WORKING PAPERS

N° 1339

May 2022

# “Prevention, Treatment, and Palliative Care: The Relative Value of Health Improvements under Alternative Evaluation Frameworks”

James K. Hammitt

Toulouse School of Economics

**Prevention, Treatment, and Palliative Care: The Relative Value of Health Improvements under Alternative Evaluation Frameworks**

James K. Hammitt

Harvard University (Center for Risk Analysis & Center for Health Decision Science)
Toulouse School of Economics, University of Toulouse-Capitole
jkh@harvard.edu

May 2022

Keywords: prevention, treatment, morbidity, social-welfare function, benefit-cost analysis, value per statistical life

JEL codes: D61, D63, D81, I10, I31

**Abstract**

The social value of decreasing health risks can be evaluated using benefit-cost analysis (BCA), cost-effectiveness analysis (CEA), or a social-welfare function (SWF). These frameworks can produce different social preference rankings of interventions depending on how their health effects and costs are distributed in a population. This paper derives social values of marginal decreases in the probability of illness, its severity (decrease in health status), lethality (conditional mortality risk), and cost under BCA, CEA, and three benchmark SWFs: utilitarian, ex ante prioritarian, and ex post prioritarian. The sensitivity of the social values of improvements in health and decreases in cost to individual circumstances are diverse. In contrast, the conditions under which a decrease in risk, severity, or lethality is socially preferred to a decrease in another of these dimensions are identical for BCA, CEA, the utilitarian and ex ante prioritarian SWFs, but can differ for the ex post prioritarian SWF.

## 1. Introduction

Quantifying the value to society of improving health is important for allocation of health and safety resources, including health-care spending, public-health interventions, and environmental, health, and safety regulations. Social values of health interventions are most often assessed using cost-effectiveness analysis (CEA) or benefit-cost analysis (BCA). Alternatively, values can be assessed using a social-welfare function (SWF). The rankings of health interventions produced by these evaluation frameworks can conflict, depending on the interventions' effects on different dimensions of the risk (e.g., prevention or treatment) and characteristics of the people who benefit (e.g., age or wealth).

Applications of CEA and BCA to evaluate health interventions are ubiquitous. CEA is most often used to evaluate health-care and public-health interventions while BCA is most often used to evaluate environmental, health, and safety regulations. SWFs are used in the optimal tax and climate-economics literatures (Tuomala 2016, Botzen and van den Bergh 2014) but rarely to evaluate health risks; recent work examines the implications of using SWFs for valuing reductions in mortality risk (Adler et al. 2014, 2021). This paper extends the use of SWFs to nonfatal health risks.

I analyze a one-period model in which an individual faces a risk of illness or injury that may prove fatal. An intervention can affect any of three dimensions of the health risk: the probability of suffering the impairment, the conditional mortality risk, and the severity of the impairment (degradation of health status or quality of life). The share of the cost of an intervention that is born by an individual decreases her wealth. The relative social values of decreasing (improving) each of these dimensions are compared under alternative evaluation frameworks, together with the sensitivity of the social values to the magnitudes of the risk dimensions and to individuals' characteristics (wealth). In addition, the conditions under which the social value of reducing one dimension exceeds the social value of reducing another are determined (e.g., the conditions under which prevention is socially more valuable than treatment).

I evaluate the demand for health interventions (i.e., their value relative to cost). Whether an intervention is socially desirable depends on how much it decreases health risk relative to its cost. An inexpensive intervention that modestly improves health can be socially preferred to an expensive intervention that produces a larger improvement. Moreover, an intervention that provides less total health can be preferred to another if it distributes the health gains more equitably. The five evaluation frameworks considered are BCA, CEA, and three "benchmark" SWFs: utilitarian, ex ante prioritarian, and ex post prioritarian.

Evaluation of health interventions must account for social concerns about efficiency (providing the most benefit for the cost) and distribution of effects across individuals. Distributional effects can be characterized in terms of the extent of inequality of some relevant dimension such as wellbeing, health, or income. Inequality aversion (with respect to some dimension) is defined as a preference for mean-preserving contractions in the distribution of that dimension (i.e., transfers from individuals with more to individuals with less). Inequality neutrality is defined as indifference to the distribution of a fixed total of the dimension.

A key difference between SWFs and the two most-commonly used frameworks, BCA and CEA, is the way in which they aggregate effects across individuals. SWFs are functions of some measure of individual wellbeing (e.g., utility). The utilitarian SWF sums individual wellbeing while prioritarian SWFs sum wellbeing transformed by a strictly increasing and concave function. The utilitarian SWF is inequality neutral with respect to wellbeing (it is unaffected by how total wellbeing is distributed) while prioritarian SWFs are inequality-averse. The difference between the ex ante and ex post prioritarian SWFs is that the ex ante formulation depends on the sum of individuals' transformed expected utilities while the ex post formulation depends on the expected value of the sum of individuals' transformed realized utilities (as described in Section 2.2).

SWFs require an interpersonally comparable measure of wellbeing. Lacking an objective alternative, the measure and its dependence on individual circumstances must be assumed. Alternatives include von Neumann-Morgenstern utility functions, subjective wellbeing or life satisfaction, and capabilities, with additional assumptions to make them interpersonally comparable (Adler 2019, Adler 2022, Adler and Decancq 2022, Bossert and Weymark 2004, Deaton and Muellbauer 1989, Fleurbaey and Blanchet 2013).

In contrast, BCA and CEA aggregate effects across individuals using more objective standards. BCA quantifies the effects of an intervention on each person's wellbeing by the individual's monetary value of the change, i.e., compensating or equivalent surplus. BCA counts a dollar of benefit as providing the same social value independently of how it is allocated. If the net social benefit of an intervention (the population sum of individuals' monetary values) is positive, then the intervention creates a potential Pareto improvement because (in principle) money could be transferred from individuals who benefit to those who are harmed so that everyone would benefit from the combined intervention and transfer scheme. BCA attempts to separate efficiency from distribution with the view that decision makers can appropriately balance effects on efficiency and distribution. Alternatively, BCA can be justified as an approximation to a utilitarian SWF with the proviso that individuals' monetary values must be weighted by their marginal utilities of wealth or income (e.g., Drèze and Stern 1987).

CEA quantifies costs and health effects using different units: costs are measured in monetary units and effects by some measure of health, often quality-adjusted life years (QALYs) or disability-adjusted life years (DALYs). Hence costs are aggregated counting a dollar of cost as producing the same social harm, independently of who bears it, and health benefits are aggregated counting a QALY or DALY as providing the same social value, independent of its distribution. While perhaps inconsistent from a welfare perspective, CEA is often perceived as preferable to BCA because it counts health improvements as equally valuable independently of distribution, while BCA counts health benefits as more valuable if accruing to individuals with higher monetary values (typically those with greater wealth).[1]

SWFs have been introduced to health economics as a method to formalize evaluation of the tradeoff between efficiency and equitable distribution of health (Wagstaff 1991, Dolan 1998). For this purpose, authors have used a restricted health-related SWF that is a function of individuals' health and longevity rather than wellbeing (e.g., Williams 1997, Bleichrodt et al. 2004, Bleichrodt and van Doorslaer 2006, Dolan and Tsuchiya 2011). Health applications of prioritarian SWFs have typically assumed certainty about outcomes (e.g., Ottersen 2013) or adopted the ex ante form (Cookson et al. 2022). However Samson et al. (2018) apply both ex ante and ex post formulations and Leach (2010) adopts an ex post prioritarian SWF to compare public and private health insurance.

Section 2 introduces the model of health risk to an individual, shows how it is interpreted under the five evaluation frameworks, and further describes the differences among the evaluation frameworks. Section 3 derives the social value of a marginal decrease in each risk dimension and of a marginal increase in wealth (decrease in cost) under each of the evaluation frameworks. Section 4 compares the social values of decreasing each of the risk dimensions and Section 5 concludes.

## 2. Health-risk model and evaluation frameworks

This section presents the model of health risk and individual wellbeing and the alternative evaluation frameworks. Because the objective of the paper is to evaluate alternative frameworks for assessing social policies, it evaluates individuals' wellbeing using expected utility theory, broadly accepted as the normative standard (e.g., Bleichrodt et al. 2001, Sugden 2022).

[1] In practice, this effect is often suppressed by using a common monetary value for each health effect for all individuals.

*2.1. Health risk and individual utility*

The health-risk model (Rheinberger et al. 2016)[2] assumes an individual seeks to maximize her expected utility. She faces a probability $p$ (baseline risk) of illness (or injury). Conditional on illness, mortality risk is $q$ (lethality). If ill, health deteriorates by a fraction $s$ (severity) defined such that $s = 0$ corresponds to full health and $s = 1$ to a health state as bad as dead ($s$ is limited to the interval from 0 to 1). Utility depends on wealth (or consumption) $c$; the utility of a bequest (the utility of wealth conditional on death) is $v(c)$ and the utility of survival equals $(1 – s)\, u(c) + v(c)$.

