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The Economic Value Associated with Avoidable Mortality

A systematic assessment by cause of death across world regions

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INTRODUCTION

Before the onset of the COVID-19 pandemic in 2020, life expectancy at birth had been steadily increasing globally (UN 2019); and the advancements to older ages and frontiers of longevity were still regularly progressing (Vaupel et al. 2021). In many countries around the world, populations are rapidly ageing, immediately following the combination of major declines in fertility and important progresses in longevity (Christensen et al. 2009). Such rapid ageing transitions are often accompanied with the development of disability and dependence, including increasing prevalence of diseases of old age. This imposes new and substantial challenges to health systems, necessitating the design of novel technologies, the implementation of innovative health services delivery platforms, and the strengthening of financial architectures (Partridge et al. 2018; Spasova et al. 2018; Tynkkynnen et al. 2022). Facing limited resources and an increasing burden of non-communicable diseases (NCDs), health systems must make difficult trade-offs when allocating resources toward improving the healthy longevity of their populations.

Researchers and policymakers utilize a variety of analytical methods for generating evidence to inform decision-making on which health policies and interventions should be prioritized, funded (or not), and implemented. Commonly used approaches include various types of multi-criteria decision analyses (MCDA) (Baltussen et al. 2018; Verguet et al. 2021) and economic evaluations, traditionally drawn from cost-effectiveness analysis (CEA) methods, of the health policies and interventions under consideration (Drummond et al. 2015; Neumann et al. 2016). Such CEA studies often use a constructed metric, like the quality-adjusted life year (QALY) or the disability-adjusted life year (DALY) (Weinstein et al. 2009; Murray & Acharia 1997), which encompass both mortality and morbidity outcomes of the disease(s) addressed by the interventions under consideration. However, using non-monetary valuations in health intervention assessments limits their broader utility, preventing comparisons with assessments of interventions outside of the health sector (for example, education and social protection) (Robinson et al. 2019).

Yet, an attractive alternative analytical method that can address this intersectoral comparison issue is benefit-cost analysis (BCA; Robinson et al. 2019; Robinson, Hammitt & O'Keeffe 2019), where both the numerator (i.e., the health benefits procured by a given intervention) and the denominator (i.e., the costs incurred by a given intervention) of the benefit-cost ratio are expressed in monetary terms (say in USD gained or spent). As an example, the Copenhagen Consensus Center[1] has long used BCA approaches to consistently compare the returns on investment of a variety of policies globally across multiple key human capital and development sectors (e.g., health, education, agriculture), including health interventions in low- and middle-income countries (LMICs) (Jamison et al. 2013; Jha et al. 2013). Likewise, in their seminal work (Jamison et al. 2013) in which they used the value of a statistical life (VSL) to estimate the monetary gains from reducing under-five mortality rates in LMICs, Jamison and colleagues demonstrated the utility of monetized health outcomes. Most recently, Khadka & Verguet (2021) adapted such VSL methods to assign an economic value to life years and develop further value of a statistical life years, and applied methodologies to assess the economic value of changing mortality risks associated with NCDs. In doing so, they pointed to the vast welfare losses associated with elevated NCD mortality rates, especially cardiovascular diseases (CVDs) and cancers.

In this chapter, we build on this previous VSL scholarship. We compute the economic impact of disease, by first quantifying the avoidable mortality by cause of death (with a focus on major NCD and injury causes) and second applying novel economic valuation methods. Specifically, we compute a monetary value for hypothetical reductions (over 2000-2050) in cause-specific mortality: first, we benchmark these reductions against a mortality frontier (lowest mortality rates achievable) by cause; and second, we assign a willingness to pay value to these reductions in cause-specific mortality. In sum, we estimate the percent of income an individual would be willing to forgo to live one year under the lowest possible mortality rate for a given cause of death. Our assessment is pursued for six large analytical regions (e.g., China, Eurasia & the Mediterranean, High-income, India, Latin America & the Caribbean, and sub-Saharan Africa) and major disease

1 www.copenhagenconsensus.com

areas (e.g., cancers, CVD), with findings presented for the years 2000, 2019, and 2050. Our objective is to provide a systematic monetary assessment of the economic value associated with mortality by cause of death (with a focus on major NCDs and injuries) globally and regionally, and to derive a metric directly comparable to annual incomes (e.g., gross national income (GNI)), so as to enable both health sector and multisectoral priority setting.

METHODS

General approach

We proceeded in three steps. First, we projected age-cause-sex-specific mortality rates into the future (2020-2050) for each country included in the analysis (webappendix Table A1). We estimated age-cause-specific mortality frontiers ($\mathcal{F}_{a,K,s}$; a = age, K = disease cause, s = sex*)[2] for the period 2000-2019, with the mortality frontiers being the lowest (10th percentile) observed mortality rates for a given cause and age group, globally. We then projected these frontiers over 2020-2050. They can be thought of as "aspirational" mortality rates (for both females and males) for countries that experience mortality rates greater than the frontier.

Second, we compared country- and cause-specific mortality rates with frontier mortality rates to yield mortality differentials (i.e., "avoidable mortality", the gap between a country's mortality rate and the frontier mortality rate). We then aggregated these differentials across six analytical regions (inspired by the classification proposed by *The Lancet* Commission on Investing in Health (Watkins et al. 2018)): China; Eurasia & the Mediterranean; India; High-income; Latin America & the Caribbean; and sub-Saharan Africa (webappendix Table A1).

Third, we assigned a monetary value to the avoidable mortality. This gave an estimated percent of annual income an individual would be willing to forgo to live one year under the lowest possible mortality rate for a given cause of death; and a metric directly comparable to national incomes (e.g., GNI). These three steps are further detailed below.

Data sources

Estimates on age-cause-sex-specific death counts for all countries for 2000-2019 were sourced from the World Health Organization's (WHO) Global Health Estimates (GHE) (WHO 2020a). We adapted WHO's comprehensive list of causes to a smaller list of mutually exclusive, collectively exhaustive set of causes primarily focused on NCDs and injuries (Table 4.1; webappendix Table A2 gives a mapping between GHE causes of death and the causes of death used in the analysis). These causes of death were selected as they were leading causes of mortality and morbidity according to burden of disease assessments (WHO 2020a; IHME 2022). For cancers, we focused on tobacco-related (e.g., lung, mouth, esophagus) and infection-related (e.g., cervix, liver, stomach) cancers; breast cancer was selected as it was the leading cancer among females (WHO 2020a; IHME 2022).

Age refers to five-year age groups (except for the first two and final age groups): 0-1, 1-4, 5-9, 10-14, 15-19, …, 75-79, 80-84, and 85+ years. Age- and sex-specific population and all-cause mortality estimates and projections for all countries for the period 2000-2050 were sourced from the United Nations (UN) 2022 World Population Prospects (WPP) (UN 2022).

Estimating the mortality frontiers

The mortality frontiers (hereafter referred to as the "frontiers") were defined as the 10th percentile of the age-cause-specific mortality rates of eligible countries in a given year (Mathers et al. 2015; Chang et al. 2024). Countries were included in the frontier analysis (webappendix Table A1) if they had populations of at least 5 million in 2019; had available income (GNI per capita, current international dollars) data for 2019; had high-quality vital registration data (as defined in WHO 2020b); and were included in GHE estimates for the year 2019. The frontiers were age- and cause-specific for all causes of death except for breast cancer and cervix uteri cancer, for which age-sex-cause-specific frontiers were computed given the sex-specific epidemiology of these two conditions.[3] The frontier was defined as the 10th percentile

2 The frontier was only sex-specific for the following two sex-specific causes: breast cancer and cervix uteri cancer. For all other causes, the frontier was selected from among sex-specific mortality rates of both sexes.

3 Male-specific cancers, such as testicular or prostate cancers were not included as they are less common and affect older ages, so their overall burden is much lower.

of eligible country mortality rates, as opposed to the minimum, to ensure stability and the absence of stochastic variation in the resulting computed frontiers (see details in webappendix Figure A1).

