

ARTICLE

The Global Burden of the COVID-19 Pandemic: Comparing Benefit–Cost Analysis and Social Welfare Analysis

Maddalena Ferranna 

Department of Pharmaceutical and Health Economics, University of Southern California, Los Angeles, CA, USA
Email: ferranna@usc.edu

Keywords: COVID-19; equity; pandemic preparedness; social welfare; utilitarianism

JEL Codes: D6; I18

Abstract

This article discusses the difference between benefit–cost analysis (BCA) and social welfare analysis in the evaluation of pandemic preparedness policies. Two social welfare approaches are considered: utilitarianism and prioritarianism. BCA sums the individuals’ monetary equivalents of the pandemic impacts. Social welfare analysis aggregates individuals’ well-being impacts. The aggregation rule identifies the normative judgments about what is fair. This article shows that the two methods yield very different estimates of the value of avoiding a future pandemic similar to the COVID-19 one. Compared to BCA, considerations about the distribution of the costs of the hypothetical intervention play a major role in the estimate of both utilitarian and prioritarian pandemic burdens: The more progressive the distribution of the costs is, the larger the net benefits of preventing the pandemic. In contrast, the BCA pandemic burden is indifferent to the distribution of the intervention costs. In addition, BCA tends to underestimate the burden suffered by low-income countries compared to social welfare analysis.

1. Introduction

The COVID-19 pandemic has forced countries to make difficult trade-offs. For example, vaccination prioritization strategies and decisions to ration treatment required weighing the relative health benefits to different people. Decisions about the extent and length of school and business shutdowns required balancing the reductions in deaths and morbidity against socioeconomic costs. Are conventional benefit–cost approaches suitable to make these kinds of trade-offs? This article challenges the use of benefit–cost analysis (BCA) in the economic evaluation of pandemic risks whose impacts are heterogeneously distributed across the population. In particular, this article argues in favor of an alternative method, social welfare analysis (SWA). The main advantage of SWA is that it enables ethical concerns about the distribution of impacts to be incorporated in the evaluation exercise in a transparent way

(Adler *et al.*, 2023). Although this article focuses on the economic evaluation of pandemic risks, its implications are wider and relate to any policy with heterogeneous impacts across the population.

This article explores the differences between BCA and SWA in the evaluation of pandemic-related policies. To illustrate the difference between the two methods, I estimate the maximum willingness-to-pay (WTP) for a pandemic preparedness intervention that is designed to prevent a pandemic similar to the COVID-19 one. Pandemic preparedness investments include, e.g. the development of vaccines against pandemic-potential pathogens (Saville *et al.*, 2022), establishing guidelines for the optimal global distribution of vaccines, therapeutics, protective equipment and other resources (Emanuel *et al.*, 2020), and strengthening epidemic surveillance systems. To determine the maximum WTP for pandemic preparedness, I consider the perspective of a supranational benevolent decision maker who aims at improving the well-being of the global population. The social value of preventing a COVID-19-like pandemic depends on the adopted value framework (BCA vs. SWA). In particular, it depends on the method to monetize health impacts and on the procedure to aggregate monetary impacts across the global population.

BCA determines the value of an intervention by converting all its health and non-health impacts into monetary equivalents based on individuals' WTP to avoid those impacts, and then summing up those monetary equivalents. Estimates of value-per-statistical-life (VSL) are typically used to monetize the value of mortality risk reductions (Hammitt, 2000). VSL represents the monetary equivalent of saving one (unidentified) life among a group of identical people. VSL estimates are derived from individuals' stated or revealed willingness to trade small changes in income for small changes in mortality risk (Viscusi, 2018). For example, if individuals are willing to pay \$10 to reduce their risk of premature death by 1 in a million, then the monetary value of saving one statistical life is \$10 million. In other words, if each member of a group of 1 million people, identical in all relevant ways, considers it in their best interest to pay \$10 to reduce the expected number of deaths within the group by one, then the value of preventing one death is \$10 million. In principle, VSL measures are heterogeneous across the population, reflecting the preferences and circumstances of different individuals (e.g., age, income, overall mortality risk) (Viscusi, 2010). Empirical VSL estimates are available for several countries and they can serve as proxies for countries with unavailable estimates, with appropriate adjustments for differences in income and other characteristics (Hammitt & Robinson, 2011; Viscusi & Masterman, 2017).

Application of BCA to the evaluation of pandemic-preparedness interventions unfolds as follows. Suppose that we are interested in determining the optimal investment in pandemic preparedness to prevent the effects of a future potential pandemic. Let us further assume that such an investment is expected to prevent D_c deaths in country c and that it will avoid country-specific income losses in the amount $\$ \Delta Y_c$. The overall cost of the investment is $\$ X$, and country c is contributing $\$ x_c \geq 0$ to its financing, with $\sum_c \$ x_c = \$ X$. A supranational benevolent authority has to decide whether such an investment is beneficial. According to BCA, the net value of the investment is equal to $\sum_c (D_c * VSL_c + \$ \Delta Y_c) - \sum_c \$ x_c$, where the term in parentheses is the monetary benefit for country c . Thus, the investment is considered beneficial as long as its overall cost $\$ X$ is lower than the sum of the country-specific monetary benefits.

Such a BCA rationale has well-known shortcomings. Since BCA sums up individuals' monetary equivalents, the distribution of the costs of the intervention has no relevance for the

benefit–cost calculus (Robinson *et al.*, 2016). Thus, it does not matter whether the investment is paid by individuals in high-income countries or by individuals in low-income countries. Presumably, many people would find the latter morally reproachful, i.e. they would attach higher value to interventions that are paid by wealthy nations than to interventions that have the same distribution of monetary benefits and the same total monetary cost but whose cost is borne by poor countries.¹ However, BCA is based on the principle that “a dollar is a dollar is a dollar.” As a consequence, monetary losses borne by low-income individuals have the same moral importance as monetary losses experienced by high-income individuals, even though the former may reduce the individuals to poverty while the latter may represent a small nuisance. Here, I focused on the distribution of the cost of the intervention, but the same principle applies to the distribution of income gains ΔY_c .

Another consequence of the “a dollar is a dollar is a dollar” principle is that the health burden – e.g. a reduction in expected remaining lifespan of Y years, or a $Y\%$ reduction in one’s quality of life for Z years – suffered by a well-off person tends to count more than an identical health burden suffered by a less well-off individual. This is due to the adoption of income-dependent VSL metrics. VSL is typically increasing in income since WTP is driven by individuals’ ability to pay. In other words, well-off individuals are likely to place higher monetary values on mortality risk reductions than less well-off individuals not necessarily because they value life more, but because they have more resources and are thus more willing to trade money for changes in risk.² Suppose that there are two alternative pandemic preparedness interventions (e.g., two different mechanisms of allocating vaccines worldwide). They both cost $\$X$ and they both prevent D deaths globally. However, the first intervention saves only people in high-income countries, while the second intervention saves only people in low-income countries. Since VSL in high-income countries is larger than VSL in low-income countries and BCA takes an unweighted sum of individuals’ net benefits, the first intervention would be considered more beneficial than the latter.

To mitigate concerns for discrimination, practical guidelines for the conduct of BCA suggest to use population-average VSLs, independent of individuals’ characteristics such as income or age (Robinson, 2007). However, it is also common practice to use different VSL estimates for different countries based on their national income (Viscusi & Masterman, 2017; Robinson *et al.*, 2019). As the pandemic preparedness example illustrates, that choice matters when evaluating interventions with supranational impacts (e.g., when determining the global value of developing new vaccines). In particular, comparisons of the burden of a pandemic across countries would place a larger value on negative health impacts experienced in high-income countries compared to the same health impacts borne by lower-income countries.

One possible solution is to adopt a global VSL estimate for all countries (Cadarette *et al.*, 2023), similarly to what is typically done at the national level. Although easy to implement,

¹ Surveys and laboratory experiments find a large degree of heterogeneity in distributive justice preferences (Schokkaert & Tarrow, 2022). In particular, a preference for income redistribution is not universal, depending on issues such as personal responsibility, perceived social mobility and relative income (Alesina & Angeletos, 2005; Alesina *et al.*, 2018; Almås *et al.*, 2020). On the other hand, equity is a major concern for many people (Kuziemko *et al.*, 2015), and transfers from the richest to the poorest are almost generally accepted (Amiel & Cowell, 1999).

² Suppose there are two individuals with the same preference parameters – so in this sense they “value life” the same – but different incomes. Even though they have the same preferences, the richer person will typically have a larger willingness to pay for mortality risk reductions because of their higher ability to pay.

the use of a single VSL estimate at the national or global level neglects potentially ethically justifiable reasons for attaching different moral values to risk reductions accruing to different people. For example, it is often considered ethically and economically reasonable to treat people in different age groups differently (Ferranna *et al.*, 2023). From a societal perspective, the death of a young person is often considered worse than the death of an old person, and not only because the former has a longer remaining life expectancy than the latter. There exists a relatively large public health literature supporting the “fair innings” principle (Harris, 1985; Williams, 1997; Bognar, 2015). The principle states that saving the life of a younger person is fairer than saving the life of an older person when each would gain the same extension in longevity because older individuals have already lived a long life and, as such, they have less claim to scarce resources.³ This issue is particularly important in the case of COVID-19, since mortality risk increases with age. Therefore, even though the dependence of WTP on income can have unacceptable ethical consequences, the use of a single VSL may also be ethically problematic. Adopting a constant value-per-statistical-life-year (VSLY) instead of a constant VSL addresses differences in remaining life expectancy between young and old people (Hammit, 2007). However, we still have the problem of how to select this constant VSLY and whether there should be cross-country differences based on income. Moreover, fair innings concerns would still play no role in the BCA results.

SWA does not face the same ethical challenges as BCA. SWA proceeds by estimating the impact of the pandemic on individuals’ well-being, and then aggregating those impacts through a social welfare function. The aggregation rule identifies the normative assumptions about distributive justice (Adler, 2019). For example, the utilitarian social welfare function assumes that total welfare is equal to the sum of individuals’ well-being. If marginal well-being is decreasing in income, the utilitarian approach is sensitive to inequalities in income. Thus, monetary impacts experienced by low-income individuals are morally more important than similar monetary impacts experienced by high-income individuals. Another popular welfare function is the prioritarian one, which assumes that total welfare is equal to the sum of a concave transformation of individuals’ well-being. Thus, the prioritarian approach is concerned with the distribution of well-being across the population, attaching higher value to well-being increments that accrue to the worse-off individuals (e.g., low-income individuals, but also individuals in poor health or young individuals).

As an approximation, SWA reduces to a weighted sum of individuals’ net monetary benefits (Adler, 2016). The weights reflect the relative moral importance of net benefits accruing to different individuals, and their form depends on the adopted welfare framework. Applied to the pandemic preparedness example, SWA would find the intervention beneficial if and only if $\sum_c \omega_c (D_c * VSL_c + \Delta Y_c - \$x_c) \geq 0$, where ω_c is the moral weight attached to net benefits experienced in country c . Therefore, under SWA, both the distribution of costs and the distribution of benefits matter. In particular, interventions paid for by poor countries will typically have lower net benefits than similar interventions paid for by rich countries.

³ Adler *et al.* (2021) show that the fair innings principle is justified only by prioritarian social welfare functions applied to lifetime well-being. The elicitation of people’s ethical preferences seems to support the notion that the young should receive priority in life saving treatments (Dolan *et al.*, 2005; Dolan & Tsuchiya, 2012). However, the support for fair innings is not universal. A substantial fraction of the population seems to hold the deontological view that all lives matter equally independently of expected benefits or individual characteristics (Adler *et al.*, 2024).

And saving lives in rich countries will not necessarily be considered more beneficial than saving an equal number of lives in poor countries.

Using data on the mortality and income consequences of the COVID-19 pandemic, I estimate the value of avoiding a future COVID-19-like pandemic using both the BCA rule, $\sum_c (D_c * VSL_c + \Delta Y_c - \$x_c)$, and the approximated social welfare one, $\sum_c \omega_c (D_c * VSL_c + \Delta Y_c - \$x_c)$. In addition, I determine the distribution of the pandemic burden across countries under the two approaches. When using the social welfare approach, I derive two different sets of weights: The first set of weights corresponds to the utilitarian aggregation rule and the second one identifies the prioritarian aggregation rule. I show that considerations about the distribution of the costs of the hypothetical intervention to prevent a COVID-19-like pandemic play a major role in the estimate of the welfare value: The more progressive is the distribution of the costs, the larger are the net benefits of preventing the pandemic. In contrast, under BCA, the value of preventing the pandemic is indifferent to the distribution of the intervention costs. In addition, compared to SWA, BCA tends to underestimate the burden suffered by low-income countries relative to high-income countries.

There is a long tradition of scholarly work advocating for the use of SWA (or its weighted-BCA approximation) in policy evaluation (e.g., Arrow, 1963, Drèze & Stern, 1987, Blackorby & Donaldson, 1990, and, more recently, Adler, 2012). One problem with SWA is that it requires an interpersonally comparable measure of individual well-being. As argued in Adler (2016) and Fleurbaey and Abi-Rafeh (2016), the reluctance to adopt SWA in policy evaluation is likely due to difficulties in measuring and ranking well-being levels across the population, especially when individuals hold heterogeneous preferences. Different approaches have been developed to measure well-being (see Adler & Decancq, 2022 for a review), and in this article I will focus on one specific approach (von Neumann-Morgenstern utilities). However, due to data limitations, I will also assume homogeneous preferences across countries and calibrate only one set of preference parameters. The assumption of homogeneous preferences is common in practical applications of SWA (Adler, 2022), and it implies interpersonally comparability of individual well-being metrics.

