Estimated impact of the 2020 economic downturn on under-5 mortality for 129 countries
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Abstract: In low- and middle-income countries (LMICs), economic recessions and downturns can lead to increased child mortality by affecting dietary, environmental, and care-seeking factors. This study estimates the potential loss of life in children under five years old attributable to economic downturns in 2020. We used a multi-level, mixed effects model to estimate the relationship between gross domestic product (GDP) per capita and under-5 mortality rates (U5MRs) specific to each of 129 LMICs. Public data were retrieved from the World Bank World Development Indicators database and the United Nations World Populations Prospects estimates for the years 1990-2020. Each country’s individual slope relationship between child mortality and GDP was used to estimate the impact on U5MR of reductions in GDP per capita of 5%, 10%, and 15%. A 5% reduction in GDP per capita in 2020 was estimated to cause an additional 282,996 deaths in children under 5 in 2020. Recessions at 10% and 15% lead to higher losses of under-5 lives, increasing to 585,802 and 911,026 additional deaths, respectively. Nearly half of all the potential under-5 lives lost in LMICs were estimated to occur in Sub-Saharan Africa. Because most of these deaths will likely be due to nutrition and environmental factors amenable to intervention, countries should ensure continued investments in food supplementation, growth monitoring, and comprehensive primary health care to mitigate protentional burdens.

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Estimated impact of the 2020 economic downturn on under-5 mortality for 129 countries

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ABSTRACT

In low- and middle-income countries (LMICs), economic recessions and downturns can lead to increased child mortality by affecting dietary, environmental, and care-seeking factors. This study estimates the potential loss of life in children under five years old attributable to economic downturns in 2020. We used a multi-level, mixed effects model to estimate the relationship between gross domestic product (GDP) per capita and under-5 mortality rates (U5MRs) specific to each of 129 LMICs. Public data were retrieved from the World Bank World Development Indicators database and the United Nations World Populations Prospects estimates for the years 1990-2020. Each country’s individual slope relationship between child mortality and GDP was used to estimate the impact on U5MR of reductions in GDP per capita of 5%, 10%, and 15%. A 5% reduction in GDP per capita in 2020 was estimated to cause an additional 282,996 deaths in children under 5 in 2020. Recessions at 10% and 15% lead to higher losses of under-5 lives, increasing to 585,802 and 911,026 additional deaths, respectively. Nearly half of all the potential under-5 lives lost in LMICs were estimated to occur in Sub-Saharan Africa. Because most of these deaths will likely be due to nutrition and environmental factors amenable to intervention, countries should ensure continued investments in food supplementation, growth monitoring, and comprehensive primary health care to mitigate protentional burdens.
Introduction

Economic downturns have occurred in almost all countries as a result of COVID-19. We know from prior research that these economic downturns have a disproportionate effect on child health and mortality in low- and middle-income countries (but not high-income countries) and that these effects are likely independent of whether or not children acquire COVID-19 disease.[1—4]

The mechanisms relating social determinants like GDP per capita to child mortality in low- and middle-income countries are presumed to act through the combined effects of environmental contamination, nutrient deficiency, maternal factors, injury, and personal illness control.[4] For example, reductions in household income can unleash dual effects of environmental contamination and nutrient deficiency as households cope with poverty by moving to poorer housing with less sanitation and more crowding, as well as shifting diets away from costly sources of protein, and micronutrients.[5] A spiral of successive gastrointestinal, skin, and respiratory infections can further deplete nutritional reserves. Parents securing supplemental income during economic hardship can subject children to less parental supervision heightening the risk of injury. Both the demand for and the supply of essential childhood health services including immunizations, micromicronutrients, and primary care can falter during a severe economic recession. The pediatric community, therefore, plays an essential role in mitigating the health harms of sudden economic downturns by offering growth monitoring, routine vaccinations, and care for respiratory and gastrointestinal infections.
| Number | Comment |
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| 1      | Are we here already distinguishing between downturn and recession? If so, please define and distinguish between the two definitions at the outset. |
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Knowing how the global 2020 economic downturn led to worsening child health and mortality can help inform policymakers, clinicians, and advocates about the magnitude of such effects and can improve strategies to reduce disease burden, especially in the face of a prolonged pandemic. To our knowledge, however, indirect health effects of economic downturn, even though past economic recessions have been shown to lead to health declines, especially among children. For example, studies from Ebola outbreaks in Africa and SARS in East Asia have highlighted the importance of national and international organizations in combating the indirect economic effects of disease on the most economically disadvantaged communities.[6,7] Further, a systematic review of the social and economic burden of seasonal influenza in low- and lower-middle-income countries found that influenza’s indirect costs, namely productivity loss, were significantly higher in low and middle income countries (LMICs) than high-income countries.[8]

Prior studies of the indirect death toll due to an epidemic-related recession or downturn may not be relevant to 2020 because prior epidemics did not spur an economic slowdown of the same magnitude as those experienced in 2020. Estimates indicate that the world economy was expected to shrink more than 5% in 2020 alone.[9–12] The economic downturns of 2020 have also been projected to reverse a sustained trend of decline in global poverty, with an estimated 42–66 million additional children falling into extreme poverty.[13,14] Additional estimates suggest that the economic effects of the COVID-19 pandemic could reverse the past 2 to 3 years of progress in infant mortality.[14]
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This study assesses the indirect economic effects of the COVID-19 pandemic by estimating the impact of different economic recession scenarios on under-5 mortality in low, lower-middle, and upper-middle-income countries. While there is some uncertainty about the final magnitude of the economic recessions of 2020, our model projects excess under-5 mortality by country that are relevant for recessions as small as $0\%$ and as large as $15\%$ to be used as reference points. Our approach draws from the empirical relationship between mortality and national income that was first noted by Preston and has been widely documented.[3] Recent studies have confirmed the adverse effect of recessions on under-5 mortality, showing that the impact in LMICs is three times larger than in countries with better economic indicators.[15–18]

Methods

Overview and Data Sources

The methodology is presented in three sections. In section one, we present the methods used to re-estimate and update Preston curves specific to each LMIC and hi provides multivariate adjusted estimates of the slope parameter relating GDP and Under-5 mortality individualized to each country’s most recent data along with 95% confidence intervals. In the second section, we apply each country’s GDP-Under-5 mortality slope parameter to estimate the one-year mortality impact of a 5%, 10%, and 15% reduction in GDP. Finally, using Monte Carlo methods, we obtain uncertainty ranges around these excess mortality projections. Admittedly, this method will offer a lower bound estimate of the full health impact of recession because the model excludes delayed mortality effects after one year, economically mediated deaths.
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| 4      | These last two sentences belong in the discussion section. |
in adults, and non-fatal effects on health, social development, and cognition that are known to follow famines and adverse childhood experiences. However, estimates of just the mortality effects of the 2020 downturns can help alert policymakers of the need to plan additional efforts to mitigate the economic threats faced by vulnerable groups.

Because recessions in high income countries are known to have only negligible if any effects on child mortality, we only included 129 countries that were classified as low-, lower-middle-, or upper-middle income in our study based on the 2020 World Bank income classification requiring an income below 12,375 US$. Annual estimates of under-5 mortality for each country were obtained from the United Nation’s World Population Prospects 2019 Revision. Data on GDP per capita (constant 2010 US$) were obtained from the World Bank World Development Indicators database. Covariates include country-year-specific characteristics and health-specific services obtained from the World Bank World Development Indicators database. We imputed missing values in GDP per capita using a five-year moving average and in some covariates using multivariate normal regression. (See the Appendix Table 1 for additional description of our imputation approach.) All estimated effects of recessions on under-5 mortality were calculated within a one-year time horizon, meaning that the increased mortality rates presented are representative of different recession scenarios occurring during 2020.