For the period 2000-2019, frontiers were calculated directly using GHE estimates. To ensure that the frontiers of lower-level causes appropriately summed to the frontiers of higher ("parent") level causes (Table 4.1), we utilized a nested, level-wise approach. We first extracted the frontier (i.e., the lowest 10th percentile of eligible country mortality rates) for all-cause mortality, that is the highest level (level 0) cause. The frontiers for the next level of causes (level 1: communicable, maternal, perinatal and nu-

TABLE 4.1 Causes of death

Level	Cause of death
1	Communicable, maternal, perinatal and nutritional conditions
2	Infectious and parasitic diseases
2	Maternal and neonatal conditions
2	Nutritional deficiencies
1	Noncommunicable diseases
2	Cardiovascular diseases
3	Ischaemic heart disease
3	Stroke
3	Other cardiovascular diseases
2	Diabetes mellitus
2	Digestive diseases
3	Cirrhosis of the liver
3	Other digestive diseases
2	Malignant neoplasms
3	Breast cancer
3	Cervix uteri cancer
3	Liver cancer
3	Mouth and oropharynx cancers
3	Oesophagus cancer
3	Stomach cancer
3	Trachea, bronchus, lung cancers
3	Other malignant neoplasms
2	Respiratory diseases
3	Chronic obstructive pulmonary disease
3	Other respiratory diseases
2	Other noncommunicable diseases
1	Injuries
2	Intentional injuries
2	Unintentional injuries
3	Road injury
3	Other unintentional injuries

Note: The causes of death utilized in this analysis were adapted from the WHO's Global Health Estimates (WHO 2020a). Level 1 and 2 causes of death are mutually exclusive and collectively exhaustive; within level 2 causes of death, level 3 causes are mutually exclusive and collectively exhaustive.
Webappendix Table A2 gives a mapping between GHE causes of death and the causes of death used in the analysis.

tritional conditions; NCDs; and injuries) were then extracted. These level 1 frontiers were then summed to calculate the parent level (level 0: all-cause) frontier. The resulting calculated level 0 all-cause frontier was then compared with the extracted level 0 all-cause frontier to determine a scaling factor. This scaling factor was then applied to the component level 1 frontiers. This process was continued for level 2 causes (e.g., CVD, malignant neoplasms) and level 3 causes (e.g., stroke, stomach cancer).

For the period 2020-2050, the frontiers were calculated based on the trends underlying the 2010-2019 frontiers (immediately described above). Log-linear models were used to project the frontier mortality rates using the following equation:

$$ln(M_{a,K,Y}) \sim C_{a,K} + \beta_{A,K} * Y \quad , \quad [1]$$

where $M_{a,K,Y}$ is the mortality rate for age group a in year Y (2000, 2019, and 2050), and cause of death K. $C_{a,K}$ is a constant term, and Y is the year. $\beta_{A,K}$ is the estimated annual rate of change (decline) of the mortality rate associated with each cause and broad age group A (0-4, 5-14, 15-29, 30-44, 45-59, 60-69, 70-84, and 85+ year-olds). The projections (based on $\beta_{A,K}$ and [1]) were conducted separately by cause K and broad age group A to ensure similar mortality trends across neighboring five-year age groups, consistent with previous projection analyses (Mathers & Loncar 2006).

When the 2010-2019 frontier mortality rates contained a zero-value (i.e., an observation of 0 deaths per 100,000 population) or when the average number of deaths (averaged over the 2010-2019 frontiers) for a given age-cause group was less than 100, then the average mortality rate (for the period 2010-2019) was used for the 2020-2050 projection for all five-year age groups within the corresponding broad age group category (yielding a constant frontier over 2020-2050). Additionally, if the regression ([1]) gave a positive trendline ($\beta_{A,K} > 0$, which would indicate increasing frontier rates over time), then the average mortality rate (across years) was also used for all five-year age groups within the corresponding broad age group category (webappendix Table A3).

Consistency with all-cause frontiers

To ensure consistency with all-cause mortality frontiers (i.e. the all-cause mortality frontiers of avoidable mortality developed under Chang et al. 2024), our all-cause frontier mortality rates (immediately described above) were scaled to these all-cause frontiers. We divided our age- and year-specific all-cause frontiers by the corresponding external age- and year-specific all-cause frontier mortality rates to produce a set of age-year-specific scaling factors between our all-cause frontiers and the Chang and colleagues' frontiers. The resulting scalars were then applied to our cause-specific frontiers (i.e., cause levels 1, 2, and 3) to ensure consistency with the avoidable mortality frontiers put forward by Chang et al. (2024).

Estimating mortality projections for the six regions

First, we projected country- and cause-specific mortality rates for the period 2020-2050 using the same methods as for the frontier mortality rate projections described immediately above. Second, we aggregated these country-specific mortality rate projections within each region studied: China; Eurasia & the Mediterranean; India; High-income; Latin America & the Caribbean; and sub-Saharan Africa. For that purpose, population weights (within each age group) based on country- and age-specific populations using 2022 WPP (UN 2022) were used to eventually yield region-age-sex-cause-specific mortality rate projections.

Economic value associated with cause-specific avoidable mortality

We denote $m(x)$ the mortality rate among the age group $[x; x+u)$, where u is the size of the age group ($u = 5$, except for 0-1, 1-4, and 85+ age groups). The probability of dying at age a, $q(a)$, is expressed as $q(a) = 1 - e^{-\int_0^a m(x)dx}$; using a discrete formulation, $q(a) \sim 1 - e^{-u\sum_{x=0}^{a} m(x)}$.

We compare a country's age group's probability of dying ("C" for country) to a reference probability of dying ("$\mathcal{F}$" for frontier), that is $q_C(a)$ to $q_{\mathcal{F}}(a)$. The difference in those probabilities can be obtained by the following "avoidable mortality": $\delta_{C,\mathcal{F}}(a) = q_C(a) - q_{\mathcal{F}}(a)$.[4] Now take the population of country C with an age distribution $\alpha_C(a)$ ($\alpha_C(a) = P_C(a)/\sum_{a=0}^{\omega} P_C(a)$, where $P_C(a)$ is the size of the age group $[a; a+u)$ and ω is the oldest age group). In addition, denote v the monetary value assigned to the change in the probability of dying ($\delta_{C,\mathcal{F},1}$ over one year) at a given age a. Then, for a given year, the aggre-

4 In what follows, we examine differentials over one-year periods, denoted $\delta_{C,\mathcal{F},1}$, where u is then set to 1 year.

gate monetary value associated with avoidable mortality (comparing "C" and "$\mathcal{F}$") will be given by:

$$V_{C,\mathcal{F}} \sim \sum_{a=0}^{\omega} \alpha_C(a) v(\delta_{C,\mathcal{F},1}(a)) \quad . \qquad [2]$$

We then assign a value to $v(\delta_{C,\mathcal{F},1}(a))$ that depends on the extent of the differential in mortality risk $\delta_{C,\mathcal{F},1}$ and on the VSL in country C (VSL_C). We apply the methods developed by Chang et al. 2024, where v increases with $\delta_{C,\mathcal{F},1}$ and its marginal rate of increase decreases with $\delta_{C,\mathcal{F},1}$ (consistent with Cardoso & Dahis (2020) and Hammitt (2020)). The value of VSL_C can be related to the VSL in the United States (VSL_{US}) using an income elasticity ε: $VSL_C = VSL_{US} * (Y_C/Y_{US})^{\varepsilon}$, where Y_C and Y_{US} are the GNI per capita of C and the United States, respectively.

To derive VSL_C, we set $\varepsilon = 0.8$ for countries with GNI per capita greater than the United States and $\varepsilon = 1.2$ for countries with lower GNI per capita (Viscusi & Materman 2017; Robinson, Hammitt, & O'Keefe 2019)[5]; we also set a floor constraint for the ratio between VSL and GNI per capita of 20. GNI per capita was expressed in current international dollars (Purchasing Power Parity (PPP); World Bank 2022) for the period 2000-2021; and were projected to 2050 using OECD's projected country-specific growth rates over 2021-2050 for listed countries, and the world average growth rate during the same time period for all other countries. We set VSL_{US} = 160 x US GNI per capita (Robinson, Hammitt, & O'Keeffe 2019); and a discount rate of 3 percent per year.

Therefore, per year and country, we computed the following proportions per cause K and age group a: $p_{C,K}(a) = \delta_{C,\mathcal{F},K,1}(a)/\sum_K \delta_{C,\mathcal{F},K,1}(a)$.