In contrast, BCA does not require a method for comparing well-being across individuals. BCA uses monetary values to compare benefits and costs across individuals, and the sum of individuals' costs and benefits determines whether the policy yields a potential Pareto improvement (Kaldor–Hicks efficiency criterion). The logic is that, when the net benefits of a policy are positive, then there are enough resources for the “winners” to compensate the “losers,” such that everyone will at the end be better off with the policy than without it. There is a large literature on the advantages and drawbacks of this view (e.g., Arrow, 1963; Harberger, 1978; Kaplow, 2004; Boadway, 2016; Hammitt, 2021). One well-recognized issue is that the compensation is hypothetical: There is no evidence that the “losers” are compensated through transfers, adjustments to the tax systems or other policies. In this article, I take the view that it is not possible to separate efficiency and equity in policy evaluation (Adler, 2016; Fleurbaey & Abi-Rafeh, 2016). If the impacts of a policy are heterogeneously distributed across the population, then the policy will have an (intended or unintended) effect on equity. BCA is not agnostic about distributive justice. On the contrary, by looking at the simple sum of individuals' WTPs, BCA is implicitly taking the moral stance that monetary benefits to the wealthy are as socially valuable as monetary benefits to the less wealthy. Even though SWA is more challenging to perform than BCA, SWA enables ethical concerns about the distribution of impacts to be incorporated in the evaluation exercise.

A few caveats before proceeding. Because of data limitations, this article focuses only on two pandemic impacts: COVID-19 deaths and income losses. The estimated global burden of the COVID-19 pandemic is conservative as additional impacts (e.g., non-COVID-19 deaths, morbidity, mental health and education losses) are ignored. Additionally, the application focuses on between-country differences in pandemic impacts, while within-country inequalities are neglected. This will lead to conservative estimates of the global pandemic burden when using a social welfare approach since the distribution of impacts across the global population is likely to be more unequal than the average distribution of impacts across countries. For example, the adoption of country-average income losses neglects that the pandemic caused some people to fall into poverty. A distribution-sensitive welfare approach would consider this outcome morally wrong, thereby increasing the overall value of preventing the pandemic.

This article is structured as follows. Section 2 summarizes the literature most closely related to this article. Section 3 introduces a stylized model to estimate the global value of preventing a COVID-19-like pandemic and derives three measures of such a value: the BCA value based on country-specific VSL measures, the utilitarian value, and the prioritarian one. Section 4 describes the data required for the analysis and presents the estimation results. I estimate the global value of preventing the pandemic and its distribution across all countries with available data. Section 5 concludes and discusses the main limitations of this article.

2. Related literature

The health, social, and economic costs of the COVID-19 pandemic are staggering. As of September 2023, almost 7 million COVID-19 deaths have been recorded globally (WHO, 2023), while estimates of excess mortality (including both estimates of undocumented COVID-19 deaths and deaths from other causes) are in the ballpark of 26 million deaths (The Economist, 2023).⁴ Global Gross Domestic Product (GDP) reduced by 3.1% in 2020 (IMF, 2021). Almost 1.6 billion students worldwide were affected by school closures because of the COVID-19 pandemic, and average learning loss amounted to roughly 35% of a school year's worth of learning (Betthäuser *et al.*, 2023). The pandemic drove massive unemployment and permanent business closures (Baek *et al.*, 2021, Fairlie *et al.*, 2023) and disrupted global supply chains (Guerrieri *et al.*, 2022). It also imposed a sizable mental health toll due to isolation, fear of contagion and loss of family and friends (Giuntella *et al.*, 2021).

The impacts of the pandemic have been very unequal across the population. On the one hand, COVID-19 mortality risk sharply increases with age (Pijls *et al.*, 2021). Due to differences in population age structure, high-income countries typically registered more COVID-19 deaths than lower-income countries. On the other hand, the COVID-19 pandemic has exacerbated existing inequalities through: patterns of infection and death that

⁴ Excess mortality is defined as the difference between overall deaths and expected deaths in the absence of the COVID-19 pandemic. Two factors explain the discrepancy between confirmed COVID-19 deaths and excess deaths. First, not all COVID-19 deaths are reported because of limited diagnostic capacity, exacerbation of comorbidities that are recorded as the main cause of death, and limited access to healthcare (Whittaker *et al.*, 2021). Second, the pandemic caused broad negative health impacts, including the disruption of routine immunization and medical screening, delays in treatments, and reduced willingness to seek care due to fear of infection or health insurance loss (Czeisler *et al.*, 2020; Richards *et al.*, 2020; Cantor *et al.*, 2022).

disproportionately affect disadvantaged populations (e.g., the overproportion of minorities and low-income individuals among essential workers); socioeconomic differences in health-care access and in ability to invest resources to control the pandemic, including the purchase of vaccines and treatments; and inadequate income relief programs to equitably share the economic burden of the pandemic (Stantcheva, 2022). Overall, the pandemic seems to have led to an increase in global income inequality (Mahler *et al.*, 2022).⁵

In the evaluation of pandemic-related policies, two main approaches have emerged: BCA based on VSL measures (e.g., Gollier, 2020; Greenstone & Nigam, 2020; Thunstrom *et al.*, 2020), and utilitarian social welfare functions (e.g., Hall *et al.*, 2020; Quaas *et al.*, 2021; Glover *et al.*, 2023). A few papers discuss nonutilitarian social welfare approaches (e.g., Ferranna *et al.*, 2022; Adler *et al.*, 2023). Here, I review only the articles that estimate the burden of the pandemic.⁶

Cutler and Summers (2020) use a BCA approach and estimate that the expected cost of the COVID-19 pandemic in the United States amounted to more than \$16 trillion. That figure is based on a population-average VSL estimate of \$7 million, and on the inclusion of losses due to premature death, long-term health impairments, mental health impairments and the economic recession. In a similar vein, Viscusi (2020) adopts income-adjusted VSL measures for different countries and estimates that the global COVID-19 mortality burden in the first half of 2020 amounted to \$3.5 trillion, with the United States experiencing 25% of the total deaths but 41% of the monetary burden. The global estimate is found by assuming a population-average VSL of \$11 million for the United States and a global income elasticity of 1 (i.e., the ratio of VSL to national income is constant across countries). In particular, the use of income-adjusted VSL measures implies that the mortality burden in the United States is valued more than the mortality burden in other countries. This ethically challenging result is not robust to social welfare evaluation methods.

The closest analysis to this article is Decerf *et al.* (2021), who estimate the global burden of the pandemic by adopting a utilitarian welfare function that depends solely on the number of people alive and on whether they are in poverty or not. The welfare loss of the pandemic is the weighted sum of the number of years lost to premature COVID-19 death and the number of additional years spent in poverty because of the pandemic. The trade-off between mortality and poverty is given by a single normative parameter. The estimated welfare loss depends largely on the increase in poverty caused by the pandemic, especially in lower-income countries. Given that the welfare metric is the number of years of life and each year of life is valued equally, impacts in high-income countries are not inflated compared to similar impacts in lower-income countries. However, the welfare measure is sensitive to differences in life expectancy across countries.

There exists also a small literature focusing on the costs of future pandemics. Fan *et al.* (2018) and Glennerster *et al.* (2023) both employ VSL measures to price pandemic risks and find that the expected global annual losses from pandemic risk range from \$500 billion (2013

⁵The debate about the global inequality impact of the pandemic is still open. Although the within-country unequal burden of COVID-19 is typically uncontested, measures of global inequality are sensitive to the specific inequality metric used in the analysis. For instance, Deaton (2021) shows that inequality in GDP across countries has reduced during the pandemic, while inequality in the global distribution of income has increased.

⁶As opposed to papers that estimate the benefits and costs of interventions to mitigate the effects of the COVID-19 pandemic (e.g., economic lockdown policies) or that discuss the allocation of vaccines and other resources (e.g., Ferranna *et al.*, 2022).

values) to \$700 billion (2021 values), respectively. The larger estimate provided by Glennerster et al. is in part due to risk updates following the COVID-19 pandemic and to the inclusion of educational losses in the calculus. Martin and Pindyck (2021) consider a utilitarian framework and estimate that the WTP to avoid major pandemics is 10% or more of annual consumption and partly driven by the risk of macroeconomic contractions. With a utilitarian welfare framework, the value of non-marginal health risks positively depends on background income risk under commonly used parameterization of the utility function.

This article focuses on the inability of BCA to account for the distributional impacts of a pandemic. Three other shortcomings of BCA have been highlighted in the literature on pandemic policies. First, morbidity consequences can be sizable (think, e.g., at long-COVID), and it is unclear how to evaluate reductions in morbidity for emerging or previously unexplored health risks (Kniesner & Sullivan, 2020; Robinson *et al.*, 2021). Second, BCA based on standard VSL estimates overestimates the value of preventing a large number of deaths (Hammit, 2020). VSL is the *marginal* rate of substitution of income for mortality risk, but pandemics entail non-marginal health risk changes. In particular, standard VSL estimates tend to overestimate individuals' WTP to reduce non-marginal risks. When the risk change is large, income constraints play an important role as individuals might be required to deplete their resources to pay for the risk reduction. Third, pandemic risks are novel and subject to large uncertainties (Berger *et al.*, 2021). However, issues of deep uncertainty and ambiguity are not featured in BCA. Although all these shortcomings are important, this article focuses exclusively on the distributional aspect.

3. Evaluation frameworks

The section introduces a simplified framework to assess the value of a hypothetical intervention to prevent the impacts of a pandemic similar to the COVID-19 one. The COVID-19 pandemic has affected people's lives along multiple dimensions, from exposing individuals to severe health risks to disrupting work habits and social relations. Impacts have also been heterogeneously distributed across the population, with older people, minorities and socioeconomic vulnerable populations often bearing the brunt of the pandemic. Notwithstanding the plethora of impacts of the pandemic, in the following I will focus only on two major impacts: deaths and income losses. This choice is dictated by data constraints and it is not meant to downplay the importance of other impacts (e.g., non-COVID-19 deaths, long-COVID, worsening of mental health, undernutrition, disruption to routine immunization and educational losses). Additionally, since consistent data across countries are missing, I disregard the within-country distribution of pandemic impacts, and focus only on between-country differences in deaths and income losses.

3.1. A stylized model

The starting point for the analysis is a measure of individual well-being. Generally speaking, well-being is assumed to depend on a bundle of attributes that are important to individuals (e.g., income, physical and mental health, longevity, quality of the environment and social

relations). Since the only COVID-19 impacts included in the analysis are death and income losses, I assume that individuals' well-being depends only on income and longevity.

Well-being and its dependence of the bundle of attributes can be measured in several ways (Adler & Fleurbaey, 2016; Adler & Decanq, 2022), including: reports of life satisfaction or experience of emotions (Layard & De Neve, 2023); attainment of a list of objective goods or "capabilities" (e.g., being healthy, having meaningful social relations) (Sen, 1999; Nussbaum, 2011); adjusting individual income by the value of nonmarket attributes based on the individual's preferences for those attributes (Fleurbaey *et al.*, 2013); and employing utility functions that represent individuals' risk preferences regarding alternative probability distributions of attributes over a lifetime (von Neumann-Morgenstern utility function) (Adler, 2019). In this article, I measure well-being through a von Neumann-Morgenstern utility function. Additionally, I assume that individuals have homogeneous preferences, i.e. there exists a single utility function for the whole population. I will not test the robustness of the results to other measures of well-being or to heterogeneous preferences.

Furthermore, I assume that the well-being metric of interest is lifetime well-being rather than sub-lifetime well-being. As a consequence, judgments about who is worse-off in a society are based on individuals' entire life trajectory and not only on their current or future circumstances. Lifetime well-being is additive in period utility and the marginal utility of income is diminishing, so that a dollar raises the utility of a poor individual more than it does that of a rich individual. To make computations tractable, I assume no time discounting and no economic growth.

Let us consider a representative individual in country c . Let y_c be the income of the representative individual. With probability p_c , the individual dies at age l_c (i.e., they live for l_c years), and with probability $1 - p_c$ the individual dies prematurely at age $a_c < l_c$ (i.e., they live for a_c years). The period utility function is $u(y_c)$, with $u'(y_c) > 0$ and $u''(y_c) < 0$. The period utility in the death state is zero. N_c is the number of people living in country c . Expected lifetime utility for the representative individual in the absence of the pandemic is equal to:

$$V_c^{NP} = p_c l_c u(y_c) + (1 - p_c) a_c u(y_c) \tag{1}$$

VSL at age a_c derives from the marginal rate of substitution between survival and income at age a_c . Given (1), $VSL_c = \frac{\partial V_c / \partial p_c}{\partial V_c / \partial y_c(a_c)} = \frac{(l_c - a_c)u(y_c)}{u'(y_c)}$, with $y_c(a_c)$ denoting income at age a_c . VSL is increasing in remaining life expectancy ($l_c - a_c$): Individuals who live longer can reap the benefits of the risk reducing intervention for more years and thus have a larger WTP for the intervention. VSL is also increasing in income y_c . First, the numerator increases in income as, by assumption, better living standards increase well-being, i.e. $u'(y_c) > 0$. Second, the denominator decreases in income since the marginal value of money decreases in income, i.e. $u''(y_c) < 0$. This leads to the contentious result that higher-income individuals attach larger value to a given health benefit than lower-income individuals because they have a larger ability to pay than their lower-income counterpart.

