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COVID-19 Age-Mortality Curves Are Flatter in Developing Countries

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Abstract

A greater share of reported COVID-19 deaths occur at younger ages in low- and middle-income countries (LMICs) compared to high-income countries (HICs). Based on data from 26 countries, people age 70 and older constitute 37 percent of deaths attributed to COVID-19 in LMICs on average, versus 87 percent in HICs. Only part of this difference is accounted for by differences in population age structure. In this paper, COVID-19 mortality rates are calculated for each age group by dividing the number of COVID-19 deaths by the underlying population. The resulting age-mortality curves are flatter in countries with lower incomes. In HICs, the COVID-19 mortality rate for those ages 70–79 is 12.6 times the rate for those ages 50–59. In LMICs, that ratio is just 3.5. With each year of age, the age-specific mortality rate increases by an average of 12.6 percent in HICs versus 7.1 percent in LMICs. This pattern holds overall and separately for men's and women's mortality rates. It reflects some combination of variation across countries in age patterns of infection rates, fatality rates among those infected, and under-attribution of deaths to COVID-19. The findings highlight that experiences with COVID-19 in wealthy countries may not be generalizable to developing countries.

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COVID-19 Age-Mortality Curves Are Flatter in Developing Countries

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1 Introduction

As of this writing, the COVID-19 pandemic continues to grow around the world. While epidemiological models suggest that rates of infection are eventually likely to reach a high level in much of the world, the eventual health impact remains uncertain. The pandemic remains in early stages in most developing countries.

The likely health impact of the virus in developing countries is a topic of urgent concern. Developing countries generally have younger populations, which should be an advantage in facing a disease which has the harshest impact for the elderly. On the other hand, developing countries have lower quality health care and less access to safe water and sanitation (World Bank 2020, June). An analysis based on age structure and comorbidity prevalence found that 16 percent of the population in Sub-Saharan Africa is at increased risk of severe COVID-19, as compared to 22 percent globally (Clark, Jit et al. 2020). Another predicts infection fatality rates (IFRs) for countries, taking into account age structure, comorbidities, and health system capacity, finding slightly lower IFRs for less developed countries than for more developed countries (Ghisolfi et al. 2020). A third study suggests that the share of COVID-19 deaths in developing countries may rise sharply as the pandemic matures (Schellekens and Sourrouille 2020).

A central question relevant to predicting the effects of the virus as the pandemic spreads is the impact on mortality by age. As the pandemic grows in developing countries, will it affect primarily the very old as it has in wealthy nations? Studies of case fatality rates (CFR) show much higher rates of death among the aged, particularly the very old (Jordan, Adab et al. 2020, Li, Xu et al. 2020, Zheng, Peng et al. 2020, Zhou, Yu et al. 2020). CFRs, however, have the disadvantage that cases are not defined consistently across countries. An alternative approach is to measure the age-specific mortality rate, using deaths attributed to COVID-19 by age group divided by the underlying population in the age group (Goldstein and Lee 2020). The analysis in this paper builds on the Goldstein and Lee analysis of 5 countries and employs data for 26 countries, including 9 middle-income countries and one low-income country.[2]

[2] Following the World Bank country classifications, the high-income countries are Australia, Canada, Chile, Denmark, France, Germany, Hungary, Italy, Japan, Netherlands, Norway, Portugal, Republic of Korea, Spain, Sweden, Switzerland, the middle-income countries are Argentina, Brazil, Colombia, Malaysia, Mexico, Pakistan, Peru, Philippines, South Africa, and the low-income country is Afghanistan.

2 Distribution of Deaths by Age

COVID-19 mortality data were gathered from official government sources. See the Appendix for a complete listing. Data were used for countries with at least 100 reported COVID-19 deaths and for which a breakdown of mortality by age was available.[3]

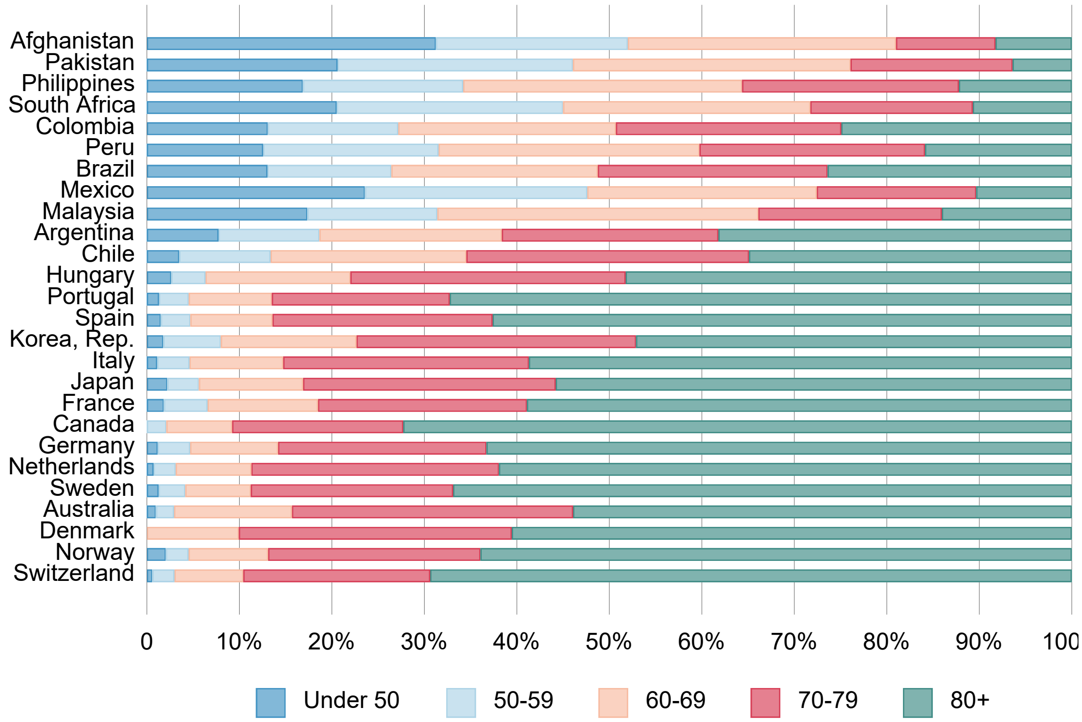
In nearly all high-income countries, people age 70 or older constitute the large majority of deaths attributed to COVID-19. For the set of high-income countries considered, on average 87 percent of COVID-19 deaths are of those age 70 or older. In contrast, in the low- and middle-income countries, on average just 37 percent are age 70 or older (Figure 1).

High-income countries have on average younger populations than low- and middle-income countries. Individuals over age 70 constitutes on average 15 percent of the population in the high-income countries analyzed in this paper vs. just 4 percent of the population in the low- and middle-income countries. To what extent can the wide variation in the age distribution of deaths be explained by the fact that high-income countries have substantially older populations who are more at risk from the disease? To consider this question, age-specific mortality rates were calculated by dividing the number of deaths attributed to COVID-19 for each 10-year age group by the population in each age group. Population data by age were taken from United Nations (2019), using the estimated populations corresponding to July 1, 2020. Because most countries group all COVID-19 deaths for those ages 80 and above in their reporting, 80+ is shown as a single category.