We then derived the following value (per year): $V_{C,\mathcal{F},K} \sim \sum_{a=0}^{\omega} \alpha_C(a) v(\delta_{C,\mathcal{F},1}(a)) p_{C,K}(a)$, aggregated per region R:

$$V_{R,K,\mathcal{F}} \sim \sum_{C \in R} w_C V_{C,K,\mathcal{F}} = \sum_{C \in R} \sum_{a=0}^{\omega} w_C \alpha_C(a) v(\delta_{C,\mathcal{F},1}(a)) p_{C,K}(a). \quad [3]$$

From [3], we obtained an economic value directly comparable to annual incomes, which captures the percent of income an individual would be willing to forgo to live one year under the lowest possible mortality rate for a given cause of death (in the region R).

Sensitivity analyses

First, we estimated the mortality frontiers in using the lowest cause-specific mortality rates, in place of the 10th percentile of the mortality rates. Second, when quantifying the economic values associated with avoidable mortality, the resulting estimates are sensitive to the VSL values assigned. Though this will not necessarily affect the relative distribution of the cause-specific allocations and associated economic values and we report economic values in terms of multiples of annual income, we applied three sets of standard sensitivity analyses related to VSL estimates (Robinson et al. 2019), in varying (i) income elasticities, to either 1.0 or 1.5; (ii) discount rates, to either 1 or 5 percent per year; and using (iii) an alternative baseline VSL-to-income ratio of 100 relative to the average income among OECD countries (in place of the VSL-to-income ratio for the United States).

All computations and simulations were conducted using R software (version 2022.02.3). All codes are available on GitHub.

RESULTS

We first report on the estimation of the mortality frontiers per cause of death and display the mortality trajectories and avoidable mortality with respect to the frontiers for the six regions. Second, we exhibit the economic values associated with avoidable mortality for each cause of death and region.

Mortality frontiers and region-specific mortality trajectories

The estimated mortality frontiers (for 2000-2050) are displayed for ages 20 years and older (the principal age groups over which NCDs manifest) for the following broad causes of death: all causes; communicable, maternal, perinatal and nutritional conditions; CVD; malignant neoplasms (cancers); and injuries (Figure 4.1).[6] As expected, the mortality frontiers are higher (corresponding to higher

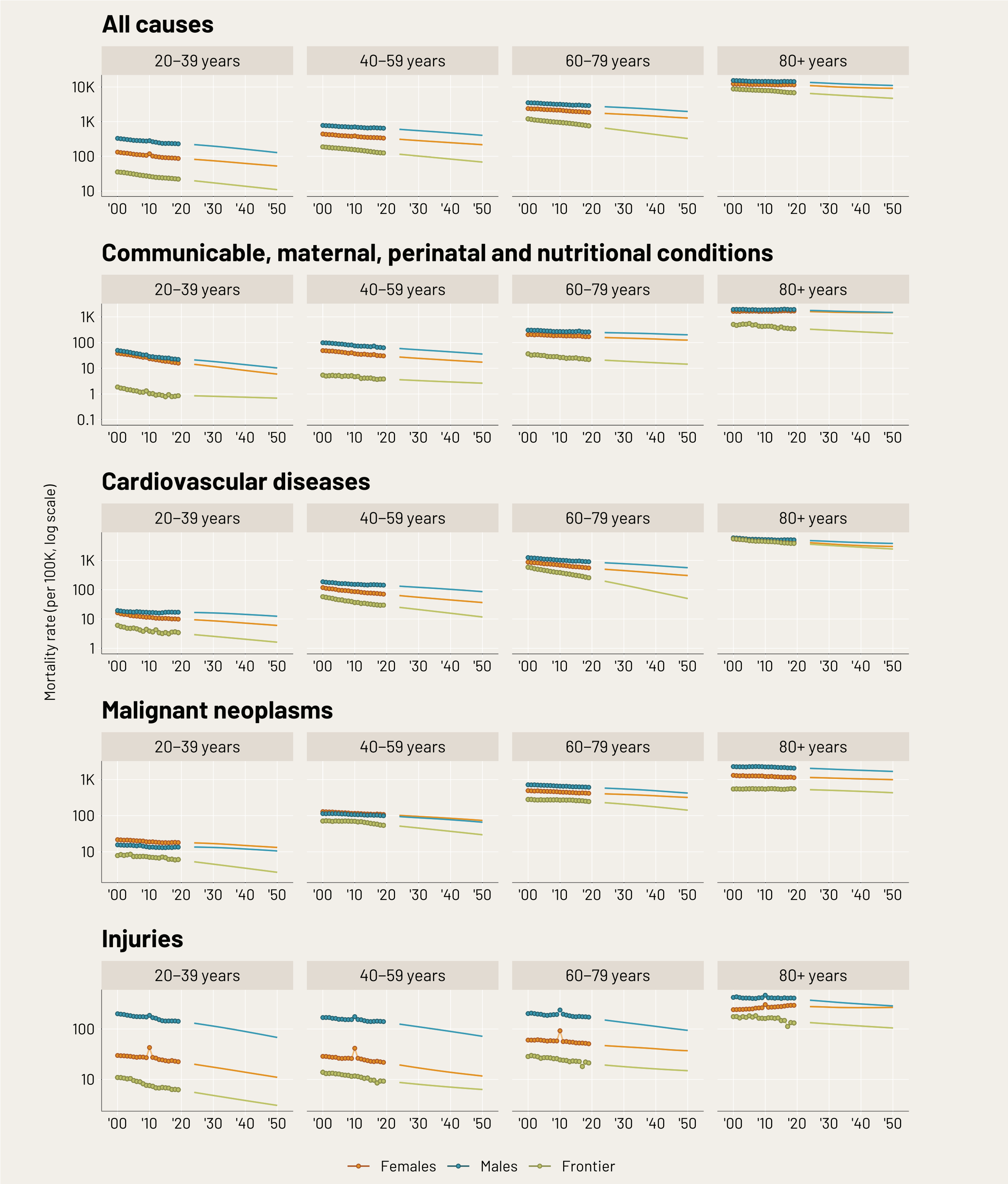
5 Alternative values of income elasticity of 1.0 and 1.5 are tested in sensitivity analyses.

6 Note that some of the slight fluctuations observed for the frontiers are due to the scaling with the all-cause frontiers estimated by Chang et al. (2024). Likewise, for the mortality trajectories, the fluctuations observed are due to the method used for calculating regional estimates (i.e., aggregation of population-weighted country-specific estimates) as well as the scaling with the all-cause frontiers.

mortality rates) for older age groups. All estimated frontiers for all causes of death are available in the webappendix (Figure B1).

Mortality trajectories for the six regions were estimated by sex for all age groups and causes of death (over 2000-2050). As an illustration, we show the trajectories for the Latin America & Caribbean region for females and males, ages 20 years and older (Figure 4.1). Likewise, as expected, the trajectories show higher mortality rates for the older age groups for all causes. In general (to a few rare exceptions), the mortality trajectories are also higher for males than for females. All mortality trajectories for regions and causes of death are collected in the webappendix (Figures B2-B8).

FIGURE 4.1 Mortality frontiers (females and males) for the period 2000-2050; *and mortality trajectories for Latin America and the Caribbean over the period 2000-2050; by sex, age group (20-39 years, 40-59 years, 60-79 years, 80+ years), and cause of death: all causes; communicable, maternal, perinatal and nutritional conditions; cardiovascular diseases; malignant neoplasms; and injuries.*



Note: Points correspond to WHO's Global Health Estimates (WHO 2020) for the period 2000-2019; the lines are projections. The impact of COVID-19 is not accounted for in these projections and therefore years 2020-2023 are not displayed.

Economic value of avoidable mortality

For the six regions and calendar years 2000, 2019, and 2050, we display the economic valuations (summed across all age groups) tied to specific causes of death (Figure 4.2 displays level 2 causes; the fractions displayed are percentages of annual income per cause, region, and year; Table 4.2). Alternative disaggregations (level 1 and level 3 causes) are shown in webappendix Figures B9 and B10, along with relative distributions of these economic valuations by cause (webappendix Figures B11, B12, and B13).