Suppose that the pandemic causes the death of D_c people in country c , thereby reducing the survival probability of the representative individual by $d_c = \frac{D_c}{N_c}$. In addition, the pandemic reduces country's income by ΔY_c . Let $\Delta y_c = \frac{\Delta Y_c}{N_c}$ be the per-capita income loss. Let us assume

that only the income at age a_c is affected.⁷ Expected lifetime utility with the pandemic is equal to:⁸

$$V_c^P = (p_c - d_c)l_c u(y_c) + (1 - p_c + d_c)a_c u(y_c) - u(y_c) + u(y_c - \Delta y_c) \tag{2}$$

The individual’s WTP at age a_c to avoid the pandemic impacts is the amount of money x such that the individual is indifferent between suffering the pandemic impacts and not suffering the pandemic impacts but paying x . Expected lifetime utility in the latter is equal to: $V_c^{NP}(x) = p_c l_c u(y_c) + (1 - p_c)a_c u(y_c) - u(y_c) + u(y_c - x)$. The individual’s WTP x is determined by solving $V_c^{NP}(x) - V_c^P = 0$ and it is approximately equal to:⁹

$$d_c \frac{(l_c - a_c)u(y_c)}{u'(y_c)} + \Delta y_c = d_c VSL_c + \Delta y_c \tag{3}$$

The value in (3) represents the individual monetary equivalent of the pandemic burden for people living in country c .

3.2. Benefit–cost analysis

BCA determines the social value of preventing the pandemic by summing individuals’ WTP to avoid the pandemic impacts. Given (3), the BCA value is given by:

$$Value^{BCA} = \sum_c N_c (d_c VSL_c + \Delta y_c) \tag{4}$$

BCA is unconcerned with the distribution of WTP in the population. Health and economic impacts experienced by low-income countries have the same moral importance as impacts experienced by high-income countries, where impacts are measured by individuals’ WTP. Let us consider a pandemic preparedness intervention that costs $\$X$. Such an intervention is expected to prevent a pandemic similar to the COVID-19 one. According to BCA, the global benefits of the intervention are equal to $\sum_c N_c (d_c VSL_c + \Delta y_c)$, and the intervention is beneficial as long as $\sum_c N_c (d_c VSL_c + \Delta y_c) - \$X \geq 0$.

⁷ The framework can be easily extended to multi-periods income losses.

⁸ An individual who dies in period a_c consumes y_c for $a_c - 1$ years and $y_c - \Delta y_c$ for 1 year. An individual who survives to age l_c consumes y_c for $a_c - 1$ years, $y_c - \Delta y_c$ for 1 year, and then y_c for $l_c - a_c$ years. Given that the probability of dying at age a_c is $1 - p_c + d_c$, lifetime well-being is equal to:

$$V_c^P = (p_c - d_c)[(a_c - 1)u(y_c) + u(y_c - \Delta y_c) + (l_c - a_c)u(y_c)] + (1 - p_c + d_c)[(a_c - 1)u(y_c) + u(y_c - \Delta y_c)]$$

The previous equation can be rewritten as equation (2).

⁹ Expression (3) is derived by taking a first-order approximation of $V_c^{NP}(x) - V_c^P = 0$ around $\Delta y_c = 0$ and $x = 0$. The difference in lifetime well-being is equal to:

$$V_c^{NP}(x) - V_c^P = p_c l_c u(y_c) + (1 - p_c)a_c u(y_c) - u(y_c) + u(y_c - x) - (p_c - d_c)l_c u(y_c) - (1 - p_c + d_c)a_c u(y_c) + u(y_c) - u(y_c - \Delta y_c) = d_c(l_c - a_c)u(y_c) + u(y_c - x) - u(y_c - \Delta y_c)$$

A first order approximation of $u(y_c - x)$ evaluated at the point x^* is equal to: $u(y_c - x^*) + u'(y_c - x^*)[y_c - x - y_c + x^*]$. When $x^* = 0$, then $u(y_c - x) \approx u(y_c) - u'(y_c)x$. Similar computations hold for $u(y_c - \Delta y_c)$: the first-order approximation evaluated at $\Delta y_c = 0$ is $u(y_c) - u'(y_c)\Delta y_c$. As a result, the first-order approximation of $V_c^{NP}(x) - V_c^P = 0$ evaluated at $\Delta y_c = 0$ and $x = 0$ yields:

$$V_c^{NP}(x) - V_c^P \approx d_c(l_c - a_c)u(y_c) + u(y_c) - xu'(y_c) - u(y_c) + \Delta y_c u'(y_c) = 0$$

After rearranging terms, I get equation (3).

3.3. Utilitarian SWA

Let us now consider the value of prevention estimated through a utilitarian social welfare function. The utilitarian aggregation rule sums individuals' lifetime well-being. Utilitarian welfare without the pandemic is equal to:

$$W_U^{NP} = \sum_c N_c V_c^{NP} = \sum_c N_c \{p_c l_c u(y_c) + (1 - p_c) a_c u(y_c)\}$$

Utilitarian welfare with the pandemic is equal to:

$$W_U^P = \sum_c N_c V_c^P = \sum_c N_c \{(p_c - d_c) l_c u(y_c) + (1 - p_c + d_c) a_c u(y_c) - u(y_c) + u(y_c - \Delta y_c)\}$$

In welfare terms, the utilitarian value of preventing the pandemic is given by:

$$\Delta W_U = W_U^{NP} - W_U^P = \sum_c N_c \{d_c (l_c - a_c) u(y_c) + u(y_c) - u(y_c - \Delta y_c)\}$$

Taking a first-order approximation of ΔW_U around $\Delta y_c = 0$, the utilitarian value is equal to a weighted sum of individuals' WTP, where the weight depends on the marginal utility of income:¹⁰

$$\Delta W_U \simeq \sum_c N_c u'(y_c) \{d_c VSL_c + \Delta y_c\} \tag{5}$$

Given the diminishing marginal utility of income assumption, the introduction of weights has two consequences compared to the BCA formula (4). First, income losses Δy_c in low-income countries are attached a larger moral weight than comparable losses in high-income countries. This is because the former reduces the well-being of low-income individuals more than the well-being of high-income individuals. Second, the well-being impact of reducing mortality in country c , $(l_c - a_c)u(y_c)$, does not depend on individuals' marginal value of money. Therefore, saving a life in high-income countries is not valued more than saving a similar life in lower-income countries only because the former has a larger ability to pay than the latter.¹¹

Expression (5) represents the utilitarian impact of the pandemic in welfare terms. To compare such a value with the cost of a hypothetical pandemic preparedness intervention, it is easier to transform the welfare value in monetary terms. This can be done by dividing the marginal utility of income $u'(y_c)$ by the marginal utility of a benchmark income level. Note that the chosen normalization will have a first-order impact on the size of the estimated value:

¹⁰ The first-order approximation of ΔW_U evaluated at $\Delta y_c = 0$ is equal to:

$$\Delta W_U \simeq \sum_c N_c \{d_c (l_c - a_c) u(y_c) + u(y_c) - u(y_c - \Delta y_c) - \Delta y_c u'(y_c)\} = \sum_c N_c u'(y_c) \left\{ d_c \frac{(l_c - a_c) u(y_c)}{u'(y_c)} + \Delta y_c \right\}$$

¹¹ Note that the utilitarian value of mortality risk reduction is increasing in income because, by construction, well-being increases in income. However, unlike BCA, the utilitarian value is independent of individuals' marginal value of money $u'(y_c)$. In other words, consider two individuals, A and B, who differ in income, with $y_A > y_B$, but who would gain the same well-being change by reducing their mortality risk, i.e. $(l_A - a_A)u(y_A) = (l_B - a_B)u(y_B)$. Then, from the utilitarian perspective, preventing the death of A is equally valuable as preventing the death of B. In contrast, BCA would recommend saving the life of A because A has a larger ability to pay, $u'(y_A) < u'(y_B)$. Note, however, that utilitarianism is not completely unaffected by the distribution of income because of the assumption that well-being increases in income (i.e., $u' > 0$). For example, if A and B gain the same life extension, $l_A - a_A = l_B - a_B$, the well-being change experienced by A is deemed larger than the well-being change experienced by B, $(l_A - a_A)u(y_A) > (l_B - a_B)u(y_B)$. Thus, in this case, preventing the death of A is more valuable than preventing the death of B from a utilitarian point of view.

The larger the benchmark income, the lower the corresponding marginal utility, and the larger the utilitarian value of preventing a pandemic.¹²

To determine the benchmark income level for the normalization, I compute the maximum amount that the benevolent supranational decision-maker would be willing to request to the global population to finance an intervention that prevents the pandemic impacts.¹³ Let X be such an amount, and let σ_c be the proportion paid by an individual in country c , with $\sum_c N_c \sigma_c = 1$. The societal WTP X for the intervention represents the monetary equivalent of the utilitarian value of the intervention. The societal WTP X is such that utilitarian welfare without the pandemic but with the investment X is equal to utilitarian welfare with the pandemic:

$$\begin{aligned} & \sum_c N_c \{p_c l_c u(y_c) + (1 - p_c) a_c u(y_c) - u(y_c) + u(y_c - \sigma_c X)\} \\ &= \sum_c N_c \{(p_c - d_c) l_c u(y_c) + (1 - p_c + d_c) a_c u(y_c) - u(y_c) + u(y_c - \Delta y_c)\} \end{aligned}$$

Solving for X and taking a first-order approximation around $\Delta y_c = 0$ and $X = 0$, we get an expression for the monetary equivalent of the utilitarian benefits to prevent a pandemic:

$$Value^U \simeq \sum_c N_c \frac{u'(y_c)}{\sum_c N_c \sigma_c u'(y_c)} \{d_c VSL_c + \Delta y_c\} \tag{6}$$

The utilitarian weights are normalized by dividing them by the weighted sum of the marginal utilities of income. The weighted sum reflects the distribution of the intervention costs. In other words, the benchmark income \hat{y} for the normalization is such that $\sum_c N_c \sigma_c u'(y_c) = u'(\hat{y})$. For example, if the costs of the pandemic preparedness intervention are equally distributed across the world population, then $\sigma_c = \frac{1}{N}$, with $N = \sum_c N_c$. If the costs are distributed proportionally to income, then $\sigma_c = \frac{y_c}{\sum_c N_c y_c}$. Note that the more regressive is

¹² Let X be the cost of the pandemic prevention policy. The policy is beneficial if and only if $X \leq \sum_c N_c \omega_c^U \{d_c VSL_c + \Delta y_c\}$, where $\omega_c^U = \frac{u'(y_c)}{u'(\hat{y})}$ and \hat{y} is the benchmark income level used to normalize the utilitarian weights. The larger is \hat{y} , the larger are the utilitarian weights and the larger is the utilitarian value of the intervention, $\sum_c N_c \omega_c^U \{d_c VSL_c + \Delta y_c\}$. Thus, the choice of \hat{y} is very consequential to determine the value of preventing the next pandemic.

¹³ For convenience, it is often suggested to use median income to normalize the weights (e.g., Liscow & Sunstein, 2023). Note that, if we knew both the benefits and the costs of the interventions, then the normalization would be inconsequential as it does not affect either which interventions have positive utilitarian net value or the ranking of interventions. For example, let us consider two policies, P1 and P2. Let $b_c^{P1} = d_c^{P1} VSL_c + \Delta y_c^{P1}$ and x_c^{P1} be the benefits and costs of intervention P1 for country c , and let $b_c^{P2} = d_c^{P2} VSL_c + \Delta y_c^{P2}$ and x_c^{P2} be the country-specific benefits and costs associated to intervention P2. P1 is ranked higher than P2 if and only if $\sum_c N_c \frac{u'(y_c)}{u'(\hat{y})} [b_c^{P1} - x_c^{P1}] \geq \sum_c N_c \frac{u'(y_c)}{u'(\hat{y})} [b_c^{P2} - x_c^{P2}]$. In this case, the choice of the benchmark income level \hat{y} does not matter since it simply rescales the net benefits. If P1 is superior to P2 at median income, it is also superior to P2 at any other income level \hat{y} ; if P1 has positive net utilitarian value at median income, it has positive net utilitarian value at any other income \hat{y} . Median income is a useful reference point because it has an intuitive explanation: The lower 50% of the income distribution have a weight larger than 1 and the upper 50% of the income distribution have a weight lower than 1; if there were no income inequality – everyone has income equal to the median income – all weights would be equal to 1. This case differs from the one considered in this article. The goal of this article is to estimate the break-even cost, i.e. the maximum intervention cost such that preventing the pandemic while paying the intervention cost is considered welfare improving. The break-even cost does depend on the normalization method.

the distribution of costs (i.e., the larger the proportion σ_c paid by individuals in low-income countries is), the higher is the denominator of (6), and the smaller is the corresponding utilitarian value of the intervention. Thus, compared to the BCA value (4), the utilitarian value depends not only on the distribution of pandemic impacts, but also on the distribution of the costs of the hypothetical intervention to prevent such a burden. Said differently, we cannot evaluate the benefits of preventing a pandemic without considering how the costs of the prevention policy are distributed. From a utilitarian point of view, preparing for a pandemic similar to COVID-19 is beneficial insofar as the intervention itself does not excessively harm low-income individuals. According to utilitarianism, an intervention that costs $\$X$ is beneficial as long as $\sum_c N_c \frac{u'(y_c)}{\sum_c N_c \sigma_c u'(y_c)} \{d_c VSL_c + \Delta y_c\} - \$X \geq 0$.¹⁴

3.4. Prioritarian SWA

Prioritarianism is an ethical view that gives extra weight to the well-being of the worse off (Adler, 2022). Thus, according to the prioritarian perspective, well-being gains experienced by the worse off are morally more valuable than similar well-being gains experienced by the better off. The prioritarian social welfare is equal to the sum of a concave transformation of individuals' well-being. If w_i is the well-being of individual i , the prioritarian social welfare is equal to $W_P = \sum_i g(w_i)$, with $g'' \leq 0$. The concavity of the function g represents social preferences for the distribution of well-being across the population. When $g'' = 0$, we obtain the utilitarian social welfare function.