**Multilevel Mixed Effects Multivariable Regression Analysis**

Regression analysis was used to estimate the Preston curve relationship between national income and under-5 mortality. First, we regressed the U5MR on GDP per capita and a set of socio-
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economic covariates. A model-based approach using an iterative process was used to fill in missing values in the set of covariates. To estimate country-specific effects of a recession, we applied a multilevel mixed-effect linear regression to the relationship between GDP per capita and U5MR for each country. To control for heterogeneity across countries, the multilevel mixed-effect linear regression included fixed effects for a country’s region and income level. (Sensitivity analyses showed that results were not sensitive to inclusion of fixed effects.) A generalized log-linear model was estimated to use the retransformation of impacts from a log-scale to natural units. Recession estimates were bracketed at 5%, 10%, and 15% reductions in country GDP per capita. Our baseline model to estimate the relationship between GDP per capita and U5MR had the following form:

\[(1) \quad \log U5MR_{jt} = \alpha_j + \beta_{1j} \log GDP_{jt} + \epsilon_{jt}\]

Where \(\beta_{1j}\) captures a country-specific relationship between GDP and under-5 mortality for years \(t = 1990-2020\) in country \(j\). Because equation (1) might omit other factors that are closely related to changes in the under-5 mortality rate, we extend equation (1) to include other country-specific factors that could affect the relationship between GDP and U5MR, as shown in equation (2) below:

\[(2) \quad \log U5MR_{jt} = \alpha_j + \beta_{1j} \log GDP_{jt} + \beta_2 Z_{jt} + \beta_3 H_{jt} + \epsilon_{jt}\]

Where \(Z_{jt}\) represents a vector of country-year-specific characteristics. These control variables were as follows: electric power consumption per capita, the proportion of seats held by women in national parliaments, and total fertility rate for country. The last vector of controls \((H_{jt})\) captures health-specific services for each country-year and includes: the number of physicians per thousand
What does it mean to "ease the retransformation"?
inhabitants and the share of children (between 12 and 23 months) who had been immunized with a diphtheria pertussis and tetanus vaccine (DPT). By measuring GDP effects on mortality net of immunization coverage, our final model (equation 2) isolates the GDP mortality effect primarily through effects on wasting, non-vaccine-related diseases, as well as parental caregiving and injury.

**Lives Lost Estimation**

Country-specific estimates of $\beta_{1j}$ were then applied to GDP per capita data to predict an estimated mortality impact under the four different scenarios – no reduction in GDP per capita (scenario 1), 5% reduction (scenario 2), a 10% reduction (scenario 3), and 15% (scenario 4). We estimate potential recession-attributable loss of life by subtracting the deaths observed in scenario 1 from the projected number of deaths under scenarios 2-4.

**Estimates of Uncertainty**

We carried out additional analyses to estimating from a normal distribution parameterized with a mean of $\beta_{1j}$ and the standard error of $\beta_{1j}$ at the country level. We performed a Monte Carlo experiment using 500 iterations to draw each country’s GDP-U5MR impact parameter from normal distributions based on estimates of the coefficient and standard error estimated from equation (\). For the simulation, the estimated log(U5MR) from each scenario was retransformed to a mortality rate and then multiplied by the population of children under 5 to produce an estimated total number of deaths under each scenario. The means and standard deviations of the incremental death projections emerging from each sample of 500
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iterations is shown in Table 3. Because the Monte Carlo results emerge from 500 iterations they differ slightly from the single iteration estimates.

**Results**

Between 1990 and 2019, there has been a sustained trend of decline in global poverty and infant mortality in LMICs. However, as hypothesized above, COVID-19 related economic downturns of 2020 are likely to reverse these positive trends.
Table 1 presents select summary statistics for variables used in the analysis for the years 2010, 2015, and 2019. (Appendix Table 1 presents annual statistics for the entire study period, 1990-2020. Values for 2020 are based on projections from various sources that do not take into account the 2020 pandemic.)
Table 1: Descriptive statistics of main variables in the sample of 129 LMIC countries (Values prior to imputation)

| Variable                                           | Year     | 2010 | 2015 | 2019 |
|----------------------------------------------------|----------|------|------|------|
| Under-five mortality rate (deaths under age 5 per 1,000 live births) | Mean     | 66.69| 43.52| 38.37|
|                                                    | Standard Deviation | 42.26| 32.34| 28.81|
|                                                    | Share of missing observations | 0.00 | 0.00 | 0.00 |
| GDP per capita constant 2010$                       | Mean     | 2,973| 3,738| 3,996|
|                                                    | Standard Deviation | 3,306| 3,163| 3,273|
|                                                    | Share of missing observations | 2.33 | 4.65 | 10.85 |
| Physicians (per 1,000 people)                      | Mean     | 0.61 | 1.19 | 1.17 |
|                                                    | Standard Deviation | 0.90 | 1.43 | 1.37 |
|                                                    | Share of missing observations | 17.05| 53.49| 100.00|
| Electric power consumption (kWh per capita)        | Mean     | 955  | 1,384| 1,467|
|                                                    | Standard Deviation | 1,279| 1,366| 1,369|
|                                                    | Share of missing observations | 32.56| 100.00| 100.00|
| Proportion of seats held by women in national parliaments (%) | Mean     | 14.80| 19.76| 22.65|
|                                                    | Standard Deviation | 10.70| 12.16| 12.33|
|                                                    | Share of missing observations | 3.88 | 2.33 | 0.78 |
| Total fertility (live births per woman)             | Mean     | 4.10 | 3.28 | 3.11 |
|                                                    | Standard Deviation | 1.51 | 1.35 | 1.24 |
|                                                    | Share of missing observations | 0.00 | 0.00 | 0.00 |
| Immunization, DPT (% of children ages 12-23 months) | Mean     | 81.69| 84.74| 88.24|
|                                                    | Standard Deviation | 15.60| 16.37| 18.41|
|                                                    | Share of missing observations | 0.78 | 0.00 | 100.00|

Source: Authors’ elaboration
Note: For a detailed description for every year, see Appendix Table 1

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1 Child immunization, DPT, measures the percentage of children ages 12-23 months who received DPT vaccinations before 12 months or at any time before the survey. A child is considered adequately immunized against diphtheria, pertussis (or whooping cough), and tetanus (DPT) after receiving three doses of vaccine. [19]
Under-5 Mortality

The results from fitting models of U5MR and GDP for each country are shown in the Appendix Figure 3. Our baseline projection is a benchmark where there is no reduction in GDP per capita (i.e., Scenario 1), and in this case the expected total number of annual under-5 lives lost in LMICs would be around 19.2 million. Under a conservative recession scenario (5% reduction on GDP per capita; Scenario 2), the total number of under-5 deaths increases to 19.5 million, or an additional 282,996 number of deaths (95% CI: 279,779-286,400). The results for each recession scenario at the country level suggest that for the scenarios of 10% and 15% GDP reductions, there is an estimated under-5 loss of life of 19.8 and 20.2 million, which corresponds to an additional 585,802 (95% CI: 579,184-592,799) and 911,026 (95% CI: 900,804-921,825) lives lost, respectively. Moreover, we estimate that 49% of the total under-5 lives lost would occur in Sub-Saharan Africa, a pattern that is observed across the four scenarios, where the total number of lives lost in this region increased up to over 470,000 between a no recession scenario and a 15% reduction in GDP per capita.

The estimated number of deaths is the largest in countries with a higher population. Consequently,
Table 2 presents results for the ten countries with the highest additional under-5 lives lost in 2020 under the four different scenarios\(^2\). Results suggest that India will be the country with the highest number of under-5 lives lost, followed by Nigeria and the Democratic Republic of the Congo. Moreover, estimates for the top 10 countries with the highest under-5 mortality rates are presented in Appendix Table 4.