Next, for each country, a standardized population was created. The standard was generated using the mean population shares for each age group across high-income countries. Finally, a hypothetical distribution of deaths for each country was calculated by multiplying the standard population shares by the corresponding age-specific COVID-19 death rates. The resulting distributions are shown in Figure 2. A comparison of the true and hypothetical distributions is summarized in Table 1.

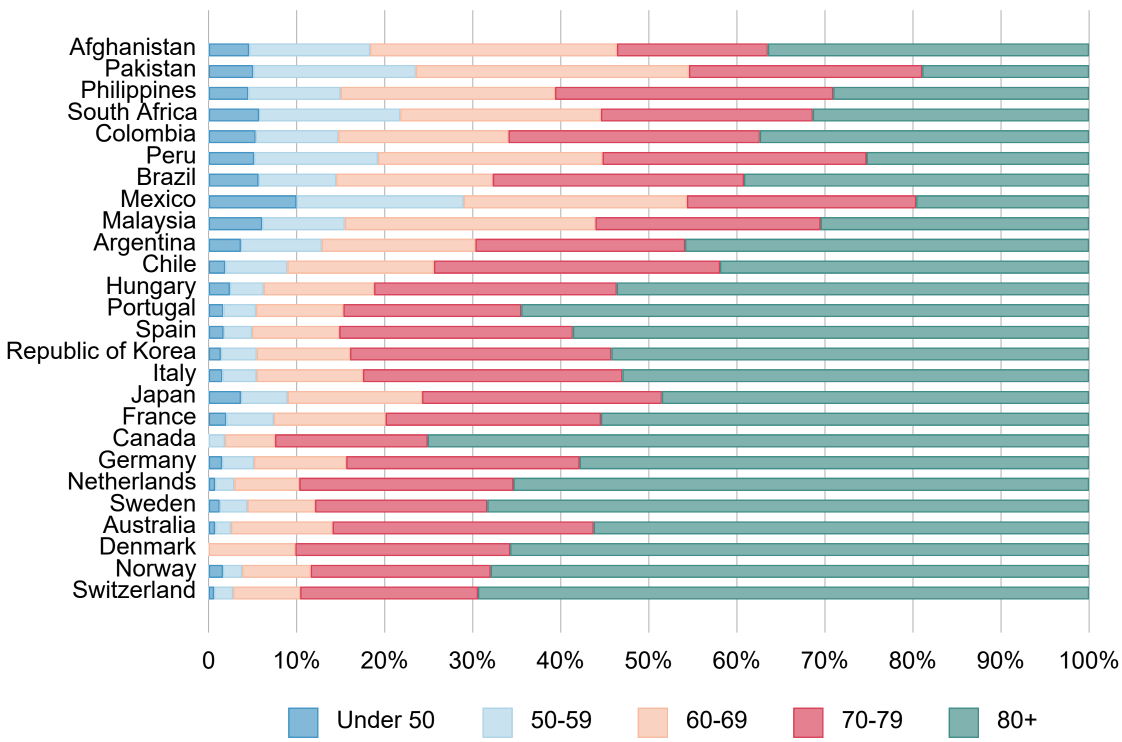
[3] The data used in this paper are the most currently available as of June 22, 2020.

Figure 1: Distribution of COVID-19 Deaths by Age Group for Each Country



Note: See Appendix for data sources. Countries are shown ranked by 2018 GDP pc in current USD from WDI.

Figure 2: Hypothetical COVID-19 Deaths by Age Group, Using Country Age-Specific COVID-19 Mortality Rates and the Mean High-Income Population Age Distribution



Note: See Appendix for data sources. Countries are shown ranked by 2018 GDP pc in current USD from WDI.

These hypothetical distributions provide the answer to the question of what the distribution of COVID-19 deaths would look like if each country had the mean high-income population age structure but its own observed age-specific COVID mortality rates. The low and middle income countries would have a larger mean share of deaths among people age 70 or older—58 percent rather than 37 percent—but still below the 87 percent share observed in high income countries. Thus, the differences in age structure can only partly account for the younger profile of deaths in developing countries.

Table 1: Shares of COVID-19 Deaths Over Age 70, Actual vs Hypothetical with HIC Age Structure

	Country	GDP per capita, 2018 (current US$)	Share of population over age 70	Actual share of reported COVID-19 deaths over age 70	Hypothetical share of COVID-19 deaths over age 70, with HIC age structure
Low- and middle-income	Afghanistan	521	2%	19%	54%
	Pakistan	1,482	3%	24%	45%
	Philippines	3,103	3%	36%	61%
	South Africa	6,374	3%	28%	55%
	Colombia	6,668	6%	49%	66%
	Peru	6,941	6%	40%	55%
	Brazil	9,001	6%	51%	68%
	Mexico	9,673	5%	28%	46%
	Malaysia	11,373	4%	34%	56%
	Argentina	11,684	8%	62%	70%
High-income	Chile	15,923	8%	65%	74%
	Hungary	16,151	13%	78%	81%
	Portugal	23,403	17%	86%	85%
	Spain	30,324	15%	86%	85%
	Republic of Korea	31,380	11%	77%	84%
	Italy	34,489	17%	85%	82%
	Japan	39,290	22%	83%	76%
	France	41,470	15%	81%	80%
	Canada	46,234	12%	91%	92%
	Germany	47,616	16%	86%	84%
	Netherlands	53,022	14%	89%	90%
	Sweden	54,651	15%	89%	88%
	Australia	57,396	11%	84%	86%
	Denmark	61,391	15%	90%	90%
	Norway	81,734	12%	87%	88%
	Switzerland	82,829	14%	90%	90%
	Mean LMIC		**4%**	**37%**	**58%**
	Mean HIC		**15%**	**87%**	**86%**