The individual's expected utility is

$$U = (1-p)[u(c)+v(c)] + p(1-q)[(1-s)u(c)+v(c)] + pqv(c)$$

$$= [1-p(q+\mathrm{s}-qs)]u(c)+v(c). \qquad (2.1)$$

As in the standard model for mortality risk (Drèze 1962, Jones-Lee 1974, Weinstein et al. 1980), assume: survival is preferred to death ($u(c) > 0$) except when health is as bad as dead ($s = 1$); the marginal utility of wealth conditional on survival is strictly greater than the marginal utility of a bequest ($u'(c) > 0$); the marginal utility of a bequest is non-negative ($v'(c) \geq 0$); and the individual is weakly averse to financial risk conditional on survival and on death ($u''(c) \leq 0$ and $v''(c) \leq 0$). With these assumptions, $-\frac{d^2U}{dsdc} > 0$, i.e., the marginal utility of health (of a decrease in severity $s$) is an increasing function of wealth and the marginal utility of wealth is an increasing function of health, a common assumption with some empirical support (Viscusi and Evans 1990, Sloan et al. 1998, Domeij and Johannesson 2006, Finkelstein et al. 2013). Note that $u(c)$ is defined as the difference in utility between survival in full health and death, not the utility of survival as in the standard model for mortality risk. The standard model does not include health states other than alive and dead and the present formulation is convenient for representing utility in impaired health as a fractional deterioration from full health toward a state as bad as dead.[3]

The model is consistent with measuring health in QALYs or DALYs. Assume the individual's preferences over lotteries on health and longevity holding wealth constant do not depend on her wealth (as is implicit in the QALY and DALY literatures). Then utility for health, longevity, and wealth can be written as a positive affine transformation $[Q\, a(c) + b(c)]$, where $Q$ is a life-year measure of

[2] Rheinberger et al. (2016) use different notation. They denote baseline risk by $q$, conditional mortality risk by $p$, and severity by $h$.
[3] The standard model of mortality risk assumes expected utility $U = (1 - p)\, u_a(c) + p\, u_d(c)$ where $u_a$ and $u_d$ are utility conditional on survival and death. The model in equation (2.1) substitutes $u_a(c) = u(c) + v(c)$ and $u_d(c) = v(c)$.

health and longevity and $a(c) > 0$ for all values of $c$ such that life is preferred to death (Hammitt 2013). Life-year measures include QALYs, DALYs, and other measures for which tradeoffs between health and longevity are independent of wealth.[4] In the model, the term $(1 - s)$ can be interpreted as future QALYs normalized such that 1 corresponds to longevity in full health and $s$ equals both the fraction of longevity the individual would sacrifice to live the rest of her life in full health (as in a time-tradeoff question) and the probability of death in a standard gamble with outcomes of survival in full health and immediate death she would judge equally desirable as living the rest of her life in the impaired health state.

The model is most naturally interpreted as a model of chronic illness, in which the health impairment persists for the rest of the individual's life ($s$ can be interpreted as incorporating any decrease in longevity conditional on illness). It can be interpreted as a model for acute illness by interpreting the utility if ill as expected lifetime utility conditional on becoming ill and recovering. In this case, severity may be decreased either by improving health status while ill or shortening the duration of illness. Nonfatal health conditions can be represented by setting lethality $q = 0$. Note that the roles of lethality $q$ and severity $s$ are symmetric; they appear in the last expression of equation (2.1) only in the term $(q + s - q\,s)$. This has implications that are highlighted below.

The individual's health risk can be mitigated by "prevention" that decreases the risk of illness $p$, by "treatment" that decreases lethality $q$, and by "palliative care" that decreases severity $s$.[5]

### *2.2. Alternative evaluation frameworks*

Interventions that affect the wellbeing of multiple individuals can be evaluated using a social-welfare function, BCA, or CEA. A social-welfare function is a function of the wellbeing levels of all individuals in a society.[6] Wellbeing must be measured so that changes (e.g., due to a health impairment) and, for some SWFs, levels are interpersonally comparable. Wellbeing can be measured by happiness, life-satisfaction, capabilities, or other concepts. In the model, wellbeing is measured by von Neumann-Morgenstern utility and the functions $u(\cdot)$ and $v(\cdot)$ are assumed to be identical across individuals. Individuals may differ in baseline risk $p$, conditional mortality risk $q$, severity of illness $s$, and wealth $c$. Assume there are no other differences between individuals that are relevant to the social value of

---

[4] If tradeoffs between health and longevity are not independent of wealth, the utility weight (health-related quality of life) or disability weight associated with a health state depends on the individual's wealth.

[5] Although palliative care typically refers to care that decreases pain without extending longevity when suffering a fatal illness, the term is used here to distinguish care that alleviates symptoms from treatment that decreases conditional mortality risk.

[6] See Adler (2019) for a comprehensive introduction to SWFs or Adler (2012), Blackorby et al. (2005), Bossert and Weymark (2004), or Weymark (2016) for additional background.

improving an individual's wellbeing and the evaluation frameworks satisfy the axiom of anonymity (social preferences are not affected by permutation of individuals' circumstances defined by the vectors ($p_i$, $q_i$, $s_i$, $c_i$), where *i* indexes individuals. An individual's expected utility $U_i$ is given by substituting her values into equation (2.1).

Let the population be fixed and include *N* individuals. The utilitarian SWF is the population sum of individuals' expected utilities,

$$S^U = \sum_{i=1}^{N} U_i = \sum_{i=1}^{N} [1 - p_i(q_i + s_i - q_i s_i)]u(c_i) + v(c_i). \quad (2.2)$$

The utilitarian SWF measures the total wellbeing in the population; it is unaffected by how wellbeing is distributed among individuals. Differences in wellbeing, but not levels, must be interpersonally comparable to determine whether an intervention that improves some people's wellbeing while worsening other's increases total wellbeing.

Prioritarian SWFs are defined as the sum of individual utility transformed by a function $g(\cdot)$ that is strictly increasing and concave. I assume throughout that *g* is differentiable and hence $g' > 0$ and $g'' < 0$. Prioritarian social welfare is increasing in the wellbeing of each individual, but social welfare is more sensitive to changes in wellbeing of individuals with lower wellbeing than to those with higher wellbeing (hence levels as well as changes of wellbeing must be interpersonally comparable). For a fixed total wellbeing in the society, prioritarian social welfare is maximized when the total is distributed equally; equivalently, social welfare is improved by a transfer of wellbeing from one individual to another at lower wellbeing. Prioritarian SWFs provide an intermediate case between utilitarian and Rawlsian (max-min) SWFs: In the limit as the transformation function becomes linear, the prioritarian SWF equals the utilitarian SWF; as the transformation function becomes increasingly concave, the prioritarian SWF approaches the Rawlsian SWF, in which social welfare is determined by the wellbeing of the worst-off individual.

When utility is uncertain or subject to risk, the prioritarian SWF depends on whether it is evaluated ex ante or ex post.[7] The ex ante prioritarian SWF is the population sum of individuals' transformed expected utilities,

$$S^{EAP} = \sum_{i=1}^{N} g(U_i) = \sum_{i=1}^{N} g\{[1 - p_i(q_i + s_i - q_i s_i)]u(c_i) + v(c_i)\}. \quad (2.3)$$

The ex post prioritarian SWF is the population sum of individuals' expected transformed utilities,

---

[7] For the utilitarian SWF, the ex ante and ex post evaluations are identical. This can be verified by replacing $g(\cdot)$ with the identity function in equations (2.3) and (2.4).

$$S^{EPP} = \sum_{i=1}^{N}(1-p_i)g[u(c_i)+v(c_i)] + p_i(1-q_i)g[(1-s_i)u(c_i)+v(c_i)] + p_i q_i g[v(c_i)]. \quad (2.4)$$

Under any of the benchmark SWFs (utilitarian, ex ante prioritarian, ex post prioritarian), the social value of a change to an individual's health risk is measured by the change in social welfare. An individual's wellbeing is improved by a decrease in any of the three dimensions of her health risk (baseline risk $p_i$, lethality $q_i$, and severity $s_i$) and by an increase in her wealth $c_i$. Define the social value of an improvement in any of these four dimensions for individual *i* as the rate of improvement in social welfare in response to a marginal improvement in the dimension, i.e., as $-\frac{\partial S^K}{\partial \theta_i}$ for $\theta_i = p_i, q_i, s_i$, and as $\frac{\partial S^K}{\partial c_i}$ for $c_i$, where $S^K = S^U, S^{EAP}, S^{EPP}$.

BCA and CEA provide measures of the social value of an intervention but, unlike SWFs, do not provide a measure of the social value of a life (e.g., $U_i$ is the social value of individual *i*'s life under the utilitarian SWF). Under BCA, interventions are evaluated as the net social benefit, defined as the sum of each individual's monetary value of the change in her wellbeing. The monetary value to an individual of a change to her health risk is measured by her compensating surplus (willingness to pay for an improvement, willingness to accept compensation for a degradation). For a marginal change in any dimension $\theta_i = p_i, q_i, s_i$, the marginal change in social net benefit equals the marginal change in the individual's utility divided by her marginal utility of wealth, i.e.,

$$-\frac{\partial S^{BCA}}{\partial \theta_i} = \frac{dc_i}{d\theta_i} = \left(-\frac{\partial U_i}{\partial \theta_i}\right) / \left(\frac{\partial U_i}{\partial c_i}\right) > 0. \quad (2.5)$$

For small changes, the evaluations under the utilitarian and prioritarian SWFs can be mimicked using weighted BCA with fixed weights (Drèze and Stern 1987, Adler 2016, Fleurbaey and Abi-Rafeh 2016). For example, from equations (2.2) and (2.5), $-\frac{\partial S^U}{\partial \theta_i} = -\frac{\partial U_i}{\partial \theta_i} = \frac{dc_i}{d\theta_i}\frac{\partial U_i}{\partial c_i}$, hence weighted BCA using each individual's marginal utility of wealth as her weight yields the change in utilitarian social welfare.

Under CEA, interventions are evaluated by the incremental cost-effectiveness ratio (ICER), defined as the sum over individuals of the incremental monetary cost divided by the sum over individuals of the incremental effect on health.[8] When health is measured in QALYs, it is independent of wealth and

[8] CEA is often conducted from alternative perspectives. Equation (2.7) corresponds to the social perspective, in which all costs are included. CEA conducted from the payer or health-care-sector perspective excludes costs not born by the government, insurer, or other specified payer. See, e.g., Sanders et al. (2016).

equal to zero in the event of death. Adapting the model of expected utility from equation (2.1), define QALYs for individual *i* as

$$Q_i = 1 - p_i(q_i + s_i - q_i s_i), \tag{2.6}$$

which is normalized so that $Q_i$ = 1 corresponds to a lifetime in full health. The ICER for an intervention is given by

$$ICER = \frac{-\sum_{i=1}^{N} dc_i}{\sum_{i=1}^{N} dQ_i}. \tag{2.7}$$

where $dc_i$ and $dQ_i$ are the effects of the intervention on individual *i*'s wealth and health (QALYs).

The effect of an intervention on social wellbeing depends on its ICER and scale (e.g., the number of individuals treated). Let $dS^{CEA} = f(ICER, scale)$ where $dS^{CEA}$ denotes the increase in social wellbeing which is a function *f* of the *ICER* and *scale* of the intervention.[9] When the costs and health effects of the intervention are both positive,[10] *ICER* and $dS^{CEA}$ are positive and $dS^{CEA}$ is a decreasing function of *ICER* and an increasing function of *scale*.