\(^2\) See Appendix Table 4 for the complete table
Certainly all lives lost are meaningful, but would it not be relevant to first present as a proportion of the general population or of the under-5 general population?
Table 2: Estimated Under-5 Lives Lost from 2020 Recessions Scaled from 5% to 15%.

| Country                        | Under 5 deaths | Lower bound (95% CI) | Upper bound (95% CI) | Under 5 deaths 5% reduction on GDP | Additional deaths 5% | Lower bound (95% CI) | Upper bound (95% CI) | Under 5 deaths 10% reduction on GDP | Additional deaths 10% | Lower bound (95% CI) | Upper bound (95% CI) | Under 5 deaths 15% reduction on GDP | Additional deaths 15% | Lower bound (95% CI) | Upper bound (95% CI) |
|--------------------------------|----------------|----------------------|----------------------|-------------------------------------|---------------------|----------------------|----------------------|-------------------------------------|---------------------|----------------------|----------------------|-------------------------------------|---------------------|----------------------|----------------------|
| India                          | 2,929,298      | 986,082              | 8,701,895            | 2,972,361                           | 43,063              | 1,024,604            | 3,018,437            | 89,139                              | 1,046,101           | 8,997,378            | 3,067,926            | 138,628                            | 1,046,101           | 8,997,378            |
| Nigeria                        | 1,503,219      | 497,646              | 4,540,714            | 1,525,317                           | 22,098              | 517,205              | 1,548,962            | 45,743                              | 1,574,358           | 71,139                | 4,693,221            | 528,124                            | 4,693,221           | 71,139                |
| Democratic Republic of the Congo | 1,388,004      | 524,706              | 3,671,682            | 1,408,409                           | 20,405              | 534,338              | 1,430,241            | 42,237                              | 1,453,691           | 65,687                | 3,802,143            | 555,796                            | 3,802,143           | 65,687                |
| China                          | 1,235,908      | 372,924              | 4,095,918            | 1,254,076                           | 18,169              | 380,064              | 1,273,517            | 37,609                              | 1,294,396           | 58,489                | 4,230,905            | 396,005                            | 4,230,905           | 58,489                |
| Pakistan                       | 1,054,683      | 371,239              | 2,996,334            | 1,070,187                           | 15,505              | 378,185              | 1,086,777            | 32,094                              | 1,104,595           | 49,912                | 3,099,329            | 393,676                            | 3,099,329           | 49,912                |
| Ethiopia                       | 992,985        | 369,329              | 2,669,755            | 1,007,582                           | 14,598              | 376,148              | 2,698,999            | 30,217                              | 2,730,228           | 46,993                | 2,763,698            | 391,343                            | 2,763,698           | 46,993                |
| United Republic of Tanzania    | 523,317        | 187,417              | 1,461,240            | 531,010                             | 7,693               | 190,917              | 1,476,931            | 15,925                              | 1,493,681           | 24,766                | 1,511,625            | 198,723                            | 1,511,625           | 24,766                |
| Indonesia                      | 461,840        | 147,090              | 1,450,106            | 468,629                             | 6,789               | 149,891              | 1,465,156            | 14,054                              | 1,481,208           | 21,856                | 1,498,392            | 156,142                            | 1,498,392           | 21,856                |
| Niger                          | 461,338        | 171,118              | 1,243,775            | 468,120                             | 6,782               | 174,273              | 1,257,434            | 14,039                              | 1,272,020           | 21,833                | 1,287,654            | 181,302                            | 1,287,654           | 21,833                |
| Bangladesh                     | 435,117        | 153,268              | 1,235,269            | 441,513                             | 6,396               | 156,135              | 1,248,500            | 13,241                              | 1,262,622           | 20,592                | 1,277,750            | 162,528                            | 1,277,750           | 20,592                |

Source: Authors’ elaboration
Figure 1 presents the number of total additional deaths from a 15% reduction in GDP per capita (e.g. Scenario 4), according to income group classification. Results show that a 15% reduction in GDP per capita will have a substantial increase in the under-5 mortality rate in LMICs, with larger estimated impacts in lower-middle income countries, where under-5 mortality rates tend to be higher.

*Figure 1. Changes in under-five mortality from a 15% recession, by country and income group*

**Sensitivity Analysis and robustness**

Table 3 presents the results from the Monte Carlo experiment on the estimated logarithm of U5MR for each country in every scenario. We observe that in all the scenarios, estimations remain between the 95 percent confidence interval, thereby validating the robustness of our approach.

*Table 3 Uncertainty analysis from a Monte Carlo experiment using estimates of Model 2.*

| Scenario        | Model 1  | Model 2  | Monte Carlo Version of Model 2 Mean (SD) | Monte Carlo Version of Model 2 95% CI | Lower bound | Upper bound |
|-----------------|----------|----------|-----------------------------------------|--------------------------------------|-------------|-------------|
| 5% Recession    | 402,847  | 282,996  | 283,090 (1,689)                         | 279,779                              | 286,400     |             |
| 10% Recession   | 837,922  | 585,802  | 585,991 (3,473)                         | 579,184                              | 592,799     |             |
| 15% Recession   | 1,309,822| 911,026  | 911,314 (5,362)                         | 900,804                              | 921,825     |             |

Source: Authors' elaboration
Discussion

We estimate that the economic downturns of 2020 significantly increased loss of life among children younger than five years old in LMICs. Many of the countries in this analysis have relatively young populations with tenuous access to stable housing, clean water, food, and primary care. The health of these children is highly susceptible to reductions in the economic well-being of their families. Children in these lower income countries are also subject to a high rate of exposure to other infectious diseases, besides COVID-19, which makes them more susceptible when the economy reduces their access to nutrition, housing, water, sanitation, and parental care.[4] Disruptions to primary health care service supply and demand will compound these threats, and thus may be a likely driver of increased mortality in these settings. Efforts to shore up the delivery of pediatric primary health care services during a recession can mitigate the mortality impact of a recession.

Our estimates match the lower range of other estimates of the indirect effects of the COVID-19 pandemic on child mortality which have primarily focused on excess mortality attributed to disruptions in delivery of key health services affecting children and mothers. Reductions in service delivery could range between 10–52% and the prevalence of wasting could increase by 10–50%.[20] The estimated death toll due to health service reductions was estimated to range from 253,500 to 1,157,000 additional child deaths over a 6 month period with 60% of these deaths, linked to reduced coverage of childbirth services and 18–23% of deaths tied to wasting.[20] Another paper which focused on malaria service delivery disruption found that 25%–75%
reductions in coverage of preventative and curative supplies and care may result in anywhere from 23,600 to 382,100 additional deaths in the most and least conservative scenarios, respectively.\[21\] In comparison, our analysis finds that 5%–15% reductions in GDP are estimated to lead to additional loss of life in children under five between 282,996 to 911,026. Our estimates are focused on those due to the reduction in GDP and do not include any direct effects of COVID-19 on children. Because our model controls for DPT vaccine delivery (i.e., our model assumes that DPT vaccine delivery is fixed) it underestimates the potential impact of economic recession through these secondary effects on services. We find that the estimated additional lives lost from 5% and 15% recessions would equate to 1.5% and 4.7% increases above baseline, respectively.

The uncertainty surrounding the actual intensity and duration of COVID-19-induced economic effects is a significant limitation of this study. The study aimed to control for uncertainty by offering a bracketed range of likely recession magnitudes from 5% to 15%, which allows countries to situate their own estimated recession rates within this range to customize results. Further limitations exist in the data that were used in this study. For example, many observations from the United Nations Inter-agency Group for Child Mortality Estimation and World Bank World Development Indicators required imputation up to 2020. Measurement of U5MR in many LMICs cannot be based on vital registration systems and must be based on demographic models of survey data produced by the United Nations. Authors also recognize alternative data sources for child mortality such as those available from the University of Washington Institute for Health Metrics and Evaluation, and acknowledge that both datasets are widely used in global health research. In addition, the study only focuses on the lives lost to children under 5 and does not examine other
short- and long-term health-related impacts due to COVID-19 related recessions. Further research should focus on the non-fatal health effects of the 2020 recessions on health, cognition, development, and school attainment.