3 Age-Mortality Profiles

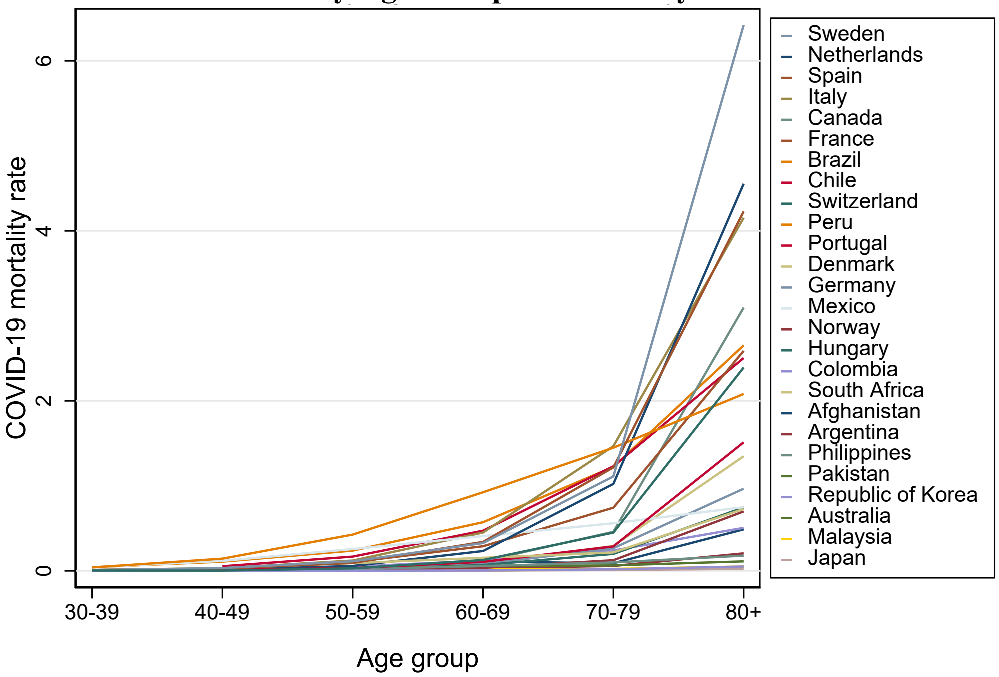
The remainder of this discussion considers the differences across countries in age-specific COVID-19 mortality rates, which in effect net out differences in age structure. Age-specific mortality rates are calculated by dividing deaths attributed to COVID by the underlying population count. They are distinct from a case fatality rate (CFR), which is the number of deaths divided by the number of recognized cases, and also from the infection fatality rate (IFR), which is the number of deaths divided by the number of people infected. The age-specific mortality calculations rely on United Nations population counts by age, which depend on the quality and availability of census and/or population registry data. Afghanistan last had a census in 1979, so its population estimates are likely to be particularly imprecise. Sweden adopted a register-based approach in 1995. All the other countries considered here have recent censuses.

For this analysis, a country-specific adjustment factor is applied to the 80+ mortality rates to account for the fact that the age distribution of the 80+ age group varies across countries. See the Appendix for details. The full set of mortality rates are shown in Figure 3. Because different countries have very different overall COVID-19 mortality, the age-specific mortality rates are at different levels. To compare the shape of the age-mortality curve across countries, normalized COVID-19 mortality rates were calculated for each country by summing up the mortality rates across age groups and then dividing the age-specific rates by this sum, so that they sum to one for any given country.

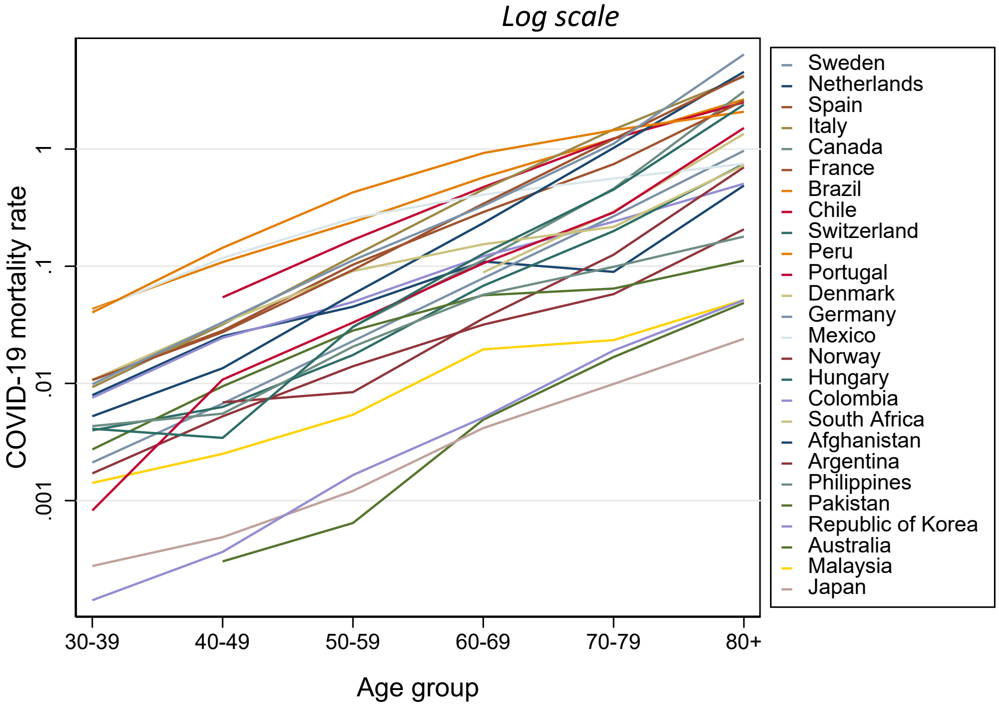
Normalized age-mortality curves are shown in Figure 4. In interpreting the normalized curves, it is important to recognize that they are only useful for comparing the shapes of the curves across countries. A comparison between countries of the normalized mortality rate for any particular age group is not informative.

The normalized curves make readily apparent the differences in curve shape across countries. Overall, higher income nations show steeper curves, i.e. in those countries death rates are much higher for the oldest groups (70-79 and 80+) than for those in the slightly younger groups (40-49, 50-59, and 60-69). The average age-specific mortality rates for the high-income countries and separately the low- and middle-income countries are shown in Figure 5. The plot of the figure on a log scale shows that the average age-specific mortality rate increases slightly with age in the high-income countries. In the low- and middle-income countries, on average, the mortality rate is flatter between ages 60-69 and 70-79.

Figure 3: Unnormalized COVID-19 Mortality Rates (Deaths per 1000 Population) by Age Group and Country

