncorrelated with income.

4. Results and Discussion

In the constant elasticity case, we estimate an elasticity for the Viscusi03 data of 0.73, with 95% confidence that ε lies between 0.62 and 0.93 (Figure 1), and an elasticity of 0.76 for Lindhjem11, with 95% confidence that ε lies between 0.46 and 1.05. Our estimate for the elasticity is larger than that found in other studies working with a data set largely from industrially developed nations (Hammitt and Robinson, 2011, and citations within), consistent with observations that elasticity declines with income. Also, although the two data sets differ strongly in estimates for VSL, they result in nearly identical values of elasticity. The multipliers differ by a factor of 4, but this does not affect our results because it does not affect relative comparisons between groups.

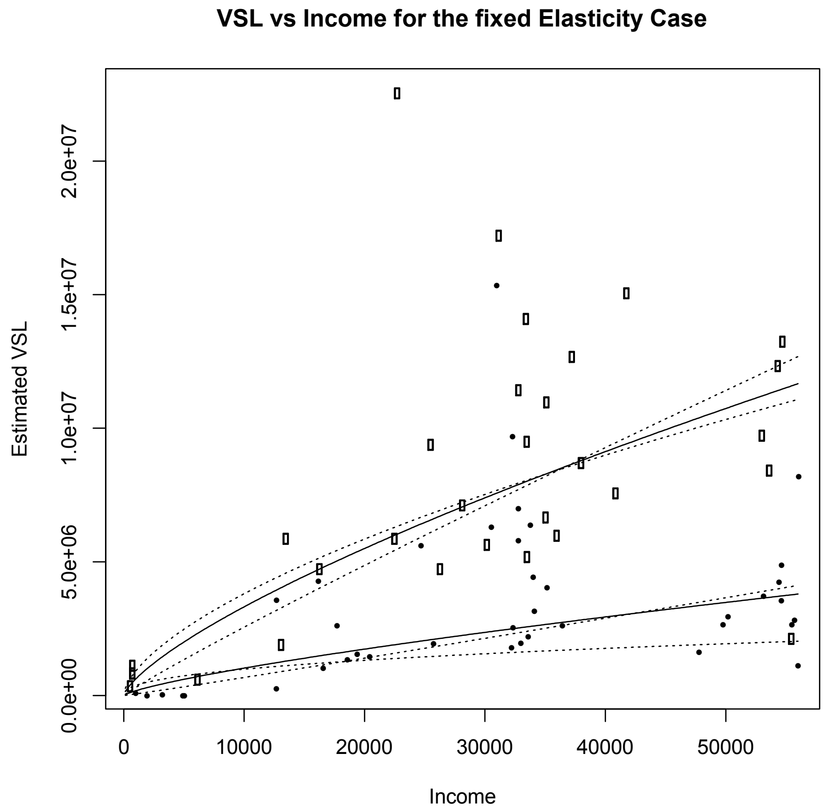

Figure 1: The Value of a Statistical Life (VSL) versus income, assuming constant elasticity. Open circles represent data from studies on risk premiums (Viscusi03), and the top curve is fit to these values. Closed circles represent studies using survey methods (Lindhjem11), and the bottom curve is fit to them. The solid lines represent the maximum likelihood fit of a constant elasticity equation to the data, with the dotted lines representing estimates using the highest and lowest elasticities in the 95% likelihood range.

Using our elasticity estimate, we can calculate the value of marginal income for individuals with income Y as:

$$m(Y) = aY^{-0.74}; Y > 0 \tag{11}$$

where factor *a* is chosen to make the value of marginal income for individuals with an income of $50,000 equal to unity. As we are interested in relative values, this arbitrary choice has no effect on our results. Figure 2 shows the relative value of marginal income at incomes greater than $150. Below $150, $m(Y)$ rises rapidly. We plot the Lindhjem data in Figure 2 because it has the larger elasticity range. The empirical determination of the relative value of a marginal dollar across income classes is applicable in the BCA of programs that disproportionately affect members of low or high income. In a review of welfare-to-work programs, Greenberg et al. (2010) observe that inclusion of the relative value of money to different income classes in BCA would lead to better informed welfare policy decisions. For example, eligibility for the US Supplemental Nutrition Assistance Program (SNAP) requires individuals' incomes to be below $14,088 a year as of 2008 (USDA, 2008). Using Eq. (11), we find that SNAP recipients near the cut-off value the marginal dollar at approximately 2.5 times that of the median American household with an income of approximately $50,000 a year. Including this information in the BCA leads to a reordering of some of the programs that Greenberg assessed and thus would be valuable information for use in analysis.

