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DISCUSSION PAPER SERIES

IZA DP No. 13549

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ABSTRACT

Lives and Livelihoods: Estimates of the Global Mortality and Poverty Effects of the COVID-19 Pandemic*

This paper evaluates the global welfare consequences of increases in mortality and poverty generated by the Covid-19 pandemic. Increases in mortality are measured in terms of the number of years of life lost (LY) to the pandemic. Additional years spent in poverty (PY) are conservatively estimated using growth estimates for 2020 and two different scenarios for its distributional characteristics. Using years of life as a welfare metric yields a single parameter that captures the underlying trade-off between lives and livelihoods: how many PYs have the same welfare cost as one LY. Taking an agnostic view of this parameter, estimates of LYs and PYs are compared across countries for different scenarios. Three main findings arise. First, as of early June 2020, the pandemic (and the observed private and policy responses) has generated at least 68 million additional poverty years and 4.3 million years of life lost across 150 countries. The ratio of PYs to LYs is very large in most countries, suggesting that the poverty consequences of the crisis are of paramount importance. Second, this ratio declines systematically with GDP per capita: poverty accounts for a much greater share of the welfare costs in poorer countries. Finally, the dominance of poverty over mortality is reversed in a counterfactual herd immunity scenario: without any policy intervention, LYs tend to be greater than PYs, and the overall welfare losses are greater.

JEL Classification: D63, I15, I32, O15
Keywords: COVID-19, welfare, poverty, mortality

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1 Introduction

In 2020, the world is experiencing possibly its most severe global crisis since the Second World War. The Covid-19 pandemic is first and foremost a health crisis. In the six months since the first cases were reported in Wuhan Province, China, in December 2019, 7.1 million cases and 406,000 deaths were confirmed worldwide by June 9,[1] and this is widely held to be an underestimate. Yet, there are other welfare costs beyond those associated with mortality induced by the disease. The disease itself and the policy and individual behavioral responses to it have induced massive economic supply and demand shocks to essentially every country in the world, triggering the deepest economic crisis since the Great Depression of the 1930s.

The fact that the bulk of the non-pharmaceutical interventions in response to the epidemic, such as lockdowns, mandatory social distancing and the like, contribute to the economic costs - by preventing many or most workers from reaching production sites and consumers from demanding certain goods and services that cannot be consumed from home - has led to important debates on the optimal policy choice in the face of an apparent trade-off between lives and livelihoods (i.e. incomes and jobs). This trade-off is for instance discussed by Gourinchas (2020).[2]

Although potentially crucial for shaping the policy response, analysis of this trade-off is complicated by the fact that it inherently involves evaluating human lives. Economists typically compare economic costs to human lives using one of three approaches: attaching a monetary value to human life (Viscusi, 1993; Rowthorn, 2020), estimating the indirect mortality that economic losses could imply (Ray and Subramanian, 2020), or resorting to social welfare defined as expected lifetime utility (Becker et al., 2005; Jones and Klenow, 2016; Alon et al., 2020).

While each of these approaches has its merits, none is problem-free. Although many economists find it meaningful to place a price on human life, most people find the idea repugnant.[3] This limits the ability of the first approach to productively inform the public and political debate. Another severe limitation of the monetary value approach is that it is typically insensitive to the distribution of economic losses, which is key when analyzing this trade-off.[4] The second approach, which involves computing the indirect mortality caused by the economic losses, requires making strong assumptions about governments' and individuals' reactions to these losses. Importantly, when investigating the indirect mortality associated with the Great Recession, studies typically find that mor-

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[1] This figure is reported on the Covid-19 Dashboard by the CSSE at Johns Hopkins University & Medicine (www.coronavirus.jhu.edu).

[2] Even if there exists such a trade-off, some policies can be dominated in terms of both their mortality and economic consequences, as shown for instance by Acemoglu et al. (2020).

[3] For instance, on May the 5th, New York governor Andrew Cuomo declared during his daily briefing: "How much is human life worth? [. . .] To me, [. . .] a human life is priceless. Period."

[4] Pindyck (2020) discusses additional limitations associated to classical VSL evaluations.

tality was actually reduced, rather than increased, during the recession (Modrek et al., 2013; Tapia Granados and Iolides, 2017).[5]

The third approach, based on social welfare analysis, has solid theoretical and ethical foundations. Yet, in its standard form, this approach generally requires selecting values for many parameters entering the definition of individuals' expected utility, such as a discount factor and the concavity of instantaneous utility. These choices are inevitably arbitrary, but they can have significant effects on the results. More importantly, none of their parameters directly and transparently captures the trade-off between human lives and economic losses. If this implicit trade-off can only be understood and discussed by specialists, this third approach cannot provide a decent basis for public debates on this trade-off. This is a major issue given that public opinion may strongly influence policy choices.[6]

Our approach is rooted in social welfare analysis, but it differs from the earlier literature in at least two important respects. First, drawing on Baland et al. (2020), we express the key trade-off in terms of years of human life, rather than in monetary units. We measure the impact of the pandemic on human lives by the number of years of life lost to Covid-induced premature mortality (lost-years, LYs), and its economic impact by the additional number of years spent in poverty (poverty-years, PYs).[7] The second difference is that this change in metric allows us to focus on a single, central normative parameter, namely the shadow price α attached to one lost-year, expressed in terms of poverty-years. Essentially this parameter captures how many poverty-years are as costly (in social welfare terms) as one lost-year.

Ideally, this parameter should take a value close to the average answer that individuals would give to the following question: how many years of your remaining life would you be willing to spend in poverty in order to increase your lifespan by one year?[8] Importantly, we do not take a view on the exact value for this parameter. Rather, we present estimates of the number of lost-years and the number of poverty-years induced by the pandemic for each country, under a few different scenarios. The estimates of PY/LY ratios are interpreted as empirical analogues to α. They tell us how many additional years are spent in poverty for each year of life lost to Covid-induced mortality in that country and scenario. It is left to the reader to form an assessment of which source of welfare loss is dominant.

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[5] A potential explanation for this finding is that behaviors change during recessions, which invalidates the assumptions on which indirect mortality assessments are based.

[6] In democratic regimes, politicians are incentivized to pander to public opinion (Maskin and Tirole, 2004). That is, a politician may intentionally select a sub-optimal policy in order to secure her re-election, if this policy is "popular" among poorly informed voters.

[7] For instance, if an additional 4 percentage points of a 10 million people population spends two years in poverty, this implies 0.8 million poverty-years.

[8] To be more precise, this question should specify that the number of years that the individual already expects to spend in poverty should not be counted in her answer.

We take a conservative approach, in the sense that our methodological choices are designed to provide an “upper-bound” to the number of lost-years and a “lower-bound” to the number of poverty-years. The number of lost-years caused by a given death is taken to be the country-specific residual life-expectancy at the age at which this death takes place.[9] The number of poverty-years generated in a given country is taken to be the variation in the country’s population living under the poverty threshold, caused by the Covid-induced drop in GDP currently forecast by Central Banks and the World Bank’s Global Economics Prospect. This variation corresponds to the number of poverty-years because we assume that these individuals only remain poor for a single year. Making this assumption is conservative because we ignore any long-term effects of additional poverty, such as insults to child development from worse nutrition in early childhood; learning costs from school closures; possible hysteresis effects of unemployment, and so on. In our baseline scenario, we also assume that the economic contraction is distribution neutral, i.e. that there is no change in inequality. This is conservative since most available evidence so far suggests that the economic costs of the pandemic disproportionately burden poorer people (Bonavida Foschiatti and Gasparini, 2020).[10]

To the best of our knowledge, we provide the first welfare analysis of the current consequences of the pandemic. Yet, our analysis is related to a number of recent papers. First, we borrow the time-units metric for a normative evaluation of the relative welfare costs of mortality and poverty from Baland et al. (2020). These authors employ that metric for an assessment of deprivation, whereas we use it for assessing welfare. Also, they apply their indicators to global deprivation before the outbreak of the pandemic. Second, Sumner et al. (2020), Laborde et al. (2020) and Lakner et al. (2020) estimate the Covid-induced increase in global poverty. We base our poverty estimates on the methodology developed by Lakner et al. (2020). Third, based on a social welfare analysis which resorts to a price for a human life, Hall et al. (2020) compute the fraction of GDP that the United States would be willing to give up in order to avoid all potential Covid-induced deaths. Fourth, Bethune and Korinek (2020) show that social welfare in the United States is not maximized under a no-intervention scenario. Fifth, Alon et al. (2020) independently investigate the differential mortality risks between developed and developing countries. In line with our findings, they find that Covid-induced mortality plays a larger role in the welfare consequences of lockdowns in developed countries than in developing countries.

Also relevant for our work, though perhaps less closely related, is the analysis by Bargain and Ulugbek (2020) on how poverty is associated with differential impacts of the pandemic on human mobility to work and, through that channel, on the spread of the

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[9] This is conservative to the extent that individuals already having health issues such as diabetes or heart problems are more susceptible to die than healthy individuals.

[10] For instance, Montenovo et al. (2020) show that already disadvantaged groups are disproportionately affected by Covid-induced job losses in the United States.

disease itself. Abay et al. (2020) investigate the economic consequences of the pandemic by using Google search data to estimate the effects of the crisis on the demand for different services across 182 countries.

The remainder of the paper is organized as follows. Section 2 provides a simple conceptual framework that explicitly anchors the comparison between lost-years and poverty-years on standard social welfare analysis. Section 3 presents mortality and poverty estimates as of early June 2020, first for a set of six countries (three developed and three developing) for which Covid-19 mortality data disaggregated by age are available (Section 3.1) and then for the rest of the world, using the age-distribution of deaths from population pyramids and infection-to-fatality ratios documented by Salje et al. (2020) and Verity et al. (2020) (Section 3.2). In both samples, the number of poverty-years is almost always at least 10 times larger than the number of lost-years. In many cases, the PY/LY ratio is above 100 or even 1,000. This suggests that, for most countries in the world, the welfare losses from the Covid-19 pandemic arise disproportionately from increases in poverty. This section also documents that the trade-off between human lives and poverty costs varies substantially with countries' GDP per capita, with developed countries facing both much larger mortality costs and much smaller poverty costs than developing countries - suggesting that the best policy responses may differ by country.

Section 4 then compares the estimated welfare consequences as of early June to a counterfactual "no-intervention" scenario in which contagion only stops when herd immunity is reached.[11] This permits a cleaner comparison of potential mortality burdens across different countries, since looking only at current mortality is hampered by the fact that countries are in different stages of the epidemic. In most countries, we find that the number of lost-years under "no-intervention" are considerably larger than the sum of the lost-years and poverty-years generated as of early June. This implies that, even if we conservatively assume that the "no-intervention" scenario has no poverty consequences, its negative welfare consequences are larger than the current welfare consequences as of early June.[12] This strongly suggests that no-intervention was - or would have been - a suboptimal policy, particularly in richer countries. Section 5 concludes.

2 A simple conceptual framework

This section briefly explains how our empirical comparison between years of life lost (LY) and additional years lived in poverty (PY) can be interpreted in terms of a standard

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[11] We follow Banerjee et al. (2020), whose "no-intervention" scenario assumes that herd immunity for Covid-19 comes about when 80% of the population is immunized.