Holding *scale* constant, the social value of a change in a dimension $\theta_i$ of health risk for individual *i* is

$$-\frac{\partial S^{CEA}}{\partial \theta_i} = -\frac{\partial S^{CEA}}{\partial ICER}\frac{\partial ICER}{\partial \theta_i} = -\frac{\partial S^{CEA}}{\partial ICER} ICER \frac{\frac{dQ_i}{d\theta_i}}{\sum_{i=1}^{N} dQ_i} > 0. \tag{2.8}$$

That is, the social value of a change to the intervention that improves risk dimension $\theta_i$ for individual *i* is proportional to the proportional change in the population health effect. The social value of an increase in wealth (decrease in cost) to individual *i* is inversely proportional to the effect of the intervention on population health, i.e.,

$$\frac{\partial S^{CEA}}{\partial c_i} = \frac{\partial S^{CEA}}{\partial ICER}\frac{\partial ICER}{\partial c_i} = \frac{\partial S^{CEA}}{\partial ICER} ICER \frac{-1}{\sum_{i=1}^{N} dQ_i} > 0. \tag{2.9}$$

---

[9] The function *f* depends on the decision problem. For example, if the decision is whether to increase spending on intervention Y by decreasing spending on intervention X, the increase in social wellbeing can be defined by $dS^{CEA} = scale\,(1/ICER_Y - 1/ICER_X)$ where *scale* is the amount of funding transferred, $ICER_Y$ and $ICER_X$ are the ICERs for the two interventions, and $dS^{CEA}$ is measured in QALYs.

[10] When costs and effectiveness are both negative, social value is larger when the ICER is larger (the cost savings are large compared with the loss of effectiveness). When the ICER is less than zero, its value bears no relationship to the social value of the intervention. If costs are negative and effectiveness is positive, the intervention increases social value; if costs are positive and effectiveness is negative, the intervention increases social value.

*2.3. Merits of alternative evaluation frameworks*

Improving the wellbeing of any individual, by decreasing her health risk or increasing her wealth, counts as a social improvement under all five of the evaluation frameworks. But when alternative policies improve the wellbeing of different individuals by different amounts, or improve the wellbeing of some while diminishing the wellbeing of others, the evaluation frameworks may rank the policies differently in terms of their contributions to social wellbeing.

Under BCA, the social value of a change (the net social benefit) is measured by the sum of individuals' monetary values of their changes in health risk and wealth. BCA is inequality neutral with respect to the distribution of these monetary quantities and to the distribution of costs. It is not inequality neutral with respect to changes in health risk; typically the monetary value of an improvement to health risk increases with wealth and so net social benefit tends to be larger when health gains are concentrated among wealthier individuals.

CEA is also inequality neutral with respect to changes in wealth (distribution of costs). In contrast, it measures changes in health risk by the sum of expected changes in effectiveness (e.g., measured by QALYs) and is inequality neutral with respect to the allocation of a total health gain in the population.

The benchmark SWFs measure social wellbeing as the sum of individuals' utilities or transformed utilities. The utilitarian SWF is inequality neutral with respect to the distribution of utility in the population; all allocations of the same total utility are ranked equally. Note that the utilitarian SWF is inequality averse with respect to wealth: under the standard assumption that utility is a concave function of wealth, social welfare given a fixed total wealth is maximized by an equal allocation over a set of otherwise identical individuals. In contrast, the prioritarian SWFs are inequality averse with respect to wellbeing; when a fixed total amount of utility is to be distributed, social welfare is maximized by distributing it equally. Hence the prioritarian SWFs are more strongly inequality averse with respect to wealth than is the utilitarian SWF.

When the consequences of a policy are uncertain, the ex ante and ex post prioritarian SWFs can rank policies differently. A key difference between them is whether they respect the ex ante Pareto principle or statewise dominance. The ex ante Pareto principle requires that if all affected individuals weakly prefer policy Y to policy Z (because each individual's expected utility under Y is at least as large as under Z), then policy Y is weakly socially preferred to policy Z. Statewise dominance (also called monotonicity) is the property that if the distribution of wellbeing under policy Z is at least as socially desirable as the distribution of wellbeing under policy Y in each possible state of nature, then policy Z is weakly socially preferred to policy Y. The ex ante prioritarian SWF satisfies the ex ante

Pareto principle but can violate statewise dominance, and the ex post prioritarian SWF satisfies statewise dominance but can violate the ex ante Pareto principle. The utilitarian SWF satisfies both the ex ante Pareto principle and statewise dominance but, unlike the prioritarian SWFs, it is inequality neutral with respect to wellbeing.[11]

Fleurbaey (2010) highlights the tension between the ex ante Pareto principle and inequality aversion over outcomes and notes that the relative appeal of these properties depends on the dependence of risks in the population. When the frequency distribution of outcomes is known but the allocation of outcomes to individuals is not (e.g., individuals' risks are independent or negatively dependent), there is little risk about the distribution of wellbeing but possibly great ex post inequality; hence the ex post perspective is appropriate. When individuals are affected similarly (risks are positively dependent) there is little or no ex post inequality but possibly significant risk about the distribution of wellbeing and the ex ante perspective is appropriate. Leach (2010) makes a similar argument in favor of using an ex post prioritarian SWF for evaluating health insurance, because most of the risk concerns which individuals will become ill rather than the population frequency of illness. (The Appendix provides a formal analysis and an example).

## 3. Social value of a decrease in health risk or cost

The social value of a marginal change to an individual's health risk or wealth is derived for the benchmark SWFs, BCA, and CEA. Results are summarized in Table 1. Note that the social value of a change to any dimension of an individual's health risk or wealth is independent of other individuals' risks and wealth. To simplify notation, I analyze the contribution to social welfare of a change for individual *i* under each evaluation framework and omit the subscript *i*.

### *3.1. Utilitarian SWF*

Under the utilitarian SWF, the contribution to social welfare of a single individual is

$$V^U = U = [1 - p(q + s - qs)]u(c) + v(c). \tag{3.1}$$

The social value of a reduction in parameter $\theta$ is $-\frac{\partial V^U}{d\theta} = -\frac{\partial U}{d\theta}$ for $\theta = p, q, s$ and the social value of an increase in wealth (decrease in cost) is $\frac{\partial V^U}{dc} = \frac{\partial U}{dc}$.

[11] Harsanyi's (1955) aggregation theorem (as discussed by Fleurbaey 2010) states that any SWF that is based on expected social utility and on individuals' expected utilities must be affine in individual utilities (as is the utilitarian SWF). Introducing a non-affine transformation function to capture inequality aversion requires violating one or the other of these conditions.

The social value of prevention (that decreases risk *p*) is given by

$$-\frac{\partial U}{\partial p} = (q + s - qs)u(c) > 0. \quad (3.2)$$

It is increasing in *q*, *s*, and *c* and is independent of *p*.

Unsurprisingly, the value of prevention is larger when the illness is more lethal or severe and the effect of health on the utility of consumption is larger. Trivially, if *q* and *s* both equal 0 (i.e., the illness is nonfatal and produces no health degradation) then the social value of prevention is zero.

The social value of treatment (that decreases lethality *q*) is given by

$$-\frac{\partial U}{\partial q} = p(1 - s)u(c) > 0. \quad (3.3)$$

It is increasing in *p* and *c*, decreasing in *s*, and independent of *q*. The value of decreasing lethality is larger when the risk of illness and wealth are larger, and when the utility of surviving the illness is larger (when health degradation is small). Trivially, the social value of a decrease in lethality is 0 if $s = 1$ (survival is no better than death) or if $p = 0$ (no risk of illness).

The social value of palliative care (that decreases severity *s*) is given by

$$-\frac{\partial U}{\partial s} = p(1 - q)u(c) > 0. \quad (3.4)$$

It is increasing in *p* and *c*, decreasing in *q*, and independent of *s*. Consistent with the symmetry between severity and lethality, the social value of decreasing severity is larger when the risk of illness and wealth are larger, and when the conditional mortality risk is smaller. If $p = 0$ or $q = 1$ the social value of decreasing health deterioration is zero because the individual either live in full health or die.

The social value of an increase in wealth *c* (the social value of a decrease in the cost of a health intervention to the individual) is given by

$$\frac{\partial U}{\partial c} = [1 - p(q + s - qs)]u'(c) + v'(c) > 0. \quad (3.5)$$

It is weakly decreasing in *c* (because $u''(c) \leq 0$ and $v''(c) \leq 0$) and decreasing in *p*, *q*, and *s* (because the marginal utility of wealth is smaller if ill or dead).

*3.2. Ex ante prioritarian SWF*

The ex ante prioritarian SWF is the sum of each individual's transformed expected utility where the transformation function *g* is strictly increasing and concave, i.e., $g' > 0$ and $g'' < 0$. The contribution to social welfare for an individual is

$$V^{EAP} = g[U] \tag{3.6}$$

where *U* is the individual's expected utility. Note that for any parameter $\theta$, the partial derivative

$$-\frac{\partial V^{EAP}}{\partial \theta} = g'[U]\left[-\frac{\partial U}{\partial \theta}\right]. \tag{3.7}$$

Hence the social value of a change to any parameter $\theta$ is proportional to its social value under the utilitarian SWF, where the proportionality factor $g'(U)$ is decreasing in the individual's expected utility.

It follows immediately that the social value of prevention is

$$-\frac{\partial V^{EAP}}{\partial p} = g'[U]\left[-\frac{\partial U}{\partial p}\right] = g'[U](q + s - qs)u(c) > 0. \tag{3.8}$$

It is increasing in *q* and *s* because an increase in either of these parameters increases $-\partial U/\partial p$ and increases $g'(U)$. It is increasing in *p* because, although that has no effect on $-\partial U/\partial p$, it increases $g'(U)$. In contrast, the effect of an increase in *c* is ambiguous: it increases $-\partial U/\partial p$ but decreases $g'(U)$. If *q* and *s* both equal 0, the social value of decreasing *p* is zero.