We observe important variations in the cause valuations across regions, as well as some slight differences when comparing females and males within the same region. CVD contributes to a very substantial economic value; for example, in 2019: around 6.8 percent of annual income in Eurasia & the Mediterranean, 7.0 percent in China, 5.2 percent in India, 3.9 percent in Latin America & the Caribbean, 3.7 percent in High-income, and 2.5 percent in sub-Saharan Africa (Table 4.2).

Furthermore, cancers (i.e., malignant neoplasms) also largely participate to the economic value of avoidable mortality, especially so in High-income (5.2 percent for females, 7.2 percent for males, of annual income in 2019) and China (3.8 percent and 6.8 percent) (webappendix Table B1). Yet, these economic values would be quite smaller in Eurasia & the Mediterranean (2.5 percent and 3.1 percent), India (1.6 percent and 1.3 percent), Latin America & the Caribbean (2.9 percent and 2.5 percent), and sub-Saharan Africa (2.2 percent and 1.1 percent).

As for injuries, they seem to be more geographically located. Indeed, injuries display substantial values for males in Latin America & the Caribbean (around 8.8 percent of annual income in 2019; compared with 1.6 percent for females) and are concentrated within intentional injuries (around 5.1 percent of male annual income in 2019); as well as for males in sub-Saharan Africa (around 7.4 percent of annual income in 2019, 3.2 percent for females) with a concentration within unintentional injuries (around 5.1 percent of male annual income in 2019) (webappendix Table B1). On the contrary, for the other four regions, the economic values for injuries were lower: between 4.1 and 4.8 percent of annual income for males, between 1.3 and 2.6 percent of annual income for females (in the year 2019).

TABLE 4.2 Economic value of avoidable mortality as a percentage of annual income by region and cause of death, for the years 2000, 2019, and 2030

Cause of death	2000	2019	2050
China			
Communicable, maternal, perinatal and nutritional conditions	2.5%	0.9%	0.2%
Infectious and parasitic diseases	1.8%	0.7%	0.1%
Maternal and neonatal conditions	0.6%	0.3%	0.1%
Nutritional deficiencies	0.0%	0.0%	0.1%
Noncommunicable diseases	10.5%	14.9%	23.6%
Cardiovascular diseases	3.7%	7.0%	12.4%
Ischaemic heart disease	0.6%	2.5%	6.2%
Stroke	2.7%	3.9%	4.4%
Other cardiovascular diseases	0.4%	0.4%	1.7%
Diabetes mellitus	0.1%	0.3%	0.6%
Digestive diseases	0.5%	0.4%	0.1%
Cirrhosis of the liver	0.4%	0.3%	0.1%
Other digestive diseases	0.1%	0.1%	0.0%
Malignant neoplasms	3.5%	5.3%	8.2%
Breast cancer	0.0%	0.1%	0.3%
Cervix uteri cancer	0.1%	0.2%	0.3%
Liver cancer	0.8%	0.5%	0.8%
Mouth and oropharynx cancers	0.1%	0.1%	0.1%
Oesophagus cancer	0.5%	0.6%	0.4%
Stomach cancer	0.8%	1.0%	0.5%
Trachea, bronchus, lung cancers	0.9%	1.9%	3.6%
Other malignant neoplasms	0.6%	1.0%	2.2%
Respiratory diseases	1.9%	1.4%	0.8%
Chronic obstructive pulmonary disease	1.8%	1.4%	0.9%
Other respiratory diseases	0.0%	0.0%	0.0%
Other noncommunicable diseases	0.7%	0.6%	1.4%

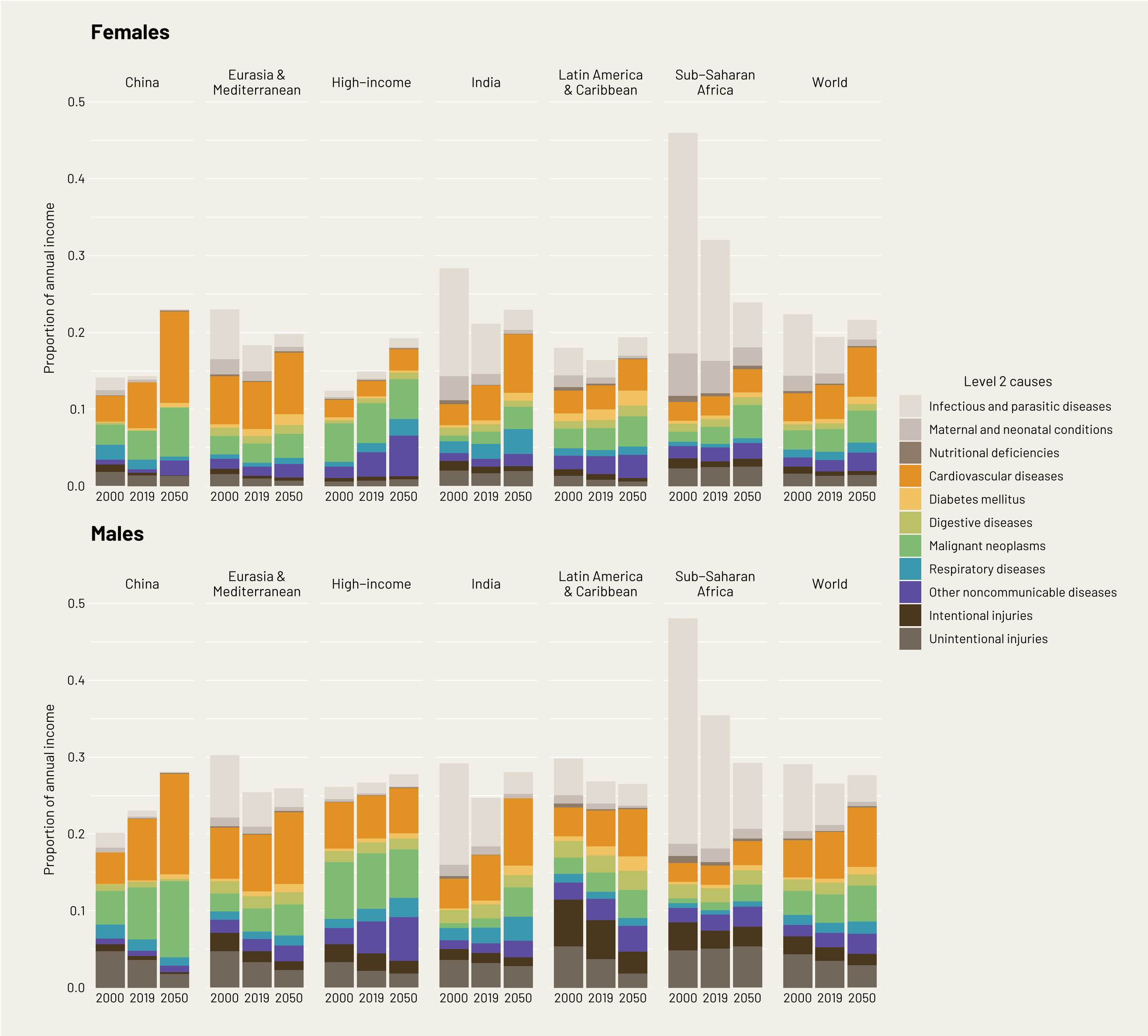
Cause of death	2000	2019	2050
Injuries	4.2%	2.9%	1.7%
Intentional injuries	0.9%	0.4%	0.1%
Unintentional injuries	3.3%	2.5%	1.6%
Road injury	1.5%	1.3%	0.6%
Other unintentional injuries	1.8%	1.2%	0.9%
Eurasia & Mediterranean			
Communicable, maternal, perinatal and nutritional conditions	9.1%	5.2%	2.8%
Infectious and parasitic diseases	7.3%	3.9%	2.0%
Maternal and neonatal conditions	1.5%	1.1%	0.6%
Nutritional deficiencies	0.2%	0.1%	0.1%
Noncommunicable diseases	12.8%	13.7%	17.8%
Cardiovascular diseases	6.4%	6.8%	8.7%
Ischaemic heart disease	3.3%	3.5%	4.8%
Stroke	2.3%	2.4%	2.8%
Other cardiovascular diseases	0.8%	0.8%	1.0%
Diabetes mellitus	0.5%	0.8%	1.3%
Digestive diseases	1.3%	1.3%	1.3%
Cirrhosis of the liver	0.9%	0.9%	0.9%
Other digestive diseases	0.3%	0.3%	0.4%
Malignant neoplasms	2.4%	2.8%	3.6%
Breast cancer	0.2%	0.3%	0.3%
Cervix uteri cancer	0.2%	0.2%	0.1%
Liver cancer	0.2%	0.3%	0.3%
Mouth and oropharynx cancers	0.2%	0.2%	0.3%
Oesophagus cancer	0.1%	0.1%	0.2%
Stomach cancer	0.2%	0.2%	0.2%
Trachea, bronchus, lung cancers	0.4%	0.5%	0.6%
Other malignant neoplasms	0.9%	1.1%	1.7%
Respiratory diseases	0.8%	0.8%	1.0%
Chronic obstructive pulmonary disease	0.5%	0.5%	0.7%
Other respiratory diseases	0.3%	0.3%	0.3%
Other noncommunicable diseases	1.5%	1.4%	1.9%
Injuries	4.7%	3.0%	2.2%
Intentional injuries	1.5%	0.9%	0.7%
Unintentional injuries	3.1%	2.2%	1.5%
Road injury	1.2%	1.1%	0.8%
Other unintentional injuries	1.9%	1.0%	0.7%
High-income			
Communicable, maternal, perinatal and nutritional conditions	1.6%	1.6%	1.8%
Infectious and parasitic diseases	1.2%	1.2%	1.4%
Maternal and neonatal conditions	0.3%	0.2%	0.1%
Nutritional deficiencies	0.1%	0.1%	0.1%
Noncommunicable diseases	14.1%	16.2%	19.2%
Cardiovascular diseases	4.1%	3.7%	4.3%
Ischaemic heart disease	2.8%	2.2%	2.2%
Stroke	0.6%	0.5%	0.7%
Other cardiovascular diseases	0.8%	1.1%	1.7%
Diabetes mellitus	0.4%	0.4%	0.5%