[12] Coming up with a convincing counterfactual under alternative policies than the one actually implemented is, of course, challenging. Nonetheless, several papers are now trying to model how behaviors and macroeconomic outcomes change during pandemics, using such counterfactuals (see Eichenbaum et al. (2020) or Garibaldi et al. (2020)).

utilitarian social welfare function, modified by the simplifying assumption that period utility depends only on being alive and non-poor, alive but poor, or dead. The approach is closely inspired by Baland et al. (2020), who apply it to a (different) problem in poverty measurement, i.e. developing poverty measures that account for premature mortality. It is modified to suit our present purpose.

Consider a fixed calendar year T. For a given country, denote the set of individuals who are alive at time T by I, indexed by i. The expected residual longevity of individual i at time T is given by $d_i - T$, where d_i is the expected year of her death. In each calendar year t with $T \leq t \leq d_i$, individual i has expected status s_{it}, which is either being poor (P) or being non-poor (NP). The expected future lifetime utility of individual i is

$$U_i = \sum_{t=T}^{d_i} u(s_{it}),$$

where u is the instantaneous utility function, with $u(NP) > u(P) > 0$.[13] Let the instantaneous utility of being dead equal zero.[14] Abstracting from future births, a simple utilitarian expected social welfare function in this country is:

$$W = \sum_{i \in I} U_i.$$

Now assume that a pandemic starts in year T and can affect individual i's lifetime utility in two ways. First, its economic costs may change her status from $s_{it} = NP$ to $s'_{it} = P$, for one or more years t following the outbreak. Let $\Delta u_p = u(NP) - u(P)$ denote the instantaneous utility loss from becoming poor for one period. Second, the mortality associated with the pandemic can advance the year of the individual's death to an earlier calendar year $d'_i \leq d_i$. Let Δu_d denote the instantaneous utility loss of losing one period due to premature mortality.[15]

Our definition of U_i implies that Δu_d should in principle depend on the counterfactual status s_{it} that individual i would have had in $t \geq d'_i$ in the absence of pandemic. To avoid the normatively unappealing consequence of valuing the cost of premature mortality differently for the poor and the non-poor, we impose that the counterfactual status s_{it} equals NP for all $d'_i \leq t \leq d_i$ and for all i. In other words, the utility loss from each year of life lost to the pandemic is $\Delta u_d = u(NP)$, identically for everyone.

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[13] For simplicity, we assume that individuals do not discount the future.

[14] Note that this formulation is inherently conservative, in the sense that income losses that take place above or below the poverty line, without causing a crossing of that line, do not contribute to welfare losses by assumption.

[15] Both Δu_p and Δu_d are assumed to be constant over time and across individuals, and thus have no i or t subscripts. Because we focus in this paper on the mortality and poverty costs of the pandemic, we abstract from various other possible effects of a pandemic, such as the long-term effects of additional malnutrition for children, or of school stoppages. Similarly, for simplicity, we do not allow for people to be made richer or to gain additional life years from the pandemic.

Continuing to use the operator Δ to denote the expected consequences of the pandemic relative to a non-pandemic counterfactual, we can write the change in individual expected utility as:

$$\Delta U_i = U'_i - U_i = \sum_{t=T}^{d'_i} \mathbb{1}(s_{it}, s'_{it}) \Delta u_p + \sum_{t=d'_i}^{d_i} \Delta u_d,$$

where $\mathbb{1}(s_{it}, s'_{it})$ takes value 1 if $s_{it} = NP$ and $s'_{it} = P$, and takes value 0 otherwise.

Since $u(P) > 0$, then $\Delta u_d > \Delta u_p$, and we can write $\Delta u_d = \alpha \Delta u_p$ for some $\alpha > 1$. Aggregating across individuals, the change in social welfare is given by:

$$\Delta W = \sum_{i \in I} \Delta U_i = \sum_{i \in I} \left(\sum_{t=T}^{d'_i} \mathbb{1}(s_{it}, s'_{it}) \Delta u_p + \sum_{t=d'_i}^{d_i} \alpha \Delta u_p \right).$$

Now define LY and PY as the sums of years lost to premature mortality and poverty, respectively, across the population, calculated as follows:

$$LY = \sum_{i \in I} (d_i - d'_i),$$

$$PY = \sum_{i \in I} \sum_{t=T}^{d'_i} \mathbb{1}(s_{it}, s'_{it}).$$

Then the total impact on welfare of the pandemic ΔW is proportional to the weighed sum of the numbers of lost-years and poverty-years, i.e.:

$$\frac{\Delta W}{\Delta u_p} = \alpha LY + PY, \tag{1}$$

where the parameter $\alpha = \frac{\Delta u_d}{\Delta u_p} > 1$ captures how many poverty-years have the same impact on welfare as one lost-year. In our framework, this parameter captures the normative trade-off between mortality and poverty costs. Although it is expressed in time-units instead of monetary-units, this parameter plays the same role as the dollar value of a human life in other analyses. In this paper, we leave to the reader the choice of her preferred value for parameter α, imposing only the lower bound at one derived above.

3 Welfare costs as of early June

In this section, we study the welfare consequences of the pandemic as of early June 2020. In particular, we are interested in the relative contribution of poverty and mortality costs to the overall welfare losses in each country. To answer this question, we estimate a country's number of lost-years and compare it to an estimate of its number of poverty-years.

Equation (1) tells us that to arrive at the relative contribution of the two components, one would need a value for α, which we wish to remain agnostic about. Our approach is to compute for each country (in each scenario) the value of α an observer would have to hold so as to judge that Covid-related mortality and additional poverty make identical contributions to the welfare costs of the pandemic, given the observed outcomes. Using a superscript A to denote actual, or estimated, outcomes, this "break-even" α, which we call $\hat{\alpha}$, is given by:

$$\hat{\alpha} = \frac{PY^A}{LY^A}.$$

For any $\alpha < \hat{\alpha}$, additional poverty is the dominant source of the current welfare costs of the pandemic.

3.1 Six countries with high-quality data

We first look at a restricted sample of six countries for which we have data on age-specific mortality from Covid-19.[16] Three of them are high-income countries: Belgium, the United Kingdom (UK) and Sweden. We selected these three countries because they had the highest number of Covid-deaths per capita as of early June.[17] The three remaining countries are developing countries for which age-specific mortality data are available as of early June: Pakistan, Peru and the Philippines. For each of these countries, we estimate LY^A and PY^A as follows.

To estimate a country's number of lost-years, we start from the age-specific mortality information: the number of Covid-related deaths distributed by age categories. Where available for individual countries, this information is obtained from Offices of National Statistics, Ministries of Health or other government offices. A specific list is included in Table A1 in the Appendix.[18] Then, for each death we assume that the number of lost-years is equal to the residual life-expectancy at the age of death, as computed from the country's pre-pandemic age-specific mortality rates, obtained from the *Global Burden of Disease* Database (Dicker et al., 2018). As noted earlier, we consider this assumption conservative, since individuals who die from Covid-19 are given the same residual life-expectancy as that of other individuals with the same age.

One particularity of Covid-19 is that its mortality is concentrated among the old. This concentration is illustrated in Figure 1, which shows a histogram by age categories of the Covid-19 deaths observed in Sweden. This concentration implies that evaluations of mortality costs based on lost-lives, which disregard the age distribution of deaths, would tend to overestimate the welfare consequences of mortality, compared to our evaluation

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[16] It is not possible to find age-specific mortality information for all countries.

[17] Belgium has the highest number, the United Kingdom has the second highest and Sweden has the fifth highest, beyond Italy and Spain, but Sweden has particularly detailed age-specific mortality information.

[18] All of our data sources are described in greater detail in the Appendix.

based on lost-years. In the case of Sweden, ignoring the age distribution of deaths would inflate the importance of mortality by a factor of 4.5.[19]

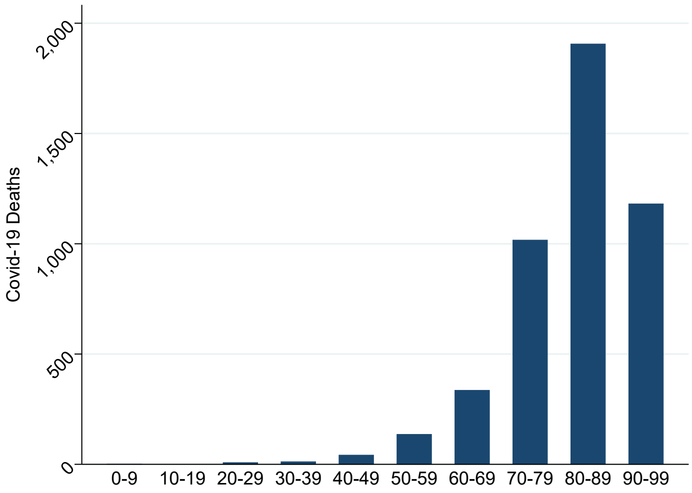

Figure 1: Distribution of Covid-19 deaths per age in Sweden as of early June.

To estimate each country's number of poverty-years, we first take the income distribution for each country from PovcalNet for 2018, which is the latest year for which data are available. Next, we scale these distributions to 2020 by assuming that all household incomes grow in accordance with growth rates in real GDP per capita, meaning that the growth is distribution-neutral. We do so under two different growth scenarios: (1) using GDP growth estimates for 2019 and 2020 from around June 2020, which incorporate the expected impacts of the pandemic and associated policy responses, and (2) using GDP growth estimates for 2019 and 2020 from around January 2020, before Covid-19 took off. Central Bank growth estimates are used for Sweden, Belgium and the United Kingdom while growth estimates from the January and June 2020 edition of the World Bank's *Global Economic Prospects* (GEP) are used for Pakistan, Peru and Philippines (The World Bank, 2020).

Finally, following Lakner et al. (2020) but using each country's most recent national poverty line, the impact of Covid-19 on poverty is computed by comparing the number of poor under the two growth scenarios.[20] Denoting the number of poor people in year

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[19] If the same number of deaths were to be distributed at random in the population, they would generate 4.5 as many lost-years as the current distribution. This factor is equal to the average residual life-expectancy in Sweden (43 years) divided by the average residual life-expectancy of those dying (9.5 years).

[20] In all projections, it is assumed that only 85 percent of growth in GDP per capita is passed through to growth in welfare observed in household surveys in line with historical evidence (Lakner et al., 2020). In contrast to the data from PovcalNet which are expressed in 2011 PPPs and in per capita terms, the national poverty lines for Pakistan, Peru and the Philippines are expressed in local currency units and per adult equivalents. To convert the national poverty lines into 2011 PPPs and per capita terms we follow the approach of Jolliffe and Prydz (2016), which is to find the poverty line in per capita 2011 PPPs that gives the same poverty rate as the national poverty line in local currency units and per adult

y estimated on the basis of the growth estimate from month m in 2020 by H_y^m, PY^A is estimated by the difference in differences:

$$PY^A = \left(H_{2020}^{June} - H_{2019}^{June}\right) - \left(H_{2020}^{Jan} - H_{2019}^{Jan}\right)$$

While we cannot rule out that GDP estimates might have changed for reasons unrelated to Covid over this time interval (January - June 2020), it is safe to say that most of the changes are due to Covid-19. The difference in differences calculation assures that changes in the 2019 growth rates, which cannot have been due to Covid-19, are eliminated. We assume that this additional poverty lasts only for one year, so that the number of poverty-years is directly equal to this additional number of poor people. Our analysis therefore focuses on the short-term effects of the pandemic on poverty.