The empirical evidence correlating health and wealth initially outlined by Samuel Preston, and later expanded by authors such as Angus Deaton, highlighted that mortality in children under-5 is one of the most significantly affected health outcomes from changes in GDP in low and lower-middle income settings.[2,3,22] This should come as no surprise, as the majority of illnesses and complications that affect children under-5 are those that can be largely avoided by routine access to pediatric and post-natal services. Malnutrition and infectious diseases like malaria are particularly lethal for young children, with both of these issues increasing in severity as socioeconomic well-being declines. Further research may benefit from further breaking down under-5 mortality rates into subset rates such as infant mortality and neonatal mortality to even more clearly define areas of intervention. Countermeasures can help to reduce these impacts through food supplementation, growth monitoring, and comprehensive primary health care. Hopefully these estimates of the magnitude of the non-COVID-19 related child mortality can help marshal the resources needed to mitigate the burden.

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REFERENCES

1. Bishai DM, Cohen R, Alfonso YN, Adam T, Kuruvilla S, Schweitzer J. Factors Contributing to Maternal and Child Mortality Reductions in 146 Low- and Middle-Income Countries between 1990 and 2010. PLOS ONE. 2016;11: e0144908. doi:10.1371/journal.pone.0144908

2. Deaton A. Health, Inequality, and Economic Development. National Bureau of Economic Research; 2001 Jun. Report No.: 8318. doi:10.3386/w8318

3. Preston SH. The Changing Relation between Mortality and Level of Economic Development. Popul Stud. 1975;29: 231–248. doi:10.2307/2173509

4. Mosley WH, Chen LC. An Analytical Framework for the Study of Child Survival in Developing Countries. Popul Dev Rev. 1984;10: 25–45. doi:10.2307/2807954

5. Scrimshaw NS, SanGiovanni JP. Synergism of nutrition, infection, and immunity: an overview. Am J Clin Nutr. 1997;66: 464S-477S. doi:10.1093/ajcn/66.2.464S

6. Bausch DG, Schwarz L. Outbreak of Ebola Virus Disease in Guinea: Where Ecology Meets Economy. PLoS Negl Trop Dis. 2014;8: e3056. doi:10.1371/journal.pntd.0003056

7. Moon S, Sridhar D, Pate MA, Jha AK, Clinton C, Delaunay S, et al. Will Ebola change the game? Ten essential reforms before the next pandemic. The report of the Harvard-LSHTM Independent Panel on the Global Response to Ebola. The Lancet. 2015;386: 2204–2221. doi:10.1016/S0140-6736(15)00946-0

8. de Francisco (Shapovalova) N, Donadel M, Jit M, Hutubessy R. A systematic review of the social and economic burden of influenza in low- and middle-income countries. Vaccine. 2015;33: 6537–6544. doi:10.1016/j.vaccine.2015.10.066

9. Nicola M, Alsafi Z, Sohrabi C, Kerwan A, Al-Jabir A, Iosifidis C, et al. The socio-economic implications of the coronavirus pandemic (COVID-19): A review. Int J Surg Lond Engl. 2020;78: 185–193. doi:10.1016/j.ijsu.2020.04.018

10. Fernandes N. Economic Effects of Coronavirus Outbreak (COVID-19) on the World Economy. Rochester, NY: Social Science Research Network; 2020 Mar. Report No.: ID 3557504. doi:10.2139/ssrn.3557504

11. IMF Blog. The Great Lockdown: Worst Economic Downturn Since the Great Depression. In: IMF Blog [Internet]. [cited 30 Aug 2020]. Available: https://blogs.imf.org/2020/04/14/the-great-lockdown-worst-economic-downturn-since-the-great-depression/
12. Global Economic Prospects, June 2020. The World Bank; 2020. doi:10.1596/978-1-4648-1553-9

13. Decerf B, Ferreira FHG, Mahler DG, Sterck O. Lives and Livelihoods: Estimates of the Global Mortality and Poverty Effects of the Covid-19 Pandemic. The World Bank; 2020. doi:10.1596/1813-9450-9277

14. UNSDG | Policy Brief: The Impact of COVID-19 on children. [cited 10 Sep 2020]. Available: https://unsdg.un.org/resources/policy-brief-impact-covid-19-children

15. Pérez-Moreno S, Blanco-Arana MC, Bárbara-Martín E. Economic cycles and child mortality: A cross-national study of the least developed countries. Econ Hum Biol. 2016;22: 14–23. doi:10.1016/j.ehb.2016.02.005

16. Maruthappu M, Watson RA, Watkins J, Zeltner T, Raine R, Atun R. Effects of economic downturns on child mortality: a global economic analysis, 1981–2010. BMJ Glob Health. 2017;2: e000157. doi:10.1136/bmjgh-2016-000157

17. Tejada CAO, Triaca LM, Liermann NH, Ewerling F, Costa JC, Tejada CAO, et al. Economic crises, child mortality and the protective role of public health expenditure. Ciência & Saúde Coletiva. 2019;24: 4395–4404. doi:10.1590/1413-812320182412.25082019

18. Ensor T, Cooper S, Davidson L, Fitzmaurice A, Graham WJ. The impact of economic recession on maternal and infant mortality: lessons from history. BMC Public Health. 2010;10: 727. doi:10.1186/1471-2458-10-727

19. World Development Indicators | DataBank. [cited 30 Aug 2020]. Available: https://databank.worldbank.org/source/world-development-indicators

20. Roberton T, Carter ED, Chou VB, Stegmuller AR, Jackson BD, Tam Y, et al. Early estimates of the indirect effects of the COVID-19 pandemic on maternal and child mortality in low-income and middle-income countries: a modelling study. Lancet Glob Health. 2020;8: e901–e908. doi:10.1016/S2214-109X(20)30229-1

21. Weiss DJ, Bertozzi-Villa A, Rumisha SF, Amratia P, Arambepola R, Battle KE, et al. Indirect effects of the COVID-19 pandemic on malaria intervention coverage, morbidity, and mortality in Africa: a geospatial modelling analysis. Lancet Infect Dis. 2021;21: 59–69. doi:10.1016/S1473-3099(20)30700-3

22. Piketty T. Capital and Ideology. Harvard University Press; 2020.
APPENDIX

Descriptive statistics

*Appendix Table 1 Descriptive Statistics of variables used for the analysis*
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 1970 | 1975 | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 | 2055 | 2060 | 2065 | 2070 | 2075 | 2080 |
| Median |    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Under five mortality (deaths) | | | | | | | | | | | | | | | | | | | | | | | | |
| under age 5 per 1,000 live | 102.40 | 100.82 | 99.98 | 97.14 | 94.00 | 92.98 | 91.40 | 87.84 | 87.00 | 82.98 | 80.50 | 77.91 | 75.24 | 72.55 | 69.94 | 67.39 | 64.92 | 62.55 | 60.29 | 58.11 | 56.02 | 54.01 |
| Standard Deviation | 7.12 | 7.22 | 7.40 | 7.68 | 8.00 | 8.20 | 8.38 | 8.66 | 8.80 | 9.00 | 9.20 | 9.40 | 9.60 | 9.80 | 10.00 | 10.20 | 10.40 | 10.60 | 10.80 | 11.00 | 11.20 | 11.40 |
| Infant mortality (deaths) | 60.62 | 59.82 | 59.00 | 57.14 | 55.00 | 53.78 | 52.50 | 51.20 | 50.00 | 48.78 | 47.50 | 46.20 | 44.90 | 43.60 | 42.30 | 41.00 | 39.70 | 38.40 | 37.10 | 35.80 | 34.50 |
| Standard Deviation | 3.24 | 3.34 | 3.44 | 3.54 | 3.64 | 3.74 | 3.84 | 3.94 | 4.04 | 4.14 | 4.24 | 4.34 | 4.44 | 4.54 | 4.64 | 4.74 | 4.84 | 4.94 | 5.04 | 5.14 | 5.24 | 5.34 |

| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
| Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year | Year |
Multiple Imputation

In order to fill in missing values in the independent control variables of interest, we performed multiple imputation using multivariate normal regression. We selected this approach because all the variables used in the analysis are continuous and because it uses an iterative Markov chain Monte Carlo method to impute missing values.