In the presence of risk, there exist two different forms of prioritarianism. Ex ante prioritarianism is concerned with the distribution of *expected* well-being across the population. Generally speaking, from the ex ante point of view, priority is given to individuals who are facing the largest mortality risk. Ex post prioritarianism is concerned with the distribution of *realized* well-being across the population. Generally speaking, from the ex post point of view, priority is given to individuals who die prematurely. Ex ante prioritarianism violates stochastic dominance, and for that reason it is problematic (Adler, 2019).¹⁵ In this article, I focus on ex post prioritarianism. I will not investigate if the ex ante approach would lead to similar conclusions as those found in this article.

Let $N_c(1 - p_c)$ be the number of people that die at age a_c without the pandemic, and let $N_c p_c$ be the number of people that live a long life, with l_c the typical longevity of individuals in country c . The people who die prematurely have a lifetime well-being equal to $a_c u(y_c)$, while the individuals who die at age l_c have a lifetime well-being equal to $l_c u(y_c)$. The prioritarian welfare in the absence of the pandemic is given by:

¹⁴ Since $\$X = \$X \sum_c N_c \sigma_c$, we also have that $\sum_c N_c \frac{u'(y_c)}{\sum_c N_c \sigma_c u'(y_c)} \{d_c VSL_c + \Delta y_c - \$X \sigma_c\} \geq 0$, which corresponds to the formula presented in the introductory section.

¹⁵ While ex ante prioritarianism violates stochastic dominance, ex post prioritarianism violates the ex ante Pareto principle. In addition, ex post prioritarianism gives no importance to how the final outcome came about (e.g., through a fair lottery or an unfair one). The choice between the ex ante and the ex post approach depends on society's ethical judgments. In this article, I adopt the ex post approach because, although individuals face a mortality risk, there is no aggregate risk (the number of deaths is deterministic). I assume that the decision-maker is interested in preventing a sure number of deaths rather than reducing inequality in individuals' risks. For a more in-depth discussion of the differences between ex ante and ex post approaches, see Fleurbaey (2010) and Adler (2012, 2019).

$$W_P^{NP} = \sum_c N_c \{ (1 - p_c)g(a_c u(y_c)) + p_c g(l_c u(y_c)) \}$$

The pandemic increases the number of people that die at age a_c and reduces the income enjoyed at age a_c . The prioritarian welfare with the pandemic is equal to:

$$W_P^P = \sum_c N_c \left\{ (1 - p_c + d_c)g(a_c u(y_c) - u(y_c) + u(y_c - \Delta y_c)) + (p_c - d_c)g(l_c u(y_c) - u(y_c) + u(y_c - \Delta y_c)) \right\}$$

In welfare terms, the prioritarian value of preventing a pandemic is approximately equal to:¹⁶

$$\Delta W^P \simeq \sum_c N_c g'(l_c u(y_c)) u'(y_c) [d_c VSL_c + \Delta y_c] \tag{7}$$

Expression (7) is derived by taking a first-order approximation of $\Delta W^P = W_{NP}^P - W_P^P$ around $\Delta y_c = 0$ and $d_c = 0$ and assuming $p_c = 1$ for simplicity. According to (7), the prioritarian welfare burden of the pandemic is approximately equal to the weighted sum of individuals’ monetary equivalents, where the weights represent the moral importance attached to the impacts experienced by different people. The prioritarian weights have two components: the marginal utility of income, $u'(y_c)$, and the priority to the worse off in well-being terms, $g'(l_c u(y_c))$. Thus, as in the utilitarian case, monetary losses borne by individuals in low-income countries are deemed morally more harmful than similar losses borne by individuals in high-income countries because the value of money decreases with income. Compared to the utilitarian case, lower-income countries get an extra weight on the grounds that they are worse off in well-being terms. Additionally, the prioritarian weight decreases in longevity l_c : Individuals who die young are deemed worse-off than individuals who live a long life. Thus, the prioritarian framework captures the “fair innings” principle according to which it is fairer to save a young life than an older one on the grounds that the latter had a better chance to a full life (Harris, 1985).

To obtain the monetary equivalent of the prioritarian value (7), I follow the same methodology as in the utilitarian case and derive the societal maximum WTP X for avoiding the pandemic impacts. Assuming that each individual in country c bears a share σ_c of the cost of the pandemic preparedness intervention, the societal maximum WTP is such that the

¹⁶ The prioritarian value of preventing a pandemic is equal to:

$$\begin{aligned} \Delta W^P &= W_{NP}^P - W_P^P \\ &= \sum_c N_c \{ (1 - p_c)g(a_c u(y_c)) + p_c g(l_c u(y_c)) - (1 - p_c + d_c)g(a_c u(y_c) - u(y_c) + u(y_c - \Delta y_c)) \\ &\quad - (p_c - d_c)g(l_c u(y_c) - u(y_c) + u(y_c - \Delta y_c)) \} \\ &= \sum_c N_c \{ (1 - p_c)[g(a_c u(y_c)) - g(a_c u(y_c) - u(y_c) + u(y_c - \Delta y_c))] \\ &\quad + p_c [g(l_c u(y_c)) - g(l_c u(y_c) - u(y_c) + u(y_c - \Delta y_c))] \\ &\quad + d_c [g(l_c u(y_c) - u(y_c) + u(y_c - \Delta y_c)) - g(a_c u(y_c) - u(y_c) + u(y_c - \Delta y_c))] \} \end{aligned}$$

The first-order approximation of ΔW^P evaluated at $\Delta y_c = 0$ $d_c = 0$ yields:

$$\Delta W^P \simeq \sum_c N_c \{ (1 - p_c)g'(a_c u(y_c))u'(y_c)\Delta y_c + p_c g'(l_c u(y_c))u'(y_c)\Delta y_c + d_c [g'(l_c u(y_c)) - g'(a_c u(y_c))] \}$$

If we further assume that $p_c \simeq 1$ (i.e., everyone is ex post identical in the population), and given that $g(l_c u(y_c)) - g(a_c u(y_c)) \simeq g'(l_c u(y_c))(l_c - a_c)u(y_c)$ (i.e., the age of death a_c is sufficiently close to the normal length of life l_c), we obtain expression (7).

prioritarian welfare with no pandemic and the intervention X is equal to the prioritarian welfare with the pandemic. In the approximation, the prioritarian pandemic value of a prevention policy is equal to:

$$Value^P \approx \sum_c N_c \frac{g'(l_c u(y_c)) u'(y_c)}{\sum_c N_c g'(l_c u(y_c)) u'(y_c) \sigma_c} \{d_c VSL_c + \Delta y_c\} \tag{8}$$

The prioritarian weights are normalized by dividing them by the weighted sum of the marginal *welfare* of income. The weighted sum reflects the distribution of the intervention costs. In other words, the benchmark income \hat{y} for the normalization is such that $\sum_c N_c g'(l_c u(y_c)) \sigma_c u'(y_c) = g'(\hat{l} u(\hat{y})) u'(\hat{y})$, where \hat{l} is the life expectancy of the individual with benchmark income \hat{y} . As in the utilitarian case, the more the costs of the hypothetical intervention are paid by low-income countries, the smaller the value of the pandemic prevention policy is. Therefore, from the prioritarian perspective, an intervention that costs $\$X$ is beneficial as long as $\sum_c N_c \frac{g'(l_c u(y_c)) u'(y_c)}{\sum_c N_c g'(l_c u(y_c)) u'(y_c) \sigma_c} \{d_c VSL_c + \Delta y_c\} - \$X \geq 0$.

4. The global value of pandemic prevention

The section provides estimates of the value of preventing a COVID-19-like pandemic for different countries in the world and for the world as a whole. Pandemic impacts include GDP losses and COVID-19 deaths. I present three different estimates of the value of pandemic prevention. First, I use a conventional BCA approach (4). The value of prevention is equal to the sum of the GDP loss and the monetary equivalent of the deaths recorded in a country. The value of saving a life is equal to income-adjusted VSLs. Then, I compute the utilitarian value using expression (6) and the prioritarian value using expression (8).

4.1. Data

I combine different data sources. Population data by age and mortality rates by age in the non-pandemic scenario are derived from the 2022 UN World Population Prospects (United Nations, 2022). In particular, the dataset includes life tables for all countries and estimates of the proportion of individuals in a given birth cohort who die at different ages. I use those data to derive population-average longevity l_c for different countries.¹⁷ GDP data are taken from the World Bank dataset (World Bank, 2023). I consider purchasing power parity GDP per capita in constant 2017 international \$.

For pandemic burdens, economic losses are given by the reduction in GDP experienced by countries during the pandemic. I consider only economic losses experienced in 2020 and 2021 to avoid any confounding with the war in Ukraine (started in February 2022). To project GDP per capita in the absence of the pandemic, I use growth projections from the International Monetary Fund published in October 2019 (IMF, 2019). Because of data constraints, I consider only COVID-19 deaths and neglect excess deaths from other causes during the pandemic. The total number of COVID-19 deaths by country is derived from Our

¹⁷ Population-average longevity is the average longevity of the population considering the population age structure and the differences in longevity across age groups.

World in Data (Mathieu *et al.*, 2020). I take the latest available figure for each country (August 1, 2023).

4.2. Calibration

In the BCA exercise, the country-specific VSL estimates are derived by adjusting the U.S. estimate for cross-country differences in income, as described in Robinson *et al.* (2019).¹⁸ I assume that the VSL for the United States is \$10 million, which is approximately 160 times the projected GDP per capita in 2020 absent the pandemic. Assuming an income elasticity of 1 (i.e., the VSL to income ratio is constant across countries), I derive VSL estimates for the other countries based on their projected income in the non-pandemic scenario.¹⁹

To calibrate expressions (6) and (8), I assume that the period utility has an isoelastic form, $u = \frac{y_c^{1-\eta} - \bar{y}^{1-\eta}}{1-\eta}$ for $\eta \neq 1$ and $u = \ln y_c$ for $\eta = 1$, where η is the elasticity of the marginal utility of income and \bar{y} denotes the subsistence income level (i.e., the minimum income for a life worth living). Additionally, I assume that welfare is described by an Atkinson social welfare function of the form: $\sum_i \frac{w_i^{1-\gamma}}{1-\gamma}$, where γ represents society’s aversion to inequality in well-being. The utilitarian case corresponds to $\gamma=0$. If $\gamma > 0$, the social welfare function is prioritarian. If $\gamma \rightarrow \infty$, we obtain an egalitarian welfare approach. Given these assumptions, the utilitarian weight is equal to $\frac{y_c^{-\eta}}{\sum_c N_c y_c^{-\eta} \sigma_c}$, while the prioritarian weight is equal to

$$\frac{I_c^{-\gamma} (y_c^{1-\eta} - \bar{y}^{1-\eta})^{-\gamma} y_c^{-\eta}}{\sum_c N_c I_c^{-\gamma} (y_c^{1-\eta} - \bar{y}^{1-\eta})^{-\gamma} y_c^{-\eta} \sigma_c} \tag{20}$$

Conservatively, I assume that the elasticity of the marginal utility of income is $\eta = 1$.²¹ The chosen value for the inequality aversion parameter γ reflects society’s ethical concerns for inequality and fairness. As a benchmark, I assume $\gamma = 1$ and test different values in sensitivity analyses.²² Finally, to compute the weights, I assume that $\sigma_c = \frac{y_c}{\sum_c N_c y_c}$. As a consequence, the cost of the hypothetical intervention is distributed across countries proportionally to their income. Assuming proportionality implies that the intervention is not going to affect the relative inequality in the global distribution of income. Weights are estimated with respect to the pre-pandemic income (i.e., 2019 GDP).

¹⁸ Presumably, individual WTP for changes in their own mortality risk includes consideration of the change in income associated with the survival curve shift. This means that there may be double-counting with the labor share of GDP. In the case of COVID, since most deaths are among the elderly (who are unlikely to be in the paid labor force), this double-counting seems unimportant. In the exercise, I assume that the value of the income loss caused by the pandemic is not captured by the VSL estimate.

¹⁹ Robinson *et al.* (2019) recommend using an income elasticity of 1.5 for lower-income countries and a lower value for higher-income countries (See also Robinson *et al.*, 2019). To simplify, I adopt a unique value for all countries and set the elasticity to 1. This value is consistent with meta-analyses of both revealed and stated preferences data, as shown in Viscusi and Masterman (2017) and Masterman and Viscusi (2018). An income elasticity of 1 was used also in Viscusi (2020) to estimate the global burden of COVID-19.

²⁰ When $\eta = 1$, the prioritarian weight becomes $\frac{I_c^{-\gamma} y_c^{-1} (\ln y_c)^{-\gamma}}{\sum_c N_c I_c^{-\gamma} y_c^{-1} (\ln y_c)^{-\gamma} \sigma_c}$.

²¹ Recent meta-analyses suggest to use values around 1.5 for the elasticity of the marginal utility of income (Groom & Maddison, 2019; Acland & Greenberg, 2023).