Cause of death	2000	2019	2050
Digestive diseases	0.9%	1.0%	1.1%
Cirrhosis of the liver	0.5%	0.5%	0.5%
Other digestive diseases	0.3%	0.4%	0.6%
Malignant neoplasms	6.2%	6.2%	5.8%
Breast cancer	0.6%	0.5%	0.4%
Cervix uteri cancer	0.1%	0.1%	0.0%
Liver cancer	0.3%	0.3%	0.3%
Mouth and oropharynx cancers	0.2%	0.2%	0.2%
Oesophagus cancer	0.2%	0.3%	0.2%
Stomach cancer	0.4%	0.3%	0.1%
Trachea, bronchus, lung cancers	2.1%	2.2%	1.5%
Other malignant neoplasms	2.6%	2.7%	3.1%
Respiratory diseases	0.9%	1.5%	2.3%
Chronic obstructive pulmonary disease	0.6%	0.9%	1.4%
Other respiratory diseases	0.3%	0.5%	0.8%
Other noncommunicable diseases	1.8%	3.7%	5.5%
Injuries	3.4%	2.9%	2.5%
Intentional injuries	1.3%	1.4%	1.0%
Unintentional injuries	1.9%	1.4%	1.4%
Road injury	1.1%	0.6%	0.5%
Other unintentional injuries	0.8%	0.8%	0.9%
India			
Communicable, maternal, perinatal and nutritional conditions	16.4%	7.8%	3.3%
Infectious and parasitic diseases	13.6%	6.4%	2.7%
Maternal and neonatal conditions	2.3%	1.2%	0.6%
Nutritional deficiencies	0.4%	0.1%	0.0%
Noncommunicable diseases	8.2%	11.6%	18.9%
Cardiovascular diseases	3.3%	5.2%	8.2%
Ischaemic heart disease	1.8%	3.2%	5.3%
Stroke	0.9%	1.3%	2.0%
Other cardiovascular diseases	0.6%	0.6%	0.8%
Diabetes mellitus	0.3%	0.6%	1.2%
Digestive diseases	1.4%	1.4%	1.2%
Cirrhosis of the liver	0.8%	0.9%	0.8%
Other digestive diseases	0.6%	0.4%	0.3%
Malignant neoplasms	0.7%	1.4%	3.4%
Breast cancer	0.0%	0.2%	0.3%
Cervix uteri cancer	0.1%	0.2%	0.2%
Liver cancer	0.0%	0.0%	0.1%
Mouth and oropharynx cancers	0.2%	0.4%	0.8%
Oesophagus cancer	0.1%	0.1%	0.2%
Stomach cancer	0.1%	0.2%	0.2%
Trachea, bronchus, lung cancers	0.1%	0.2%	0.4%
Other malignant neoplasms	0.2%	0.4%	1.4%
Respiratory diseases	1.6%	2.0%	3.2%
Chronic obstructive pulmonary disease	1.0%	1.4%	2.6%
Other respiratory diseases	0.5%	0.6%	0.6%
Other noncommunicable diseases	1.1%	1.1%	1.9%
Injuries	4.2%	3.6%	3.3%
Intentional injuries	1.3%	1.1%	0.9%

Cause of death	2000	2019	2050
Unintentional injuries	2.8%	2.5%	2.4%
Road injury	0.8%	0.9%	0.8%
Other unintentional injuries	2.0%	1.6%	1.5%
Latin America & Caribbean			
Communicable, maternal, perinatal and nutritional conditions	6.0%	3.6%	3.2%
Infectious and parasitic diseases	4.2%	2.6%	2.6%
Maternal and neonatal conditions	1.3%	0.8%	0.3%
Nutritional deficiencies	0.5%	0.2%	0.2%
Noncommunicable diseases	11.1%	12.8%	16.9%
Cardiovascular diseases	3.3%	3.9%	5.1%
Ischaemic heart disease	1.4%	1.9%	2.9%
Stroke	1.2%	1.1%	1.0%
Other cardiovascular diseases	0.7%	0.8%	1.1%
Diabetes mellitus	0.9%	1.3%	1.9%
Digestive diseases	1.5%	1.6%	1.9%
Cirrhosis of the liver	0.8%	0.7%	0.8%
Other digestive diseases	0.7%	0.9%	1.2%
Malignant neoplasms	2.3%	2.7%	3.8%
Breast cancer	0.2%	0.3%	0.4%
Cervix uteri cancer	0.3%	0.3%	0.2%
Liver cancer	0.1%	0.2%	0.2%
Mouth and oropharynx cancers	0.1%	0.1%	0.1%
Oesophagus cancer	0.1%	0.1%	0.1%
Stomach cancer	0.3%	0.3%	0.3%
Trachea, bronchus, lung cancers	0.3%	0.4%	0.5%
Other malignant neoplasms	1.1%	1.3%	2.2%
Respiratory diseases	1.0%	0.9%	1.0%
Chronic obstructive pulmonary disease	0.5%	0.5%	0.7%
Other respiratory diseases	0.5%	0.4%	0.4%
Other noncommunicable diseases	2.0%	2.5%	3.2%
Injuries	6.7%	5.1%	2.8%
Intentional injuries	3.4%	2.9%	1.6%
Unintentional injuries	3.3%	2.3%	1.2%
Road injury	1.6%	1.3%	0.6%
Other unintentional injuries	1.7%	1.0%	0.6%
Sub-Saharan Africa			
Communicable, maternal, perinatal and nutritional conditions	33.5%	20.0%	9.5%
Infectious and parasitic diseases	29.0%	16.6%	7.2%
Maternal and neonatal conditions	3.6%	3.0%	1.8%
Nutritional deficiencies	0.9%	0.4%	0.4%
Noncommunicable diseases	7.5%	8.5%	11.4%
Cardiovascular diseases	2.4%	2.5%	3.0%
Ischaemic heart disease	0.7%	0.8%	1.2%
Stroke	1.0%	1.0%	1.1%
Other cardiovascular diseases	0.7%	0.6%	0.7%
Diabetes mellitus	0.4%	0.5%	0.7%
Digestive diseases	1.4%	1.4%	1.4%
Cirrhosis of the liver	0.8%	0.8%	0.8%
Other digestive diseases	0.5%	0.6%	0.7%