The social value of treatment is given by

$$-\frac{\partial V^{EAP}}{\partial q} = g'[U]\left[-\frac{\partial U}{\partial q}\right] = g'[U]p(1 - s)u(c) > 0. \tag{3.9}$$

It is increasing in *q* (because that increases $g'(U)$) and increasing in *p* (which increases both $g'(U)$ and $-\partial U/\partial q$). In contrast, the effects of *s* and *c* are ambiguous: an increase in *s* decreases $-\partial U/\partial q$ but increases $g'(U)$ and an increase in *c* increases $-\partial U/\partial q$ but decreases $g'(U)$. If $s = 1$ or $p = 0$, the social value is zero.

The social value of palliative care is symmetric to the effect of treatment and is given by

$$-\frac{\partial V^{EAP}}{\partial s} = g'[U]\left[-\frac{\partial U}{\partial s}\right] = g'[U]p(1 - q)u(c) > 0. \tag{3.10}$$

It is increasing in *s* (because that increases $g'(U)$) and increasing in p (which increases both $g'(U)$ and $-\partial U/\partial s$). In contrast, the effects of *q* and *c* are ambiguous: an increase in *q* decreases $-\partial U/\partial s$ but increases $g'(U)$ and an increase in $c$ increases $-\partial U/\partial s$ but decreases $g'(U)$. If $q = 1$ or $p = 0$, the social value is zero.

The social value of a marginal increase in $c$ is given by

$$\frac{\partial V^{EAP}}{\partial c} = g'[U][1 - p(q + s - qs)]u'(c) > 0. \tag{3.11}$$

The effects of $p$, $q$, and $s$ are all ambiguous: an increase in any of these dimensions decreases $\partial U/\partial c$ but increases $g'(U)$. In contrast, the social value of a marginal increase in $c$ is smaller when $c$ is larger (i.e., for wealthier individuals); an increase in $c$ decreases both $\partial U/\partial c$ and $g'(U)$.

*3.3. Ex post prioritarian SWF*

The ex post prioritarian SWF is the sum of each individual's expected transformed utility where the transformation function $g$ is strictly increasing and concave, i.e., $g' > 0$ and $g'' < 0$. The contribution to social welfare for an individual is

$$V^{EPP} = (1 - p)g[u(c) + v(c)] + p(1 - q)g[(1 - s)u(c) + v(c)] + pqg[v(c)]. \tag{3.12}$$

The social value of prevention is given by

$$-\frac{\partial V^{EPP}}{\partial p} = g[u(c) + v(c)] - \big[(1 - q)g[(1 - s)u(c) + v(c)] + qg[v(c)]\big] > 0. \tag{3.13}$$

It is the difference in expected transformed utility between full health and illness. It is independent of $p$, increasing in $q$ and $s$, and the effect of $c$ is ambiguous. Trivially, the social value of prevention is zero if both $q$ and $s$ equal zero, i.e., for a benign illness.

The social value of treatment is given by

$$-\frac{\partial V^{EPP}}{\partial q} = p\{g[(1 - s)u(c) + v(c)] - g[v(c)]\} > 0 \tag{3.14}$$

(unless $p = 0$ or $s = 1$). It is the difference in transformed utility between surviving with impaired health and death multiplied by the risk of illness $p$. It is increasing in $p$, independent of $q$, decreasing in $s$, and the effect of $c$ is ambiguous.

The social value of palliative care is given by

$$-\frac{\partial V^{EPP}}{\partial s} = p(1 - q)g'[(1 - s)u(c) + v(c)]u(c) > 0 \tag{3.15}$$

(unless $p = 0$ or $q = 1$). It is the marginal increase in transformed utility from decreasing health deterioration multiplied by the probability of being ill and surviving. It is increasing in $p$ and $s$, decreasing in *q*, and the effect of *c* is ambiguous. Note that the effects of *q* and *s* are not symmetric, as they are under the other evaluation frameworks. The reason is that health degradation *s* affects the outcome of the illness and appears within the argument of *g* while *q* is a probability and so it never appears within the argument of *g*.

The social value of an increase in *c* is given by

$$\frac{\partial V^{EPP}}{\partial c} = (1-p)g'[u(c)+v(c)][u'(c)+v'(c)]$$

$$+p(1-q)g'[(1-s)u(c)+v(c)][(1-s)u'(c)+v'(c)]+pqg'[v(c)]v'(c)>0. \quad (3.16)$$

The effects of an increase in *p*, *q*, *s*, and *c* are all ambiguous.

*3.4. Benefit-cost analysis*

Under BCA, the social value of an intervention is the sum of individuals' monetary values for the changes they face. The monetary value of a change in any dimension $\theta$ of the health risk is the change in the individual's expected utility divided by her expected marginal utility of wealth (i.e., her expected opportunity cost of spending),

$$-\frac{\partial V^{BCA}}{\partial \theta} = \frac{dc}{d\theta} = \left(-\frac{\partial U}{\partial \theta}\right) / \left(\frac{\partial U}{\partial c}\right). \quad (3.17)$$

Setting $\theta$= *c* confirms that the social value of a change to an individual's wealth is independent of the individual's health risk and wealth. The social values of changes in risk, lethality, and severity are equal to the corresponding changes under the utilitarian SWF, $\partial U/\partial \theta$, divided by the expected marginal utility of wealth $U' = \partial U/\partial c$. Hence the social value of a decrease in each of the risk dimensions is positive but the sensitivity of the social values to the levels of other dimensions are not necessarily the same as for the utilitarian SWF, because changes in the levels of the other dimensions can affect the expected opportunity cost of spending.

The social value of prevention

$$-\frac{dc}{dp} = \frac{(q+s-qs)u(c)}{[1-p(q+s-qs)]u\prime(c)+v\prime(c)} > 0 \quad (3.18)$$

(unless *q* and *s* both equal 0, i.e., for a disease that has no effects on health). It is increasing in *p*, *q*, *s*, and *c*: an increase in *q*, *s*, or *c* increases the numerator and decreases the denominator; an increase in *p* decreases the denominator.

The social value of treatment

$$-\frac{dc}{dq}=\frac{p(1-s)u(c)}{[1-p(q+s-qs)]u\prime(c)+v\prime(c)}>0 \quad (3.19)$$

(unless $p$ = 0 or $s$ = 1). It is increasing in $p$, $q$, and $c$ and decreasing in $s$. Increases in $p$ or $c$ increase the gain from survival (the numerator) and decrease the expected opportunity cost of spending (the denominator); an increase in $q$ decreases the denominator and an increase in $s$ decreases the numerator by a larger proportion than it decreases the denominator.[12]

The social value of palliative care

$$-\frac{dc}{ds}=\frac{p(1-q)u(c)}{[1-p(q+s-qs)]u'(c)+v'(c)}>0 \quad (3.20)$$

(unless $p$ = 0 or $q$ = 1). Consistent with the symmetry of the effects of $q$ and $s$, the social value of palliative care is increasing in $p$, $s$, and $c$ and decreasing in $q$.

*3.5. Cost-effectiveness analysis*

Under CEA, the social value of an intervention is determined by the ICER and scale; when costs (reductions in wealth) and effects are both positive, the increase in social value is larger when the ICER is smaller.

The measure of effectiveness $Q$ (equation (2.6)) is a special case of expected utility $U$ (equation (2.1)) that is independent of wealth. Hence a decrease in baseline risk, lethality, and severity each increase effectiveness and yield a positive social value. The sensitivities of these values to the other dimensions are the same as for the utilitarian SWF except they are independent of wealth. The social value of an increase in wealth is positive and is independent of wealth and the dimensions of the health risk $p$, $q$, and $s$.

*3.6. Summary*

The social value of a beneficial change to an individual, whether a decrease in risk, lethality, or severity of an illness, or an increase in wealth, is always positive (except in limiting cases such as

[12] An implication of this formula is that the effect of health quality on the marginal rate of substitution of wealth for mortality risk (the value per statistical life, VSL) is non-negative. Let $p$ = 1. Then $VSL=-\frac{dc}{dq}=\frac{(1-s)u(c)}{(1-q)(1-s)u\prime(c)+v\prime(c)}$. If $v'(c)$ = 0, VSL is independent of $s$; if $v'(c)$ > 0, a decrease in $s$ (an improvement in health) increases the numerator by a larger factor than it increases the denominator so VSL increases. In the standard model of VSL, the effect of health is ambiguous; better health can increase the expected opportunity cost of spending by a larger factor than it increases the utility gain from survival (Hammitt 2000).

where the illness causes no harm). In contrast, the sensitivity of these social values to the health-risk dimensions and individual characteristics (wealth) are diverse, as summarized in Table 1. The social value of mitigating health risk is larger for wealthier individuals under the utilitarian SWF and BCA, can be larger or smaller under the two prioritarian SWFs, and is independent of wealth under CEA. The social value of an increase in wealth (equivalently, of decreasing the individual's cost) is smaller for individuals facing worse health risks under the utilitarian SWF; can be smaller or larger for such individuals under the prioritarian SWFs, and is independent of health risk under BCA and CEA. The main diagonal of each panel of Table 1 reveals that the social value of a decrease in risk, lethality, or severity is independent of the level of that dimension under the utilitarian SWF and CEA, and increasing in the level of that dimension under the ex ante prioritarian SWF and BCA. Under the ex post prioritarian SWF, the social value of a decrease in risk or lethality is independent of the level of that dimension and the social value of a decrease in severity is increasing in severity.

**4. Comparative social values of prevention, treatment, and palliative care**

The previous section reveals that, while the social value of a change in any parameter that improves individual wellbeing is positive under all five evaluation frameworks, the patterns of sensitivity of the social values to individuals' health risk and wealth are diverse. This section evaluates the relative social value of small reductions in each of the three health-risk dimensions. Pairwise comparisons show it is not true that reducing one of the dimensions is always preferred to reducing another under any of the evaluation frameworks. For example, it is not true that prevention always has a higher social value than treatment or palliative care.

The conditions under which decreasing one risk dimension has a larger social value than decreasing another are identical for four of the evaluation frameworks (utilitarian and ex ante prioritarian SWFs, BCA, and CEA) but differ for the ex post prioritarian SWF. The parallelism of results under the four evaluation frameworks results because, for these frameworks, the social value of decreasing each risk dimension is proportional to its social value under the utilitarian SWF. Hence if the social value of reducing one dimension is larger than that of another under the utilitarian SWF, the same result holds under the ex ante prioritarian SWF, BCA, and CEA. I exploit this parallelism below. In contrast, the results under the ex post prioritarian SWF differ.