The method uses data augmentation to simulate unobserved missing values. The data augmentation process consists of two steps. In the first step, missing values in \( x_i \) are replaced by draws from the conditional posterior distribution of \( x_{i(m)} \) given the observed data and current values of model parameters independently for each \( i \). In a second step, the new values of the parameters are drawn from their conditional posterior distribution given the observed data and the data imputed in the previous step. These processes are repeated for a number of iterations, which is determined by the length of the burn-in period and the number of iterations between imputations. The length of the burn-in period must be large enough in order to ensure that the chain converges to the stationary distribution. The number of iterations between imputation should be large enough to ensure that the random draws are approximately independent.

For this study, we imputed 65 additional data-sets, since the largest share of missing values in a variable was around 55%. The number of iterations used in the burn-in period to reach stationarity was 2500. In order to reduce the correlation between sets of imputed values, 900 iterations of the Markov chain Monte Carlo were performed between imputations. We used an informative ridge prior distribution for the Markov chain Monte Carlo procedure; we selected this prior because in
some countries had few observations. Appendix table 2 presents a summary of our multiple imputation and Appendix Figure 1 demonstrates convergence of the Markov chain Monte Carlo algorithm.

*Appendix Table 2 Multiple imputation summary*

| Variable                                           | Complete | Incomplete | Imputed | Total |
|---------------------------------------------------|----------|------------|---------|-------|
| GDP per capita constant 2010$                      | 3625     | 374        | 374     | 3999  |
| Log GDP per capita constant 2010$                  | 3748     | 251        | 251     | 3999  |
| Physicians (per 1,000 people)                      | 1853     | 2146       | 2146    | 3999  |
| Electric power consumption (kWh per capita)        | 2132     | 1867       | 1867    | 3999  |
| Proportion of seats held by women in national parliaments (%) | 2738     | 1261       | 1261    | 3999  |
| Immunization, DPT (% of children ages 12-23 months) | 3639     | 360        | 360     | 3999  |

Source: Authors’ elaboration
Appendix Figure 1 Convergence of the Markov chain Monte Carlo (MCMC)

Source: Authors' elaboration
Appendix Figure 2 Autocorrelation of the Worst linear function

The auto-correlation disappears after 25 lags, which ensures that there is independence between imputations.
Estimation of the U5MR time trajectories at country level

Appendix Figure 3 Estimated effect of GDP reductions on U5MR at country level (fitted values)

Source: Author's estimation
Source: [Author/Institution]
Source: Author's elaboration
# Estimations

## Model 1

(Appendix Table 3 Estimated effect of GDP reduction on U5M (model without controls))

| Country                  | Under 5 deaths | 95% Confidence interval - lower bound | 95% Confidence interval - upper bound | Under-5 deaths 5% reduction on GDP | 95% Confidence interval - lower bound | 95% Confidence interval - upper bound | Incremental Deaths at 5% Recession | Under 5 deaths 10% reduction on GDP | 95% Confidence interval - lower bound | 95% Confidence interval - upper bound | Incremental Deaths at 10% Recession | Under 5 deaths 15% reduction on GDP | 95% Confidence interval - lower bound | 95% Confidence interval - upper bound | Incremental Deaths at 15% Recession |
|--------------------------|----------------|--------------------------------------|--------------------------------------|------------------------------------|--------------------------------------|--------------------------------------|------------------------------------|-------------------------------------|--------------------------------------|--------------------------------------|------------------------------------|-------------------------------------|--------------------------------------|--------------------------------------|-------------------------------------|
| Afghanistan              | 279,869        | 113,507                              | 690,059                              | 286,568                            | 116,685                              | 703,787                              | 6,699                              | 293,803                             | 120,129                              | 718,566                              | 13,935                             | 301,651                             | 123,878                              | 734,543                             | 21,782                              |
| Albania                  | 3,055          | 1,037                                | 8,998                                | 3,128                              | 1,067                                | 9,172                                | 73                                 | 3,207                               | 1,099                                | 9,360                                | 152                                | 3,293                               | 1,134                                | 9,562                                | 238                                |
| Algeria                  | 93,430         | 31,775                               | 274,723                              | 95,667                             | 32,682                               | 280,038                              | 2,236                              | 98,082                              | 33,665                               | 285,756                              | 4,652                              | 100,702                             | 34,737                               | 291,931                             | 7,272                              |
| Angola                   | 125,443        | 44,014                               | 358,663                              | 128,650                            | 45,267                               | 365,628                              | 3,008                              | 131,899                             | 46,626                               | 373,120                              | 6,256                              | 135,422                             | 48,107                               | 381,212                             | 9,779                              |
| Argentina                | 48,814         | 15,518                               | 153,549                              | 49,982                             | 15,963                               | 156,500                              | 1,168                              | 51,244                              | 16,446                               | 159,672                              | 2,430                              | 52,613                               | 16,972                               | 163,098                             | 3,799                              |
| Armenia                  | 4,020          | 1,382                                | 11,695                               | 4,116                              | 1,421                                | 11,920                               | 96                                 | 4,220                               | 1,464                                | 12,164                               | 200                                | 4,332                               | 1,510                                | 12,427                              | 313                                |
| Azerbaijan               | 13,915         | 4,647                                | 41,661                               | 14,248                             | 4,780                                | 42,465                               | 333                                | 14,687                              | 4,924                                | 43,330                               | 693                                | 14,998                              | 5,081                                | 44,265                              | 1,083                              |
| Bangladesh               | 515,704        | 198,110                              | 1,342,442                            | 528,048                            | 203,698                              | 1,368,869                            | 12,345                            | 541,381                             | 209,755                              | 1,397,309                            | 25,677                             | 555,841                             | 216,352                              | 1,428,843                           | 40,137                             |
| Belarus                  | 8,845          | 2,930                                | 26,706                               | 9,057                              | 3,013                                | 27,221                               | 212                                | 9,286                               | 3,104                                | 27,775                               | 440                                | 9,534                               | 3,203                                | 28,374                              | 688                                |
| Benin                    | 774            | 266                                  | 2,251                                | 793                                | 274                                  | 2,295                                | 19                                 | 813                                 | 282                                  | 2,342                                | 39                                 | 834                                 | 291                                  | 2,393                               | 60                                 |
| Benin                    | 67,402         | 25,807                               | 176,040                              | 69,015                             | 26,535                               | 179,504                              | 1,613                              | 70,758                              | 27,324                               | 183,231                              | 3,356                              | 72,648                              | 28,184                               | 187,259                             | 5,246                              |
| Bhutan                   | 1,470          | 521                                  | 4,149                                | 1,505                              | 535                                  | 4,250                                | 35                                 | 1,543                              | 551                                  | 4,316                                | 73                                 | 1,584                              | 569                                  | 4,410                               | 114                                |
| Bolivia                  | 29,709         | 10,691                               | 82,555                               | 30,420                             | 10,995                               | 84,164                               | 711                                | 31,188                              | 11,324                               | 85,895                               | 1,479                              | 32,021                              | 11,683                               | 87,765                              | 2,312                              |
| Bosnia and Herzegovina   | 2,259          | 755                                  | 6,737                                | 2,313                              | 777                                  | 6,887                                | 54                                 | 2,372                              | 800                                  | 7,028                                | 112                                | 2,435                              | 826                                  | 7,179                               | 176                                |
| Botswana                 | 3,998          | 1,381                                | 12,290                               | 4,094                              | 1,338                                | 12,526                               | 96                                 | 4,197                              | 1,379                                | 12,781                               | 199                                | 4,310                              | 1,423                                | 13,056                              | 311                                |
| Brazil                   | 181,631        | 57,287                               | 575,867                              | 185,979                            | 58,931                               | 586,924                              | 4,348                              | 190,674                             | 60,715                               | 598,814                              | 9,043                              | 195,767                             | 62,658                               | 611,651                             | 14,136                             |