These are conservative assumptions, in the sense of yielding a small number of poverty-years, for at least two reasons. First, we assume that the additional poverty generated by the pandemic lasts only for one year. This assumption also allows us to avoid using GDP forecasts beyond 2020, the uncertainty around which is extremely large. Second, our baseline scenario assumes that all incomes grow - or shrink - in the same proportion, although there are reasons to believe that the poor could be affected more than proportionally by the recession (Bonavida Foschiatti and Gasparini, 2020).

The results for our six countries are summarized in Table 1. We explain how to read Table 1 using the case of Sweden. The first six rows present basic economic and demographic indicators, such as Sweden's GDP per capita, population, life-expectancy at birth, etc. The second panel presents mortality statistics. Given the age-distribution of the 4,639 Covid-related deaths recorded in Sweden (shown in row 7), each death leads on average to 9.5 lost-years. The total number of years of life lost in Sweden (up to early June 2020) is obtained by multiplying these two numbers: 43,973. The third panel turns to the economic shock. The Central Bank of Sweden forecasts a GDP reduction of 11.5 percentage points as a result of the Covid-19 pandemic. Under our distribution-neutral growth assumption, this GDP reduction leads to an additional 410,000 poor people, with respect to the national poverty line of 28.9 dollars per person per day (in 2011 PPP exchange rates). As we conservatively assume they are poor for one year only, this figure is directly equal to the number of poverty-years. The last row in Table 1 provides the "break-even" $\hat{\alpha}$ ratios. In the case of Sweden, there are 9.4 times as many poverty-years as lost-years. This means that the two sources of welfare costs would have the same magnitude if 9.4 poverty-years were judged to be as bad as one lost-year. Finally, we provide the *per-capita* numbers of lost-years and poverty-years, which simplifies comparisons. In Sweden, the additional poverty corresponds to 0.0409 years

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equivalents. The national poverty line used for Sweden, Belgium and the United Kingdom is 60% of median income in 2019. We keep this lined fixed at the 2019 level also for 2020 to avoid a shift in poverty lines.

per person while the number of lost-years corresponds to 0.0044 years per person.

Table 1: Estimation of the pandemic's welfare costs in six countries as of early June 2020 (baseline, distribution-neutral contraction)

	(1) Belgium	(2) Sweden	(3) UK	(4) Pakistan	(5) Peru	(6) Philippines
Economic and demographic characteristics						
GDP p.c. in 2017 (2011 PPP$)	43,133	47,261	40,229	4,764	12,517	7,581
National poverty line (2011 PPP$)	27	28.9	25.8	2.8	5.3	2.6
Population (in millions)	11.59	10.10	67.88	221.0	32.98	109.5
Life expectancy at birth	81.18	82.31	80.78	65.98	80.24	69.51
Age (mean)	41.42	41.14	40.62	25.86	32.53	28.53
Residual life expectancy (mean)	42.01	43.06	42.40	46.25	50.55	44.92
Covid-19 mortality, current scenario						
Number of deaths	9,605	4,639	48,848	2,056	5,465	1,002
LYs per death	9.467	9.479	10.14	18.46	21.97	16.90
LYs per person	0.00785	0.00435	0.00730	0.000172	0.00364	0.000155
Covid-19 economic shock						
On GDP per capita (in %)	-8.5	-11.5	-14.5	-6.7	-13.1	-8.4
On poverty HC (in million)	0.32	0.41	4.37	7.39	1.58	2.96
On poverty HCR	0.0279	0.0409	0.0644	0.0335	0.0480	0.0270
Break-even $\hat{\alpha}$	3.553	9.383	8.816	194.8	13.20	174.8

The main finding of this section, from an inspection of Table 1, is that the poverty costs are very substantial relative to the mortality costs. This is obvious in the case of Pakistan and the Philippines, for which the break-even $\hat{\alpha}$ are 195 and 175, respectively. It is relatively clear as well in the case of Peru, for which break-even $\hat{\alpha}$ is 13. If one were to take the view that $\alpha = 10$, then Sweden and the United Kingdom would be very near the break-even point at which the welfare costs of the pandemic arise in equal parts from greater poverty and mortality. Under that assumption ($\alpha = 10$), Belgium (with $\hat{\alpha} = 3.6$) would be the only country in our sample for which Covid-induced mortality is the dominant source of welfare losses from the current crisis. All things considered, it seems safe to say that, given individual and public policy responses, the poverty costs of the pandemic in these six countries are not dwarfed by its mortality costs. Indeed, for most plausible parameter estimates, the reverse is true (at least) in Pakistan and the Philippines.

3.2 The whole world

The findings above suggest that the poverty effects of the pandemic are substantial, even in relation to its mortality effects. They also hint at a possible pattern where that cost ratio is much larger for developing countries relative to developed countries. To investigate those conjectures further, we go beyond our six-country sample, and extend the analysis to as many countries as possible.

Unfortunately, publicly available data on Covid-related deaths are not distributed by age-categories for most countries in the world, which prevents us from directly computing the number of lost-years. In order to overcome this problem, we assume that country-specific infection probabilities are independent of age. Then, using estimates of Covid's age-specific infection-to-fatality ratios (IFR), we can infer the infection rate necessary to yield the number of deaths observed in the country, given its population pyramid. For developing countries, we use the age-specific IFR ratios estimated for China by Verity et al. (2020). For developed countries, we use analogous ratios estimated for France by Salje et al. (2020).

Formally, let N_{aj} denote the size of the population of age a in country j, d_{aj} the number of Covid-related deaths at age a in country j, d_j the total number of Covid-19 deaths in country j, and μ_{aj} the IFR at age a in country j. The proportion of people who are or have already been infected by Covid-19 in country j is estimated as:

$$\varphi_j = \frac{d_j}{\sum_{a=0}^{99} N_{aj}\mu_{aj}}. \tag{2}$$

The number of Covid-related deaths at age a in country j is given by

$$d_{aj} = \varphi_j N_{aj}\mu_{aj}. \tag{3}$$

Our global estimates of the poverty impacts of Covid-19 come from Lakner et al. (2020). There are two methodological differences between these estimates and those reported in Section 3.1. First, rather than using growth data from Central Banks, GDP estimates now come exclusively from the January and June 2020 editions of the World Bank's *Global Economic Prospects* (GEP) (The World Bank, 2020), supplemented with the April 2020 and October 2019 editions of the IMF's *World Economic Outlook* (WEO) when countries are not in the GEP (which mostly applies to high-income countries). As before, the extrapolation assumes distribution-neutral (negative) growth. Figure 2 below plots this difference in forecasts – the GDP shock due to Covid – against GDP per capita for the 150 countries in our sample. We continue to assume that this additional poverty lasts only for a single year, so that the number of poverty-years is equal to this additional number of poor people.

Second, instead of using national poverty thresholds, we use the World Bank's income class poverty thresholds, as derived by Jolliffe and Prydz (2016), namely \$1.90 per person per day in low-income countries (LICs); \$3.20 a day in lower-middle-income countries (LMICs); \$5.50 a day in upper-middle-income countries (UMICs); and \$21.70 a day in high-income countries (HICs). These lines were obtained as the median national poverty lines for each income category in a data set constructed by those authors.

Figure 3 shows the break-even $\hat{\alpha}$ for all 150 countries in our global sample, plotted

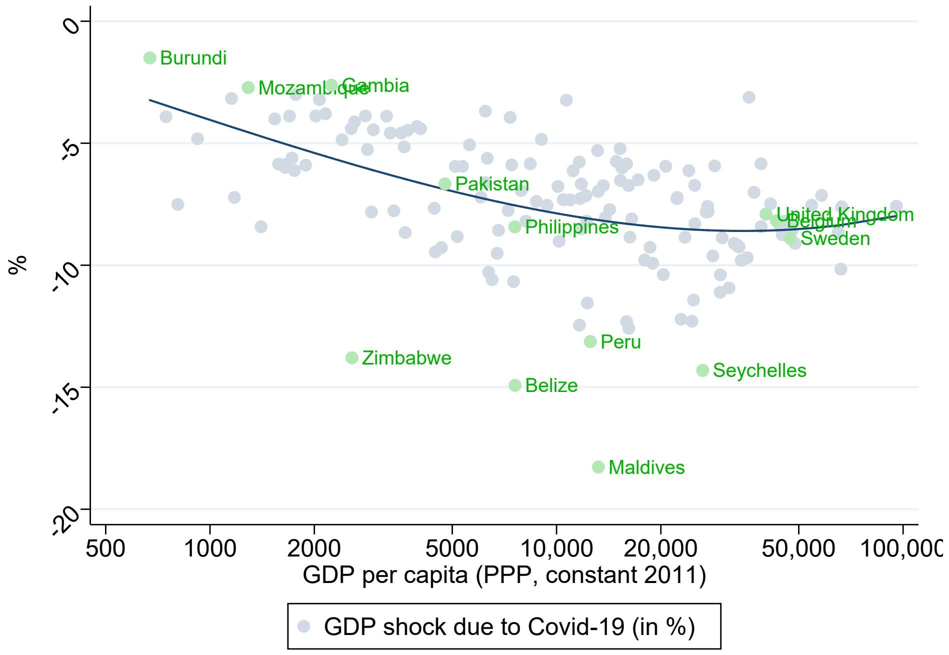

Figure 2: Shock to GDP due to Covid-19 (baseline estimates)

against GDP per capita. In order to average-out some of the measurement errors, we fit a line through these ratios for each income-based group of countries: LICs, LMICs, UMICs, and HICs. Noting that both axes in Figure 3 are in logarithmic scale, we observe a very pronounced negative slope in the relationship, despite the fact that poverty lines increase between country categories. Naturally, the downward slope is even more pronounced when a constant poverty line is used, as shown in Figure A.9 in the Appendix, for the international poverty line of \$1.90 per day. In fact, the fitted break-even $\hat{\alpha}$ ratios for low-income countries exceed 1,000, and, for middle-income countries, they are generally greater than 100. If we take seriously the interpretation of α suggested earlier - a value close to the average answer that individuals would give as to how many years of their remaining life they would be willing to spend in poverty in order to increase their lifespan by one year - then these empirical estimates of the break-even $\hat{\alpha}$ are extremely large, suggesting that the welfare costs from poverty typically dominate the mortality costs in poor countries. They are also quite large in many high-income countries, though not uniformly so: about a third of the HICs have $\hat{\alpha}$ in the $[1, 10]$ range.