We can also use our results to begin to speak more quantitatively about trade-offs that may result if poverty reduction policies lead to lower growth rates. For example, Dikhanov (2005) proposed several scenarios for potential future poverty reduction. These scenarios involved income redistribution from the world's wealthy to its poorest citizens. The report estimated that nearly 400 million people could be moved across the poverty threshold (defined as an annual income of $700, converted using PPP) by taxing the richest 5% of the world's population at a marginal rate of 7.5%, and transferring the wealth equally to those in the lowest three deciles (this would be equivalent to a transfer of 1.8% of the wealth from the top decile). Although this is a valuable result, it is not clear how to compare the benefits and costs of the transfer. Moreover, it is open to criticism by those who would suggest that GDP growth is a better focus for policy makers, and again it is difficult to weigh the benefits of wealth transfer versus potential growth reducing aspects of such a policy. Because we now have a metric for comparing utility across income classes, we could instead ask how much growth, equally distributed across deciles, would be required to lead to the same societal utility benefit as a wealth transfer. We find that, for our estimated elasticity of 0.74 (midway between our two results), a one-time transfer of the sort mentioned would provide utility benefits equal to 17.6% (95% certainty range: 11.1–82%) GDP growth. In other words, it would take 10 years of an additional 1.6% annual growth to create a benefit equal to this one-time transfer. If the growth reduction were smaller than this, then the transfer would be utility enhancing.

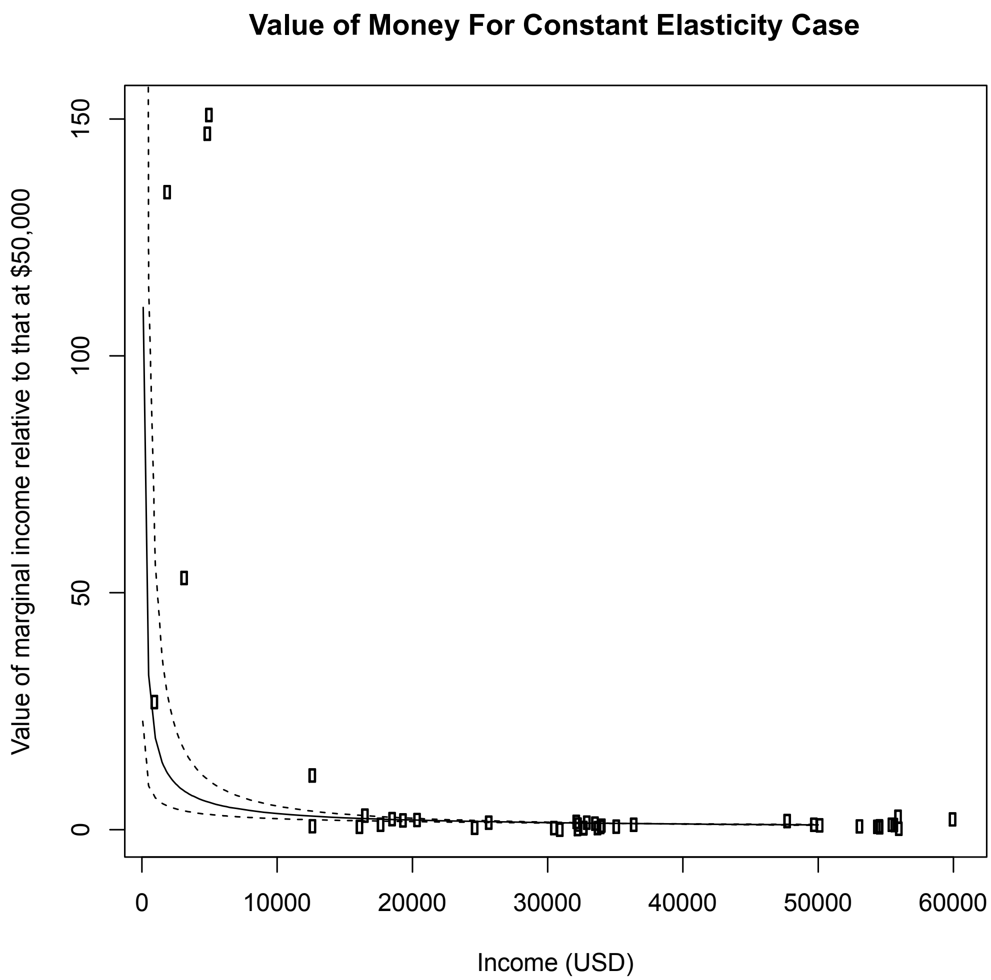

Figure 2: The relative value of money, assuming constant elasticity. The estimated value of money at different income levels, normalized to unity at an income of $50,000. The solid line represents the maximum likelihood estimate, with the dotted lines representing the 95% likelihood range. Points are the calculated value at $50,000, divided by the estimates for VSL from our data set.