²² Being an ethical parameter, there is no “correct” value for γ . The literature on the elicitation of ethical preferences suggests that people hold heterogeneous views concerning the acceptable level of inequality in well-being (Schokkaert & Tarrow, 2022). For convenience, here I adopt a well-being inequality aversion of 1 in the main analysis and test larger numbers in sensitivity analyses (inequality aversion of 2 and 10).

4.3. Results

Table 1 reports the number of official COVID-19 deaths and the estimated per capita GDP loss for each country with available data. The last three columns in Table 1 summarize the main results of this article. The fourth column reports the BCA value of preventing the

Table 1. Burden of the pandemic around the world and the value of prevention

Location	COVID-19 deaths per 100,000 people	GDP loss per capita (\$)	Value of prevention per capita (\$)		
			BCA	Utilitarianism	Prioritarianism
World	89	1,920	6,200	4,900	4,800
Afghanistan	19	900	1,000	7,700	10,200
Albania	127	1,090	3,900	4,700	4,300
Algeria	15	2,220	2,500	3,600	3,400
Angola	5	1,500	1,600	3,900	4,500
Antigua and Barbuda	156	9,420	15,100	11,000	9,600
Argentina	287	2,070	12,200	9,200	8,200
Armenia	315	3,180	10,400	12,100	11,600
Aruba	274	10,770	28,700	11,700	9,600
Australia	86	3,670	10,500	3,500	2,700
Austria	252	8,370	30,900	9,200	7,000
Azerbaijan	99	1,640	3,900	4,600	4,600
Bahamas	206	11,280	22,400	11,100	9,700
Bahrain	104	4,950	13,300	4,400	3,500
Bangladesh	17	680	800	2,500	2,700
Barbados	220	4,640	10,300	10,700	9,500
Belarus	75	-360	1,900	1,700	1,500
Belgium	295	5,200	29,700	9,600	7,300
Belize	170	2,160	4,600	8,500	8,700
Benin	1	450	500	2,400	3,100
Bhutan	3	4,750	4,800	6,800	6,600
Bolivia	183	2,310	4,800	9,400	10,400
Bosnia and Herzegovina	506	390	12,400	14,000	12,700
Botswana	106	3,760	6,300	7,000	7,100
Brazil	327	1,410	9,100	10,400	9,600
Brunei Darussalam	36	9,910	13,500	3,700	3,000
Bulgaria	566	1,920	23,000	16,500	14,500
Burkina Faso	2	330	300	2,700	3,600
Burundi	0	40	0	1,000	1,600
Cabo Verde	70	3,950	4,800	10,300	10,300
Cambodia	18	1,230	1,400	5,100	5,600
Cameroon	7	630	700	3,000	3,700

Table 1. Continued

Location	COVID-19 deaths per 100,000 people	GDP loss per capita (\$)	Value of prevention per capita (\$)		
			BCA	Utilitarianism	Prioritarianism
Canada	138	6,620	17,500	5,900	4,600
Central African Republic	2	170	200	3,300	5,500
Chad	1	470	500	5,000	7,700
Chile	314	3,490	16,000	10,800	9,100
China	9	840	1,100	1,100	1,000
Colombia	276	2,810	9,300	10,600	9,700
Comoros	19	550	700	3,300	4,000
Congo, Dem. Rep.	1	130	100	2,100	3,000
Congo, Rep.	7	1,080	1,100	5,100	6,200
Costa Rica	182	2,240	8,300	6,700	5,700
Cote d'Ivoire	3	1,010	1,000	3,400	4,100
Croatia	454	2,350	23,700	13,500	11,200
Cyprus	152	5,990	16,200	6,500	5,100
Czechia	408	5,820	32,600	13,300	10,600
Denmark	149	3,410	17,000	5,000	3,800
Djibouti	17	750	900	3,100	3,600
Dominica	102	5,490	7,500	10,100	9,600
Dominican Republic	39	3,830	5,000	4,600	4,200
Ecuador	200	1,930	5,600	8,200	8,000
Egypt	22	1,520	1,900	2,800	2,700
El Salvador	67	1,190	2,100	4,000	4,000
Equatorial Guinea	11	320	600	600	600
Estonia	219	880	13,500	6,300	5,200
Eswatini	119	-20	1,600	3,100	3,700
Ethiopia	6	270	300	2,300	2,900
Fiji	95	6,360	8,400	10,600	10,700
Finland	182	3,280	17,400	6,000	4,600
France	248	6,420	24,600	9,000	7,000
Gabon	13	2,730	3,000	3,500	3,500
The Gambia	14	460	500	4,000	5,300
Georgia	457	2,720	13,700	15,200	14,300
Germany	210	4,680	22,800	7,100	5,500
Ghana	4	910	900	3,000	3,400
Greece	359	4,770	21,800	12,300	10,000
Grenada	190	5,180	9,900	10,700	9,900
Guatemala	113	950	2,500	4,900	5,100
Guinea	3	310	300	2,100	2,800
Guinea-Bissau	8	430	500	4,000	5,500
Guyana	161	-13,160	-9,900	-12,800	-13,000

Table 1. Continued

Location	COVID-19 deaths per 100,000 people	GDP loss per capita (\$)	Value of prevention per capita (\$)		
			BCA	Utilitarianism	Prioritarianism
Haiti	7	490	500	2,800	3,400
Honduras	107	1,220	2,200	6,500	7,000
Hungary	490	3,710	29,300	15,000	12,700
Iceland	50	11,250	15,800	4,700	3,500
India	38	1,810	2,200	5,600	5,900
Indonesia	59	2,190	3,300	4,600	4,700
Iran	165	-1,270	2,500	2,900	2,700
Iraq	57	4,440	5,400	8,700	9,000
Ireland	181	-11,060	14,200	2,700	2,000
Israel	133	4,080	12,900	5,200	4,200
Italy	324	4,970	27,100	10,600	8,200
Jamaica	127	1,980	4,100	6,600	6,600
Japan	60	2,910	6,900	2,800	2,200
Jordan	125	1,370	3,300	5,800	5,600
Kazakhstan	98	4,350	8,500	5,400	5,000
Kenya	11	800	900	3,200	3,900
Kiribati	18	160	200	1,800	2,300
Korea	68	1,730	6,400	2,500	2,000
Kuwait	60	9,500	14,100	5,000	4,000
Kyrgyz Republic	15	1,400	1,500	4,900	5,400
Laos	9	1,630	1,700	3,700	3,900
Latvia	398	2,060	21,800	11,800	10,000
Lebanon	199	8,060	13,500	13,200	11,700
Lesotho	31	310	400	2,900	4,100
Liberia	6	170	200	2,200	3,000
Libya	94	9,180	12,600	9,300	8,500
Lithuania	353	940	21,900	9,800	8,200
Luxembourg	154	11,360	39,700	5,800	4,200
Madagascar	5	510	500	5,500	7,300
Malawi	13	290	300	3,600	4,900
Malaysia	110	6,890	11,700	7,100	6,100
Maldives	60	12,740	14,700	12,000	10,200
Mali	3	530	500	4,100	5,600
Malta	163	11,180	23,100	8,400	6,700
Marshall Islands	41	10	400	1,100	1,300
Mauritania	21	1,380	1,600	4,800	5,400
Mauritius	81	8,960	12,000	8,500	7,500
Mexico	262	3,500	11,900	9,900	9,400
Micronesia	57	400	700	3,400	3,800

Table 1. Continued

Location	COVID-19 deaths per 100,000 people	GDP loss per capita (\$)	Value of prevention per capita (\$)		
			BCA	Utilitarianism	Prioritarianism
Moldova	370	1,580	9,200	12,000	11,800
Mongolia	67	3,640	5,000	6,700	6,500
Montenegro	423	5,730	20,300	15,800	13,900
Morocco	44	1,750	2,300	4,700	4,700
Mozambique	7	350	400	4,700	6,700
Myanmar	36	1,610	1,900	6,500	7,300
Namibia	160	2,250	4,800	8,000	8,900
Nauru	8	-520	-400	-600	-700
Nepal	39	990	1,200	5,300	6,000
Netherlands	131	5,420	17,300	5,100	3,900
New Zealand	62	3,990	8,300	3,200	2,600
Nicaragua	4	-260	-200	-700	-700
Niger	1	260	300	3,600	5,100
Nigeria	1	750	800	2,500	3,200
North Macedonia	475	2,790	15,500	15,500	14,100
Norway	103	5,000	15,700	4,000	3,000
Oman	101	4,030	9,500	4,700	4,000
Pakistan	13	450	600	1,800	2,000
Palau	50	6,430	7,800	7,400	7,400
Panama	196	14,060	24,400	12,400	10,800
Papua New Guinea	7	790	800	3,500	4,200
Paraguay	294	1,880	8,300	10,200	9,800
Peru	650	3,140	16,400	21,500	20,400
Philippines	58	3,250	4,100	7,800	7,800
Poland	300	1,970	17,900	9,000	7,500
Portugal	263	5,890	20,600	9,800	7,800
Qatar	26	7,500	11,200	2,100	1,500
Romania	347	3,160	19,800	11,000	9,400
Russia	276	1,290	13,300	8,200	7,400
Rwanda	11	620	700	5,000	6,400
Samoa	14	1,950	2,100	5,500	5,700
Sao Tome and Principe	35	340	600	2,400	2,800
Saudi Arabia	26	5,820	7,800	2,800	2,300
Senegal	11	680	700	3,600	4,200
Serbia	263	750	8,400	7,700	6,900
Seychelles	161	7,220	14,700	8,400	7,400
Sierra Leone	1	350	400	3,500	4,900
Singapore	33	-2,780	2,500	400	300

Table 1. Continued

Location	COVID-19 deaths per 100,000 people	GDP loss per capita (\$)	Value of prevention per capita (\$)		
			BCA	Utilitarianism	Prioritarianism
Slovak Republic	375	3,240	22,500	11,700	9,800
Slovenia	445	4,360	32,100	13,800	10,900
Solomon Islands	21	600	700	4,400	5,200
Somalia	8	120	100	2,000	3,100
South Africa	171	2,040	5,800	7,000	7,300
Spain	256	9,860	26,600	10,900	8,500
Sri Lanka	77	2,540	4,200	5,200	4,800
St. Kitts and Nevis	96	12,520	17,300	9,300	8,200
St. Lucia	227	7,720	13,300	14,400	13,400
St. Vincent and the Grenadines	119	1,830	4,500	5,300	5,100
Sudan	11	510	600	2,300	2,700
Suriname	228	8,200	14,900	13,500	12,800
Sweden	233	2,990	22,700	7,200	5,400
Switzerland	160	4,720	22,700	5,400	4,000
Tajikistan	1	80	100	400	500
Tanzania	1	470	500	3,100	3,800
Thailand	48	3,680	5,100	4,700	4,500
Timor-Leste	10	-1,840	-1,800	-8,000	-9,100
Togo	3	280	300	2,400	3,100
Tonga	11	900	1,000	2,700	2,800
Trinidad and Tobago	287	5,330	16,900	11,200	10,000
Tunisia	238	2,600	6,800	10,300	9,700
Turkey	119	-1,080	4,300	2,500	2,200
Tuvalu	9	1,130	1,200	4,100	4,900
Uganda	8	440	500	3,500	4,600
Ukraine	277	1,420	7,100	9,200	8,800
United Arab Emirates	25	11,590	14,400	3,400	2,600
United Kingdom	338	9,470	35,000	12,400	9,800
United States	333	5,110	38,400	10,300	8,100
Uruguay	223	3,410	11,800	8,400	7,500
Uzbekistan	3	960	1,000	2,200	2,400
Vanuatu	4	780	800	4,400	5,100
Vietnam	44	1,470	2,200	3,600	3,400
Zambia	20	500	600	3,000	3,800
Zimbabwe	35	480	600	4,600	6,200

Notes: The “Baseline” scenario assumes $\eta = 1$, $\gamma = 1$, and $\sigma_c = \frac{y_c}{\sum_{N,c} y_c}$ (the costs of the intervention are distributed proportionally to income). The \$ values are rounded to the nearest tenth (GDP loss) or nearest hundredth (value of prevention per-capita).

COVID-19 pandemic that is derived using country-specific VSL estimates; the fifth column reports the utilitarian value and the last column reports the value computed with a prioritarian welfare function. The row titled “World” summarizes the global economic and health losses of COVID-19 and the global value of preventing a COVID-19-like pandemic.

In absolute terms, the countries with the largest number of recorded COVID-19 deaths are the United States (1.13 million deaths), Brazil (0.70 million deaths) and India (0.53 million deaths). In per-capita terms, the largest cumulative death rate has been experienced in Peru (650 deaths per 100,000 people). The number of official COVID-19 death rates tends to be larger in higher-income countries than in lower-income countries, but there is a lot of variation within country-income groups (Figure 1a). This reflects, among other factors, the older age structure of the population in higher-income countries.

Total GDP loss was largest in India (\$2.5 trillion), United States (\$1.7 trillion), and China (\$1.2 trillion). In per-capita terms, the largest GDP loss occurred in Panama (\$14,000). As a percentage of GDP, the largest loss was registered in the Maldives (62% of 2019 GDP) (Figure 1b). In comparison, the GDP loss experienced in the United States amounted to \$5,000 per capita, or 8% of 2019 GDP. Note that GDP loss is estimated compared to IMF growth projections made before the pandemic and they depend on the accuracy of those projections. For example, some countries grew more during the pandemic than what was earlier projected (e.g., Ireland). The estimated GDP loss thus results to be negative. From the adopted data, it is impossible to disentangle whether the growth occurred because of the pandemic or despite the pandemic (e.g., because of bias in the projections or because of local conditions). Likewise, for countries with a positive GDP loss, this loss has to be intended with respect to what was projected in 2019, and it might well underestimate or overestimate the pandemic loss. Additionally, the total estimated GDP loss sums yearly losses. Many countries started the recovery process in 2021 once vaccines became available. The total loss thus may underestimate the economic burden felt in 2020, as well as overestimate the one experienced in 2021.