This finding is further emphasized when considering less conservative estimates of the number of poverty-years generated by the pandemic. Our baseline estimates rely on the assumption that all incomes would shrink in the same proportion. Yet, the poor could be affected more than proportionally by the recession, in which case inequality would increase. The results of Bonavida Foschiatti and Gasparini (2020) for Argentina suggest that the recession generated by the response to the Covid-19 pandemic could increase the Gini coefficient by 3.6%. In order to account for possible increases in inequality, we

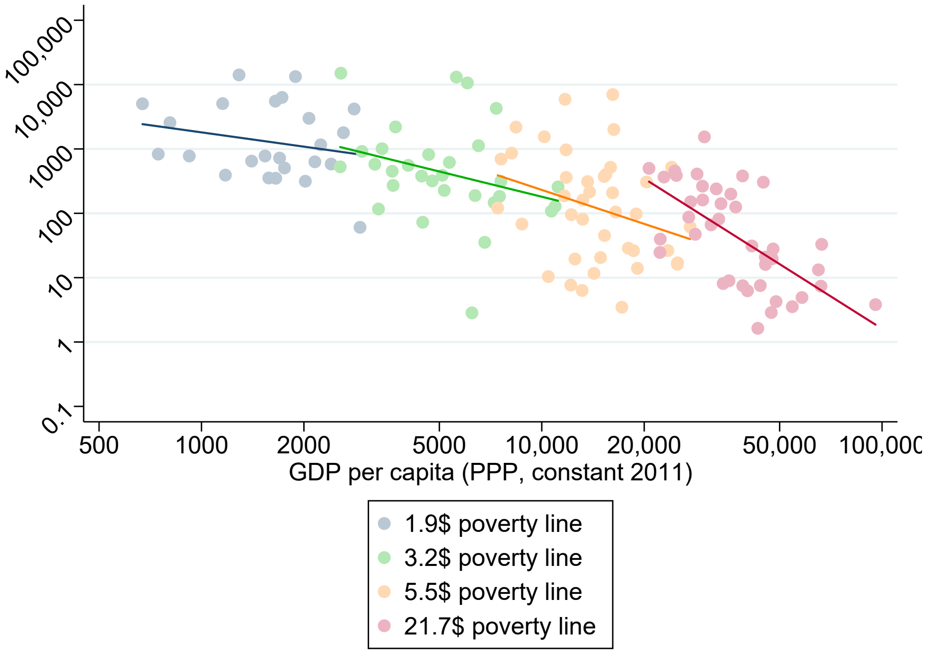

Figure 3: Break-even $\hat{\alpha}$ in all countries as of early June 2020 (baseline, distribution-neutral contraction)

compute a second estimate of poverty-years that is based on a 3.6% increase in Gini coefficients of all countries in 2020.[21]

We also consider the poverty impact in case the pandemic requires more stringent and sustained lockdown measures. To this end, we utilize the fact that the GEP also provides a downside growth scenario, which precisely assumes a worse and longer recovery phase (see Figure A.8).[22] Analogues of Figure 3 for each of these alternative poverty scenarios are shown in Figure A.10 in the Appendix.

Overall, Figures 3 and A.10 confirm that, if the epidemic suddenly ended at the beginning of June 2020, its poverty costs would in most countries be very large relative to its mortality costs, and especially so in developing countries. Importantly, however, this finding does not mean that lockdowns were misguided, excessively long, or too strongly enforced. Our findings so far do not allow any conclusions on the optimality of actual policy responses. They merely allow us to quantify different sources of the welfare impact of the crisis (the epidemic taken together with actual policy responses), as it unfolded up to early June.

There are two reasons why these results cannot be used to assess the policy response.

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[21] One challenge with modeling the impact of changes in Gini coefficients is that there are infinitely many possible distributional changes resulting in the same change in the Gini. Using the framework of Lakner et al. (2020), we assume that inequality increases in a manner consistent with a linearly increasing growth incidence curve, approximating what was found in Argentina.

[22] For most high-income countries, for which we are using WEO forecasts rather than GEP, there is only one GDP scenario, so the baseline and downside scenarios coincide.

First, different countries are still in different phases of the epidemic, and cross-country comparisons of break-even $\hat{\alpha}$ must take that into account. Second, the observed outcomes (which incorporate the actual responses) must be compared to plausible counterfactuals corresponding to alternative policy responses, to assess their relative merits. This is what we turn to next, using a counterfactual "no-intervention" policy scenario as a comparator.

4 Welfare costs under no-intervention

In this section, we investigate what the relative *potential* sizes of the two sources of welfare costs might be in a counterfactual "no-intervention" policy scenario. This allows us to shed light on the question of whether no-intervention could have been a superior policy response to that observed so far.

A no-intervention scenario implies that the epidemic only stops in a country once herd-immunity is achieved. We follow Banerjee et al. (2020) who consider that herd-immunity is achieved when 80% of the population has been infected by the virus. Under this scenario, all countries have the same infection rate, which allows comparing their potential mortality costs. We err on the side of caution by assuming that the poverty costs in the no-intervention scenario are zero. This is a conservative assumption, since even in the absence of lockdowns or other policy-driven measures, aversion behavior by individual workers and consumers is nonetheless likely to have led to non-trivial economic contractions. From Equation (1), we have that the actual welfare consequences ΔW^A would be equal to the no-intervention welfare consequences ΔW^{NI} when

$$\alpha LY^A + PY^A = \alpha LY^{NI} + PY^{NI}.$$

As we assume zero economic consequences under our no-intervention scenario ($PY^{NI} = 0$), this yields a second, different threshold value for the α parameter, namely $\tilde{\alpha}$:

$$\tilde{\alpha} = \frac{PY^A}{LY^{NI} - LY^A}$$

This is the value of α at which, given the estimated magnitudes of LY^A, PY^A, and LY^{NI}, the counterfactual welfare costs of mortality under the no-intervention scenario would equal the actual costs, $\alpha LY^A + PY^A$. For any $\alpha > \tilde{\alpha}$, the welfare consequences under the herd immunity scenario would have been worse than those estimated for the actual outcome.[23]

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[23] It should be evident that $\tilde{\alpha}$ is completely different from $\hat{\alpha}$, for any given country. In particular, $\tilde{\alpha}$ depends on counterfactual estimates of mortality under no-intervention in that country.

4.1 Heterogenous mortality under no-intervention

In this section, we perform a cross-country comparison of potential mortality burdens LY^{NI} under the no-intervention scenario. This exercise reveals the large quantitative differences in the potential number of lost-years between developing and developed countries.

We compute a country's potential number of lost-years under herd-immunity as follows. We assume an 80 % infection rate in all age categories of the population. The number of infected individuals in each age-category is computed from the country's population pyramid. The probability that an infected individual of a given age dies is deduced from age-specific infection-to-fatality ratios (IFR), once again using the IFR estimates for China from Verity et al. (2020) for developing countries, and those for France from Salje et al. (2020) for developed countries. Then, the number of lost-years for a given death is the country's residual life-expectancy at the age of death. Summing the lost-years over all deaths provides the potential number of lost-years.

We consider two no-intervention scenarios. Under the "saturation" scenario, we assume that contagion is fast and hospitals are overwhelmed by the flow of infected individuals in need of care. In order to reflect this, the IFR used assumes that all patients who would need intensive care cannot access ICU and die. This is our reference no-intervention scenario. Under the "no-saturation" scenario, we assume that contagion is slow and hospitals are not overwhelmed by the flow of infected individuals in need of care. Then, the IFRs used assume that all patients who would need intensive care have access to ICU. See Appendix A2 for more details.

Our estimates of the potential number of lost-years can differ across countries for three reasons: population pyramids, residual life-expectancies and IFR ratio used. We find that the potential mortality burden is several times larger in high-income countries than in low-income countries. This is despite the use of IFR from China in the latter countries, which implies more lost-years than the IFR from France would. To a large extent, this difference is the consequence of the concentration of Covid-deaths in old-age categories, as already illustrated in Section 3.1. Hence, younger populations in less developed countries reduce their potential mortality burden. An additional, but related, reason for this difference is that residual life-expectancies at given ages are smaller in less developed countries.

Table 2 illustrates the heterogenous mortality burdens for two countries: Japan and Zimbabwe. The population of Japan is considerably older than that of Zimbabwe. For instance, a third of Japan's population is older than 60 years, whereas less than 5% of Zimbabwe's population falls into that category. Residual life-expectancy in Japan is larger than that of Zimbabwe in each age-category presented. For instance, individuals in the 60+ population expect *on average* to live for 16 years in Japan, and only for 11 years in Zimbabwe.

Table 2: Mortality risks in Japan and Zimbabwe

	(1) Japan	(2) Zimbabwe
Population per age group (%)		
0-29	26.6	69.5
30-59	39.0	25.8
60+	34.4	4.69
Residual life-expectancy per age group		
0-29	69.1	52.7
30-59	40.1	28.8
60+	15.6	11.2
Covid-19 LYs per person		
No intervention and no saturation	0.102	0.0212
No intervention and saturation	0.204	0.0298

Moving beyond that illustrative two-country example, Figure 4 plots years of life lost to Covid-19 under the no-intervention scenarios (LY^{NI} per person) - both with and without saturation - against GDP per capita for all countries in our sample. Notice that once again both axes are in logarithmic scale. The figure shows that potential mortality burdens are several times larger in high-income countries than in low-income countries. Under the "saturation" scenario, a large fraction of high-income countries have a per capita number of lost-years above 0.1 years per person. This is in sharp contrast with low-income countries, whose per capita number of lost-years is always below 0.05 years per person under the same scenario. In particular, the number is 0.2 years per person in Japan and 0.03 years per person in Zimbabwe, implying that the potential mortality burden in Japan is more than six times larger. Strikingly, high-income countries still have considerably larger potential mortality burdens under the "no-saturation" scenario than low-income countries under the "saturation" scenario. In particular, the number of lost-years per person is more than three times larger in Japan under the "no-saturation" scenario than in Zimbabwe under the "saturation" scenario.

Another striking aspect of Figure 4 is the heterogeneity of mortality burdens even among countries with similar levels of GDP per capita. Above \$5,000 per capita, one country can have more than twice the mortality burden of another country with similar GDP per capita. This illustrates the roles that population pyramids and residual life-expectancies play in shaping Covid-19 mortality, quite separately from pure income considerations.

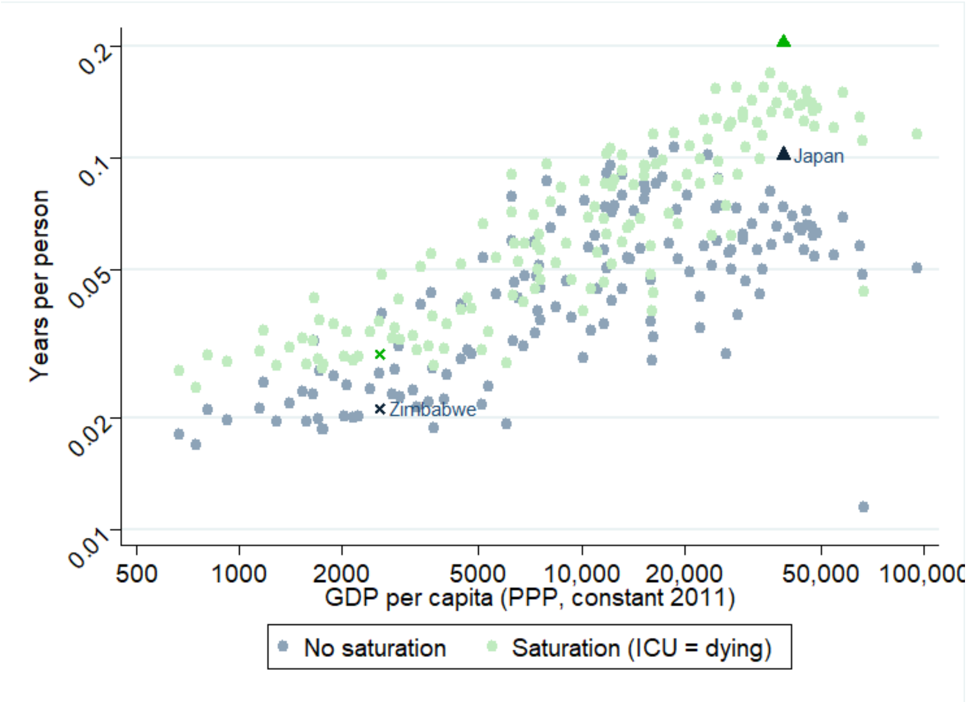

Figure 4: Per capita number of lost-years under two no-intervention scenarios

We also observe that the size of potential mortality burdens seems limited. These limited burdens follow from the small fraction of infected people who eventually die (typically smaller than 1% (Salje et al., 2020)) and the high concentration of deaths among the very old. In the case of Japan, whose population is particularly old, the potential number of lost-years under "saturation" corresponds to less than 0.4% of the total number of years at stake (the population multiplied by its average residual life-expectancy). This explains why economic losses may be a significant source of welfare costs in this pandemic.