Figure 3 shows the estimated fit using an income-dependent elasticity. The best-fit equations are:

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$$L = 1.502 \times 10^7 e^{-20,700/Y}; Y > 0, \text{from risk data} \qquad (12)$$

$$L = 5.28 \times 10^6 e^{-23,100/Y}; Y > 0, \text{from survey data} \qquad (13)$$

There are several reasons to prefer the model with a variable elasticity over that with a fixed elasticity. First, the income elasticity of VSL has been shown to decrease with income (Hammitt and Robinson, 2011). Moreover, if we allow ε to vary with income, then it has a value of 0.52 (Viscusi03) or 0.58 (Lindhjem11) at Y = $40,000. These are fairly consistent with a number of recent estimates from various US Government agencies, using high income samples: 0.4 for the EPA (USEPA, 1999), 0.47 for the Department of Homeland Security (Robinson, 2008; USCG, 2008), and 0.55 for the Department of Transportation (USDOT, 2009; see Hammitt and Robinson, 2011 for more discussion of these values). Thus, allowing ε to vary over a large range of incomes allows for more consistent results with studies done using a smaller income range.

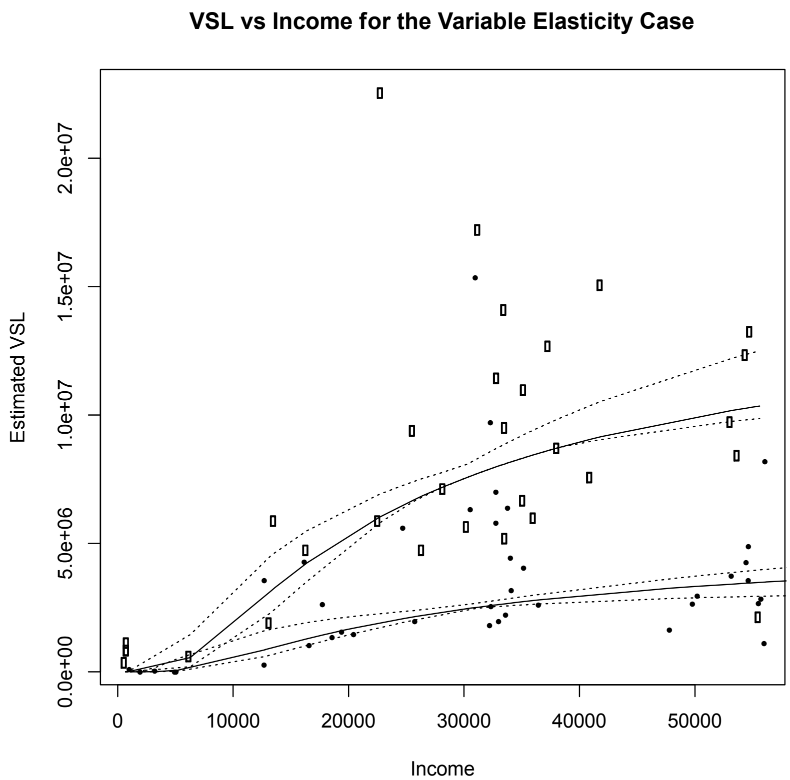

Figure 3: The Value of a Statistical Life (VSL) versus income, assuming a variable elasticity. Open circles represent data from studies on risk premiums (Viscusi03), and the top curve is fit to these values. Closed circles represent studies using survey methods (Lindhjem11), and the bottom curve is fit to them. The solid line represents the maximum likelihood fit of a variable elasticity equation to the data, with the dotted lines representing the 95% likelihood range.

Estimates for the marginal value of a dollar, however, become unreasonably large within the range that we are interested in estimating (e.g., the value at $1500 is over 100,000 times the value at $50,000). This points to a potential weakness in using VSL estimates based upon willingness to pay (WTP) to determine value.

This formulation is problematic for two reasons. First, when thinking about the value to a person of their own life, WTP incorrectly assumes an initial allocation that requires a person to pay for the privilege of existence. If we want to know how much money is "worth" to an individual in comparison to their own life, then we need to assume an initial allocation in which they possess their life and must be induced to accept risk. Thus, we are more interested in their willingness to accept compensation (WTA) than WTP (Graham, 2007) (this type of argument is controversial, however, as WTA is unbounded and WTP is more consistently used in most analysis). Our concern is also a practical one that can be seen in these results: an individual with zero income or wealth necessarily has zero WTP, regardless of how much they value their own life. This presents a problem because it leads to the outcome that a person with no income places an infinite value on a marginal dollar. However, even a destitute, risk-averse individual would presumably require some positive compensation to increase their risk of death, and it is this value that we would like to measure.