The global value of preventing a COVID-19-like pandemic amounts to \$48 trillion (or about \$6,200 per capita) when we evaluate mortality risks using country-specific VSL estimates. Such a measure is sensitive to country-differences in economic conditions. For example, the value of pandemic prevention in the United States is estimated at \$13 trillion (\$38,400 per capita). This corresponds to 27% of the global value even though only 16% of global deaths and 12% of the global GDP loss were experienced in the country. In contrast, the value of pandemic prevention in India amounts to \$3 trillion (\$2,200 per capita), or 6% of the global value, even though the country registered 8% of the global number of deaths and 17% of the global GDP loss. Had the mortality burden in India been evaluated at the United States VSL, the total value of prevention in India would have increased to \$8 trillion.

Both the utilitarian and the prioritarian values of pandemic prevention are smaller than the one derived using conventional BCA methods. In the utilitarian case, the value of prevention amounts to \$4,900 per capita (or \$16 trillion), while it equals \$4,800 per capita in the prioritarian case. There are two reasons behind this result. The first reason concerns the distribution of the costs of the hypothetical intervention. Standard BCA is indifferent to the distribution of costs: A policy paid by rich individuals has exactly the same net benefits as an identical policy (in terms of total costs and total benefits) that is paid by poor individuals. In contrast, with a distribution-sensitive welfare framework, the distribution of costs matters. The more the costs of the hypothetical intervention are borne by poor countries, the lower is the net social value of the intervention. The proportional-cost rule

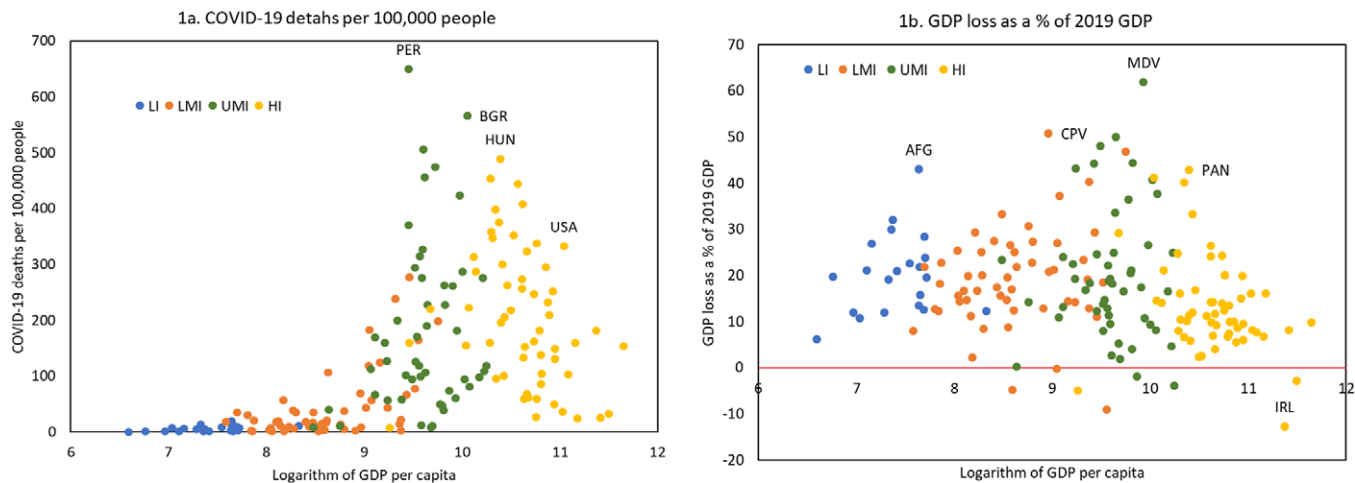


Figure 1. Correlation between pandemic outcomes and 2019 Gross Domestic Product (GDP) per capita.

Notes: In both figures, the x-axis displays the natural logarithm of GDP per capita in 2019 (PPP, constant 2017 international \$). In (a), the y-axis represents the number of official COVID-19 deaths per 100,000 people. In (b), the y-axis represents the total GDP loss over the period 2020–2021 as a percentage of 2019 GDP. Each dot represents a country. In (b), two observations were dropped to ease the readability of the graph: Guyana (GDP loss = −102% of 2019 GDP) and Timor-Leste (GDP loss = −49% of 2019 GDP). Countries are divided into income groups based on the 2023 World Bank classification (HI, high-income countries; LI, low-income countries, LMI, lower-middle-income countries, UMI, upper-middle-income countries). Country acronyms: AFG, Afghanistan; BGR, Bulgaria; CPV, Cabo Verde; HUN, Hungary; IRL, Ireland; MDV, Maldives; PAN, Panama; PER, Peru; USA, United States.

assumed in the exercise implies that the hypothetical intervention has no impact on relative income inequality. Yet, the mere fact that low-income countries would pay some of the costs tends to reduce the overall value of pandemic prevention.

The second reason concerns the distribution of the pandemic impacts. Both the utilitarian and the prioritarian approaches attach more weight to losses experienced in lower-income countries than comparable losses borne in higher-income countries. Therefore, compared to BCA, both utilitarianism and prioritarianism reduce the value of prevention in high-income countries and increase the value of prevention in low-income countries. For example, from a utilitarian point of view, the benefits of prevention in the U.S. amount to \$10,300 per capita, almost a fourth of the BCA estimate (\$38,400 per capita). In contrast, the utilitarian benefits of prevention in India are equal to \$5,600 per capita, while the BCA estimate amounts to \$2,200 per capita. The largest utilitarian value of pandemic prevention is recorded in Peru (\$21,500 per capita), the country with the largest death rate. Since COVID-19 mortality and income loss tend to be larger in higher-income countries than in lower-income countries, the utilitarian and prioritarian adjustments both reduce the overall value of pandemic prevention compared to standard BCA. Had the pandemic impacts been more regressive (with larger deaths and income losses in lower-income countries than higher-income countries), then utilitarianism and prioritarianism would increase the overall value of prevention compared to BCA.

In this specific example, there is little difference between the utilitarian and the prioritarian overall value of pandemic prevention. Compared to utilitarianism, prioritarianism tends to attach even more weight to losses experienced in lower income countries on the grounds that individuals living in low-income countries are worst-off in well-being terms. The low well-being ranking is due to both low income and low average longevity. Given the proportional-cost rule and the larger health and economic impacts of the pandemic in higher-income countries, a concern for the worst-off tends to further decrease the prioritarian value of pandemic prevention compared to utilitarianism.

Thus, utilitarianism and prioritarianism both favor policies that reduce inequality across individuals. The utilitarian framework is concerned with inequality in income due to the decreasing marginal utility of income assumption. The prioritarian framework is concerned with inequality in well-being, which, in turn, is affected by inequality in income and inequality in health (here proxied by longevity). The larger the reduction in (income or well-being) inequality brought about by the policy, the larger the value of preventing a pandemic. Given that, in the example, everyone contributes to the policy costs but high-income countries benefit the most from the policy, the prioritarian value is lower than the utilitarian one, which, in turn, is lower than the BCA value. Note that this ranking is driven by the specific assumptions about the distribution of pandemic impacts and policy costs and it will not hold in general.

4.4. Sensitivity analysis

Table 2 summarizes the results of sensitivity analyses around some of the main parameters. The first row reports the value of pandemic prevention in the baseline scenario as described in **Table 1**. Both the utilitarian and the prioritarian values decrease if the elasticity η of the marginal utility of income increases. In that case, an even larger weight is associated with monetary losses borne by low-income countries. Since the COVID-19 mortality losses tend to be larger in high-income countries than lower-income countries, increasing the elasticity η

Table 2. The global per-capita value of pandemic prevention under different scenarios

Scenario	BCA	Utilitarianism	Prioritarianism
Baseline	\$6,200	\$4,900	\$4,800
The elasticity of the marginal utility of income η is 1.5	\$6,200	\$4,400	\$4,200
The inequality aversion parameter γ is equal to 2	\$6,200	\$4,900	\$4,200
The inequality aversion parameter γ is equal to 10	\$6,200	\$4,900	\$3,400
The hypothetical intervention is paid only by high-income countries ($\sigma_c = 0$ for low-income and middle-income countries)	\$6,200	\$13,800	\$16,800
The hypothetical intervention is paid by low- and middle-income countries ($\sigma_c = 0$ for high-income countries)	\$6,200	\$1,800	\$1,500
The cost of the hypothetical intervention is equally shared across countries ($\sigma_c = \frac{1}{N}$ for all countries)	\$6,200	\$2,100	\$1,700
The elasticity of VSL to income is 1.5 in low- and middle-income countries and 0.6 in high-income countries	\$5,800	\$4,300	\$4,100

Notes: The “Baseline” scenario assumes $\eta = 1$, $\gamma = 1$ and $\sigma_c = \frac{y_c}{\sum_c N_c y_c}$ (the costs of the intervention are distributed proportionally to income). Each of the sensitivity scenarios modify only one baseline assumption, while keeping the others unmodified. When $\eta = 1.5$, the subsistence income is set at \$365. In scenarios where only some countries pay the intervention (only high-income countries or only low- and middle-income countries), the intervention costs are equally divided among the contributing countries.

has the overall effect of reducing the value of avoiding a pandemic similar to the COVID-19 one. An increase in the inequality aversion parameter γ leads to similar results. The prioritarian benefits of pandemic prevention decrease since a large part of the benefits accrue to the better off in well-being terms.

Changing the distribution σ_c of the costs of the intervention has dramatic effects on the utilitarian and prioritarian values. While the BCA value of pandemic prevention is unaffected by the distribution of costs, both the utilitarian and the prioritarian values steeply increase when the pandemic preparedness intervention is paid only by high-income countries, to the point of being larger than the BCA value. For example, the utilitarian value of prevention goes from \$4,900 to \$13,800. On the other hand, a more regressive distribution of the intervention costs (e.g., all individuals pay the same dollar amount or only lower-income countries pay for the intervention) decreases both the utilitarian and the prioritarian values of pandemic prevention. The utilitarian value of pandemic prevention is larger than the prioritarian one in all scenarios, except when costs are borne only by high-income countries. In this case, lower-income countries are benefitting from the policy without sustaining any cost, i.e. the policy produces net positive benefits to the most disadvantaged populations. Even though the pandemic impacts are skewed toward high-income countries, the policy is

undoubtedly improving the well-being of the worst-off compared to the pandemic case. That explains why the prioritarian value is larger than the utilitarian one in this scenario.

The main policy implication of these results is that investing in pandemic preparedness is a good use of money when the investment is paid mostly by high-income countries. If lower income countries were asked to contribute significantly to the investment, then paying for pandemic preparedness may be more welfare-reducing than the pandemic itself.

The last row of [Table 2](#) shows what would happen if we used different income elasticities of VSL for lower-income and higher-income countries, as recommended in Robinson *et al.* (2019). In particular, the income elasticity of VSL is set at 1.5 for low- and middle-income countries and at 0.6 for high-income countries. The latter is based on a recent meta-regression analysis for the United States (Viscusi & Masterman, 2017). The overall value of preventing the pandemic decreases independently of the evaluation framework, but differences across frameworks persist.

5. Discussion and conclusions

In this article, I explore the differences between BCA and SWA in the evaluation of interventions that aim at preventing future pandemics similar to the COVID-19 one. I show that BCA and SWA lead to very different recommendations. BCA determines the burden of pandemics by summing up the individuals' monetary equivalents of the pandemic impacts. This overall burden is then compared to the total cost of the intervention. Thus, BCA is indifferent to the distribution of both monetary benefits and monetary losses. As a result, pandemic preparedness interventions are ranked independently of who bear the costs of the interventions. Additionally, since VSL typically increases in income, interventions that prevent pandemic-related mortality in high-income countries tend to be ranked higher than interventions that prevent similar losses in lower-income countries. In contrast, both utilitarian and prioritarian welfare frameworks are sensitive to the distribution of monetary benefits and costs, and impacts experienced by high-income individuals are not valued more than similar impacts experienced by low-income individuals only because the former have a higher ability to pay than the latter. Moreover, considerations about the distribution of the costs of the intervention play a major role in the value assessment under a social welfare approach: The more regressive is the distribution of costs, the lower is the value of a given intervention. This implies that, from a welfare perspective, we cannot measure the burden of future pandemics and discuss policies to prevent such a burden without reflecting on who is going to pay for those policies. Cost-sharing issues affect, for example, the funding and development of novel vaccines, as well as the funding of financing mechanisms for enhancing pandemic preparedness in low- and middle-income countries.

The COVID-19 pandemic has sparked renewed interest in pandemic preparedness. A small literature has tackled the issue of how much countries should invest to prepare for future pandemics given potential competing uses of limited resources (e.g., Fan *et al.*, 2018; Glennerster *et al.*, 2023). BCA has been the go-to methodology. The main lesson from this article is that the BCA estimates may lead to welfare-reducing choices if the distribution of the intervention costs and of the associated benefits are not carefully accounted for – unless the intervention is accompanied by an appropriate redistribution mechanism that sufficiently reduces inequality in well-being. This article has focused on the estimate of the COVID-19 pandemic burden around the world. Those estimates are informative about the optimal

investment in pandemic preparedness to prevent another pandemic similar to COVID-19. Of course, the framework can be extended to reflect about the optimal investment to prevent any type of pandemic.