Finally, recall that these mortality comparisons are based on a policy scenario implying similar infection rates in all countries. At this stage, many alternative scenarios are still possible, and we do not speculate on which are more likely. Yet, *realized* mortality tolls could still be larger in low-income countries than in high-income countries. This would for instance be the case if the latter are able to stop the epidemic at current infection rates while the former are unable to do so.

4.2 Actual versus "no-intervention" welfare consequences

Finally, we turn to the comparison between the actual and no-intervention welfare consequences. As explained above, the latter are larger than the former if $\alpha > \tilde{\alpha}$.

The first finding of this section is that, except for a few very poor countries, the welfare consequences under the no-intervention scenario are greater (i.e. *worse*) than the actual welfare losses as of early June, for any plausible α.[24] This implies that doing nothing was a dominated policy response in many countries, at least if the epidemic progressively disappears after early June and if Covid-induced poverty lasts for one year only.

This finding ensues from Figure 5, which shows break-even $\tilde{\alpha}$ under "saturation" mortality and with poverty computed for income class-specific poverty thresholds, as before. The figure uses the baseline growth estimates and the distribution-neutral growth assumption. The graph shows that break-even $\tilde{\alpha}$ are less than one in almost all developed and in most developing countries. But, as we saw in Section 2, α is theoretically bounded below at 1, so the estimated welfare outcomes are worse under no-intervention for all admissible normative criteria.

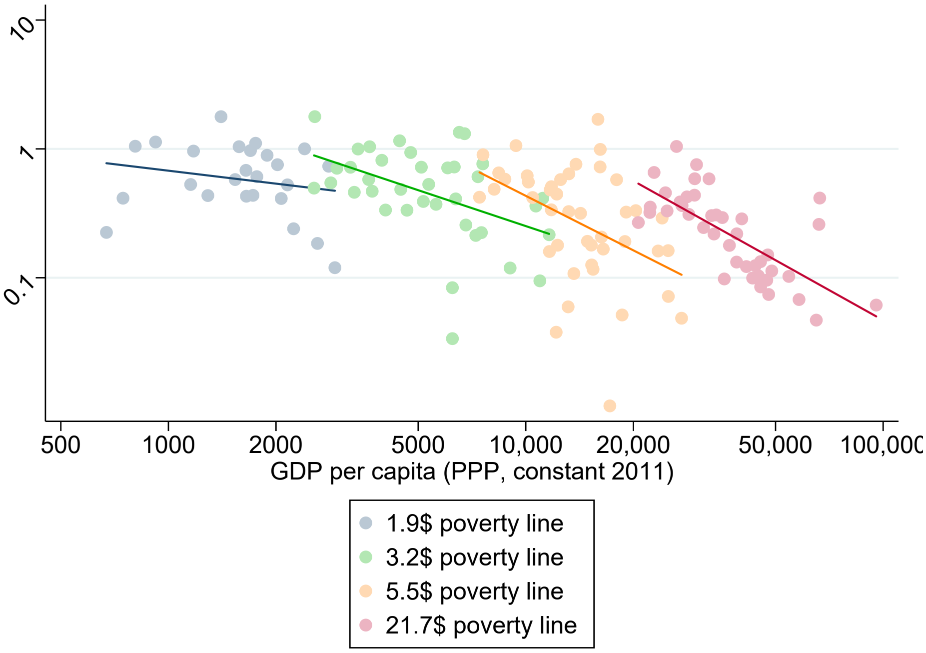

Figure 5: Break-even $\tilde{\alpha}$ in all countries as of early June 2020 (baseline, distribution-neutral contraction, no-intervention scenario with saturation, group-specific poverty thresholds)

We argue that the sub-optimality of no-intervention *in developed countries* is robust to taking less conservative poverty estimates. First and foremost, we assume conservatively that the no-intervention scenario has zero poverty costs, which is implausible. Second, if we relax our assumption that additional poverty only lasts for one year, and assume that the current poverty costs are in fact two or three times larger than our estimates, the result still holds for developed countries. Indeed, as shown in Table 3, the median break-even $\tilde{\alpha}$ for this group of countries is never larger than one-third under the various scenarios considered. In the case of upper-middle income countries, the median break-even $\tilde{\alpha}$ is never greater than one under the various scenarios considered, which also

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[24] Recall that $\alpha > 1$.

suggests sub-optimality of no-intervention for these countries.

Table 3: Lives and livelihoods - break-even $\tilde{\alpha}$ as of early June 2020, under "no intervention" scenario and saturation, medians by World Bank (WB) income groups

	(1) LIC	(2) LMIC	(3) UMIC	(4) HIC	(5) World
Median of economic and demographic characteristics					
GDP p.c. in 2017 (2011 PPP$)	1,697	5,481	13,822	35,938	11,676
Residual life expectancy	47.82	46.47	45.11	41.86	45.12
Median of Covid-19 mortality, no intervention and saturation					
Deaths per capita	0.00169	0.00289	0.00503	0.0113	0.00434
LYs per death	17.77	16.10	14.97	11.89	14.95
LYs per person	0.0302	0.0445	0.0762	0.128	0.0655
Median shock on poverty HCR					
Poverty line (median)	1.9	3.2	5.5	21.7	5.5
Baseline scenario, distribution-neutral	0.019	0.021	0.021	0.028	0.023
Baseline scenario, +3.6% in Gini	0.036	0.0355	0.043	0.040	0.037
Median break-even $\tilde{\alpha}$, no intervention and saturation					
Baseline scenario, distribution-neutral	0.609	0.491	0.323	0.259	0.387
Baseline scenario, +3.6% in Gini	1.089	0.869	0.642	0.354	0.646

Yet, we cannot rule out no-intervention as a plausible policy in some low-income countries. Their median break-even $\tilde{\alpha}$ are slightly larger than one under one of the two scenarios shown in Table 3. At least some low-income countries have break-even $\tilde{\alpha}$ larger than two (see Figure 5). For values of $\tilde{\alpha}$ in that range, the welfare comparison in the poorest countries remains theoretically ambiguous, although only for observers placing a low normative value on an additional year of life relative to a year in poverty.

Given an observer's fixed normative choice of α, the lower $\tilde{\alpha}$ the greater the welfare losses associated with the no-intervention scenario, relative to the actual early June estimates. The downward-sloping relationship in Figure 5 thus indicates that the welfare losses from policy inaction relative to the responses observed until early June 2020 increase sharply with GDP per capita. This effect is emphasized when using a common poverty line for all countries, such as the international extreme poverty line (IPL) of $1.90 a day (Ferreira et al., 2016). Figure 6 provides a scatter plot of $\tilde{\alpha}$ for all countries using the IPL. The slope of the fitted line is very steep. When using extreme poverty in all countries, we obtain $\tilde{\alpha}$ values well below 0.1 in high-income countries.[25] This is because even in the case of a deep recession, high-income countries would have very little extreme poverty, because incomes are far above the extreme threshold.

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[25] Even when using the $3.2 a day or $5.5 a day lines instead of the extreme line, break-even $\tilde{\alpha}$ values remain below 0.1 in high-income countries. See Figure A.11 in the Appendix.

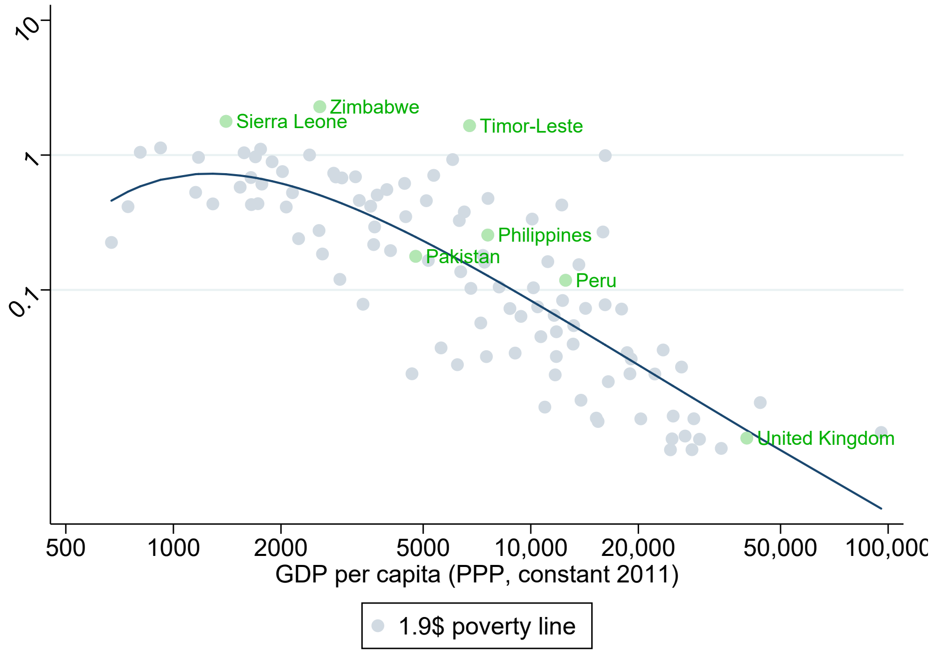

Figure 6: Break-even $\tilde{\alpha}$ in all countries as of early June 2020 (baseline, distribution-neutral contraction, no-intervention scenario with saturation, extreme poverty threshold)

This finding suggests that a country's optimal intervention is likely to differ as a function of its development level. For a given rate of infection and negative GDP shock, the relative sizes of the two sources of welfare consequences vary greatly with GDP per capita. On average, the more developed the country, the larger are the mortality costs and the smaller are the poverty costs. We have shown that these differences are quantitatively large. This implies that best policy responses might be more targeted towards containing infections in developed countries and towards containing poverty in developing countries - even though we treat the value of a human life as identical across countries throughout.