For the ex ante prioritarian SWF, the proportionality factor relative to the social value of risk reduction under the utilitarian SWF is the slope of the transformation function *g* evaluated at the individual's expected utility; for BCA, it is the reciprocal of the individual's expected marginal utility of wealth. For CEA, the social value of a decrease in a risk dimension is larger if that change produces a larger increase in effectiveness $Q$ (equation (2.6)), and $Q$ is a special case of expected utility $U$ (equation (2.1)). Results of this section are summarized in Table 2.

*4.1. Utilitarian SWF, ex ante prioritarian SWF, BCA, and CEA*

Begin by comparing the social values under the utilitarian SWF; the results under the ex ante prioritarian SWF, BCA, and CEA are identical. Comparing the social value of reducing lethality $q$ with the social value of reducing severity $s$ shows that the social value of a reduction is larger for whichever parameter is larger. That is,

$$-\frac{\partial U}{dq} > -\frac{\partial U}{ds}$$

$$p(1-s)u(c) > p(1-q)u(c)$$

$$q > s. \tag{4.1}$$

This result follows from the symmetry of $q$ and $s$ in individual expected utility (equation (2.1)).

Comparing the social value of prevention with the social value of treatment,

$$-\frac{\partial U}{dp} > -\frac{\partial U}{dq}$$

$$(q + s - qs)u(c) > p(1-s)u(c)$$

$$s + q(1-s) > p(1-s)$$

$$\frac{s}{1-s} > p - q. \tag{4.2}$$

If $s > 1/2$, the left-hand side is greater than one and the condition is satisfied for all values of $p$ and $q$. If risk of illness $p$ is less than lethality $q$ (as it is for a rare but lethal disease), the right-hand side is less than zero and the condition is satisfied for all values of severity. Alternatively, if risk exceeds lethality (for a common but rarely fatal disease), the condition is satisfied only if the health deterioration is sufficiently large. For a common, rarely fatal, and mild disease, the social value of treatment is larger than that of prevention. Intuitively, if $s \approx 0$, the harm from illness is the mortality risk $p\ q$. The marginal effect of prevention $dp$ is to decrease mortality risk by $q\ dp$ and the marginal effect of treatment $dq$ is to decrease mortality risk by $p\ dq$. If $p > q$, treatment produces a larger decrease in mortality risk than does prevention.

Finally, comparing the social values of prevention and palliative care,

$$-\frac{\partial U}{dp} > -\frac{\partial U}{ds}$$

$$(q + s - qs)u(c) > p(1 - q)u(c)$$

$$q + s(1 - q) > p(1 - q)$$

$$\frac{q}{1-q} > p - s. \tag{4.3}$$

Note the symmetry with expression (4.2) comparing the social values of prevention and treatment. If $q > 1/2$, the condition is satisfied for all values of $p$ and $s$. If risk is smaller than health deterioration (for a rare but severe disease), the right-hand side is less than zero and the condition is always satisfied. Alternatively, if risk is greater than health deterioration (for a common but mild disease), the condition is satisfied only if the disease is sufficiently lethal. For a common, mild, and rarely fatal disease, the social value of palliative care is larger than that of prevention. Parallel to the comparison of prevention and treatment, if $q \approx 0$ the risk is of becoming ill with expected severity $p\, s$. Prevention decreases the expected harm by $s\, dp$ and care decreases it by $p\, ds$; if $p > s$, care provides a larger benefit than prevention.

Combining the last two results, prevention tends to be more valuable than treatment or palliative care for rare but not for common diseases. The social value of prevention is less than the social values of treatment (decreasing lethality) and palliative care (decreasing health deterioration) if baseline risk is large and both lethality and severity are small, i.e., for common but mild and rarely fatal illnesses. In contrast, if the risk of illness is small, the social values of treatment and care are small (because they are unlikely to be needed) and prevention has the larger social value.

*4.2. Ex post prioritarian SWF*

Next, compare the social values under the ex post prioritarian SWF. The results depend on the curvature of the transformation function $g$. If $g$ is nearly linear, the conditions are almost the same as the corresponding conditions for the other four evaluation frameworks. I derive conditions under which decreasing one risk dimension has a larger social value than decreasing another and compare them with the conditions for the other evaluation frameworks derived in the previous subsection.

The social value of treatment exceeds the social value of palliative care if and only if

$$-\frac{\partial V^{EPP}}{\partial q} > -\frac{\partial V^{EPP}}{\partial s}$$

$$g[(1 - s)u(c) + v(c)] - g[v(c)] > (1 - q)g'[(1 - s)u(c) + v(c)]u(c). \tag{4.4}$$

The left-hand side is the difference in transformed utility between illness and death and the right-hand side is the marginal improvement in expected transformed utility from decreasing severity. Using the mean-value theorem to rewrite the left-hand side yields

$$(1-s)u(c)g'(x) > (1-q)u(c)g'[(1-s)u(c)+v(c)] \tag{4.5}$$

where *x* is some value such that $v(c) < x < (1-s)u(c)+v(c)$. Further manipulation yields

$$\frac{1-s}{1-q} > \frac{g'[(1-s)u(c)+v(c)]}{g'(x)} < 1. \tag{4.6}$$

If $s < 1$ the right-hand side of expression (4.6) is strictly less than one. If $q \geq s$, the left-hand side is greater than or equal to one. Hence for a disease that is more lethal than severe, expression (4.6) is satisfied and the social value of treatment (reducing lethality *q*) exceeds the social value of palliative care (reducing severity *s*). By continuity, the social value of treatment exceeds that of care for some values of $q < s$, where the difference between these values can be larger when *g* is more concave (and when *s* is smaller). Alternatively, if severity *s* is sufficiently greater than lethality *q*, the condition is violated and the social value of care is larger than that of treatment. If $s = 1$ the social value of decreasing *q* is zero and cannot exceed that of decreasing *s*; in this case, the illness is as bad as death so there is no benefit to decreasing lethality.

Expression (4.6) is weaker than the condition for the other evaluation frameworks (expression (4.1)); if treatment is more valuable than palliative care under the utilitarian and other evaluation frameworks, it is also more valuable under the ex post prioritarian SWF. This follows because the ex post prioritarian SWF is more sensitive than the other evaluation frameworks to improvements when realized wellbeing is low, i.e., in the worst outcome. Because death is worse than sickness (if $s < 1$), treatment is socially more valuable than palliative care when $q = s$, and even for some values of $q < s$. In contrast, treatment is more valuable than care under the other evaluation frameworks only if $q > s$.

Comparing the social value of prevention with the social value of treatment,

$$-\frac{\partial V^{EPP}}{\partial p} > -\frac{\partial V^{EPP}}{\partial q}$$

$$g[u(c)+v(c)] - \{(1-q)g[(1-s)u(c)+v(c)] + qg[v(c)]\} >$$

$$p\{g[(1-s)u(c)+v(c)] - g[v(c)]\}. \tag{4.7}$$

The left-hand side is the difference in expected transformed utility between full health and illness and the right-hand side is the difference in transformed utility between survival if ill and death, multiplied by baseline risk $p$. If $p$ is sufficiently small, treatment is unlikely to be useful, the right-hand side is close to zero, inequality (4.7) is satisfied, and the social value of prevention exceeds that of treatment. Similarly, if severity $s$ is sufficiently large, the difference in transformed utility between survival if ill and death is small and the condition is satisfied. Alternatively, if $q$ and $s$ are sufficiently small, the illness is mild and the left-hand side approaches zero; if the risk $p$ is not too small, the condition is violated and the social value of treatment exceeds the social value of prevention.

Inequality (4.7) is stronger than the corresponding condition (4.2) for the other evaluation frameworks. To see this, rearrange expression (4.7) to obtain

$$p < \frac{g[u(c)+v(c)]-\{(1-q)g[(1-s)u(c)+v(c)]+qg[v(c)]\}}{g[(1-s)u(c)+v(c)]-g[v(c)]}$$

$$< \frac{[u(c)+v(c)]-\{(1-q)[(1-s)u(c)+v(c)]+q[v(c)]\}}{[(1-s)u(c)+v(c)]-[v(c)]} = q + \frac{s}{1-s}. \tag{4.8}$$

The inequality follows from the concavity of $g$. From expression (4.2), prevention has a larger social value than treatment under the other evaluation frameworks if (and only if) $p$ is less than the last expression in (4.8). Hence if prevention has a larger social value than treatment under the ex post prioritarian SWF, the same is true for the other evaluation frameworks. Moreover, there are parameter values for which treatment has a larger social value than prevention under the ex post prioritarian SWF but not under the other evaluation frameworks. For example, let $s$ be infinitesimally larger than 1/2. Then inequality (4.2) is satisfied for all values of $p$ and $q$ and prevention has a larger social value than treatment under the other evaluation frameworks. If $p \approx 1$ and $q \approx 0$, inequality (4.7) simplifies to approximately

$$g[u(c)+v(c)] - g\left[\frac{1}{2}u(c)+v(c)\right] > g\left[\frac{1}{2}u(c)+v(c)\right] - g[v(c)], \tag{4.9}$$

which is false because $g$ is concave. Again, the explanation is that the ex post prioritarian SWF is more sensitive to improvements when realized wellbeing is low: The incremental social benefit of living with an illness with severity slightly larger than 1/2 rather than dying exceeds the incremental benefit of living in full health rather than with the illness. The opposite is true for the other evaluation frameworks.

Finally, comparing the social value of prevention with the social value of palliative care yields

$$-\frac{\partial V^{EPP}}{\partial p} > -\frac{\partial V^{EPP}}{\partial s}$$

$$g[u(c)+v(c)] - \{(1-q)g[(1-s)u(c)+v(c)] + qg[v(c)]\} >$$

$$p(1-q)g'[(1-s)u(c)+v(c)]u(c). \tag{4.10}$$

The left-hand side is the difference in expected transformed utility between full health and illness and the right-hand side is the marginal improvement in transformed utility from decreasing severity multiplied by the probability of being ill and surviving.