The analysis has several limitations. First of all, due to data constraints, the application focuses exclusively on the direct mortality and income consequences of the COVID-19 pandemic. I also looked only at short-term economic costs. The estimates are thus quite conservative as I neglected the morbidity consequences of COVID-19, other types of health impacts (e.g., on mental health or non-COVID-19 mortality), as well as long-term health or income losses due to, e.g. long-COVID, educational setbacks, and poor access to healthcare. Additionally, there are not yet enough data to judge the inequality impacts of COVID-19 within different countries, e.g. whether, all things considered, the world's very poorest have suffered the most or whether the pandemic had any effect on inequalities in longevity or income. Although there is ample evidence of inequality in impacts at both the national and international levels, household-level survey data to run individual-level comparisons are not yet consistently available.

The application is based on a simplified model of pandemic impacts. For example, I do not explicitly account for differences in the population age structure across countries. A more realistic model would consider a more refined age distribution of deaths across countries and the impact of COVID-19 on such a distribution, instead of assuming that people either live a full life or die prematurely at age a_c . I also excluded potential economic growth and age differences in income, as well as positive discounting. Presumably, positive discounting would reduce the benefits of saving lives, while positive income growth would increase them.

Furthermore, I use approximated formulas to estimate the utilitarian and prioritarian burdens of the pandemic. Because of the simplified model, those approximated formulas have a clean and intuitive interpretation. The choice of using simple approximations is to make the comparison with BCA more straightforward. Had I estimated the welfare burden of the pandemic without the approximation, it would have been more difficult to determine whether the departure from BCA was due to the concern for equity or the reliance on non-marginal risks. Nevertheless, it is questionable whether the marginal risk assumption is appropriate in the case of pandemics (Robinson *et al.*, 2021), even though it has been widely used in the pandemic literature so far (e.g., Fan *et al.*, 2018; Viscusi, 2020; Glennerster *et al.*, 2023). Future work could relax this assumption and investigate the sensitivity of economic evaluation to the chosen value framework. For example, Adler *et al.* (2023) pursue this direction by estimating the value of lockdown policies in the United States through a distribution-sensitive welfare framework and without the adoption of the small risk assumption.

In measuring the well-being impacts of the pandemic, I relied on the assumption of homogeneous preferences. The homogeneous preference assumption simplifies the framework, but it neglects that individuals do have different preferences. A proper account of the well-being impacts of the pandemic should allow for the possibility that individuals have different opinions about what matters in life. For example, the willingness to take risks is often found to reduce with age (Dohmen *et al.*, 2017), and there seem to be consistent cross-country differences in preferences based on customs and social norms (Falk *et al.*, 2018). With a few exceptions (e.g., Boarini *et al.*, 2022), the homogeneity assumption is ubiquitous in the literature estimating differences in welfare across countries.

The choice of well-being measure plays a major role in the conceptualization of welfare and equitable distributions. This article has focused on the standard notion of von Neumann-Morgenstern utility as a measure of individual well-being, with lifetime utility being concave in income but linear in longevity. The results of this article have to be interpreted in reference to the chosen well-being measure. For example, I show that utilitarian weights do not depend on longevity, while prioritarian weights do. Other specifications of lifetime utility and other measures of well-being may lead to different results. In particular, it would be fruitful to explore whether the main results of this article are robust to the specific well-being measure adopted. Moreover, I focused exclusively on an ex post measure of well-being and welfare. Such an ex post approach presupposes that the policy maker cares about the distribution of *realized* well-being across the population. It would be interesting to investigate whether the global distribution of pandemic burdens is affected by the choice of welfare perspective.

Contrary to BCA, the estimation of the pandemic welfare impacts requires a larger amount of information. Indeed, we need data not only on the aggregate mortality, morbidity and economic losses due to the pandemic, but also on how those impacts are distributed across the population of interest and whether there is any correlation with pre-existing inequities in health, income or other attributes. The stylized model considered in this article was parsimonious in terms of data. More realistic applications will be more data intensive.

Although this article focuses on COVID-19 and the value of pandemic prevention, the issues discussed in this article are not unique to pandemic policies, but they apply to any intervention with unequal impacts across the population. It is often claimed that standard BCA is a methodology to identify the most efficient policy and that equity concerns should play no role in the process. However, the adoption of BCA principles implicitly entails a stance on equity: All individual monetary impacts have the same moral importance independently of who is experiencing the (positive or negative) impacts. SWA provides a valuable and flexible framework to identify policies that increase overall well-being and promote its fair distribution. For this reason, this article argues that SWA should be routinely used in policy evaluation.

Acknowledgments. The author thanks the editor and the three reviewers for their valuable comments. This article builds on a 2022 conference held by the Brocher Foundation, “Healthy, Wealthy, and Wise – The Ethics of Health Valuation,” organized by Nir Eyal (Rutgers University), Samia Hurst (University of Geneva), Lisa A. Robinson (Harvard University) and Daniel Wikler (Harvard University). The author thanks the Brocher Foundation and conference participants for their support and helpful comments. This special issue was supported by the Brocher Foundation, with supplemental funding from the Rutgers University Center for Population-Level Bioethics; the University of Geneva Institute for Ethics, History, and the Humanities and the University of Bergen Centre for Ethics and Priority Setting. More information on the Brocher Foundation is available at: <https://fondation-brocher.ch/>.

Competing interest. The author declares none.

References

- Acland, Daniel, and David H. Greenberg. 2023. “The Elasticity of Marginal Utility of Income for Distributional Weighting and Social Discounting: A Meta-Analysis.” *Journal of Benefit-Cost Analysis*, 14(2): 386–405.
- Adler, Matthew D. 2012. *Well-Being and Fair Distribution: Beyond Cost-Benefit Analysis*. New York: Oxford University Press.

- Adler, Matthew D. 2016. "Benefit-Cost Analysis and Distributional Weights: An Overview." *Review of Environmental Economics and Policy*, 10(2): 264–285.
- Adler, Matthew D. 2019. *Measuring Social Welfare: An Introduction*. New York: Oxford University Press.
- Adler, Matthew D. 2022. "Theory of Prioritarianism." In Adler, Matthew D., and Ole F. Norheim (Eds.) *Prioritarianism in Practice*, pp. 37–127. New York: Cambridge University Press.
- Adler, Matthew D., Richard Bradley, Maddalena Ferranna, Marc Fleurbaey, James K. Hammitt, Rémi Turquier, and Alex Voorhoeve. 2023. "How to Balance Lives and Livelihoods in a Pandemic." In Wilkinson, Dominic, and Julian Savulescu (Eds.) *Pandemic Ethics: From COVID-19 to Disease X*, pp. 189–209. Oxford: Oxford University Press.
- Adler, Matthew D., and Koen Decancq. 2022. "Well-Being Measurement." In Adler, Matthew D., and Ole F. Norheim (Eds.) *Prioritarianism in Practice*, pp. 128–171. New York: Cambridge University Press.
- Adler, Matthew D., Maddalena Ferranna, James K. Hammitt, and Nicolas Treich. 2021. "Fair Innings? The Utilitarian and Prioritarian Value of Risk Reduction Over a Whole Lifetime." *Journal of Health Economics*, 75: 102412.
- Adler, Matthew D., Maddalena Ferranna, Eugénie de Laubier, James K. Hammitt, and Nicolas Treich. 2024. "Fair Innings: An Empirical Test." Working Paper.
- Adler, Matthew D., and Marc Fleurbaey. 2016. *Oxford Handbook of Wellbeing and Public Policy*. New York: Oxford University Press.
- Alesina, Alberto, and George-Marios Angeletos. 2005. "Fairness and Redistribution." *American Economic Review*, 95: 960–980.
- Alesina, Alberto, Stefanie Stantcheva, and Edoardo Teso. 2018. "Intergenerational Mobility and Support for Redistribution." *American Economic Review*, 108: 521–554.
- Almås, Ingvild, Alexander W. Cappelen, and Bertil Tungodden. 2020. "Cutthroat Capitalism versus Cuddly Socialism: Are Americans More Meritocratic and Efficiency-Seeking than Scandinavians?" *Journal of Political Economy*, 128: 1753–1788.
- Amiel, Yoram, and Frank Cowell. 1999. *Thinking About Inequality: Personal Judgment and Income Distributions*. Cambridge: Cambridge University Press.
- Arrow, Kenneth J. 1963. *Social Choice and Individual Values*. New York: John Wiley & Sons, Inc..
- Baek, Chae Won, Peter B. McCrory, Todd Messer, and Preston Mui. 2021. "Unemployment Effects of Stay-At-Home Orders: Evidence from High-Frequency Claims Data." *Review of Economics and Statistics*, 103: 979–993.
- Berger, Loïc, Nicolas Berger, Valentina Bosetti, Itzhak Gilboa, Lars Peter Hansen, Christopher Jarvis, Massimo Marinacci, and Richard D. Smith. 2021. "Rational Policymaking During a Pandemic." *Proceedings of the National Academy of Sciences*, 118(4): e2012704118.
- Bethäuser, Bastian A., Anders M. Bach-Mortensen, and Per Engzell. 2023. "A Systematic Review and Meta-Analysis of the Evidence on Learning During the COVID-19 Pandemic." *Nature Human Behavior*, 7: 375–385.
- Blackorby, Charles, and David Donaldson. 1990. "A Review Article: The Case Against the Use of the Sum of Compensating Variations in Cost-Benefit Analysis." *Canadian Journal of Economics*, 23: 471–494.
- Boadway, Robin. 2016. "Cost-Benefit Analysis." In Adler, Matthew D., and Marc Fleurbaey (Eds.) *Oxford Handbook of Well-Being and Public Policy*, pp. 47–81. New York: Oxford University Press.
- Boarini, Romina, Marc Fleurbaey, Fabrice Murtin, and Paul Schreyer. 2022. "Well-Being During the Great Recession: New Evidence from a Measure of Multi-Dimensional Living Standards with Heterogeneous Preferences." *Scandinavian Journal of Economics*, 124: 104–138.
- Bognar, Greg. 2015. "Fair Innings." *Bioethics*, 29: 251–261.
- Cadarette, Daniel, Maddalena Ferranna, Jeff W. Cannon, Kaja Abbas, Fiona Giannini, Leo Zucker, and David E. Bloom. 2023. "The Full Health, Economic, and Social Benefits of Prospective Strep A Vaccination." *npj Vaccines*, 8: 166.
- Cantor, Jonathan, Neeraj Sood, Dena M. Bravata, Megan Pera, and Christopher Whaley. 2022. "The Impact of the COVID-19 Pandemic and Policy Response on Health Care Utilization: Evidence from County-Level Medical Claims and Cellphone Data." *Journal of Health Economics*, 82(102581).
- Cutler, David M., and Lawrence H. Summers. 2020. "The COVID-19 Pandemic and the \$16 Trillion Virus." *JAMA*, 324(15): 1495–1496.
- Czeisler, Mark É., Kristy Marynak, Kristie E.N. Clarke, Zainab Salah, Iju Shakya, JoAnn M. Thierry, Nida Ali, Hannah McMillan, Joshua F. Wiley, Matthew D. Weaver, Charles A. Czeisler, Shantha M.W. Rajaratnam, and Mark E. Howard. 2020. "Delay or Avoidance of Medical Care Because of COVID-19-Related Concerns—United States, June 2020." *Morbidity and Mortality Weekly Report*, 69(36): 1250–1257.