Table 4 summarizes our main estimates for the four income categories of countries and for the world, under our different scenarios. These estimates are the building blocks behind our break-even $\hat{\alpha}$ and $\tilde{\alpha}$. The table reiterates the point that for LICs, PYs are on average of the same magnitude than LYs in all no-intervention scenarios, while for HICs LYs dominate in the no-intervention scenarios or if considering the frugal \$1.90 poverty line. For the world as a whole, PYs dominate greatly in the current scenario but are surpassed by LYs in both no intervention scenarios. Table 4 also provides a sense of the additional increases in poverty likely to arise if the pandemic-induced recession is inequality-increasing, instead of distribution neutral. Applying a stylized "Argentina" growth incidence curve across all countries, as described above, adds 62 million poverty-years when the IPL is used for all countries, and 133 million PYs when the income-class-specific "WB classification" poverty lines are used.[26]

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[26] These conclusions are qualitatively unchanged when using the downside growth scenario (results

Table 4: Lives and livelihoods - pandemic's aggregate effects on mortality and poverty (Current = early June 2020)

	(1) LIC	(2) LMIC	(3) UMIC	(4) HIC	(5) World
Total number of Covid-19 deaths, in million					
Current scenario	0.000773	0.0171	0.0883	0.290	0.397
No intervention, no saturation	1.015	9.396	14.82	7.387	32.66
No intervention, saturation	1.159	10.23	15.61	13.28	40.32
Total increase in lost-years, in million					
Current scenario	0.0113	0.221	1.204	2.893	4.330
No intervention, no saturation	14.73	121.4	195.9	73.75	406.4
No intervention, saturation	20.59	153.7	227.8	157.9	560.7
Total increase in poverty-years, in million					
Distribution-neutral scenario					
1.9 PPP-$ poverty line	13.74	47.12	6.780	0.235	68.22
WB classification poverty line	13.74	138.7	53.90	28.46	234.8
+3.6% in Gini scenario					
1.9 PPP-$ poverty line	21.00	91.58	16.43	0.569	130.5
WB classification poverty line	21.00	196.4	106.5	44.44	368.3

5 Concluding remarks

The Covid-19 pandemic has generated huge losses in well-being around the world, by increasing mortality, causing ill-health and suffering, closing schools, etc. In combination with individual and policy responses, the pandemic has also generated a large global negative economic shock, with GDP declines currently expected to range from 4.8% on average in low-income countries to 8.9% on average in high-income countries. These marked economic contractions are causing substantial increases in poverty, reversing – at least temporarily – a hitherto sustained trend of decline in global poverty.

In this paper we focus on the mortality and poverty costs of the pandemic. We propose a simple framework to conduct a welfare evaluation of those costs, relying on a comparison of the number of years lost to Covid-19 deaths (lost-years) with the number of additional person-years spent in poverty in 2020. The welfare weights associated with these two quantities are transparently captured by a single normative parameter α, which denotes how much worse a lost-year is than a poverty-year in social welfare terms. We are agnostic about its value, imposing only that it is bounded below at one. Our approach is to compare it to empirical estimates of the ratio of poverty-years to lost-years in each

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available upon request).

country: α would have to be at least as high as that ratio for an observer to judge that the mortality cost exceeds the poverty cost.

Drawing on a rich combination of data sources on Covid-19 mortality, on demographic structures and age distributions, and on income distributions for 150 countries in the world, we estimate that the pandemic has generated 4.3 million lost years and as many as 68.2 million additional poverty years globally (using the extremely frugal international poverty line of 1.90 per day) by early June 2020. If median poverty lines are used for LICs, LMICs, UMICs and HICs, we estimate that 235 million poverty-years are being generated this year.

Across countries, the poverty-years to lost-years ratio ranges from just above 1 to more than 10,000. It is 3.6 in Belgium and 195 in Pakistan, for example. We document a very strong association between this ratio and GDP per capita, with poverty costs being systematically larger in poorer than in richer countries, both in absolute terms and relative to mortality costs. These results are for our baseline scenario, which conservatively assumes a distribution-neutral allocation of the income losses associated with the declines in GDP. Poverty costs are even greater in an alternative scenario where we allow for some increase in inequality, based on the pattern estimated for Argentina by Bonavida Foschiatti and Gasparini (2020). For most developing countries, it is difficult then to avoid the conclusion that one would have to place a very low weight on the welfare cost of falling into poverty to conclude that mortality costs exceed poverty costs.

It is important to note that this does *not* mean that public interventions aimed at containing the spread of the virus have been "a cure worse than the disease". Indeed, we show that, for most countries, the absence of any non-pharmaceutical interventions would have led to mortality costs that far exceed the total welfare losses accrued as of early June. In a counterfactual scenario in which infection rates are allowed to rise until stopped by herd-immunity, the ratio of poverty-years to lost-years is typically below one (the lower bound for α) for most countries. Indeed, for most high-income countries the number of lost-years under "no-intervention" is (at least) twice as large as the sum of the lost-years and poverty-years generated as of early June, under all our scenarios. Thus, we must conclude that for these countries no-intervention was a dominated response. Interventions were successful in slowing the spread of the disease and, even if they led to increases in poverty, welfare losses were substantially lower.

As with our estimates for early June, the mortality costs of the pandemic differ markedly between developed and developing countries in the counterfactual, no-intervention scenario. For given infection rates, developed countries face mortality costs several times higher than those of developing countries, because their populations are considerably older, and because they have longer residual life-expectancies at given ages. For poverty, on the other hand, developing countries have a larger fraction of their population living on incomes close to the poverty lines we use.

As a result, the welfare costs from increased poverty relative to those from increased mortality are much higher for poorer countries and tend to fall markedly with income per capita. There is, of course, non-trivial variation at each level of GDP per capita, reflecting differences in demography, inequality, and policy choices. But the evidence we present makes it difficult to escape the conclusion that the optimal policy response to the pandemic is not "one size fits all". It will almost certainly differ across countries, with policy makers in poorer countries being justifiably more concerned with the poverty costs faced by their populations than those in richer countries.

We have not sought to identify the optimal position countries should take when facing policy trade-offs. We do not even believe that there necessarily *is* a trade-off between "lives and livelihoods" for every policy response to Covid-19. Developing a vaccine, for example, would clearly reduce both lost-years and poverty-years in the future. The same is likely true for early contact-tracing and large-scale testing. Imposing social-distancing early likely dominates doing it late (Demirguc-Kunt et al., 2020), and so on.

What we hope to have contributed is a simple and transparent approach to estimating the relative welfare costs of Covid-induced increases in mortality and poverty. The evidence we have assembled suggests that there are very large poverty costs across the world, and particularly in developing countries. A concern with these poverty effects is clearly ethically legitimate and economically important. We hope our approach can contribute to more informed public debates on policy choices aimed to mitigate the welfare costs of the pandemic.

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A Appendix

A.1 Data sources

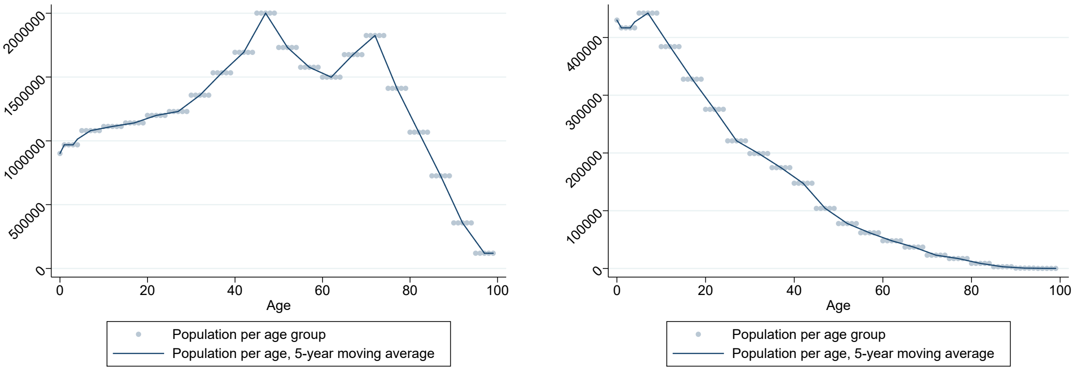
Table A.1: Data sources

Variables	Sources	Transformation
Population per age group	Global Burden of Disease (Dicker et al., 2018)	
	UN population division	Missing data imputed using IHME data Smoothing using 5-year moving average
Covid-19 mortality	Our World in Data (7/6/2020)	
Covid-19 mortality per age group		
Belgium	Sciensano (7/6/2020)	Smoothing using 9-year moving average
Sweden	Statista (5/6/2020)	Smoothing using 9-year moving average
England and Wales	Office for National Statistics (22/5/2020)	
Scotland	National Records of Scotland (31/5/2020)	Smoothing following data from England and Wales
Northern Ireland	Department of Health (6/6/2020)	Smoothing following data from England and Wales
Pakistan	http://covid.gov.pk (8/6/2020)	Smoothing using 9-year moving average
Peru	Ministry of Health (7/6/2020)	Smoothing using 9-year moving average
Philippines	Department of Health (7/6/2020)	Smoothing using 9-year moving average
United Kingdom	Authors' estimates	Aggregation of data from constituent countries Smoothing using 5-year moving average
All countries	Authors' estimates	See section A.2
Infection to Fatality Ratio (IFR)		
IFR in LIC and MIC	Verity et al. (2020)	Exponential fit (see Section A.2)
IFR in HIC	Salje et al. (2020)	Exponential fit (see Section A.2)
IFR if health care saturation	Authors' estimates	Maximum of P(ICU|infected) and IFRs
Mortality from other causes in 2017	Global Burden of Disease (Dicker et al., 2018)	
GDP per capita in 2011 PPP$	World Bank, World Development Indicators	
GDP growth forecast		
Belgium	National Bank of Belgium	
Sweden	Sveriges Riksbank (Central Bank of Sweden)	
United Kingdom	Bank of England	
LIC and MIC	World Bank, Global Economic Prospects	
HIC	IMF, World Economic Outlook	
Poverty forecast	PovcalNet and Lakner et al. (2020)	

A.2 Variables

Data sources are described in table A.1. The following transformations were applied to the data.

Population by age The population data from the UN population division are organized in 5-year categories. The population data from the IHME are also organized in 5-year categories, except the category 0-4 which is split in two (0-1 and 1-4). For each country, we first split the population of the age category 0-4 into two sub-categories following the same distribution as the 0-1 and 1-4 categories in the IHME data. We smooth the resulting data using 5-year moving averages. The results are shown in figure A.1 for Japan and Zimbabwe. Smoothing is expected to lead to more precise results. For Belgium, for example, the correlation between the 5-year moving average and population by age from STATBEL is slightly larger (0.997) than the correlation between the original data and STATBEL population by age (0.994).



(a) Japan (b) Zimbabwe

Figure A.1: Age pyramids for Japan and Zimbabwe

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Mortality by age We use data on population and number of deaths by age category from the Institute of Health Metrics and Evaluation. The most recent data are for the year 2017. We first smooth the two variables using 5-year moving averages. We then calculate the mortality by age as the ratio of the number of deaths by age (moving average) to the population by age (moving average). The results are shown in figure A.2 for Japan and Zimbabwe.