If *p* is sufficiently small or *q* is sufficiently large, palliative care is unlikely to be useful, the right-hand side is close to zero, the condition is satisfied, and the social value of prevention exceeds that of care. Alternatively, if $q \approx 0$, expression (4.10) simplifies to approximately

$$g[u(c)+v(c)]-g[(1-s)u(c)+v(c)] > pg'[(1-s)u(c)+v(c)]u(c), \tag{4.11}$$

which implies

$$\frac{p}{s} < \frac{g[u(c)+v(c)]-g[(1-s)u(c)+v(c)]}{sg\prime[(1-s)u(c)+v(c)]u(c)} < 1. \tag{4.12}$$

The right-hand of inequality (4.12) is less than one because *g* is concave. Hence if $p \geq s$, the inequality is violated and palliative care is socially more valuable than prevention. If $p/s$ is sufficiently small, the inequality is satisfied and prevention is socially more valuable than care.

If $s \approx 0$, expression (4.10) simplifies to approximately

$$q\{g[u(c)+v(c)]-g[v(c)]\} > p(1-q)g'[u(c)+v(c)]u(c), \tag{4.13}$$

which implies

$$p\,\frac{1-q}{q} < \frac{g[u(c)+v(c)]-g[v(c)]}{g\prime[u(c)+v(c)]u(c)} > 1. \tag{4.14}$$

Inequality (4.14) is satisfied if $p \leq q/(1 - q)$. That is, for a mild disease, prevention has a higher social value than care if baseline risk *p* is small compared with lethality *q*. If a disease is highly lethal, palliative care is unlikely to be useful.

Condition (4.10) is neither weaker nor stronger than the corresponding condition for the other evaluation frameworks (4.3). Let $s = 0$ and $p = 1$. If $q \leq 1/2$, condition (4.3) is violated and prevention is socially less valuable than palliative care for the other evaluation frameworks. However, for $q = 1/2$ condition (4.14) is satisfied and prevention is more valuable than care under the ex post prioritarian SWF. Alternatively, if $s \approx 1$ and either $q > 0$ or $p < 1$, inequality (4.3) is satisfied and prevention is more valuable than palliative care under the other evaluation frameworks. In this case, expression (4.10) simplifies to approximately

$$g[u(c) + v(c)] - g[v(c)] > p(1 - q)g'[v(c)]u(c), \quad (4.15)$$

which implies

$$p(1 - q) < \frac{g[u(c)+v(c)]-g[v(c)]}{g'[v(c)]u(c)} < 1. \quad (4.16)$$

If $p$ (1 - $q$) $\geq 1$, inequality (4.16) is violated and palliative care is more valuable than prevention under the ex post prioritarian SWF.

The difference between the results for the ex post prioritarian SWF and the other evaluation frameworks are again because the ex post prioritarian SWF is more sensitive to improvements when realized wellbeing is low. Specifically, the value of a marginal decrease in severity (provided by palliative care) is a convex function of the level of severity under the ex post prioritarian SWF but is independent of the level of severity for the other evaluation frameworks (compare the marginal social value of decreasing severity under the ex post prioritarian SWF, equation (3.15), with that under the utilitarian SWF, equation (3.4)). The marginal social value of decreasing severity under the ex post prioritarian SWF is proportional to the slope of the transformed value of ill health (i.e., to $g'[(1 - s)\ u(c) + v(c)]$) which is an increasing function of severity $s$. Compared with the slope of the chord of $g[(1 - s)\ u(c) + v(c)]$ between $s = 1$ and $s = 0$, the slope at $s \approx 1$ can be made arbitrarily large and the slope at $s \approx 0$ arbitrarily small (but positive) by increasing the concavity of $g$. Hence palliative care has a relatively small social value when $s \approx 0$ (the first example) and a relatively large value when $s \approx 1$ (the second example).

*4.3 Summary*

Table 2 summarizes the conditions under which the social value of decreasing one of the health-risk dimensions exceeds the social value of decreasing another dimension. The conditions are identical for the utilitarian and ex ante prioritarian SWFs, BCA, and CEA. For the ex post prioritarian SWF, the conditions depend on the curvature of the transformation function $g$. If $g$ is nearly linear, the conditions are almost the same as for the other evaluation frameworks but if $g$ is strongly concave, the conditions can differ.

Comparing treatment (decreasing lethality) with palliative care (decreasing severity), the social value is greater for decreasing whichever parameter is larger under the utilitarian and ex ante prioritarian SWFs, BCA, and CEA. This follows because the effects on individual wellbeing of lethality ($q$) and severity ($s$) are symmetric (equation (2.1)). Under the ex post prioritarian SWF, treatment has a larger social value than care when $q \geq s$ and even for some values of $q < s$, if the difference is not too great and the transformation function $g$ is sufficiently concave. The difference between the result for the ex post prioritarian SWF and the other evaluation frameworks is that the former is more sensitive to improvements when realized wellbeing (the outcome) is poor. Because death is worse than illness (for $s < 1$), decreasing lethality is relatively more valuable than decreasing severity under the ex post prioritarian SWF.

Comparing prevention (decreasing risk $p$) with either treatment (decreasing lethality $q$) or palliative care (decreasing severity $s$), prevention tends to have a larger social value than treatment or care if the risk $p$ is small (in this case, neither treatment nor care is likely to be useful). For the utilitarian and ex ante prioritarian SWFs, BCA, and CEA, prevention has a larger social value than treatment if the disease is severe ($s \geq 1/2$ is sufficient) or lethal (large $q$); it has a larger social value than palliative care if the disease is lethal ($q \geq 1/2$ is sufficient) or severe (large $s$).

The condition under which prevention is socially more valuable than treatment is stronger for the ex post prioritarian SWF than for the other evaluation frameworks. Again, because the ex post prioritarian SWF is more sensitive to improvements when the outcome is poor, decreasing the risk of death (through treatment) tends to be more valuable than decreasing the risk of illness. In contrast, the condition under which prevention is socially more valuable than palliative care for the ex post prioritarian SWF is neither stronger nor weaker than the corresponding condition for the other evaluation frameworks. Again because of its greater sensitivity when the outcome is poor, the marginal social value of care (decreasing health deterioration) is relatively large for severe illness and relatively small for mild illness. For a severe disease, the ex post prioritarian SWF can rank palliative care as more valuable than prevention while the other frameworks provide the opposite ranking, and for a mild disease both rankings can be reversed.

## 5. Conclusions

Multiple frameworks are available to evaluate the social values and costs of interventions to mitigate health risks. BCA and CEA are widely employed in practice but may not adequately account for social preferences regarding the distribution of health risks and costs. Social-welfare functions provide a more flexible method to incorporate concerns for efficiency (maximizing health, minimizing costs) with concerns about equitable distribution. Utilitarian, ex ante, and ex post prioritarian SWFs provide useful benchmarks.

The social values of reductions in the risk, conditional mortality, and severity of illness, and in the cost of health interventions, are positive under all five of the evaluation frameworks examined: BCA, CEA, and the utilitarian, ex ante prioritarian, and ex post prioritarian SWFs. The social values can depend on the affected individual's health risk and wealth. As summarized by Table 1, the patterns of dependence are diverse across the evaluation frameworks. Not surprisingly, higher baseline risk increases the social value of treatment (to reduce lethality) and palliative care (to reduce health degradation) under all five of the frameworks, because it increases the chance of benefiting from these interventions. Higher risk also increases the value of prevention (decreasing risk) under BCA and the ex ante prioritarian SWF, though it has no effect under the other evaluation frameworks, which are linear in probability of illness.

The harm from illness depends on its lethality (conditional mortality) and severity (health degradation). In the model studied here, the effects of these dimensions are symmetric under all of the evaluation frameworks except the ex post prioritarian SWF. Despite the symmetry, the patterns are diverse. The own effect of greater lethality or severity on the social value of decreasing that dimension is positive under the ex ante prioritarian SWF and BCA and zero under the utilitarian SWF and CEA. The cross effect of decreasing the other dimension on the social value is negative under the utilitarian and ex post prioritarian SWFs, BCA, and CEA and ambiguous under the ex ante prioritarian SWF.

The effect of wealth on the social value of decreasing any of the health-risk dimensions is positive under the utilitarian SWF and BCA, ambiguous under both prioritarian SWFs, and zero under CEA.

Comparing the social values of marginal reductions in risk, lethality, and severity reveals that no single dimension dominates; which reduction is socially more valuable depends on the levels of the risk dimensions (but not on wealth). Despite other differences between BCA, CEA, the utilitarian SWF, and the ex ante prioritarian SWF, the ranking of the social values of decreasing risk dimensions is identical under these frameworks. Moreover, the ranking is similar under the ex post prioritarian SWF if the transformation function $g$ is close to linear.

Over all the evaluation frameworks studied, prevention (decreasing risk of illness) tends to have a higher social value than treatment (decreasing lethality) or palliative care (decreasing health degradation) when the risk of illness is small. Intuitively, treatment and care are unlikely to be useful in this case. For a common disease (high risk of illness), treatment or care may be more valuable than prevention. In contrast, when comparing the social values of treatment with care, the social value is larger for decreasing the larger of the two dimensions (except that for the ex post prioritarian SWF, decreasing lethality can be more valuable than decreasing severity even when severity exceeds lethality). Consistent with intuition, decreasing lethality is of limited value when the alternative to death is living in a health state that is nearly as bad as dead; symmetrically, decreasing health degradation is of limited value when the illness is likely to prove fatal.

The analysis suggests the choice of evaluation framework can have important implications for ranking alternative health interventions. The evaluation frameworks are based on different ethical foundations and require different types of information. BCA and CEA are conceived as methods to measure the efficiency of an intervention (maximizing health, minimizing cost) with the notion that distributional effects are best evaluated separately and balanced judgmentally against efficiency when choosing among interventions. Nevertheless, these frameworks embed assumptions about how to compare benefits and harms to different individuals: under BCA and CEA, an increment to wealth is valued equally across individuals. An increment to health is valued equally across individuals under CEA (with health measured in QALYs or DALYs) and valued in proportion to the individual's monetary value for the health increment under BCA, which increases with wealth. (In practice, BCAs typically do not differentiate but use a population average monetary value of health for all individuals.) In contrast, SWFs can more flexibly incorporate concerns for both efficiency and equity, though at the cost of assuming a method to compare wellbeing interpersonally. The utilitarian SWF counts an increase in wellbeing as equally valuable across individuals and the prioritarian SWFs count an increase as more valuable when it goes to a less well-off individual. The concavity of the transformation function $g$ determines the degree of priority assigned to individuals at lower wellbeing; applying a prioritarian SWF requires choosing a particular transformation function (or evaluating results using several transformation functions).