- Deaton, Angus. 2021. "COVID-19 and Global Income Inequality." *LSE Public Policy Review*, 1(4): 1.
- Decerf, Benoit, H. G. Ferreira Francisco, Daniel G. Mahler, and Olivier Sterck. 2021. "Lives and Livelihoods: Estimates of the Global Mortality and Poverty Effects of the COVID-19 Pandemic." *World Development*, 146: 105561.
- Dohmen, Thomas, Armin Falk, H. H. Golsteyn Bart, David Huffman, and Uwe Sunde. 2017. "Risk Attitudes Across the Life Course." *Economic Journal*, 127(605): F95–F116.
- Dolan, Paul, and Aki Tsuchiya. 2012. "It Is the Lifetime That Matters: Public Preferences Over Maximising Health and Reducing Inequalities in Health." *Journal of Medical Ethics*, 38: 571–573.
- Dolan, Paul, Rebecca Shaw, Aki Tsuchiya, and Alan Williams. 2005. "QALY Maximisation and People's Preferences: A Methodological Review of the Literature." *Health Economics*, 14: 197–208.
- Drèze, Jean, and Nicholas Stern. 1987. "The Theory of Cost-Benefit Analysis." In Auerbach, Alan, and Martin Feldstein (Eds.) *Handbook of Public Economics*, Vol. 2, pp. 909–989. Amsterdam: North-Holland.
- Emanuel, Ezekiel J., Govind Persad, Adam Kern, Allen Buchanan, Cécile Fabre, Daniel Halliday, Joseph Heath, Lisa Herzog, R.J. Leland, Ephrem T. Lemango, Florencia Luna, Matthew S. McCoy, Ole F. Norheim, Trygve Ottersen, G. Owen Schaefer, Kok-Chor Tan, Christopher Heath Wellman, Jonathan Wolff and Henry S. Richardson. 2020. "An Ethical Framework for Global Vaccine Allocation." *Science*, 369(6509): 1309–1312.
- Fairlie, Robert, Frank M. Fossen, Reid Johnsen, and Gentian Droboniku. 2023. "Were Small Businesses More Likely to Permanently Close in the Pandemic?" *Small Business Economics*, 60: 1613–1629.
- Falk, Armin, Anke Becker, Thomas Dohmen, Benjamin Enke, David Huffman, and Uwe Sunde. 2018. "Global Evidence on Economic Preferences." *The Quarterly Journal of Economics*, 133(4): 1645–1692.
- Fan, Victoria Y., Dean T. Jamison, and Lawrence H. Summers. 2018. "Pandemic Risk: How Large Are the Expected Losses?" *Bulletin World Health Organization*, 96(2): 129–134.
- Ferranna, Maddalena, James K. Hammitt, and Matthew D. Adler. 2023. "Age and the Value of Life." In Bloom, David E., Sousa-Poza, Alfonso, and Uwe Sunde (Eds.), *Handbook of the Economics of Ageing*. London: Routledge, Taylor and Francis Group, pp. 566–574.
- Ferranna, Maddalena, J. P. Sevilla, and David E. Bloom. 2022. "Prioritarianism and the COVID-19 Pandemic." In Adler, Matthew D., and Ole F. Norheim (Eds.), *Prioritarianism in Practice*, pp. 572–650. New York: Cambridge University Press.
- Fleurbaey, Marc. 2010. "Assessing Risky Social Situations." *Journal of Political Economy*, 118(4): 649–680.
- Fleurbaey, Marc, and Rossi Abi-Rafteh. 2016. "The Use of Distributional Weights in Benefit–Cost Analysis: Insights from Welfare Economics." *Review of Environmental Economics and Policy*, 10(2): 286–307.
- Fleurbaey, Marc, Stéphane Luchini, Christophe Muller, and Erik Schokkaert. 2013. "Equivalent Income and Fair Evaluation of Health Care." *Health Economics*, 22(6): 711–729.
- Giuntella, Osea, Kelly Hyde, Silvia Saccardo, and Sally Sadoff. 2021. "Lifestyle and Mental Health Disruptions During COVID-19." *Proceedings of the National Academy of Sciences*, 118(9).
- Glennerster, Rachel, Christopher M. Snyder, and Brandon Joel Tan. 2023. "Calculating the Costs and Benefits of Advance Preparations for Future Pandemics." *IMF Economic Review*, 71: 611–648.
- Glover, Andrew, Jonathan Heathcote, Dirk Krueger, and José-Víctor Ríos-Rull. 2023. "Health versus Wealth: On the Distributional Effects of Controlling a Pandemic." *Journal of Monetary Economics*, 140: 34–59.
- Gollier, Christian. 2020. "Cost-Benefit Analysis of Age-Specific Deconfinement Strategies." *Journal of Public Economic Theory*, 22(6): 1746–1771.
- Greenstone, Michael, and Vishan Nigam. 2020. "Does Social Distancing Matter?" University of Chicago Becker Friedman Institute for Economics Working Paper No. 2020–26. https://bfi.uchicago.edu/wp-content/uploads/BFI_WP_202026.pdf.
- Groom, Ben, and David Maddison Pr. 2019. "New Estimates of the Elasticity of Marginal Utility for the UK." *Environmental and Resource Economics*, 72: 1155–1182.
- Guerrieri, Veronica, Guido Lorenzoni, Ludwig Straub, and Iván Werning. 2022. "Macroeconomic Implications of COVID 19: Can Negative Supply Shocks Cause Demand Shortages?" *American Economic Review*, 112: 1437–1474.
- Hall, Robert E., Charles I. Jones, and Peter J. Klenow. 2020. "Trading-Off Consumption and COVID-19 Deaths." *Federal Reserve Bank of Minneapolis Quarterly Review*, 42(1): 1–13.
- Hammitt, James K. 2000. "Valuing Mortality Risk: Theory and Practice." *Environmental Science and Technology*, 34: 1396–1400.
- Hammitt, James K. 2007. "Valuing Changes in Mortality Risk: Lives Saved versus Life Years Saved." *Review of Environmental Economics and Policy*, 1: 228–240.

- Hammitt, James K. 2020. "Valuing Mortality Risk in the Time of COVID-19." *Journal of Risk and Uncertainty*, 61 (2): 129–154.
- Hammitt, James K. 2021. "Accounting for the Distribution of Benefits and Costs in Benefit-Cost Analysis." *Journal of Benefit-Cost Analysis*, 12(1): 64–84.
- Hammitt, James K., and Lisa A. Robinson. 2011. "The Income Elasticity of the Value per Statistical Life: Transferring Estimates Between High- and Low-Income Populations." *Journal of Benefit-Cost Analysis*, 2(1): 1–29.
- Harberger, Arnold C. 1978. "On the Use of Distributional Weights in Social Cost-Benefit Analysis." *Journal of Political Economy*, 86: 87–120.
- Harris, John. 1985. *The Value of Life*. London: Routledge and Kegan Paul.
- IMF (International Monetary Fund). 2019. *World Economic Outlook October 2019: Global Manufacturing Downturn, Rising Trade Barriers*. <https://www.imf.org/en/Publications/WEO/Issues/2019/10/01/world-economic-outlook-october-2019>.
- IMF (International Monetary Fund). 2021. *World Economic Outlook October 2021: Recovery During a Pandemic*. <https://www.imf.org/en/Publications/WEO/Issues/2021/10/12/world-economic-outlook-october-2021>.
- Kaplow, Louis. 2004. "On the (Ir)relevance of Distribution and Labor Supply Distortion to Government Policy." *Journal of Economic Perspectives*, 18: 159–175.
- Kniesner, Thomas J., and Ryan Sullivan. 2020. "The Forgotten Numbers: A Closer Look at COVID-19 Non-Fatal Valuations." *Journal of Risk and Uncertainty*, 61(2): 155–176.
- Kuziemko, Ilyana, Michael I. Norton, Emmanuel Saez, and Stefanie Stantcheva. 2015. "How Elastic Are Preferences for Redistribution? Evidence from Randomized Survey Experiments." *American Economic Review*, 105(4): 1478–1508.
- Liscow, Zachary D. and Cass R. Sunstein. 2023. "Efficiency vs. Welfare in Benefit-Cost Analysis: The Case of Government Funding." <https://ssrn.com/abstract=4589563>.
- Layard, Richard, and Jan-Emmanuel De Neve. 2023. *Wellbeing: Science and Policy*. Cambridge: Cambridge University Press.
- Mahler, Daniel G., Nishant Yonzan, and Christoph Lakner. 2022. "The Impact of COVID-19 on Global Inequality and Poverty," World Bank Policy Research Working Paper 10198. World Bank, Washington, DC. <http://hdl.handle.net/10986/38114>.
- Martin, Ian W. R., and Robert S. Pindyck. 2021. "Welfare Costs of Catastrophes: Lost Consumption and Lost Lives." *The Economic Journal*, 131(634): 946–969.
- Masterman, Clayton J., and W. Kip Viscusi. 2018. "The Income Elasticity of Global Values of a Statistical Life: Stated Preference Evidence." *Journal of Benefit-Cost Analysis*, 9(3): 407–434.
- Mathieu, Edouard, Hannah Ritchie, Lucas Rodés-Guirao, Cameron Appel, Charlie Giattino, Joe Hasell, Bobbie Macdonald, Saloni Dattani, Diana Beltekian, Esteban Ortiz-Ospina, and Max Roser. 2020. "Coronavirus Pandemic (COVID-19)." <https://ourworldindata.org/coronavirus> (accessed August 10, 2023).
- Nussbaum, Martha C. 2011. *Creating Capabilities: The Human Development Approach*. Cambridge: Harvard University Press.
- Pijls, Bart G., Shahab Jolani, Anique Atherley, Raissa T. Derckx, I. R. Dijkstra Janna, H. L. Franssen Gregor, Stevie Hendricks, et al. 2021. "Demographic Risk Factors for COVID-19 Infection, Severity, ICU Admission and Death: A Meta-Analysis of 59 Studies." *BMJ Open*, 11: e044640.
- Quaas, Martin F., Jasper N. Meya, Hanna Schenck, Björn Bos, Moritz A. Drupp, and Till Requate. 2021. "The Social Cost of Contacts: Theory and Evidence for the First Wave of the COVID-19 Pandemic in Germany." *PLoS One*, 16(3): e0248288.
- Richards, Mike, Michael Anderson, Paul Carter, Benjamin L. Ebert, and Elias Mossialos. 2020. "The Impact of the COVID-19 Pandemic on Cancer Care." *Nature Cancer*, 1: 565–567.
- Robinson, Lisa A. 2007. "How U.S. Government Agencies Value Mortality Risk Reductions." *Review of Environmental Economics and Policy*, 1: 283–299.
- Robinson, Lisa A., James K. Hammitt, and Lucy O’Keeffe. 2019. "Valuing Mortality Risk Reductions in Global Benefit–Cost Analysis." *Journal of Benefit–Cost Analysis*, 10(S1): 15–50.
- Robinson, Lisa A., James K. Hammitt, Michele Cecchini, Kalipso Chalkidou, Karl Claxton, Maureen Cropper, Patrick Hoang-Vu Eozenou, David de Ferranti, Anil B. Deolalikar, Frederico Guanais, Dean T. Jamison, Soonman Kwon, Jeremy A. Lauer, Lucy O’Keeffe, Damian Walker, Dale Whittington, Thomas Wilkinson, David Wilson, and Brad Wong. 2019. "Reference Case Guidelines for Benefit-Cost Analysis in Global Health and Development." Funded by the Bill & Melinda Gates Foundation. Also available on SSRN: <https://ssrn.com/abstract=4015886>.

- Robinson, Lisa A., James K. Hammitt, and Richard J. Zeckhauser. 2016. "Attention to Distribution in U.S. Regulatory Analyses." *Review of Environmental Economics and Policy*, 10: 308–328.
- Robinson, Lisa A., Mike R. Eber and James K. Hammitt. 2021. "Valuing COVID-19 Mortality and Morbidity Risk Reductions." U.S. Department of Health and Human Services. <https://aspe.hhs.gov/reports/valuing-covid-19-risk-reductions-hhs-rias>.
- Robinson, Lisa A., Ryan Sullivan, and Jason F. Shogren. 2021. "Do the Benefits of COVID-19 Policies Exceed the Costs? Exploring Uncertainties in the Age-VSL Relationship." *Risk Analysis*, 41(5): 761–770.
- Saville, Melanie, Jakob P. Cramer, Matthew Downham, Adam Hacker, Nicole Lurie, Lieven Van der Veken, Mike Whelan, and Richard Hatchett. 2022. "Delivering Pandemic Vaccines in 100 Days — What Will It Take?" *New England Journal of Medicine*, 387(2): e3.
- Schokkaert, Erik, and Benoît Tarrow. 2022. "Empirical Research on Ethical Preferences: How Popular is Prioritarianism?" In Adler, Matthew D., and Ole F. Norheim (Eds.), *Prioritarianism in Practice*, pp. 459–517. New York: Cambridge University Press.
- Sen, Amartya K. 1999. *Commodities and Capabilities*. Delhi: Oxford University Press.
- Stantcheva, Stephanie. 2022. "Inequalities in the Times of a Pandemic." *Economic Policy*, 37(109): 5–41.
- The Economist. 2023. "The Economist's Excess Deaths Model" <https://github.com/TheEconomist/covid-19-the-economist-global-excess-deaths-model> (accessed August 10, 2023).
- Thunstrom, Linda, Stephen C. Newbold, David Finnoff, Madison Ashworth, and Jason F. Shogren. 2020. "The Benefits and Cost of Flattening the Curve for COVID-19." *Journal of Benefit-Cost Analysis*, 11(2): 1–17.
- United Nations. 2022. Department of Economic and Social Affairs, Population Division. World Population Prospects 2022. <https://population.un.org/wpp/> (accessed August 10, 2023).
- Viscusi, W. Kip. 2010. "The Heterogeneity of the Value of Statistical Life: Introduction and Overview." *Journal of Risk and Uncertainty*, 40: 1–13.
- Viscusi, W. Kip. 2018. *Pricing Lives: Guideposts for a Safer Society*. Princeton: Princeton University Press.
- Viscusi, W. Kip. 2020. "Pricing the Global Health Risks of the COVID-19 Pandemic." *Journal of Risk and Uncertainty*, 61: 101–128.
- Viscusi, W. Kip, and Clayton J. Masterman. 2017. "Income Elasticities and Global Values of a Statistical Life." *Journal of Benefit-Cost Analysis*, 8(2): 226–250.
- Whittaker, Charles, G. T. Walker Patrick, Mervat Alhaffar, Arran Hamlet, Bimandra A. Djaafara, Azra Ghani, Neil Ferguson, Maysoun Dahab, Francesco Checchi, and Oliver J. Watson. 2021. "Under-Reporting of Deaths Limits Our Understanding of True Burden of Covid-19." *BMJ*, 375: n2239.
- Williams, Alan. 1997. "Intergenerational Equity: An Exploration of the 'Fair-Innings' Argument." *Health Economics*, 6: 117–132.
- World Bank. 2023. "GDP per capita, PPP (constant 2017 international \$)." <https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.KD> (accessed August 10, 2023).
- WHO (World Health Organization). 2023. "WHO Coronavirus (COVID-19) Dashboard." <https://covid19.who.int/> (accessed August 10, 2023).