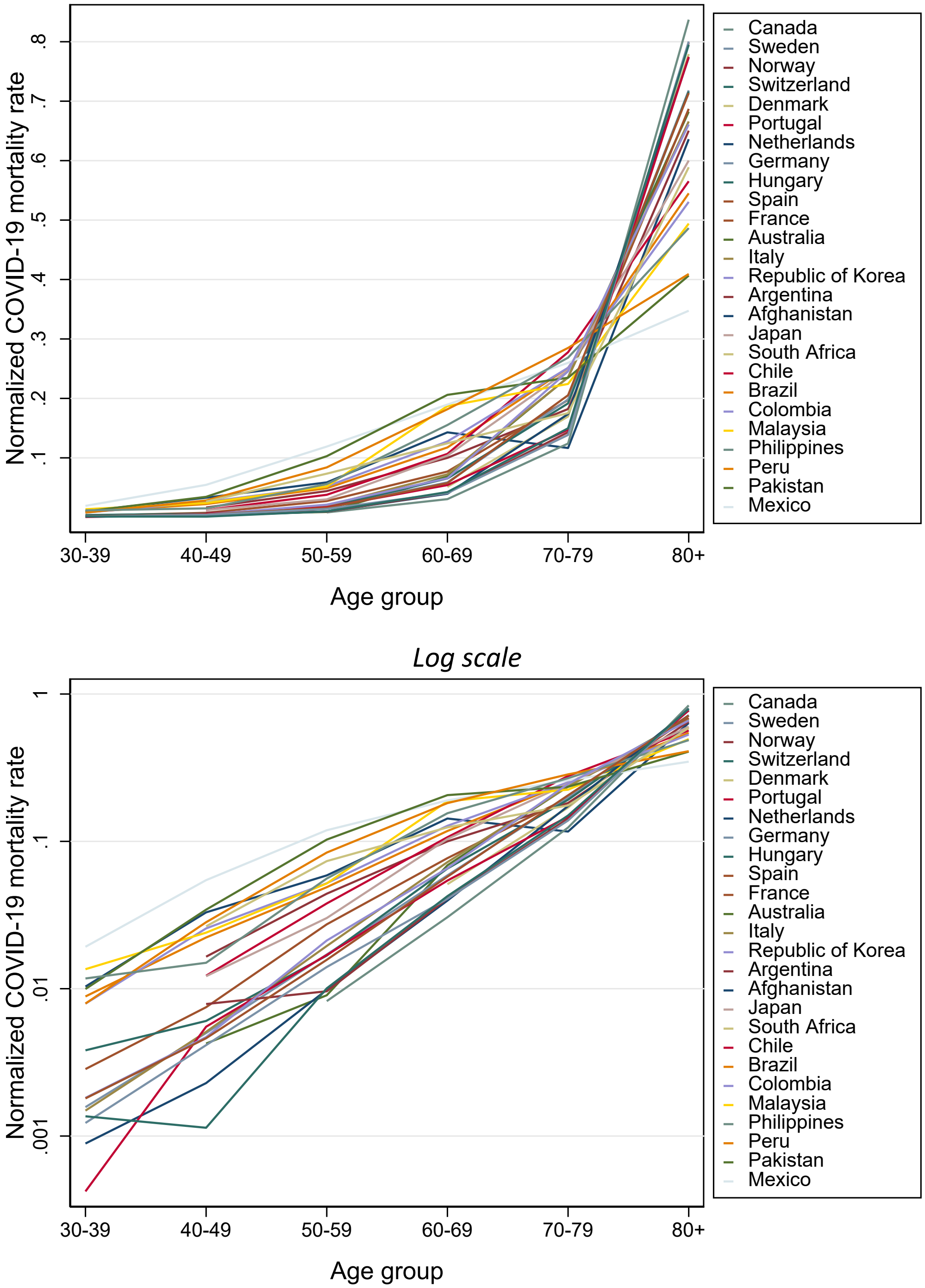


Log scale



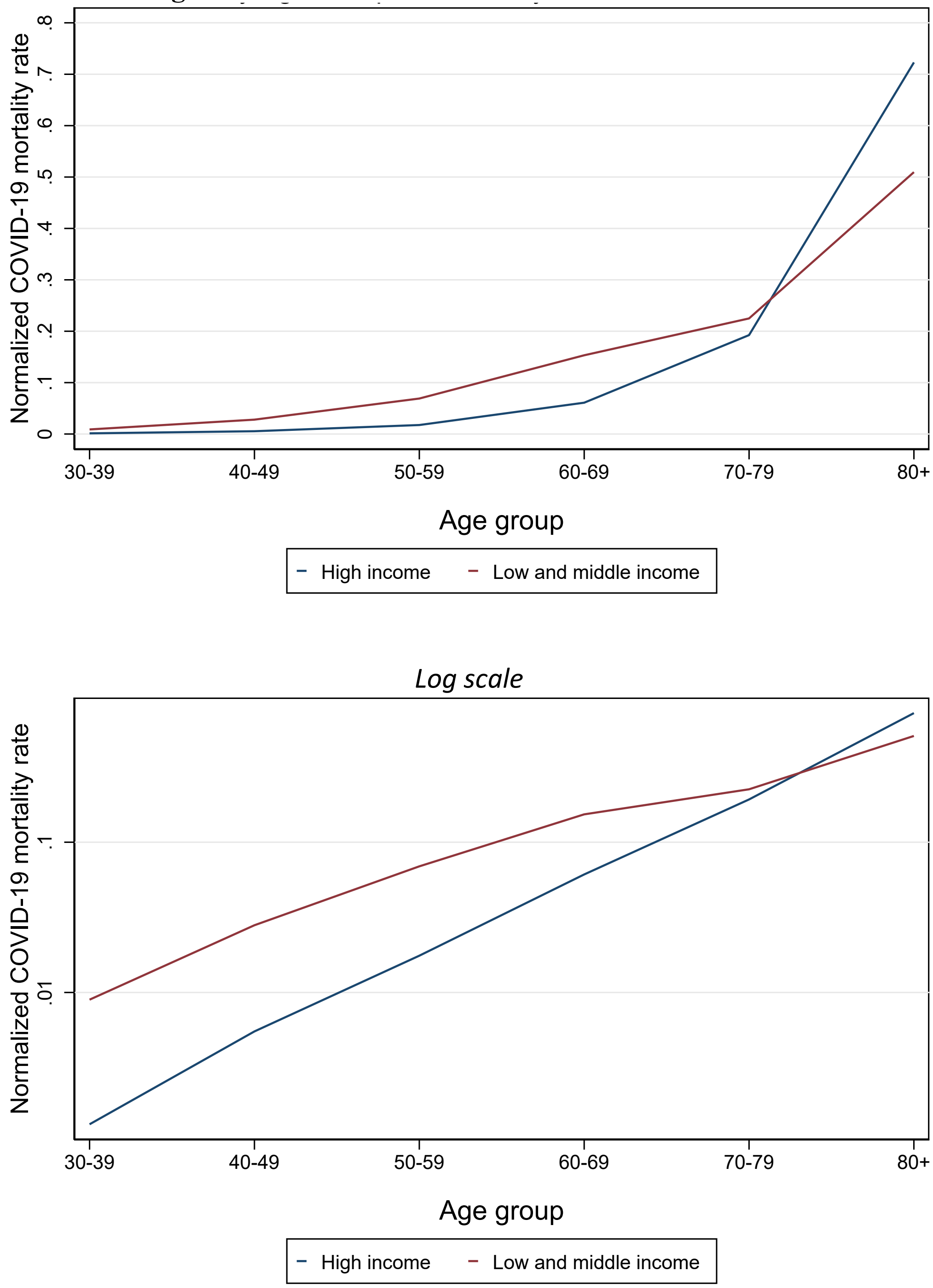
Note: See Appendix for data sources.

Figure 4: Normalized COVID-19 Mortality Rates by Age Group and Country



Note: See Appendix for data sources. For each country normalized age-specific mortality rates across all ages sum to 1.

Figure 5: Mean Normalized COVID-19 Mortality Rates by Age Group and Country, High-Income vs Low- and Middle-Income Countries



Note: See Appendix for data sources. For each country group normalized age-specific mortality rates across all ages sum to 1. In available data, both Norway and Chile aggregate all deaths under age 40, and Denmark aggregates deaths under age 60. Consequently, the calculations of means for the above figures exclude Norway and Chile for the 30-39 age group and exclude Denmark for the 30-39, 40-49, and 50-59 age groups.

4 Variation across Countries

The shape of each country's age-mortality curve can be summarized in terms of the percent rate of increase in probability of COVID-19 death per year of additional age after age 40, calculated by simply fitting a line to the age-specific mortality rates as follows:

$$\log\big(r(x,i)\big) = \alpha_i + \beta_i x$$

where the COVID-19 age-specific mortality rate is $r(x,i) = \frac{D(x,i)}{N(x,i)}$ for the ten-year age group age x to age x + 9, (x = 40, 50, 60, 70, 80) in country j, $D(x,i)$ is the number of deaths attributed to COVID-19 in the age group and $N(x,i)$ is the population of the age group in country i.[4] The adjusted mortality rates for the 80+ group were used for the x=80 points. The coefficients, β_i , are the rates of increase per year of age in probability of death due to COVID-19. These estimates are shown in Figure 6. The mortality rate from COVID-19 rises at a rate per year of age ranging from 4.5 percent in South Africa to 15.3 percent in Canada. With each year of age, the age-specific mortality rate increases by an average of 12.6 percent in high-income countries versus 7.1 percent in low- and middle-income countries. Figure 7 shows the relationship between GDP per capita on a log scale and the rate of increase per year of age in the mortality rate.