Cause of death	2000	2019	2050
Malignant neoplasms	1.0%	1.7%	3.3%
Breast cancer	0.1%	0.3%	0.5%
Cervix uteri cancer	0.3%	0.3%	0.5%
Liver cancer	0.1%	0.1%	0.2%
Mouth and oropharynx cancers	0.0%	0.1%	0.1%
Oesophagus cancer	0.1%	0.1%	0.1%
Stomach cancer	0.0%	0.1%	0.1%
Trachea, bronchus, lung cancers	0.0%	0.0%	0.1%
Other malignant neoplasms	0.4%	0.8%	1.6%
Respiratory diseases	0.6%	0.5%	0.6%
Chronic obstructive pulmonary disease	0.2%	0.2%	0.3%
Other respiratory diseases	0.4%	0.3%	0.4%
Other noncommunicable diseases	1.7%	2.0%	2.4%
Injuries	6.0%	5.3%	5.7%
Intentional injuries	2.4%	1.5%	1.7%
Unintentional injuries	3.6%	3.8%	4.0%
Road injury	1.8%	2.1%	2.5%
Other unintentional injuries	1.7%	1.6%	1.5%
World			
Communicable, maternal, perinatal and nutritional conditions	10.1%	6.3%	3.9%
Infectious and parasitic diseases	8.4%	5.1%	3.0%
Maternal and neonatal conditions	1.5%	1.1%	0.7%
Nutritional deficiencies	0.3%	0.1%	0.2%
Noncommunicable diseases	11.0%	13.1%	17.5%
Cardiovascular diseases	4.2%	5.2%	7.0%
Ischaemic heart disease	1.9%	2.6%	3.8%
Stroke	1.6%	1.9%	2.1%
Other cardiovascular diseases	0.7%	0.7%	1.1%
Diabetes mellitus	0.4%	0.6%	1.0%
Digestive diseases	1.1%	1.1%	1.2%
Cirrhosis of the liver	0.7%	0.7%	0.7%
Other digestive diseases	0.4%	0.4%	0.5%
Malignant neoplasms	2.8%	3.4%	4.4%
Breast cancer	0.2%	0.2%	0.4%
Cervix uteri cancer	0.1%	0.2%	0.2%
Liver cancer	0.3%	0.3%	0.3%
Mouth and oropharynx cancers	0.2%	0.2%	0.3%
Oesophagus cancer	0.2%	0.2%	0.2%
Stomach cancer	0.4%	0.4%	0.2%
Trachea, bronchus, lung cancers	0.7%	0.9%	1.0%
Other malignant neoplasms	1.0%	1.2%	1.9%
Respiratory diseases	1.2%	1.2%	1.5%
Chronic obstructive pulmonary disease	0.8%	0.9%	1.1%
Other respiratory diseases	0.3%	0.3%	0.4%
Other noncommunicable diseases	1.4%	1.7%	2.5%
Injuries	4.6%	3.6%	3.2%
Intentional injuries	1.6%	1.1%	1.0%
Unintentional injuries	3.0%	2.4%	2.2%
Road injury	1.3%	1.2%	1.1%
Other unintentional injuries	1.7%	1.2%	1.1%

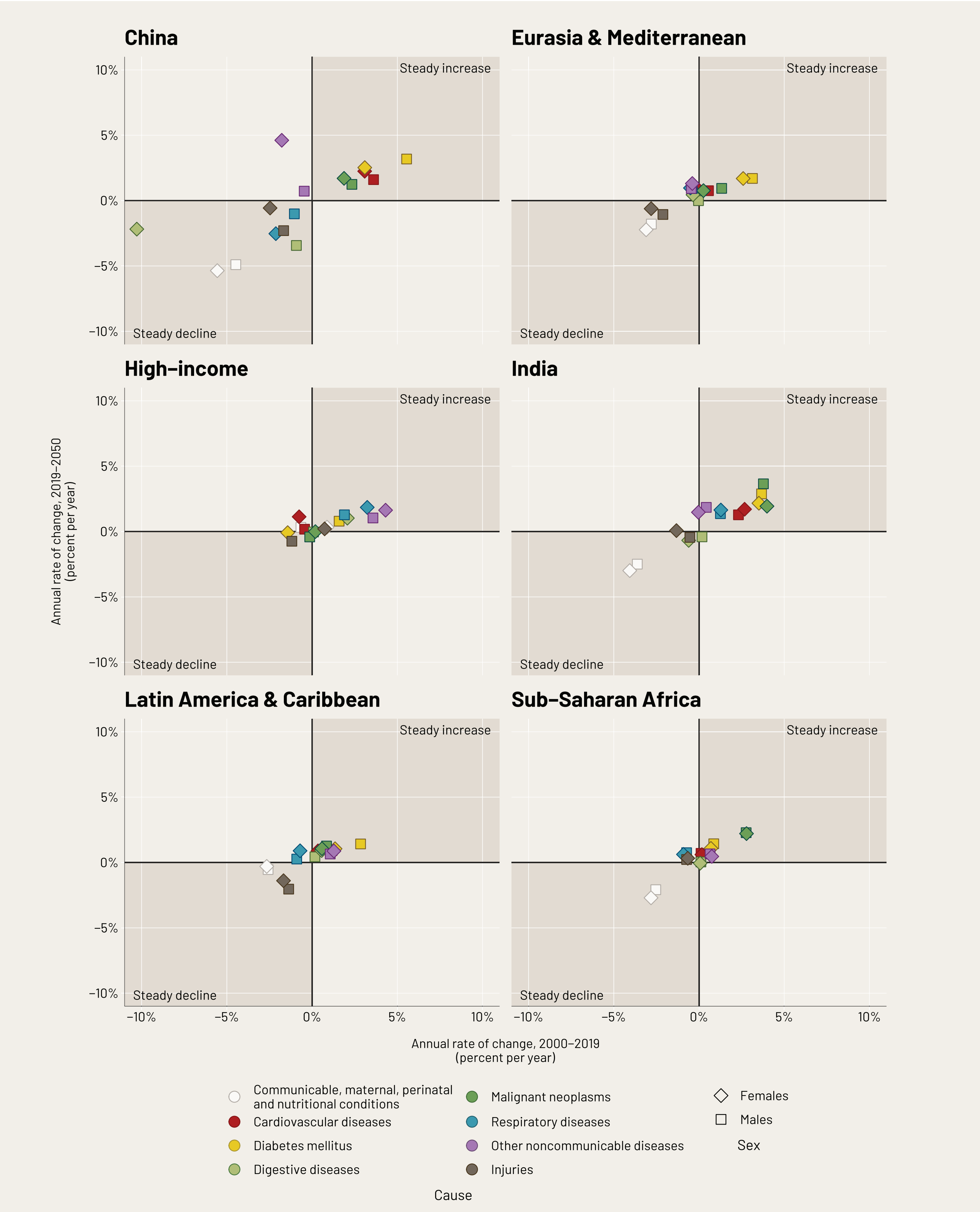
FIGURE 4.2 Economic values of avoidable mortality, *measured as proportion of annual income, assigned to selected causes of death for the six regions, in the years 2000, 2019, and 2050*



We note that the economic value attributable to the cause category "communicable, maternal, perinatal and nutritional conditions" would be very substantial in sub-Saharan Africa (20.4 percent for females, 19.6 percent for males, of annual income in 2019), and quite large, yet to a lesser extent in India (8.1 percent and 7.5 percent). This is notably due to large young populations, especially in sub-Saharan Africa (UN 2022), as well as to high mortality rates for these causes of death. The economic values for these causes of death would however be much smaller in the other four regions, particularly so in high-income (1.5 percent for females, 1.8 percent for males) and China (0.8 percent for females, 1.1 percent for males), geographical locations that are most advanced into the epidemiological transition from communicable to non-communicable diseases.

Lastly, in almost all regions, we could point to the rapid expansion of avoidable deaths associated with NCDs, in particular CVD and cancers, and to the fast compression of avoidable mortality from communicable, perinatal, maternal and nutritional diseases, into the future (from 2000 to 2019 and 2050; Figure 4.3). This is a testimony of the still advancing epidemiological transition from communicable to non-communicable diseases and of the ageing of populations.