These problems are resolved if, instead, we consider the WTA. Moreover, if we are attempting to use life value as our base unit of measure, rather than a dollar, then WTA is really the correct measure, as reduced risk avoidance becomes the fundamental currency – it is what, theoretically, people pay with, rather than for. However, the studies in our sample generally attempt to measure WTP rather than WTA because the former is considered more economically reasonable (as it is bounded).

The divergence of WTP and WTA at low levels of income is expected to be significant, as the income effect becomes large in this region (although, as Zhao and Kling, 2001 point out, the income effect is not the only reason for their divergence). WTA should be bounded below by the WTP curve, but ought to intercept the y-axis at a positive value, which would keep the value of money for the very poor from becoming near infinite.

Our calculations provide a first estimate for a justifiable relationship between money and utils, although we feel that the estimates could be greatly improved by an effort to determine WTA, especially for low income populations.

5. Conclusions

When constructing a metric for the comparison of policies, we find that there are two possible extreme positions: either consumption (as measured by money) is of equal value to all people, or people (as measured by risk aversion) are of equal value. The former option is clearly absurd, and yet it is the basis upon which we generally calculate economic efficiency when comparing political choices, under the cover of Kaldor-Hicks compensation assumptions. This is despite the fact that we know in most cases that compensation will not take place. The latter option, by contrast, is both ethically defensible and produces results that are consistent with behavioral observations.

Layard et al. (2008) also attempt to estimate the relative value of money using subjective well-being as their method of interpersonal comparison. As noted earlier, we believe that the value of life is more defensible as a base metric, but their results are instructive. They use the following equation:

$$W = \begin{cases} a\dfrac{Y^{1-\rho}-1}{1-\rho} & \text{if } \rho \neq 1 \\ \log Y & \text{if } \rho = 1 \end{cases} \qquad (14)$$

where W is well-being, Y is income, a is a constant, and ρ can be thought of as an elasticity term. They found a ρ of 1.26 for the relationship of subjective well-being and income, suggesting that benefits to well-being from added income decline even more rapidly than would be expected in a logarithmic relationship. This is relatively consistent with our analysis: if the marginal value of income falls off quickly, then we would expect the amount of money that one would be willing to accept to compensate for added risk would increase relatively rapidly with income. As expected, we found that the ratio of the estimated VSL to income declines very slowly with increasing income: in the constant elasticity case, the VSL of a person making approximately $1000 per year is approximately 600 times their annual income, whereas the VSL for a person making $50,000 per year is approximately 200 times their annual income. In the variable elasticity case, VSL is actually lower than annual income up until approximately $2000–$3000, depending upon the data set.

The income weights we calculate here in the fixed elasticity case are lower than the values suggested by the British Green Book (Treasury, 2003), where the elasticity is assumed to be unity. Moreover, in the variable elasticity case, our result that elasticities in the high income ranges are relatively low would result in a lower calculated impact from redistributional policies at income levels likely to be found in developed countries.

Income weights are not uncontroversial because they result in policies that may favor economically inefficient outcomes, and thus lead to suboptimal results. Certainly, they run the risk of concluding that policies are advisable even if the resources to enact these policies do not exist. Harberger (1978) addresses these topics and concludes that income weights should not be larger than the administrative costs of income transfer, because otherwise actual transfer would be preferable. This conclusion, however, is weakened by the observation that such transfers rarely occur as a result of individual policies to which BCA is applied. Brent (1996) points out that Harberger's result also rests on the assumption that the tax transfer system has been set optimally, which he argues is not the case. In any event, it is important to realize that income weights are not without detractors.

We believe that the technique of using estimated VSL to determine the relative value of money to those in different income groups, and thus producing a defensible social welfare function, represents a significant potential improvement over current benefit-cost methodology. However, the variation in methodologies for estimating VSL remains wide and significant. Our analysis here suggests that in order to utilize mortality risk aversion with confidence, it will be necessary to compare across a wide range of incomes using a highly consistent instrument for determining VSL. Moreover, a focus upon WTA in the construction of this data set would be ideal, as this is the value that we are ultimately interested in, although there are currently very few such studies. WTA would allow for the construction of a meaningful value curve even at low levels of income, because the WTA for VSL is unlikely to approach zero. Both improvements require significant survey resources and were beyond the scope of this preliminary study.

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