Another way to summarize the difference across countries is to consider the ratio of mortality rates between particular age groups. In lower- and middle-income countries, the mortality rate for people ages 70-79 is on average 3.5 times the rates for those ages 50-59. This ratio averages 12.6 in the high-income countries in our sample.[5]

A roughly similar relationship is seen for all-cause mortality across countries. In low- and middle-income countries, while mortality rates are higher at all ages, the mortality rate increases at a lower rate with age. Figure 8 shows the all-cause age-mortality curve for the same countries shown in the previous figures. Figure 9 shows a scatter plot of the rates of increase of all-cause mortality vs. COVID-19 mortality.[6]

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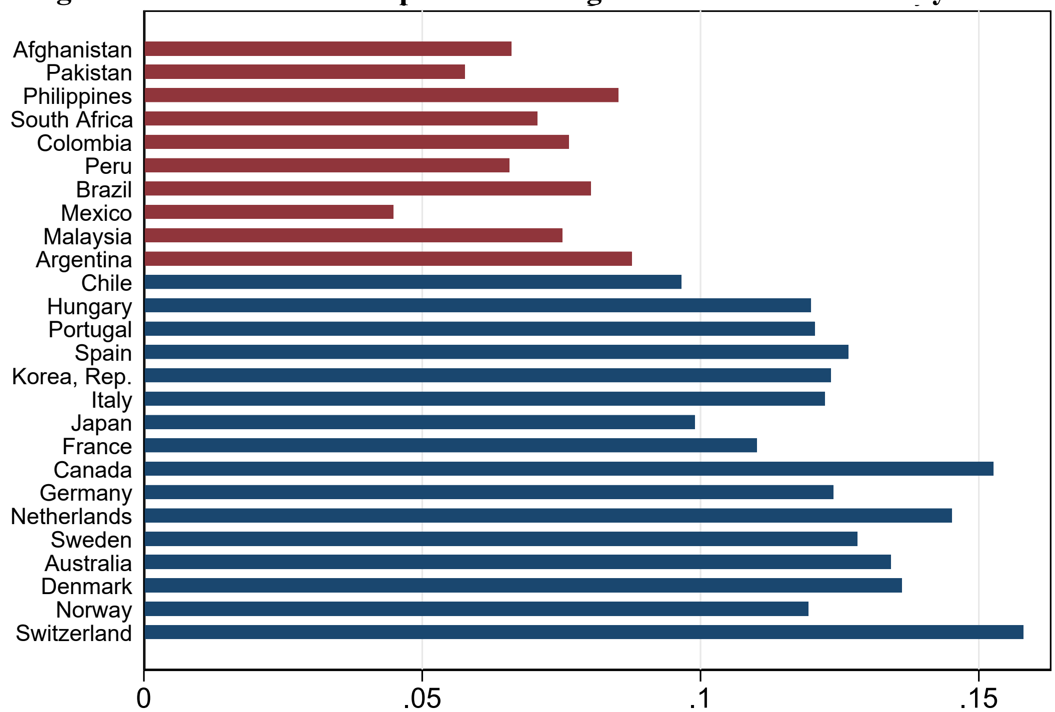
[4] The slope is fitted starting at age 40 because there are very few deaths in most countries below age 40 and also because for all-cause mortality the Gompertz slope is a poor fit under age 40 Wachter, K. W. (2014). Essential demographic methods, Harvard University Press..

[5] The 70-79 age group is used for this ratio because there is greater uncertainty associated with the calculation of the mortality rate of the 80+ group due to the fact that the age distribution of the 80+ population varies across countries. The adjustment factor described in the Appendix attempts to take this into account, but the adjustment is an approximation and depends on the reliability of data on the distribution of ages within the 80+ population group.

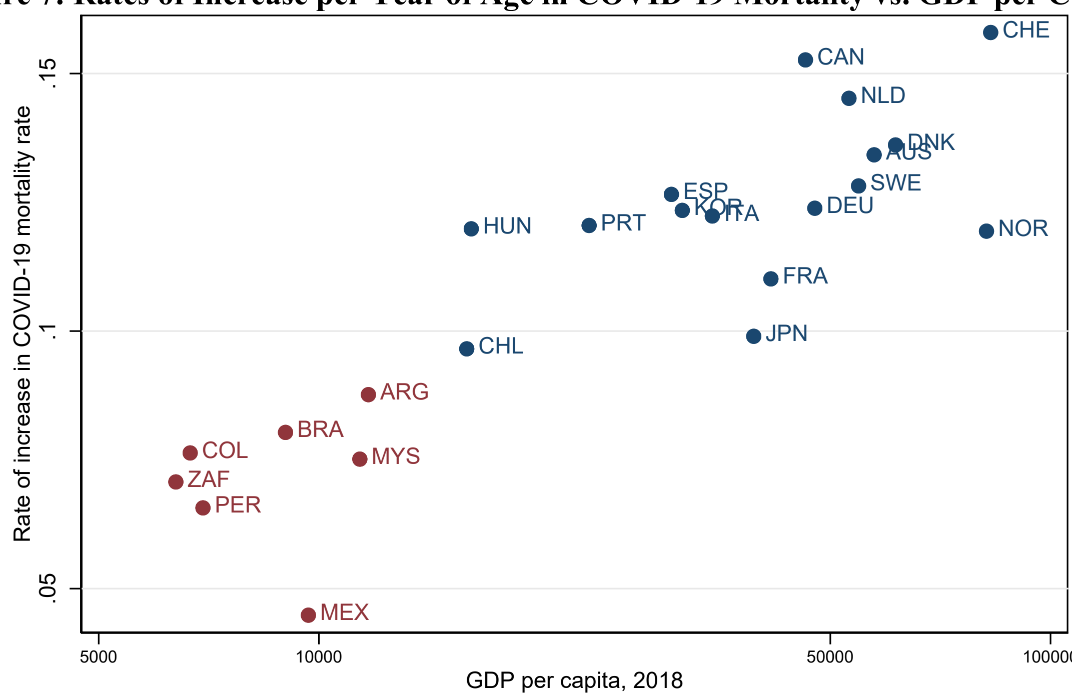
[6] The rates of increase for all-cause mortality were calculated in the same way as for COVID-19 mortality, except using 5-year age groups from 40-44 to 85-89.