Residual life expectancy by age The maximal age in our data is 99. We denote m_{aj} the probability that an individual of age a in country j has of dying within a year and λ_{aj} its residual life expectancy. For each country, we calculate the residual life expectancy at 99 as $1/m_{99,j}$. We calculate the median value of the estimates obtained for each country

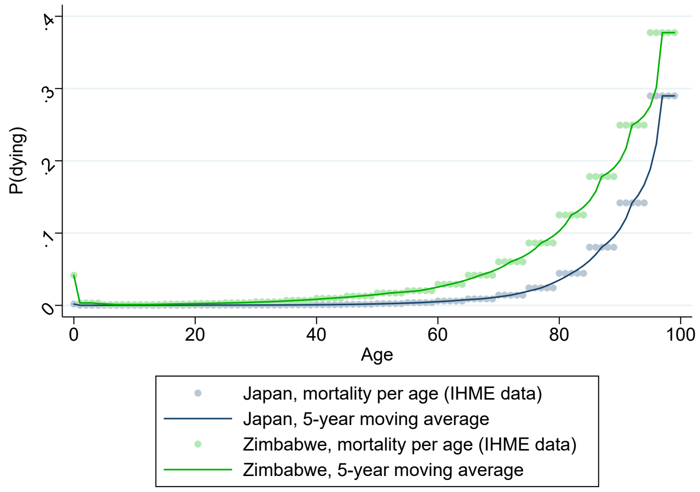
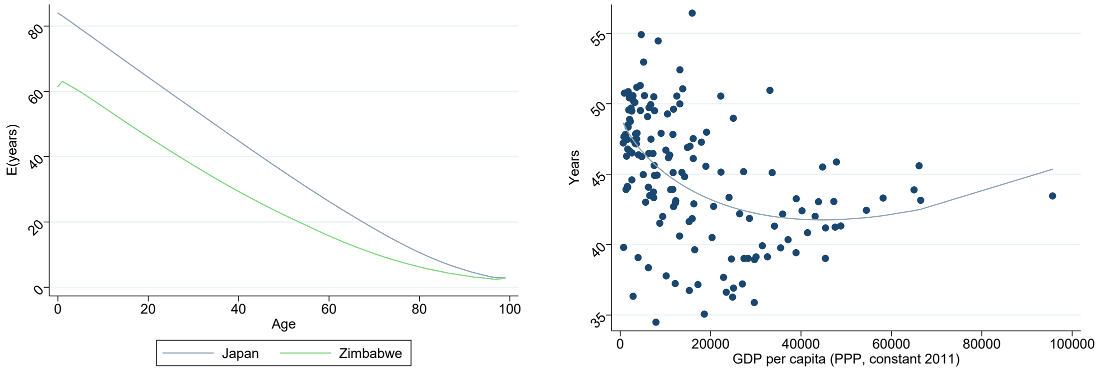


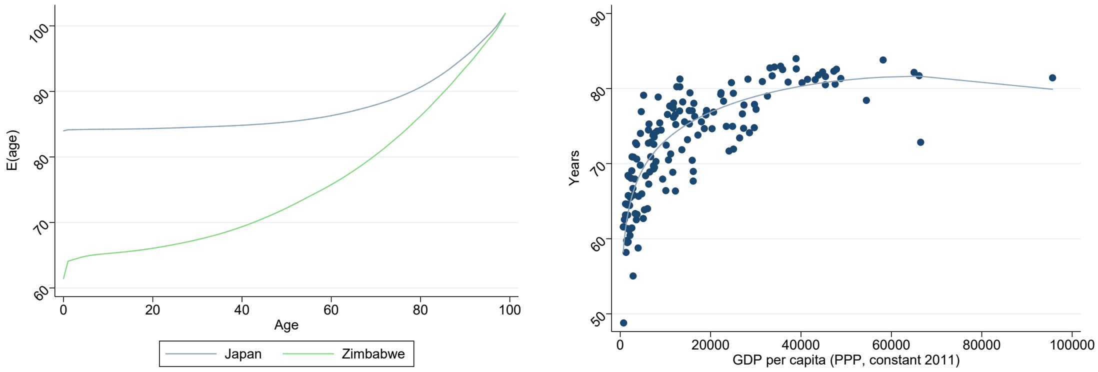
Figure A.2: Mortality by age for Japan and Zimbabwe

and assume that the result - 2.9 years - is the residual life expectancy at 99 for all countries. We then calculate λ_{aj} backwards for all ages, as $\lambda_{aj} = 0.5m_{aj} + (1 + \lambda_{a+1,j})(1 - m_{aj})$. The life expectancy at age a is given by $l_{aj} = a + \lambda_{aj}$. The residual life expectancy and life expectancy at age a are shown in figure 3(a) for Japan and Zimbabwe. The average residual life expectancy in country j is given by $\bar{l_j} = \sum_{a=0}^{99} N_{aj}\lambda_{aj}/N_j$, where N_{aj} is the size of the population of age a in country j and N_j is the total population of country j.

Infection Fatality Rate (IFR) For high-income countries, we use IFR estimates from Salje et al. (2020), who analyzed data on Covid-19 mortality from France. For low-income and middle-income countries, we use IFR estimates from Verity et al. (2020), who analyzed data on Covid-19 mortality from China. Both IFR estimates are provided for 10-year age categories below 80 years old and then one 80+ residual category. The literature on Covid-19 suggests that Covid-19 mortality is increasing exponentially with age (Promislow, 2020). We therefore smooth the IFR estimates of Verity et al. (2020) and Salje et al. (2020) using an exponential fit. Results are shown in figure A.4. For the "no-intervention" scenario leading to herd immunity, it is likely that the IFR would be higher than the estimates of Verity et al. (2020) and Salje et al. (2020) because health care systems would be saturated. For this no-intervention scenario with saturation of health care systems, we construct a higher-bound IFR by assuming that all infected individuals needing intensive care die. For this purpose, we use the data of Salje et al. (2020) and multiply the probability to be hospitalized if infected by the probability to go to intensive care if hospitalized. We smooth the series using an exponential fit. When this higher-bound IFR is lower than the IFR estimated by Verity et al. (2020) and Salje et al. (2020), we consider the maximum of the values.



(a) Residual life expectancy by age (b) Average residual life expectancy



(c) Life expectancy by age (d) Life expectancy at birth

Figure A.3: Residual life expectancy and life expectancy

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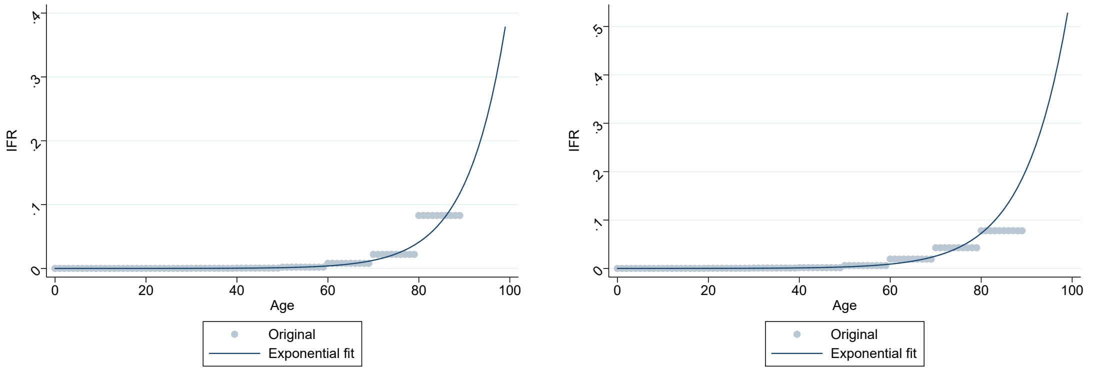

(a) IFR from (Salje et al., 2020) (b) IFR from (Verity et al., 2020)

Figure A.4: IFR estimates in China (Verity et al., 2020) and France (Verity et al., 2020)

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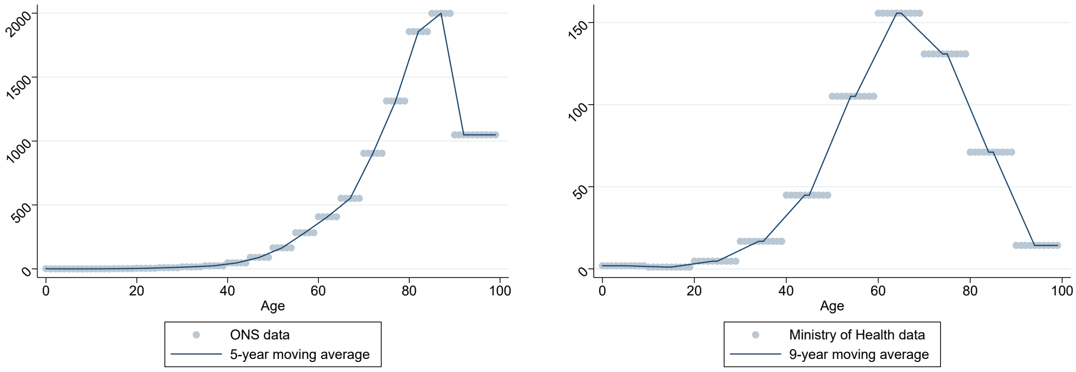
Covid-19 deaths by age For Belgium, Sweden, the United Kingdom (UK), Pakistan, Peru, and the Philippines, we have data on Covid-19 deaths by age category from early June 2020. We use a 5-year moving average to smooth the UK data, which are organized in 5-year categories. For other countries, categories are of 10 years or larger. We use

9-year moving averages to smooth the data. Results are shown in figure A.5.

For other countries, we estimate Covid-19 deaths by age by exploiting the IFR estimates and by assuming that the probability of Covid-19 infection is independent of age. We consider three scenarios. First, the current scenario. We denote d_{aj} the number Covid-19 deaths and μ_{aj} the IFR at age a in country j. The total number of Covid-19 deaths in country j is denoted d_j (data were taken from Our World in Data). Our estimate of the proportion of people infected in country j is given by $\varphi = d_j / \sum_{a=0}^{99} N_{aj}\mu_{aj}$. The number Covid-19 deaths at age a in country j is given by $d_{aj} = \varphi N_{aj}\mu_{aj}$. The second and third scenarios assume that nothing is done to stop the spread of the epidemic, which infects 80% of the population until reaching herd immunity (Banerjee et al., 2020). In this case, $d_{aj} = 0.8 N_{aj}\mu_{aj}$. The two "herd immunity" scenarios differ in the IFR assumed (no saturation versus saturation of the health care systems).



(a) United Kingdom

(b) Peru

Figure A.5: Covid-19 deaths

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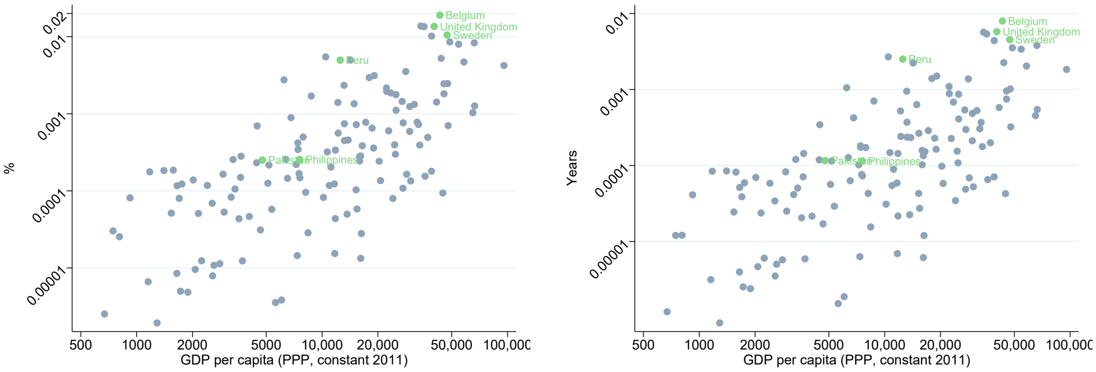
Years of life lost due to Covid-19 The total number of years of life lost due to Covid-19 in country j is given by $\delta_j = \sum_{a=0}^{99} d_{aj}\lambda_{aj}$. Results are shown in figure A.6 for the current scenario and in figure A.7 for the "herd immunity" scenarios.