FIGURE 4.3 Rates of change (percent per year) of the economic values of avoidable mortality assigned to selected causes of death *(communicable, maternal, perinatal and nutritional conditions; cardiovascular diseases; malignant neoplasms; injuries) for the six regions, over the time periods 2000-2019 and 2019-2050.*



Specifically, from 2000 to 2050, we observe steady declines in the economic value associated with avoidable mortality from communicable, perinatal, maternal and nutritional diseases coupled with steady expansions of the economic value of avoidable mortality from CVD (except for sub-Saharan Africa) and cancers in China, India, and sub-Saharan Africa. For the other regions, the extents of these CVD and cancer expansions would be smaller, especially so in High-income, which displays a rather stagnant picture. Overall, this dynamic evolution into the future crucially emphasizes the paramount challenges and economic losses ahead tied to the expansion of CVD and cancers, replacing communicable, perinatal, maternal and nutritional diseases, particularly in the emerging economies of China, India, and sub-Saharan Africa.

Sensitivity analyses

When using the lowest mortality rates (in place of the 10^{th} percentile of the mortality rates; webappendix Figure C1) or when applying standard BCA sensitivity analyses (Robinson et al. 2019), we did not observe qualitatively distinct findings, though quantitatively the findings would be impacted. This was the case, whether we prescribed different income elasticities, of 1.0 and 1.5 (webappendix Figures C2, C3), where economic values would decrease (increase) with a higher (lower) income elasticity; or varied discount rates, to 1 and 5 percent per year (webappendix Figures C5, C6), where we observed modest changes; or we set an alternative baseline VSL-to-income ratio of 100 relative to OECD countries (instead of 160 relative to the United States; webappendix Figure C4), where economic values would decrease.

DISCUSSION

We described in this chapter analytical methods to compute the monetary values linked with mortality risk reductions associated with specific causes of death, across six regions. The economic framework presented provides a systematic monetary assessment of the burden of avoidable mortality, which can be useful in quantifying the costs and benefits of both health and non-health interventions, and allow comparisons within the health sector as well as beyond across sectors (e.g., health, education, transport, agriculture).

Our assessment shows that the implications of controlling NCDs and injuries could be substantial in terms of economic value and that the costs of inaction would be enormous, especially for CVD. Indeed, we found that the economic value associated with avoidable CVD mortality would be universally large, in the order of 3 to 7 percentage points of annual income in the year 2019 for example. We also observed that the economic value of avoidable cancer mortality would be large in high-Income and China; and, for injury, it would be substantial for males in Latin America & the Caribbean (intentional injuries) and males in sub-Saharan Africa (unintentional injuries).

While the extents of these hypothetical mortality reductions needed not be monetized, importantly, in computing these economic values, we assigned willingness to pay values for cause-specific mortality reductions and provided a metric (i.e., percent of annual income) that is directly comparable to GNIs and annual budgetary allocations. As such, we produced potential willingness to pay estimates (e.g., multipliers of GNIs per capita; Bertram et al. 2016, Woods et al. 2016) against which one could gauge the cost-effectiveness of interventions (say as potential "best-buys"). We also estimated sizeable monetary values for the mortality reduction gains that could be obtained with scaling up key interventions and benefit packages addressing NCDs and injuries (e.g., health taxes, primary and secondary prevention of CVD; NCD Countdown 2030 collaborators 2022). In sum, our dual focus on mortality frontiers and modulated monetary valuation of the size of mortality risk reductions provides a priority-setting dimension complementary to cause-of-death distributions (webappendix Figure D1).

Relatedly, a few similar studies (in spirit) have been conducted in the literature. Most importantly, Bloom and colleagues have pioneered comparable BCA methods and published seminal works as part of making the investment case for NCDs (Bloom et al. 2011). They have also led macroeconomic modeling to assess the economic losses attributable to NCDs in a few Asian nations including China, Japan, and South Korea (Bloom et al. 2020) and to cancers globally (Chen et al. 2023). These works, like ours, demonstrated the very substantial welfare impact of NCDs, at the global and regional levels. Also, Khadka &

Verguet (2021) further developed VSL approaches to quantify the monetary values associated with NCDs in a systematic manner, and like our assessment, estimated that the welfare losses associated with NCDs, particularly for CVD and cancers, would be very substantial in the coming decades for LMIC economies. Similarly, Arias and colleagues (2022) pointed to the potentially large economic losses tied to mental disorders using somewhat comparable approaches.

Nevertheless, our analysis presents important limitations. First, we used global estimates of cause-specific mortality, which are based on incomplete and uncertain data, particularly in low- and lower-middle income countries (WHO 2020a).

Second, we forecasted future trends (over the period 2020-2050) in age-cause-sex-specific frontier mortality rates and country groupings based on previous trends (over the period 2010-2019) using simple log-linear extrapolations into the future. A more complex modeling approach could be pursued, yielding probabilistic distributions of a space of plausible future outcomes (Kontis et al. 2017). Yet, this would likely bring additional complications for interpretation without, however, being further grounded within empirical data. Also, we did not consider the short- or long-term impacts of the COVID-19 pandemic on age-cause-specific mortality rates in our forecasts. In addition, for the estimation of the mortality frontiers, we mostly used high-income country data, because high-quality vital registration data for LMICs outside of the Latin America & Caribbean region remain scarce and because high-income countries would likely achieve the lowest mortality rates (WHO 2020a; IHME 2022). Such frontier trajectories could however be revisited as more data become available, and alternative mortality frontiers could be constructed (e.g., region-specific mortality frontiers in place of global mortality frontiers). Likewise, different percentiles (5th, 20th, 30th or lowest) of mortality rates could be tested in place of the 10th percentiles used here. The changes might quantitatively affect our findings, yet only likely to a modest level if, for example, we used the lowest mortality rates in place of the 10th percentiles (webappendix Figures A1, C1). Relatedly, differences in cause-of-death patterns across geographies and over time may relate to quality and practices in cause-of-death assignments as opposed to real epidemiological differences, especially for related causes (e.g., diabetes and CVD). Our methods are based on quantification of the economic value of avoidable mortality, which by design excludes non-fatal conditions, such as mental conditions and sensory disorders (e.g., vision and hearing impairments). We likely underestimate the economic value of non-fatal conditions by looking only at avoidable mortality.

Third, there are major limitations with the implementation of VSL approaches for economic valuation, in particular the high sensitivity of the VSL estimates to income elasticity parameters (Viscusi & Aldy 2003; Robinson, Hammitt & O'Keeffe 2019; webappendix Figures C2, C3). Importantly, we have made a number of argued prescriptions regarding the parametrization of our estimations, including the specification of a modulating function varying with the extent of mortality risk reductions (using Chang et al. (2024), consistent with Hammitt (2020) and Cardoso & Dahis (2020)). In this respect, caution should be exercised when comparing the economic values associated with avoidable mortality across regions. Furthermore, to many, VSL approaches raise ethical dilemmas, that is, notably, to eventually yield a monetary value for life years. Yet, often, VSL estimates are misunderstood as economic values one society assigns to one life; while they rather capture the trade-offs individuals are willing to make in giving up a portion of their income in exchange for small reductions in their mortality risk over a given year (Robinson et al. 2019). Also, BCA is only one (among many other possible) method for priority setting, nonetheless attractive for making multisectoral comparisons. Critically, the quantitative values extracted from VSL estimates are sensitive to income elasticities and the income differentials across countries. Fourth, while we were able to compute monetary values associated with longevity losses due to specific causes of death, this only provides one element (i.e., a valuation of health gains) for use in BCAs. Evidently, we would also need the costing of interventions and the valuation of morbidity reduction and other non-health benefits (e.g., financial protection) (Verguet, Laxminaryan & Jamison 2015; Verguet & Norheim 2022), so as to fully assess the returns on investment from controlling NCDs and injuries.

In summary, we produced a systematic economic valuation of the burden of avoidable mortality by cause of death, with a focus on major NCDs and injuries, in LMICs. This economic framework can point to the very large economic value linked to NCDs and injuries, amounting to several percentage points of annual incomes. It can also be further adapted to estimate the economic returns from investing in the health sector and, in this particular study, toward NCD and injury interventions. In doing so, it allows both economic comparisons of such investments both within the health sector as well as across other sectors.