Figure 6: Rate of Increase per Year of Age in COVID-19 Mortality Rate



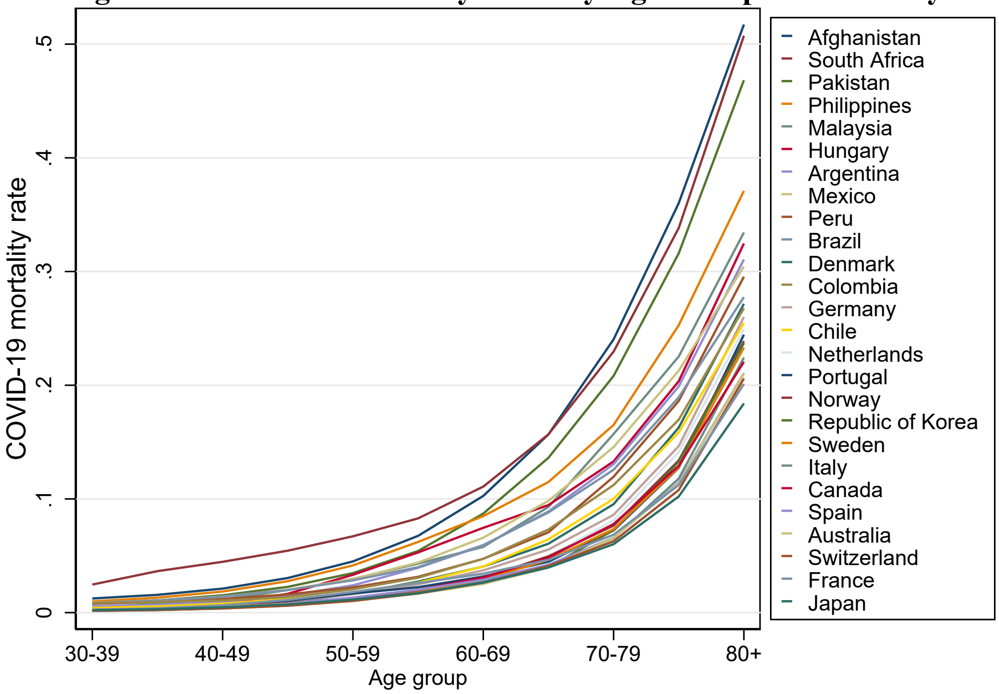
Source: Author's analysis. Countries are ranked by GDP per capita LMICs are shown in red and HMICs in blue.

Figure 7: Rates of Increase per Year of Age in COVID-19 Mortality vs. GDP per Capita

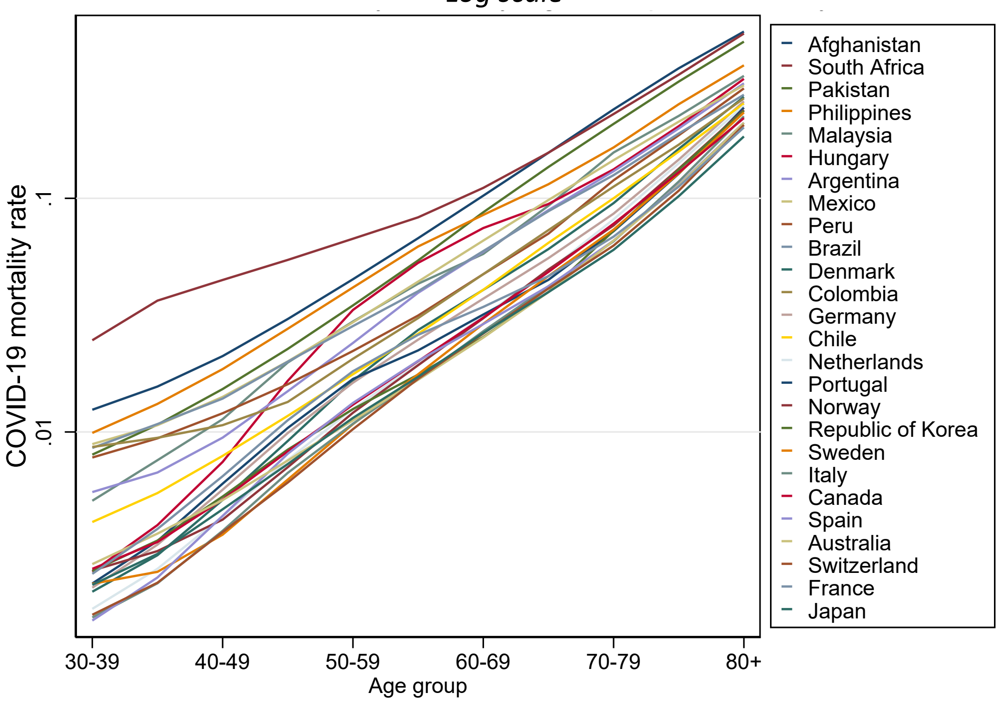


Source: Author's analysis, World Development Indicators for GDP per capita (current US$). GDP per capita is on a log scale. LMICs are shown in red and HMICs in blue.

Figure 8: All-Cause Mortality Rates by Age Group and Country

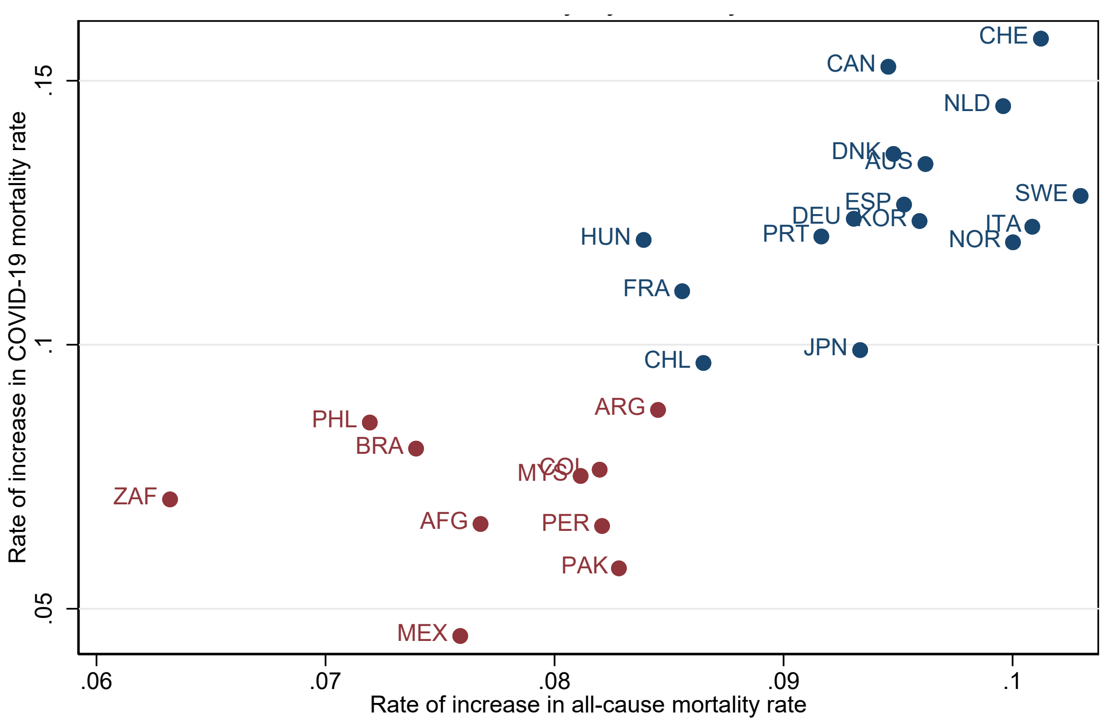


Log scale



Note: Author's estimates based on data from (United Nations 2019)

Figure 9: Rates of Increase per Year of Age in COVID-19 Mortality vs. Rate of Increase per Year of Age in All-Cause Mortality by Country



Source: Author's analysis. LMICs are shown in red and HMICs in blue.