22
| Country                        | Population |
|-------------------------------|------------|
| Bulgaria                      | 4,484      |
| Burkina Faso                  | 449,031    |
| Burundi                       | 1,892      |
| Cameroon                      | 130,780    |
| Central African Republic      | 44,619     |
| Chad                          | 120,242    |
| China                         | 1,275,963  |
| Colombia                      | 55,252     |
| Comoros                       | 4,052      |
| Congo                         | 19,540     |
| Costa Rica                    | 4,653      |
| Cuba                          | 9,095      |
| Côte d'Ivoire                 | 126,899    |
| Dem People's Republic of Korea| 41,451     |
| Democratic Republic of the Congo| 906,013  |
| Djibouti                      | 1,882      |
| Dominican Republic            | 15,264     |
| Ecuador                       | 29,711     |
| Egypt                         | 299,137    |
| El Salvador                   | 12,418     |
| Equatorial Guinea             | 2,489      |
| Eritrea                       | 14,973     |
| **Total**                     | **318,483**|
| Country         | Code | Population | GDP (Billion) | GDP Per Capita (USD) |
|----------------|------|------------|---------------|---------------------|
| Eswatini       | 432  | 2.676      | 911           | 7,862               |
| Ethiopia       | 404  | 8,196      | 92,740        | 9,768               |
| Fiji           | 442  | 1,541      | 9,679         | 1,974               |
| Gabon          | 408  | 4,679      | 6,970         | 8,139               |
| Gambia         | 686  | 9,769      | 9,769         | 1,036               |
| Georgia        | 780  | 6,970      | 6,970         | 9,769               |
| Ghana          | 302  | 2,676      | 2,676         | 1,036               |
| Grenada        | 126  | 42         | 42            | 42                  |
| Guatemala      | 521  | 4,888      | 4,888         | 4,888               |
| Guinea         | 686  | 9,679      | 9,679         | 1,036               |
| Guinea-Bissau  | 625  | 9,679      | 9,679         | 1,036               |
| Guyana         | 521  | 4,888      | 4,888         | 4,888               |
| Haiti          | 521  | 4,888      | 4,888         | 4,888               |
| Honduras       | 397  | 1,036      | 1,036         | 1,036               |
| India          | 302  | 4,888      | 4,888         | 4,888               |
| Indonesia      | 521  | 4,888      | 4,888         | 4,888               |
| Iran (Islamic Republic of) | 408 | 1,036      | 1,036         | 1,036               |
| Iraq           | 780  | 9,679      | 9,679         | 1,036               |
| Jamaica        | 397  | 1,036      | 1,036         | 1,036               |
| Jordan         | 404  | 9,679      | 9,679         | 1,036               |
| Kazakhstan     | 302  | 4,888      | 4,888         | 4,888               |
| Kenya          | 780  | 9,679      | 9,679         | 1,036               |
| Kiribati       | 408  | 1,036      | 1,036         | 1,036               |
| Kyrgyzstan     | 404  | 9,679      | 9,679         | 1,036               |
| Lao People's Democratic Republic | 408 | 1,036      | 1,036         | 1,036               |
| Lebanon        | 780  | 9,679      | 9,679         | 1,036               |
| Lesotho        | 442  | 1,036      | 1,036         | 1,036               |
| Libya          | 404  | 9,679      | 9,679         | 1,036               |
| Country                  | Population |
|-------------------------|------------|
| Madagascar             | 219,003    |
| Malawi                 | 151,606    |
| Russian Federation     | 142,829    |
| Moldova                | 32,124     |
| Republic of Philippines | 32,324    |
| Maldives               | 525        |
| Mali                   | 155,656    |
| Montenegro             | 543        |
| Morocco                | 73,082     |
| Mozambique             | 251,430    |
| Myanmar                | 143,552    |
| Namibia                | 5,995      |
| Nepal                  | 115,550    |
| Nicaragua              | 18,802     |
| Niger                  | 243,175    |
| Nigeria                | 856,896    |
| North Macedonia        | 1,909      |
| Pakistan               | 1,000,517  |
| Papua New Guinea       | 27,906     |
| Paraguay               | 12,496     |
| Peru                   | 46,124     |
| Philippines            | 242,622    |
| Republic of Moldova    | 4,440      |
| Russian Federation     | 114,014    |
| Rwanda                 | 78,646     |

Microstates (Federated States of)

| Country                  | Population |
|-------------------------|------------|
| Micronesia (Fed. States of) | 294        |
| Mongolia                | 7,499      |
| Montenegro              | 543        |
| Morocco                 | 73,082     |
| Mozambique              | 251,430    |
| Myanmar                 | 143,552    |
| Namibia                 | 5,995      |
| Nepal                   | 115,550    |
| Nicaragua               | 18,802     |
| Niger                   | 243,175    |
| Nigeria                 | 856,896    |
| North Macedonia         | 1,909      |
| Pakistan                | 1,000,517  |
| Papua New Guinea        | 27,906     |
| Paraguay                | 12,496     |
| Peru                    | 46,124     |
| Philippines             | 242,622    |
| Republic of Moldova     | 4,440      |
| Russian Federation      | 114,014    |
| Rwanda                  | 78,646     |
| Country                          | Population |
|---------------------------------|------------|
| Saint Lucia                     | 150        |
| Saint Vincent and the Grenadines| 122        |
| Samoa                           | 558        |
| Sao Tome and Principe            | 1,081      |
| Senegal                         | 83,013     |
| Serbia                          | 6,675      |
| Sierra Leone                     | 62,849     |
| Solomon Islands                  | 3,296      |
| Somalia                         | 96,456     |
| South Africa                     | 86,983     |
| South Sudan                      | 75,191     |
| Sri Lanka                        | 34,005     |
| Sudan                            | 183,077    |
| Suriname                         | 759        |
| Syrian Arab Republic             | 36,882     |
| Tajikistan                       | 51,143     |
| Thailand                         | 59,407     |
| Timor-Leste                      | 7,193      |
| Togo                             | 56,223     |
| Tonga                            | 245        |
| Tunisia                          | 19,417     |
| Turkey                           | 72,774     |
| Turkmenistan                     | 10,168     |
| Uganda                           | 308,549    |
| Ukraine                          | 48,486     |
| Country                  | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|--------------------------|------|------|------|------|------|------|------|------|------|------|
| United Republic of      | 383.628 | 449.719 | 582.974 | 592.811 | 153.934 | 1,002.340 | 9.183 | 402.728 | 158.503 | 1,023.266 | 18.711 | 413.486 | 163.477 | 1,045.838 | 28.858 |
| Tanzania                 | 89.351 | 102.296 | 346.099 | 91.785 | 53.312 | 255.899 | 2.134 | 95.890 | 34.207 | 256.064 | 4.439 | 96.090 | 35.289 | 261.643 | 6.959 |
| Vanuatu                  | 992   | 333   | 2,787  | 1,016  | 363   | 2,682  | 24   | 1,041  | 374   | 2,900  | 49   | 1,069  | 366   | 2,963  | 77   |
| Vietnam                  | 39.990 | 10.728 | 148.677 | 40.950 | 11.057 | 131.662 | 957  | 41.984 | 11.381 | 154.876 | 1.991 | 43.105 | 11.754 | 158.350 | 3.113 |
| Vietnam (Republic of)    | 226.042 | 83.356 | 412.969 | 211.432 | 85.718 | 404.956 | 5.411 | 237.296 | 88.279 | 637.854 | 11.254 | 243.634 | 91.069 | 651.789 | 17.593 |
| Yemen                    | 186.570 | 74.594 | 466.635 | 193.656 | 76.687 | 475.890 | 4.466 | 195.859 | 78.956 | 485.854 | 9.289 | 201.091 | 81.425 | 496.623 | 14.521 |
| Zimbabwe                 | 89.936 | 33.110 | 228.893 | 91.065 | 34.047 | 255.272 | 2.129 | 93.385 | 35.063 | 248.606 | 4.428 | 95.888 | 36.170 | 254.945 | 6.922 |
| Zambia                   | 72.349 | 27.282 | 185.724 | 74.081 | 28.561 | 193.484 | 1.722 | 72.872 | 25.208 | 197.899 | 3.602 | 77.880 | 20.127 | 201.827 | 5.031 |
| Total                    | 1,029,267 | 371,514 | 17,512,184 | 462,817 | 17,667,229 | 837,522 | 16,139,129 | 1,309,022 |