(a) Per years of life left (in %)

(b) Per capita

Figure A.6: Years of life lost due to Covid-19 - current scenario

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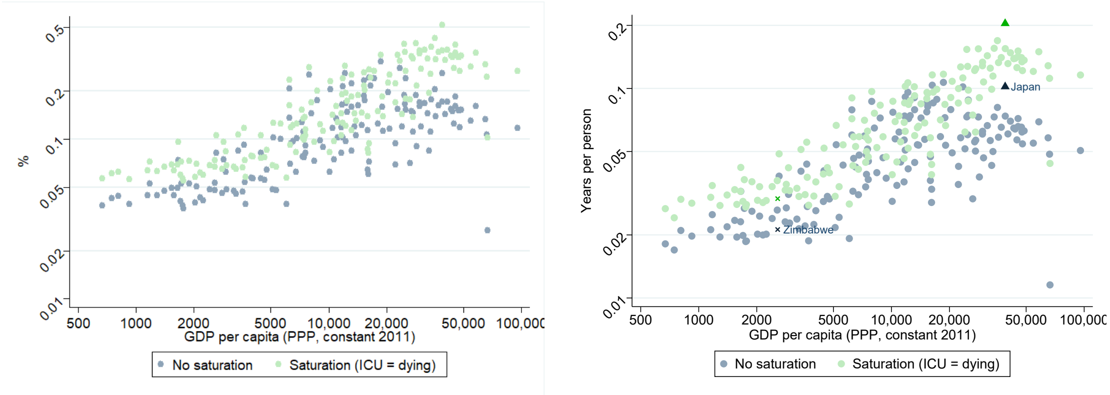

(a) Per years of life left (in %)

(b) Per capita

Figure A.7: Years of life lost due to Covid-19 - “herd immunity” scenarios

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B Supplementary figures and tables for publication online

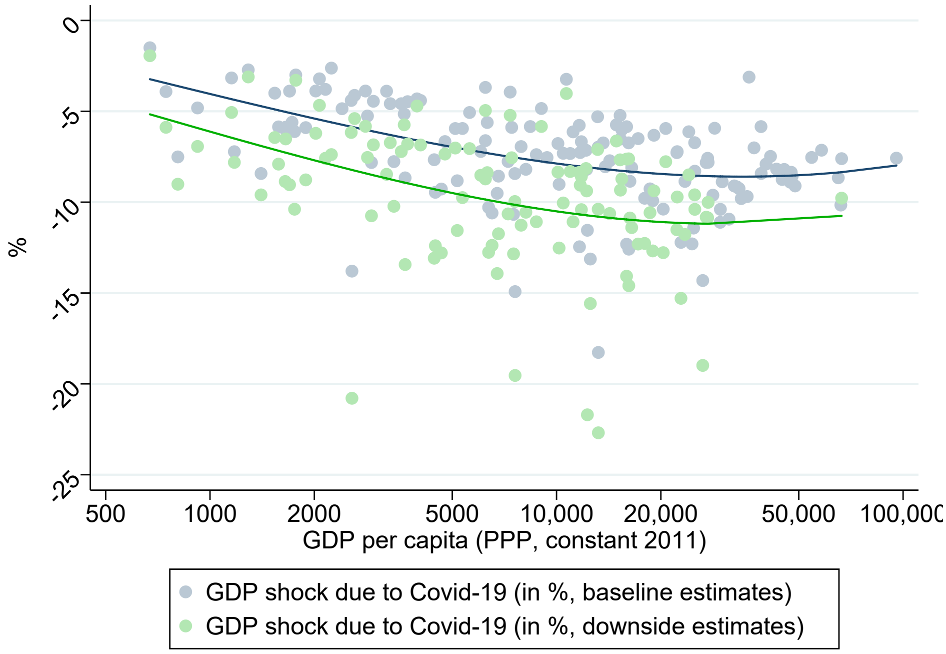


Figure A.8: Shock to GDP due to Covid-19 (baseline and downside estimates)

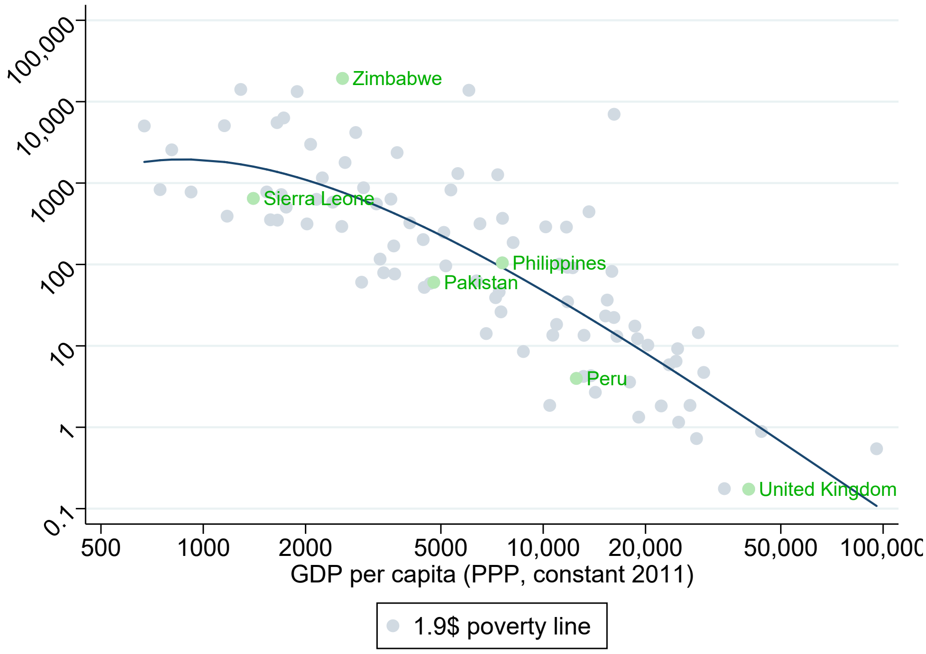
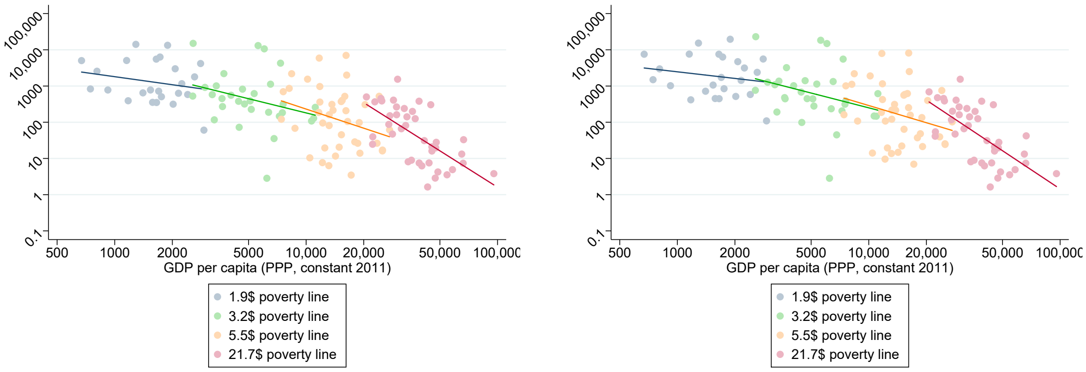
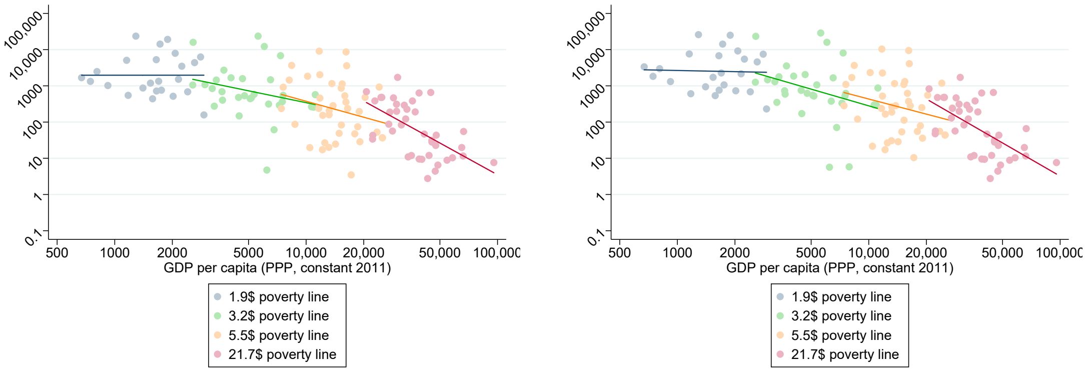


Figure A.9: Break-even $\hat{\alpha}$ for the 1.9 PPP-$ poverty line and the baseline growth scenario, Covid-19 mortality as of early June 2020



(a) Baseline, distribution-neutral

(b) Downside, distribution-neutral



(c) Baseline, +3.6% in Gini

(d) Downside, +3.6% in Gini

Figure A.10: Break-even $\hat{\alpha}$ as of early June 2020 for the different scenarios of economic shock

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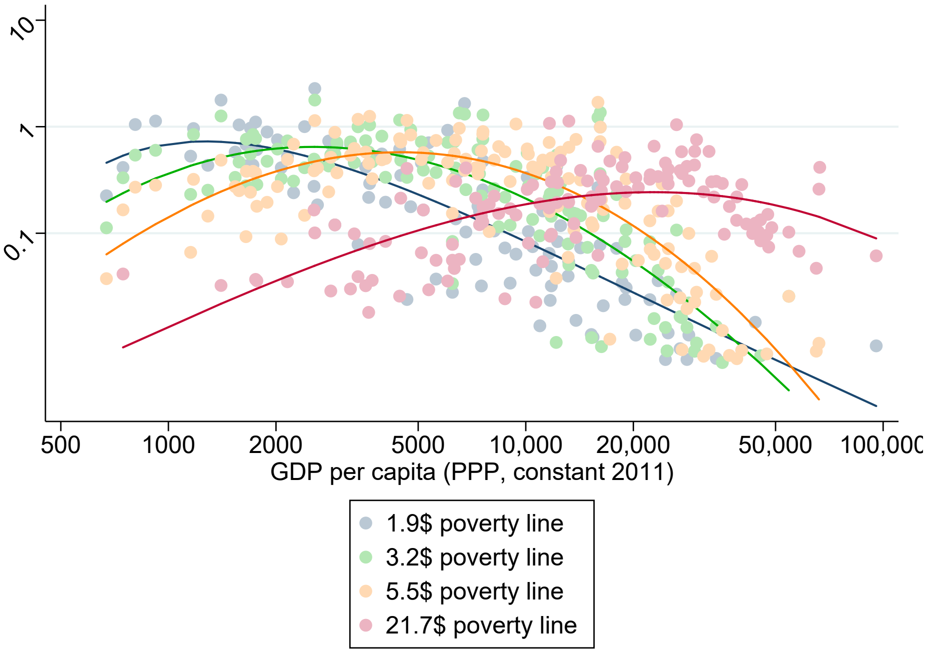

Figure A.11: Break-even $\tilde{\alpha}$ for different poverty lines (baseline scenario, distribution-neutral), Covid-19 mortality estimated in a no-intervention scenario with saturation of health care system