The pattern of mortality risk by age across countries from COVID-19 resembles the pattern for all-cause mortality, matching the observation that the patterns of mortality from COVID-19 resemble those for mortality generally. The disease kills principally those who were already at highest risk of death: the aged and those with comorbidities. Likewise, in the United States African-Americans are at higher risk of death from COVID-19 and have higher mortality risk overall at all ages (Yancy 2020). Similarly, ethnic minorities in the United Kingdom are at highest risk of dying of COVID-19 (Public Health England 2020).

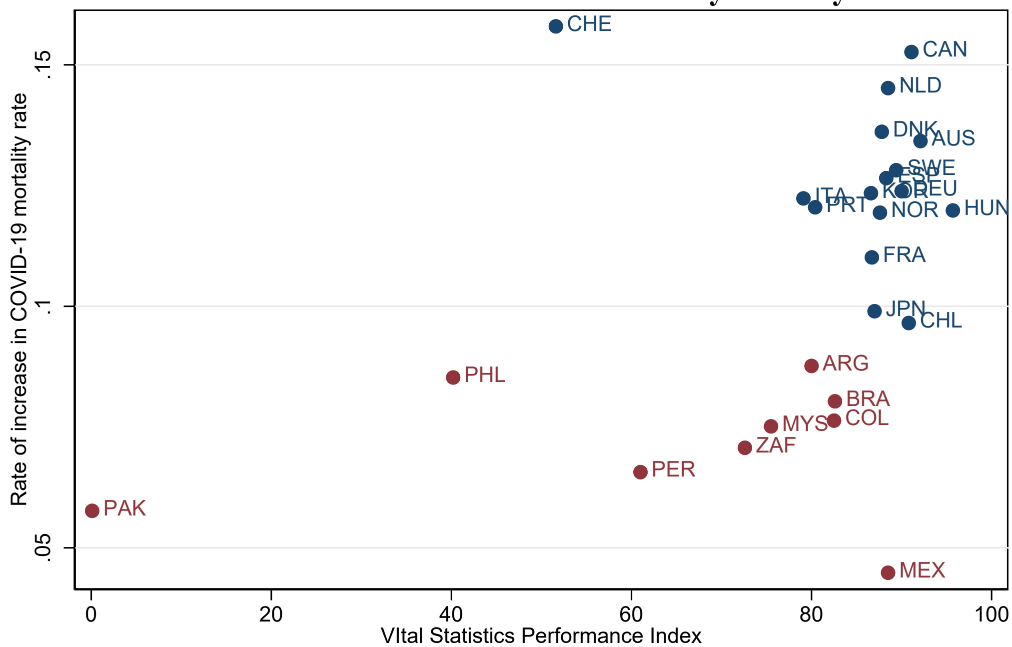
5 Possible Explanations for Variation across Countries

Rules and practices for classifying deaths by particular causes vary by country, and the same is true for classification of COVID-19 deaths. The extent to which deaths are attributed to COVID-19 varies depending on the overall effectiveness of the country's vital statistics system in generating cause of death information, the country's guidelines for attributing deaths to COVID-19, and the extent to which accurate COVID-19 diagnosis through testing and other means is available. In virtually all countries with a substantial number of COVID-19 deaths, it is likely that some deaths due to COVID-19 are not attributed to the disease. The magnitude of under-attribution may also vary by age. Differences across countries in the relative levels of under-attribution by age group could contribute to generating differences in the observed COVID-19 age-mortality curves. Figure 10 shows the rate of increase of the COVID-19 mortality rate plotted against a measure of the overall quality of death reporting data.[7] A few of the middle-income countries with flatter age-mortality curves—Pakistan, the Philippines, and Peru—rate low by this index, but other middle-income countries have death reporting systems considered equal in quality to those of high-income countries. Thus, the variation across countries in the slope of the age-mortality curves cannot be fully explained by the overall quality of cause of death data. However, differences in COVID-19 death attribution among older people could be responsible for part or even all of the observed difference between advanced and developing countries. It is likely that deaths due to COVID-19 are more likely to be correctly attributed to the disease when the death occurs in a hospital. In wealthy countries, a large share of deaths occurs in hospitals and other institutions. In developing countries, where a larger fraction die outside of hospitals, if deaths of older people are seen as more expected (given higher mortality rates for older people generally), their deaths may be especially likely to be under-attributed to COVID.

If the flatter COVID-19 age-mortality curves in developing countries do reflect in part the underlying reality and not only differences in data collection and attribution, the possible explanations fall into two broad categories. The varying patterns by age across countries may reflect 1) differences in infection rates and/or 2) mortality rates among those infected.

[7] The Vital Statistics Performance Index is a country-level composite index of measures of cause of death data: quality of cause of death reporting, quality of age and sex reporting, internal consistency, completeness of death reporting, level of cause-specific detail, and data availability/timeliness.

Figure 10: Rates of Increase per Year of Age in COVID-19 Mortality vs. Vital Statistics Performance Index by Country

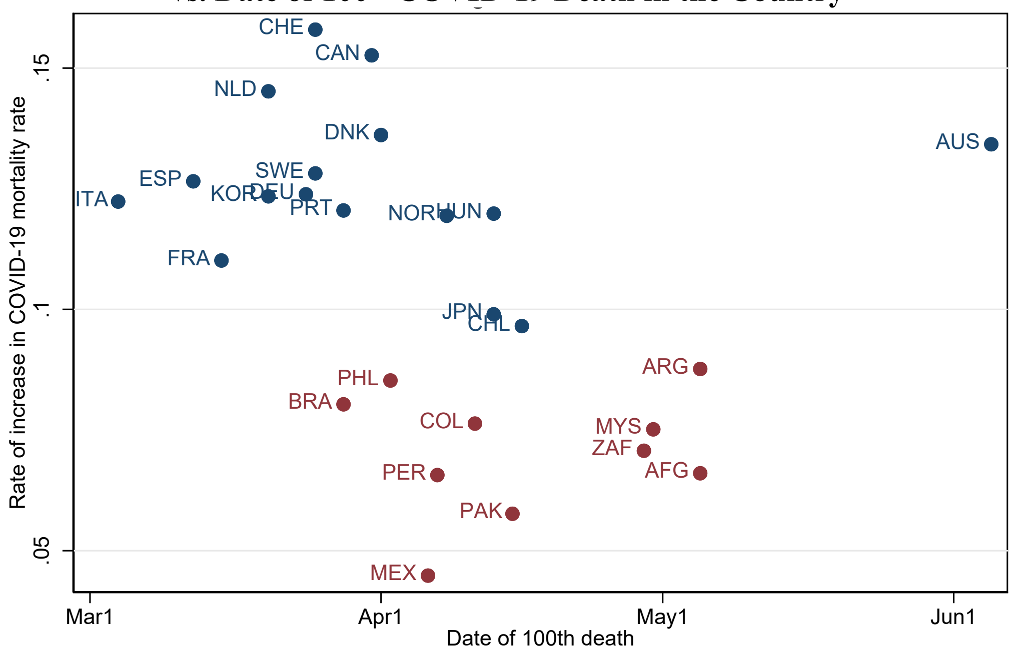


Source: Author's analysis. LMICs are shown in red and HMICs in blue. The Vital Statistics Performance Index (Phillips, Lozano et al. 2014) is based on analysis of the 2013 Global Burden of Disease data.