Source: Authors' elaboration
### Appendix Table 4: Estimated Under-5 Lives Lost from 2020 Recession Scaled from 5% to 15%.

| Country                          | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 |
|----------------------------------|------------|------------|------------|------------|
|                                  | No Recession | 5% Recession | 10% Recession | 15% Recession |
| Burundi                          | 9.68       | 9.82       | 9.97       | 10.14      |
| Niger                            | 9.64       | 9.78       | 9.93       | 10.09      |
| Democratic Republic of the Congo| 8.77       | 8.9        | 9.04       | 9.18       |
| Central African Republic         | 7.33       | 7.44       | 7.55       | 7.68       |
| Mali                             | 7.15       | 7.26       | 7.37       | 7.49       |
| Chad                             | 6.54       | 6.63       | 6.73       | 6.84       |
| Mozambique                       | 6.37       | 6.46       | 6.56       | 6.67       |
| Burkina Faso                     | 6.3        | 6.4        | 6.5        | 6.6        |
| Somalia                          | 6.14       | 6.23       | 6.32       | 6.43       |
| Sierra Leone                     | 6.13       | 6.22       | 6.31       | 6.42       |

Source: Authors' elaboration
### Model 2

**Appendix Table 4 Estimated effect of GDP reduction on U5M (model with controls)**

| Country            | Under 5 deaths | 95% Confidence Interval - lower bound | 95% Confidence Interval - upper bound | Under 5 deaths % reduction on GDP | 95% Confidence Interval - lower bound | 95% Confidence Interval - upper bound | Incremental Deaths at 9% Recession | Under 5 deaths 10% reduction on GDP | 95% Confidence Interval - lower bound | 95% Confidence Interval - upper bound | Incremental Deaths at 10% Recession | Under 5 deaths 15% reduction on GDP | 95% Confidence Interval - lower bound | 95% Confidence Interval - upper bound | Incremental Deaths at 15% Recession |
|--------------------|----------------|--------------------------------------|--------------------------------------|---------------------------------|--------------------------------------|--------------------------------------|-----------------------------------|---------------------------------|---------------------------------|--------------------------------------|-----------------------------------|---------------------------------|---------------------------------|-----------------------------------|-----------------------------------|
| Afghanistan        | 323,613        | 120,308                              | 870,476                              | 328,370                         | 122,533                              | 879,983                              | 4,757                             | 333,460                         | 124,920                         | 890,133                              | 9,484                             | 338,927                         | 127,492                         | 901,013                           | 15,315                           |
| Albania            | 2,394          | 752                                  | 7,622                                | 2,429                           | 766                                  | 7,701                                | 35                                | 2,466                           | 781                             | 7,785                                | 73                                | 2,907                           | 798                             | 7,875                             | 113                              |
| Algeria            | 110,808        | 34,603                               | 354,838                              | 112,437                         | 35,262                               | 358,513                              | 1,629                             | 114,180                         | 35,971                         | 362,432                              | 3,372                             | 116,052                         | 36,735                         | 366,626                           | 5,244                            |
| Angola             | 235,624        | 75,729                               | 733,123                              | 239,088                         | 77,167                               | 740,769                              | 3,464                             | 242,794                         | 78,712                         | 748,924                              | 7,170                             | 246,775                         | 80,377                         | 757,656                           | 11,151                           |
| Argentina          | 53,650         | 15,722                               | 183,073                              | 54,438                          | 16,025                               | 184,938                              | 789                               | 55,282                          | 16,349                         | 186,926                              | 1,633                             | 57,189                          | 16,700                         | 189,054                           | 2,539                            |
| Armenia            | 3,166          | 1,000                                | 10,018                               | 3,212                           | 1,019                                | 10,123                               | 47                                | 3,262                           | 1,040                         | 10,234                              | 96                                | 3,316                          | 1,062                         | 10,353                           | 150                              |
| Azerbaijan         | 12,099         | 3,740                                | 39,138                               | 12,277                         | 3,812                                | 39,542                               | 178                               | 12,467                         | 3,888                         | 39,971                              | 368                               | 12,671                         | 3,971                         | 40,431                           | 573                              |
| Bangladesh         | 435,117        | 153,268                              | 1,255,269                            | 441,513                         | 136,135                              | 1,248,500                            | 6,396                             | 448,358                         | 159,212                        | 1,262,622                            | 13,241                            | 455,709                         | 162,528                        | 1,277,750                        | 20,592                           |
| Belarus            | 7,379          | 2,244                                | 24,266                               | 7,487                           | 2,287                                | 24,517                               | 108                               | 7,663                           | 2,333                         | 24,784                              | 225                               | 7,728                          | 2,382                         | 25,070                           | 349                              |
| Belize             | 749            | 237                                  | 2,367                                | 760                             | 241                                  | 2,392                                | 11                                | 772                            | 246                           | 2,418                              | 23                                | 784                            | 252                           | 2,446                             | 35                               |
| Benin              | 98,813         | 34,464                               | 281,314                              | 100,266                         | 35,109                               | 286,346                              | 1,453                             | 101,820                        | 35,801                         | 289,583                              | 3,007                             | 103,489                        | 36,547                         | 293,050                           | 4,767                            |
| Bhutan             | 1,332          | 435                                  | 4,078                                | 1,352                           | 444                                  | 4,120                                | 20                                | 1,373                          | 453                           | 4,166                              | 41                                | 1,395                          | 462                           | 4,214                             | 63                               |
| Bolivia (Plurinational State of) | 29,494 | 9,774                                | 88,998                               | 29,928                         | 9,959                                | 89,932                               | 434                               | 30,391                         | 10,158                        | 90,929                              | 898                               | 30,890                         | 10,372                        | 91,996                            | 1,396                            |
| Bosnia and Herzegovina | 1,702 | 521                                  | 5,557                                | 1,727                           | 531                                  | 5,614                                | 25                                | 1,753                          | 542                           | 5,676                              | 52                                | 1,782                          | 553                           | 5,741                             | 81                               |
| Botswana           | 5,091          | 1,534                                | 16,899                               | 5,166                          | 1,563                                | 17,072                               | 75                                | 5,246                          | 1,595                         | 17,257                              | 155                               | 5,332                          | 1,629                         | 17,455                            | 241                              |
| Brazil             | 182,846        | 53,523                               | 624,640                              | 185,534                         | 54,554                               | 630,985                              | 2,688                             | 188,410                        | 55,662                        | 637,751                              | 5,564                             | 191,499                        | 56,857                        | 644,969                           | 8,653                            |
| Bulgaria           | 3,723          | 1,113                                | 12,449                               | 3,778                          | 1,135                                | 12,577                               | 55                                | 3,836                          | 1,158                         | 12,713                              | 113                               | 3,889                          | 1,182                         | 12,858                            | 176                              |
| Burkina Faso       | 218,887        | 79,526                               | 602,461                              | 222,105                         | 81,005                               | 608,984                              | 3,218                             | 225,548                        | 82,591                        | 615,948                              | 6,661                             | 226,246                        | 84,300                        | 625,410                           | 10,359                           |
| Burundi            | 196,778        | 78,436                               | 503,757                              | 201,700                         | 79,854                               | 509,463                              | 2,922                             | 284,827                        | 81,756                        | 515,559                              | 6,049                             | 268,185                        | 83,013                        | 522,098                           | 9,407                            |
| Country                      | Area   | Population |
|------------------------------|--------|------------|
| Cabo Verde                   | 1,146  | 367        |
| Cambodia                     | 59,438 | 20,803     |
| Cameroon                     | 183,530| 63,386     |
| Central African Republic     | 54,126 | 20,663     |
| Chad                         | 191,519| 68,658     |
| China                        | 1,235,908| 372,924   |
| Colombia                     | 51,670 | 15,615     |
| Comoros                      | 5,310  | 1,842      |
| Congo                        | 29,476 | 9,685      |
| Costa Rica                   | 4,588  | 1,351      |
| Cuba                         | 8,100  | 2,669      |
| Côte d'Ivoire                | 185,002| 63,376     |
| Democratic Republic of Korea | 37,542 | 10,563     |
| Democratic Republic of the Congo | 1,388,004 | 524,706 |
| Djibouti                     | 2,076  | 583        |
| Dominican Republic           | 16,310 | 4,937      |
| Ecuador                      | 30,859 | 9,623      |
| Egypt                        | 339,094| 110,682    |
| El Salvador                  | 11,381 | 3,664      |
| Equatorial Guinea            | 4,411  | 1,284      |
| Eritrea                      | 19,306 | 6,022      |
| Estonia                      | 3,328  | 1,046      |
| Ethiopia                     | 992,985| 369,329    |
| Fiji                         | 1,887  | 593        |