CEA is perhaps the least demanding in the information it requires: the principal requirement is a method to quantify effectiveness. When QALYs or DALYs are used, they provide sufficient structure so that the only preference information that must be estimated is the utility or disability weight associated with the health impairment. In practice, estimates are constrained by the assumption that the utility weight is between zero and one and can be further restricted by comparison with estimated utility weights for other health impairments. BCA requires estimates of the monetary value of changes in fatal and nonfatal health risks; methods for estimating these values are well-developed but there are relatively few estimates for nonfatal health effects and uncertainty ranges are broad (these values can also be constrained by comparing estimates for more- and less-severe impairments). The SWFs require a method for interpersonal comparison of changes in wellbeing and, for the prioritarian SWFs, levels of wellbeing. Lacking any objective method, these are based on judgments that have developed over time (e.g., the assumption that utility is an increasing concave function of wealth or consumption). Application of an SWF requires a specific choice of utility function and the prioritarian SWFs require choice of a particular transformation function $g$, the concavity of which determines the degree of priority assigned to individuals at lower wellbeing. The evaluation of an intervention using an SWF can be mimicked using weighted BCA where the weights account for the relationship between wellbeing and wealth (for the utilitarian SWF) and the additional relationship between wellbeing and social priority (for the prioritarian SWFs).

**Acknowledgements**

I thank the editor, Mathias Kifmann, and an anonymous reviewer for their careful reading and useful suggestions and my co-authors of related papers Matthew Adler, Maddalena Ferranna, Daniel Herrera-Araujo, Christoph Rheinberger, and Nicolas Treich for many helpful discussions. I acknowledge funding from the U.S. National Science Foundation (award number 1824492) and the French National Research Agency (ANR) under the Investments for the Future program (Investissements d'Avenir, grant ANR-17-EURE-0010).

**Appendix**

To illustrate how the ex ante and ex post prioritarian SWFs can satisfy or violate the ex ante Pareto principle and statewise dominance, it is useful to account for the probabilistic dependence or correlation of individual outcomes. Let there be *N* individuals indexed by *i* and *J* possible states of nature $s_j$ with probabilities $\pi_j$. Let $u_{ij}$ denote the utility of individual *i* in state *j*.

Ex ante prioritarian social welfare equals the sum of individuals' transformed expected utilities

$$S^{EAP} = \sum_{i=1}^{N} g\left[\sum_{j=1}^{J} \pi_j u_{ij}\right]. \tag{A.1}$$

It does not depend on the degree of inequality among outcomes in a state of nature and can violate statewise dominance (as shown below).

Ex post prioritarian social welfare equals the expected value of prioritarian social welfare in each state of nature (the sum of individuals' transformed utilities). This is equivalent to the sum of individuals' expected transformed utilities

$$S^{EPP} = \sum_{j=1}^{J} \pi_j \sum_{i=1}^{N} g(u_{ij}) = \sum_{i=1}^{N}\left[\sum_{j=1}^{J} \pi_j g(u_{ij})\right]. \tag{A.2}$$

The first expression in equation (A.2) shows that the ex post prioritarian SWF exhibits inequality aversion with respect to individuals' utilities in each state of nature; transferring a small amount of utility from someone who is better off in state *j* to someone who is worse off in that state increases ex post prioritarian social welfare.

The second expression in equation (A.2) shows how the ex post prioritarian SWF can violate the ex ante Pareto principle; it evaluates policies as the sum of individuals' expected transformed utilities. In effect, the ex post prioritarian SWF adds a degree of risk aversion over an individual's utility, which already encompasses the individual's risk aversion over outcomes.

For another perspective on the conflict between satisfying statewise dominance or the ex ante Pareto principle, assume the states of nature are equally probable, $\pi_j = 1/J$ all $j$. Consider the possibility of transferring a small amount of utility $\Delta$ from individual $i$ in state $j$ to individual $h$ in state $k$ when part of the utility is lost in transit (a so-called leaky-bucket transfer). If $\Delta$ is small and the loss in transit is sufficiently small, this transfer increases ex post prioritarian social welfare $S^{EPP}$ whenever $u_{ij} > u_{hk}$. In contrast, the transfer always decreases ex ante prioritarian social welfare $S^{EAP}$.

If $i$ and $h$ are different individuals in the same state $j = k$, the transfer decreases inequality and increases prioritarian social welfare in that state, and hence weakly increases prioritarian social welfare in every state. Nevertheless, ex ante prioritarian social welfare $S^{EAP}$ declines, violating statewise dominance. Alternatively, if $i = h$ and $j \neq k$, the transfer is from one state to another for the same individual and decreases that individual's expected utility. Nevertheless, ex post prioritarian social welfare $S^{EPP}$ increases, violating the ex ante Pareto principle.

As discussed in Section 2.3, the appeal of the ex ante and ex post SWFs depends on the dependence among individuals' risks. If risks are perfectly dependent then individuals' outcomes are identical and there is no inequality in any state ($u_{ij} = u_{hj}$ for all individuals $i$, $h$ and all states $j$). In this case,

$$S^{EAP} = Ng\left[\sum_{j=1}^{J} \pi_j u_{ij}\right], \qquad \text{(A.3)}$$

and

$$S^{EPP} = N\left[\sum_{j=1}^{J} \pi_j g(u_{ij})\right] \qquad \text{(A.4)}$$

(the values are the same for any individual $i$).

$S^{EAP}$ is a monotonically increasing function of each individual's expected utility while $S^{EPP}$ is not. With no inequality there is no justification for distorting the individuals' evaluations to account for inequality aversion.

Alternatively, if the states are equally probable and individuals' risks are negatively dependent in such a way that in every state the fraction of individuals experiencing outcome $j$ equals the expected fraction $N\,\pi_j$, then each individual's expected utility is equal to $\sum_{j=1}^{J} \pi_j u_{ij}$, which is independent of $i$. In this case, $S^{EAP}$ is again given by equation (A.3). In contrast,

$$S^{EPP} = \sum_{i=1}^{N} g(u_{ij}), \qquad \text{(A.5)}$$

which accounts for inequality aversion over the realized distribution of outcomes (and has the same value for all states $j$).

Table A.1[13] provides an example in which the ex post prioritarian SWF satisfies statewise dominance but violates the ex ante Pareto principle and the ex ante prioritarian SWF satisfies the ex ante Pareto principle but violates statewise dominance. For both states of nature, social welfare under the prioritarian SWF is larger for policy Z than for policy Y: given $s_1$, $S^P$ = 15 for policy Z and 14 for policy Y; given $s_2$, $S^P$ = 12 for policy Z and 11 for policy Y.[14] Hence social welfare under the ex post prioritarian SWF is larger under policy Z ($S^{EPP}$ = 13.5) than policy Y ($S^{EPP}$ = 12.5). In contrast, for both individuals ($h$ and $k$), expected utility under policy Y exceeds expected utility under policy Z; hence social welfare under the ex ante prioritarian SWF is larger under policy Y ($S^{EAP}$ = 15.2) than policy Z ($S^{EAP}$ = 13.6).

[13] Table A.1 is adapted from Table 4.7 of Adler (2019).

[14] Conditional on the state of nature $s_j$ there is no uncertainty and prioritarian social welfare is given by $S^P = \sum_{i=1}^{N} g(u_{ij})$.

**References**

Adler, M.D., “Benefit–Cost Analysis and Distributional Weights: An Overview,” *Review of Environmental Economics and Policy* 10: 264–285, 2016.

Adler, M.D., “Theory of Prioritarianism,” in M.D. Adler and O.F. Norheim (eds.), *Prioritarianism in Practice*, pp. 37-127, Cambridge University Press, Cambridge 2022.

Adler, M.D., and K. Decancq, “Well-Being Measurement,” in M.D. Adler and O.F. Norheim (eds.), *Prioritarianism in Practice*, pp. 128-171, Cambridge University Press, Cambridge 2022.

Adler, M.D., J.K. Hammitt, and N. Treich, “The Social Value of Mortality Risk Reduction: VSL vs. the Social Welfare Function Approach,” *Journal of Health Economics* 35: 82-93, 2014.

Adler, M.D., M. Ferranna, J.K. Hammitt, and N. Treich, “Fair Innings? The Utilitarian and Prioritarian Value of Risk Reduction over a Whole Lifetime,” *Journal of Health Economics* 75: 102412, 2021.

Adler, M.D., *Measuring Social Welfare: An Introduction*, Oxford University Press, Oxford, 2019.

Adler, M.D., *Well-Being and Fair Distribution: Beyond Cost-Benefit Analysis*, Oxford University Press, Oxford, 2012.

Blackorby, C., W. Bossert, and D. Donaldson, *Population Issues in Social Choice Theory, Welfare Economics, and Ethics*, Cambridge University Press, Cambridge, 2005.

Bleichrodt, H., and E. van Doorslaer, “A welfare economics foundation for health inequality measurement,” *Journal of Health Economics* 25: 945–957, 2006.

Bleichrodt, H., E. Diecidue, and J. Quiggin, “Equity Weights in the Allocation of Health Care: The Rank-Dependent QALY Model,” *Journal of Health Economics* 23: 157-171, 2004.

Bleichrodt, H., J.L. Pinto, and P.P. Wakker, ”Making Descriptive Use of Prospect Theory to Improve the Prescriptive Use of Expected Utility,” *Management Science* 47: 1498–1514, 2001.

Bossert, W., and J.A. Weymark, “Utility in Social Choice,” in S. Barberà, P.J. Hammond, and C. Seidl (eds.), *Handbook of Utility Theory, Vol. 2*, pp. 1099–1177, Kluwer Academic, Boston, 2004.

Botzen, W.J.W., and J.C.J.M. van den Bergh, “Specifications of Social Welfare in Economic Studies Of Climate Policy: Overview of Criteria and Related Policy Insights,” *Environmental and Resource Economics* 58, 1–33, 2014.