REFERENCES

1. Arias D, Saxena S, Verguet S. Quantifying the global burden of mental disorders and their economic value. eClinical Medicine 2022; 54:101675.
2. Baltussen R, Marsh K, Thakola P, et al. Multicriteria decision analysis to support health technology assessment agencies: benefits, limitations, and the way forward Value Health 2019; 22(11):1283-1288.
3. Bertram MY, Lauer JA, De Joncheere K, Edejer T, Hutubessy R, Kieny M-P, Hill SR. Cost-effectiveness thresholds: pros and cons. Bulletin of the World Health Organization 2016; 94(12):925-930.
4. Bloom, D.E., Cafiero, E.T., Jané-Llopis, E, Abrahams-Gessel, S, Bloom, L.R., Fathima, S, et al. The Global Economic Burden of Non-communicable Diseases [Internet]. Geneva: World Economic Forum; Available from: http://www3.weforum.org/docs/WEF_Harvard_HE_GlobalEconomicBurdenNonCommunicableDiseases_2011.pdf.
5. Bloom DE, Chen S, Kuhn M, McGovern ME, Oxley L, Prettner K. The economic burden of chronic diseases: Estimates and projections for China, Japan, and South Korea. The Journal of the Economics of Ageing. 2020 Oct 1;17:100163.
6. Cardoso DS, Dahis R. 2020. Value of a Statistical Life Under Large Mortality Risk Change: Theory and an Application to COVID-19'. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3599529.
7. Chang AY, Stevens GA, Cardoso DS, Cao B, Jamison DT. The economic burden of avoidable mortality, 2000-2050. In Unlocking the Power of Healthy Longevity: Compendium of Research for the Healthy Longevity Initiative. Washington, DC: World Bank. 2024.
8. Chen S, Cao Z, Prettner K, et al. Estimates and projections of the global economic cost of 29 cancers in 204 countries and territories from 2020 to 2050. JAMA Oncology 2023; 9(4):465-472.
9. Christensen K, Doblhammer G, Rau R, Vaupel JW. Ageing populations: the challenges ahead. Lancet 2009; 374:1196-1208.
10. Drummond MF, Sculpher MJ, Claxton K, Stoddart GL, Torrance GW. Methods for the economic evaluation of health care programmes (4th ed.). Oxford, UK: Oxford University Press; 2015.
11. Hammitt JK. 2020. Valuing Mortality Risk in the Time of COVID-19'. Journal of Risk and Uncertainty 61 (2):129-54.
12. Institute for Health Metrics and Evaluation (IHME). GBD 2019. Seattle: University of Washington, 2022. Available from: https://vizhub.healthdata.org/gbd-compare/.
13. Jamison DT, Summers LH, Alleyne G, et al. Global health 2035: a world converging within a generation. Lancet 2013; 382:1898-1955.
14. Jamison DT, Jha P, Laxminarayan R, Ord T. Infectious disease. In: Global problems, smart solutions: costs and benefits, Lomborg B (editor). Cambridge, UK: Cambridge University Press, 2013.
15. Jha P, Hum R, Nugent R, Verguet S, Bloom D. Chronic disease. In: Global problems, smart solutions: costs and benefits, Lomborg B (editor). Cambridge, UK: Cambridge University Press, 2013.
16. Khadka A, Verguet S. The economic value of changing mortality risk in low- and middle-income countries: a systematic breakdown by cause of death. BMC Medicine 2021; 19:156.
17. Kontis V, Bennett JE, Mathers CD, et al. Future life expectancy in 35 industrialised countries: projections with a Bayesian model ensemble. Lancet 2017; 389:1323-1335.
18. Mathers CD, Loncar D. 2006. Projections of Global Mortality and Burden of Disease from 2002 to 2030. PLoS Medicine 3 (11):e442.
19. Mathers CD, Stevens GA, Boerma T, White RA, Tobias MI. Causes of international increases in older age life expectancy. Lancet 2015; 385(9967):540-548.
20. Murray CJ, Acharya AK. Understanding DALYs (disability-adjusted life years). Journal of Health Economics 1997; 16(6):703-730.
21. NCD Countdown 2030 collaborators. NCD Countdown 2030: efficient pathways and strategic investments to accelerate progress towards the Sustainable Development Goal target 3.4 in low- and middle-income countries. Lancet 2022; 399:P1266-1278.
22. Neumann PJ, Sanders GD, Russell LB, Siegel JE, Ganiats TG. Cost-Effectiveness in Health and Medicine (2nd ed.). Oxford, UK: Oxford University Press; 2015.
23. Robinson LA, Hammitt JK, O'Keeffe L. Valuing mortality risk reductions in global benefit-cost analysis. Journal of Benefit Cost Analysis 2019; 10(suppl 1):15-50.
24. Robinson LA, Hammitt JK, Cecchini M, Chalkidou K, Claxton K, Hoang-Vu Eozenou P, de Ferranti D, et al. 2019. Reference Case Guidelines for Benefit-Cost Analysis in Global Health and Development, May, 126.
25. Partridge L, Deelen J, Slagboom PE. Facing up to the global challenges of ageing. Nature 2018; 561:45-56.
26. Spasova S, Baeten R, Vanhercke B. Challenges in long-term care in Europe. Eurohealth Observer 2018; 24(4):7-12.
27. Tynkkynnen L-K, Pulkki J, Tervonen-Goncalves, et al. Health system reforms and the needs of the ageing population – an analysis of recent policy paths and reform trends in Finland and Sweden. European Journal of Ageing 2022; 19:221-232.
28. United Nations. Department of Economic and Social Affairs. World Population Prospects 2022. New York, NY: United Nations, 2022. Available from: https://population.un.org/wpp/ (accessed April 26, 2022).
29. Vaupel JW, Villavicencio F, Bergeron-Boucher M-P. Demographic perspectives on the rise of longevity. PNAS 2021; 118(9):e2019536118.
30. Verguet S, Laxminarayan R, Jamison DT. Universal public finance for tuberculosis treatment in India: an extended cost-effectiveness analysis. Health Economics 2015; 24(3):318-332.
31. Verguet S, Hailu A, Eregata GT, et al. Toward universal health coverage in the post-COVID-19 era. Nature Medicine 2021; 27(3):380-387.
32. Verguet S, Norheim OF. Estimating and comparing health and financial risk protection outcomes in economic evaluations. Value in Health 2022; 25(2):238-246.
33. Viscusi K, Aldy JE. The value of a statistical life: a critical review of market estimates throughout the world. Journal of Risk and Uncertainty 2003; 27:5-76.

34. Viscusi K, Masterman CJ. Income elasticity and the global value of a statistical life. Journal of Benefit-Cost Analysis 2017; 8(2):226-250.
35. Watkins DA, Yamey G, Schaferhoff M, Adeyi O, Alleyne G, Alwan A, et al. Alma-Ata at 40 years: reflections from the *Lancet* Commission on Investing in Health. Lancet 2018; 392:P1434-1460.
36. Watkins DA, Qi J, Kawakatsu Y, Pickergill SJ, Horton SE, Jamison DT. Resource requirements for essential universal health coverage: a modelling study based on findings from *Disease Control Priorities*, 3rd edition. Lancet Global Health 2020; 8(6):e829-e839.
37. Weinstein MC, Torrance G, McGuire A. QALYs: the basics. Value in Health 2009; 12(2)(suppl 1):S5-S9.
38. Woods B, Revill P, Sculpher M, Claxton K. Country-level cost-effectiveness thresholds: initial estimates and the need for further research. Value in Health 2016; 19(8):929-935.
39. World Bank. World Development Indicators. Available from: https://datatopics.worldbank.org/world-development-indicators/ (accessed May 13, 2022).
40. World Health Organization. 2020a. Global Health Estimates. 2020. Available from: https://www.who.int/data/global-health-estimates.
41. Word Health Organization. 2020b. WHO methods and data sources for country-level causes of death 2000-2019. Available from: https://cdn.who.int/media/docs/default-source/gho-documents/global-health-estimates/ghe2019_cod_methods.pdf?sfvrsn=37bcfacc_5.