| Country                      | Area   | Population |
|------------------------------|--------|------------|
| Cabo Verde                   | 1,146  | 3,582      |
| Cambodia                     | 59,438 | 20,312     |
| Cameroon                     | 183,530| 63,403     |
| Central African Republic     | 54,126 | 20,043     |
| Chad                         | 191,519| 69,935     |
| China                        | 1,235,908| 4,005,918 |
| Colombia                     | 51,670 | 15,915     |
| Comoros                      | 5,310  | 1,530      |
| Congo                        | 29,476 | 9,869      |
| Costa Rica                   | 4,588  | 1,584      |
| Cuba                         | 8,100  | 2,669      |
| Côte d'Ivoire                | 185,002| 64,560     |
| Democratic Republic of Korea | 37,542 | 10,563     |
| Democratic Republic of the Congo | 1,388,004 | 524,706 |
| Djibouti                     | 2,076  | 583        |
| Dominican Republic           | 16,310 | 4,937      |
| Ecuador                      | 30,859 | 9,623      |
| Egypt                        | 339,094| 110,682    |
| El Salvador                  | 11,381 | 3,664      |
| Equatorial Guinea            | 4,411  | 1,284      |
| Eritrea                      | 19,306 | 6,022      |
| Estonia                      | 3,328  | 1,046      |
| Ethiopia                     | 992,985| 369,329    |
| Fiji                         | 1,887  | 593        |
| Country                  | Population |
|--------------------------|------------|
| Gabon                    | 6,873      |
| Gambia                   | 25,061     |
| Georgia                  | 4,272      |
| Ghana                    | 156,000    |
| Grenada                  | 128        |
| Guatemala                | 47,406     |
| Guinea                   | 117,136    |
| Guinea-Bissau            | 18,386     |
|Guyana                   | 1,467      |
| Haiti                    | 49,167     |
| Honduras                 | 24,945     |
| Hungary                  | 9,922      |
| Iceland                  | 323,330    |
| Iran (Islamic Republic of)| 125,719    |
| Iraq                     | 121,740    |
| Jamaica                  | 3,971      |
| Jordan                   | 24,699     |
| Kazakhstan               | 25,519     |
| Kenya                    | 277,366    |
| Kiribati                 | 508        |
| Kyrgyzstan               | 22,676     |
| Laos People's Democratic Republic | 22,522 |
| Lebanon                  | 9,088      |
| Lesotho                  | 8,928      |
| Liberia                  | 44,683     |
| Libya                    | 9,972      |
| Madagascar               | 245,912    |
| Malawi                   | 173,658    |
| Malaysia                 | 33,845     |

31
| Country                        | Population     |
|-------------------------------|----------------|
| Maldives                      | 529            |
| Mali                          | 257,889        |
| Mauritania                    | 28,358         |
| Russian Federation            | 100,190        |
| Moldova                       | 3,073          |
| Republic of Philippines       | 240,542        |
| Peru                          | 46,296         |
| Paraguay                      | 12,704         |
| Guinea                        | 32,868         |
| Papua New Guinea              | 92,564         |
| Philippines                   | 91,223         |
| Saint Lucia                   | 134            |
| Micronesia (Fed. States of)   | 320            |
| Mongolia                      | 8,259          |
| Montenegro                    | 457            |
| Morocco                       | 71,179         |
| Mozambique                    | 328,481        |
| Myanmar                       | 123,623        |
| Namibia                       | 7,403          |
| Nepal                         | 80,023         |
| Nicaragua                     | 16,495         |
| Niger                         | 461,338        |
| Nigeria                       | 1,503,219      |
| North Macedonia               | 1,505          |
| Pakistan                      | 1,054,683      |
| Papua New Guinea              | 32,868         |
| Paraguay                      | 12,704         |
| Peru                          | 46,296         |
| Philippines                   | 240,542        |
| Republic of Moldova           | 3,073          |
| Russian Federation            | 100,190        |
| Rwanda                        | 91,223         |
| Saint Lucia                   | 134            |

32
| Country and Region                  | Population 2020 |
|------------------------------------|-----------------|
| Saint Vincent and the Grenadines   | 115             |
| Sao Tome and Principe               | 1,419           |
| Senegal                            | 114,939         |
| Serbia                             | 5,194           |
| Sierra Leone                        | 71,002          |
| Solomon Islands                     | 4,201           |
| Somalia                             | 173,482         |
| South Africa                        | 99,249          |
| South Sudan                         | 97,763          |
| Sri Lanka                           | 33,501          |
| Sudan                               | 256,024         |
| Suriname                            | 809             |
| Syrian Arab Republic                | 39,592          |
| Tajikistan                          | 46,998          |
| Thailand                            | 52,894          |
| Timor-Leste                         | 7,888           |
| Togo                                | 67,490          |
| Tonga                               | 298             |
| Tunisia                             | 18,764          |
| Turkey                              | 68,071          |
| Turkmenistan                        | 10,026          |
| Uganda                              | 415,087         |
| Ukraine                             | 33,813          |
| United Republic of Tanzania         | 523,317         |
| **Total**                           | **1,913,060**   |
| Country  | 2013     | 2014     | 2015     | 2016     | 2017     | 2018     | 2019     | 2020     |
|---------|----------|----------|----------|----------|----------|----------|----------|----------|
| Ubolimwe | 71,320   | 25,685   | 204,277  | 72,368   | 24,112   | 217,624  | 1,048    | 75,490   |
| Vunrua   | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vunuva   | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vunwee   | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vunuva   | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vunuva   | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vunuva   | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vunuva   | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vunuva   | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |
| Vollomwe | 1,254    | 466      | 3,753    | 1,252    | 413      | 3,793    | 18       | 1,372    |

Total: 19,265,631  18,033,631  282,996  19,836,436  588,805  20,160,661  911,074

Source: Authors' elaboration
Sensitivity analysis

Appendix Table 5 Sensitivity analysis of incremental deaths (95% Confidence Intervals)

![Graphs showing sensitivity analysis for GDP reduction of 5%, 10%, and 15% with iteration and incremental deaths.]