Cookson, R., O.F. Norheim, and I. Skarda, “Prioritarianism and Health Policy,” in M.D. Adler and O.F. Norheim (eds.), *Prioritarianism in Practice*, pp. 260-316, Cambridge University Press, Cambridge 2022.

Deaton, A., and J. Muellbauer, *Economics and Consumer Behavior*, Cambridge University Press, Cambridge, 1980.

Dolan, P. and A. Tsuchiya, “Determining the Parameters in a Social Welfare Function using Stated Preference Data: An Application to Health,” *Applied Economics* 43: 2241–2250, 2011.

Domeij, D., and M. Johannesson, “Consumption and Health,” *Contributions to Macroeconomics* 6(1): article 6, 2006.

Drèze, J., ”L’Utilitè Sociale d’une Vie Humaine,” *Revue Française de Recherche Opèrationelle* 6: 93-118, 1962.

Drèze, J., and N. Stern, “The Theory of Cost-Benefit Analysis,” in A.J. Auerbach and M. Feldstein (eds.), *Handbook of Public Economics, Vol. II*, pp. 909-989, Elsevier Science Publishers, Amsterdam, 1987.

Finkelstein, A., E.F.P. Luttmer, and M.J. Notowidigdo, "What Good is Wealth Without Health? The Effect of Health on the Marginal Utility of Consumption," *Journal of the European Economic Association* 11: 221–258, 2013.

Fleurbaey, M., "Health, Wealth, and Fairness," *Journal of Public Economic Theory* 7: 253–284, 2005.

Fleurbaey, M., "Assessing Risky Social Situations," *Journal of Political Economy* 118: 649-680, 2010.

Fleurbaey, M., and D. Blanchet, *Beyond GDP: Measuring Welfare and Assessing Sustainability*, Oxford University Press, Oxford, 2013.

Fleurbaey, M., and R. Abi-Rafeh, "The Use of Distributional Weights in Benefit–Cost Analysis: Insights from Welfare Economics," *Review of Environmental Economics and Policy* 10: 286-307, 2016.

Hammitt, J.K., "Admissible Utility Functions for Health, Longevity, and Wealth: Integrating Monetary and Life-Year Measures," *Journal of Risk and Uncertainty* 47: 311–325, 2013.

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

Harsanyi, J.C., "Cardinal Welfare, Individualistic Ethics, and Interpersonal Comparisons of Utility," *Journal of Political Economy* 63: 309–21, 1955.

Jones-Lee, M., "The Value of Changes in the Probability of Death or Injury," *Journal of Political Economy* 82: 835-849, 1974.

Leach, J., "Ex Post Welfare under Alternative Health Care Systems," *Journal of Public Economic Theory* 12: 1027–1057, 2010.

Ottersen, T., "Lifetime QALY Prioritarianism in Priority Setting," *Journal of Medical Ethics* 39: 175–180, 2013.

Rheinberger, C.M., D. Herrera-Araujo, and J.K. Hammitt, "The Value of Disease Prevention vs. Treatment, *Journal of Health Economics* 50: 247-255, 2016.

Samson A-L., E. Schokkaert, C. Thébaut, B. Dormont, M. Fleurbaey, S. Luchini, and C. Van de Voorde, "Fairness in Cost-Benefit Analysis: A Methodology for Health Technology Assessment," *Health Economics* 27: 102–114, 2018.

Sanders, G.D., P.J. Neumann, A. Basu, D.W. Brock, D. Feeny, M. Krahn, K.M. Kuntz, D.O. Meltzer, D.K. Owens, L.A. Prosser, J.A. Salomon, M.J. Sculpher, T.A. Trikalinos, L.B. Russell, J.E. Siegel, and T.G. Ganiats, "Recommendations for Conduct, Methodological Practices, and Reporting of Cost-effectiveness Analyses: Second Panel on Cost-Effectiveness in Health and Medicine," *Journal of the American Medical Association* 316: 1093-1103, 2016.

Sloan, F.A., W.K. Viscusi, H.W. Chesson, C.J. Conover, and K. Whetten-Goldstein, "Alternative Approaches to Valuing Intangible Health Losses: The Evidence for Multiple Sclerosis," *Journal of Health Economics* 17: 475-97, 1998.

Sugden, R., "Debiasing or Regularisation? Two Interpretations of the Concept of 'True Preference' in Behavioural Economics," *Theory and Decision* 92: 765-784, 2022.

Tuomala, M., *Optimal Redistributive Taxation*, Oxford University Press, Oxford, 2016.

Viscusi, W.K., and W.N. Evans, "Utility Functions that Depend on Health Status: Estimates and Economic Implications," *American Economic Review* 80: 353-374, 1990.

Wagstaff, A., "QALYs and the Equity-Efficiency Trade-off," *Journal of Health Economics* 10: 21-41, 1991.

Weinstein, M.C., D.S. Shepard, and J.S. Pliskin, “The Economic Value of Changing Mortality Probabilities: A Decision-Theoretic Approach,” *Quarterly Journal of Economics* 94: 373-396, 1980.

Weymark, J.A., “Social Welfare Functions,” in M.D. Adler and M. Fleurbaey (eds.), *The Oxford Handbook of Well-Being and Public Policy*, pp. 126–159, Oxford University Press, Oxford, 2016.

Williams, A., “Intergenerational Equity: An Exploration of the ‘Fair Innings’ Argument,” *Health Economics* 6: 117–132, 1997.

Table 1. Social value of decreasing alternative dimensions of health risk, or decreasing cost of an intervention (increasing wealth)

| | Parameter affected | Risk (*p*) | Lethality (*q*) | Severity (*s*) | Wealth (*c*) |
|---|---|---|---|---|---|
| Utilitarian SWF | Risk (*p*) | 0 | + | + | + |
| | Lethality (*q*) | + | 0 | - | + |
| | Severity (*s*) | + | - | 0 | + |
| | Wealth (*c*) | - | - | - | - |
| Ex ante prioritarian SWF | Risk (*p*) | + | + | + | +/- |
| | Lethality (*q*) | + | + | +/- | +/- |
| | Severity (*s*) | + | +/- | + | +/- |
| | Wealth (*c*) | +/- | +/- | +/- | - |
| Ex post prioritarian SWF | Risk (*p*) | 0 | + | + | +/- |
| | Lethality (*q*) | + | 0 | - | +/- |
| | Severity (*s*) | + | - | + | +/- |
| | Wealth (*c*) | +/- | +/- | +/- | +/- |
| BCA | Risk (*p*) | + | + | + | + |
| | Lethality (*q*) | + | + | - | + |
| | Severity (*s*) | + | - | + | + |
| | Wealth (*c*) | 0 | 0 | 0 | 0 |
| CEA | Risk (*p*) | 0 | + | + | 0 |
| | Lethality (*q*) | + | 0 | - | 0 |
| | Severity (*s*) | + | - | 0 | 0 |
| | Wealth (*c*) | 0 | 0 | 0 | 0 |

Note: Symbols describe the sign of the effect of an increase in the column parameter on the social value of a marginal decrease of the row parameter. Symbols denote increase (+), decrease (-), no effect (0), ambiguous effect (+/-).

Table 2. Comparative social values of reductions in risk dimensions

| Comparison of interventions | Utilitarian SWF, ex ante prioritarian SWF, BCA, CEA (necessary and sufficient conditions) | Ex post prioritarian SWF (sufficient conditions) | Comparison of sufficient conditions |
|---|---|---|---|
| Treatment (decrease $q$) preferred to palliative care (decrease $s$) | $q > s$ | $q \geq s < 1$ | Treatment preferred to palliative care: ex post prioritarian SWF sufficient for other evaluation frameworks |
| Prevention (decrease $p$) preferred to treatment (decrease $q$) | $\frac{s}{1-s} > p - q$ | $p = 0$ or $s = 1$<br>For violation:<br>$q = 0$ and $s = 0$ | Treatment preferred to prevention: other frameworks sufficient for ex post prioritarian SWF |
| Prevention (decrease $p$) preferred to palliative care (decrease $s$) | $\frac{q}{1-q} > p - s$ | $p = 0$ or $q = 1$<br>$s = 0$ and $p \leq \frac{q}{1-q}$<br>For violation:<br>$s = 1$ and $p(1-q) \geq 1$<br>$q = 0$ and $p \geq s$ | Neither condition implies the other |

Table A.1. Comparison of ex ante and ex post prioritarian SWFs

| Policy | | Y | | | Z | |
|---|---|---|---|---|---|---|
| State of nature | $s_1$ | $s_2$ | | $s_1$ | $s_2$ | |
| Utilitarian | $u_{ij}$ | $u_{ij}$ | E($u_{ij}$) | $u_{ij}$ | $u_{ij}$ | E($u_{ij}$) |
| Individual *i* | 9 | 100 | 54.5 | 49 | 36 | 42.5 |
| Individual *h* | 121 | 1 | 61 | 64 | 36 | 50 |
| $S^U$ | 130 | 101 | 115.5 | 113 | 72 | 92.5 |
| Ex ante prioritarian | g($u_{ij}$) | g($u_{ij}$) | g[E($u_{ij}$)] | g($u_{ij}$) | g($u_{ij}$) | g[E($u_{ij}$)] |
| Individual *i* | 3 | 10 | 7.4 | 7 | 6 | 6.5 |
| Individual *h* | 11 | 1 | 7.8 | 8 | 6 | 7.1 |
| $S^{EAP}$ | 14 | 11 | 15.2 | 15 | 12 | 13.6 |
| Ex post prioritarian | g($u_{ij}$) | g($u_{ij}$) | E[g($u_{ij}$)] | g($u_{ij}$) | g($u_{ij}$) | E[g($u_{ij}$)] |
| Individual *i* | 3 | 10 | 6.5 | 7 | 6 | 6.5 |
| Individual *h* | 11 | 1 | 6 | 8 | 6 | 7 |
| $S^{EPP}$ | 14 | 11 | 12.5 | 15 | 12 | 13.5 |

Notes: $u_{ij}$ = utility of person *i* in state of nature *j*. $s_j$ = state of nature, probability of each state = 1/2. $g(u) = \sqrt{u}$.