The relative rate of infection of older people may vary across countries. Intergenerational households are much more common in low- and middle-income countries, which may mean that older people are more exposed to infection risk, particularly given the often crowded dwellings. Roughly 20 percent of households in LMICs have at least one household member under age 20 and one over age 60, as compared to just 5 percent in high-income countries (Winskill, Whittaker et al. 2020). In 54 LMICs with recent Demographic and Health Surveys, just half of the households have no more than two people per sleeping room (Brown, Ravallion et al. 2020). On the other hand, in HICs a greater share of older people are long-term care facility residents, who appear to be particularly at risk. Approximately a quarter of all COVID-19 deaths in the United Kingdom have been residents of care facilities and by one estimate 43 percent of deaths in the United States are care facility residents or staff (New York Times 2020, Public Health England 2020). Older people in developing countries, who are less likely to live in care facilities with a concentrated number of people vulnerable to the disease, may have thus faced lower risk of infection, even living in multigenerational households.

Different timing of the impact of the onset of the disease could also potentially influence the pattern infection of age. In countries that were struck in an early phase of the pandemic, it came largely as a surprise. In contrast, for countries where the disease emerged at a later stage, there was greater opportunity to take preventative measures, including those to protect older people. Figure 11 shows the dates of the 100th death due to the virus in each country plotted against rates of increase by age of the COVID-19 mortality. By this metric, COVID-19 arrived later on average to the countries with flatter age-mortality curves

Figure 11: Rates of Increase per Year of Age in COVID-19 Mortality vs. Date of 100th COVID-19 Death in the Country



Note: See Appendix for data sources. LMICs are shown in red and HMICs in blue.

Age-specific mortality rates among those infected may also vary by age due to a wide variety of factors. Non-communicable diseases (NCDs) are more widespread in HICs. NCDs like chronic cardiac disease, non-asthmatic chronic pulmonary disease, chronic kidney disease, liver disease and obesity are key risk factors for mortality among COVID-19 patients (Docherty, Harrison et al. 2020). Goldberg and Reed (2020) find that the higher prevalence of obesity in high income and upper-middle income countries partially explains variation in COVID-19 death rates across countries. Ghisolfi, Almas et al. (2020) predict IFRs across countries and find that for low income countries in particular taking comorbidities into account increases their predicted fatality rates. It is not clear, however, how variation in overall rates of NCDs impacts the age profile of COVID-

19 mortality. In a comment on Dowd, Andriano et al. (2020), Nepomuceno, Acosta et al. (2020) compare the age profiles across Italy, Brazil, and Nigeria of major COVID-19 risk factors. They note higher rates of chronic kidney disease and chronic obstructive pulmonary disease across the age distribution in Brazil and Nigeria and also point out that in those countries, as compared to Italy, cardiovascular disease is much more prevalent in younger ages but less common at older ages. They conclude that it is possible that "younger individuals in low- and middle-income countries may be at a substantially higher risk of severe COVID-19 illness than individuals of the same age in high-income settings once age-related health conditions are considered." The authors of the original article responded, agreeing that "less-healthy countries may see a shift toward a younger age distribution of COVID-19 deaths relative to wealthier and healthier countries, consistent with high rates of comorbidities such as diabetes and hypertension in Latin American countries" (Dowd, Andriano et al. 2020).

A related point is that a form of survivor bias may come into play. High quality in medical care in wealthier nations keeps many older people alive despite weak health conditions that make them vulnerable to COVID-19. Older people in developing countries could be on average healthier than those in wealthier countries because those with non-COVID-19 conditions would have been at high risk for death at a younger age. If this is the case, older people in developing countries might be more resilient to the disease.

Differences in health system capacity and quality are another potential driver of differences in age-specific mortality rates among those infected. More limited access to health care would be expected to increase mortality rates for severe COVID-19 patients, regardless of age. Rough measures of health system capacity and quality—the number of hospital beds and doctors per 1,000 population—are correlated with GDP per capita and thus with the steepness of the COVID-19 age-mortality curves, as shown in Figures 12 and 13.

Figure 12: Rates of Increase per Year of Age in COVID-19 Mortality vs. Hospital Beds per 1000 People by Country

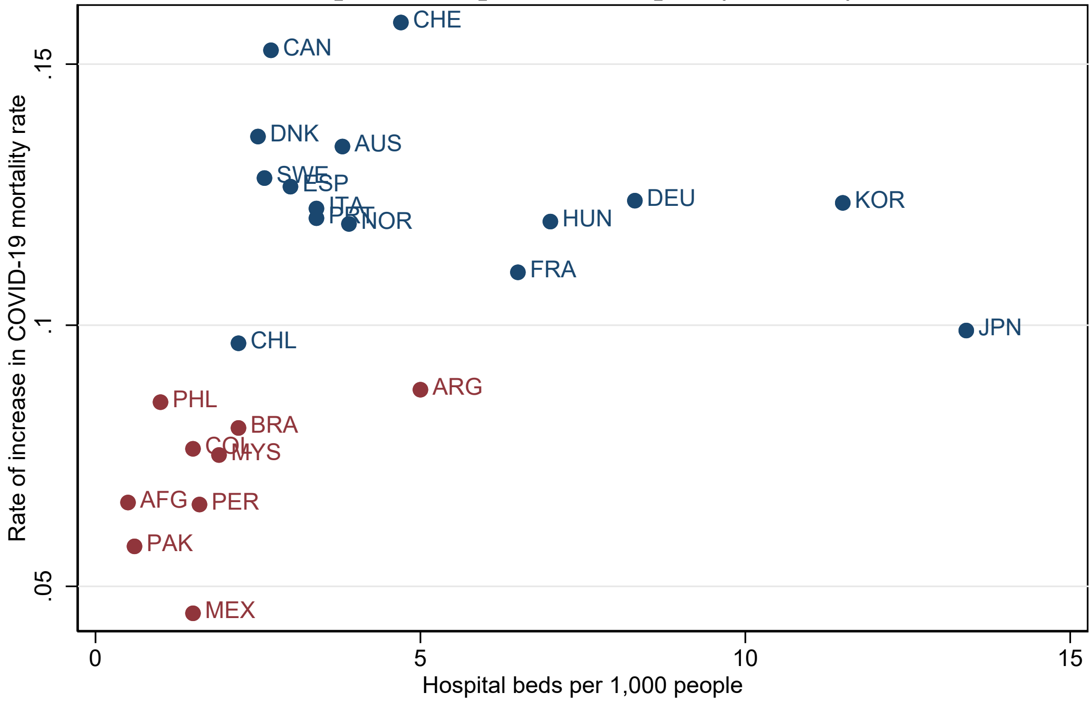
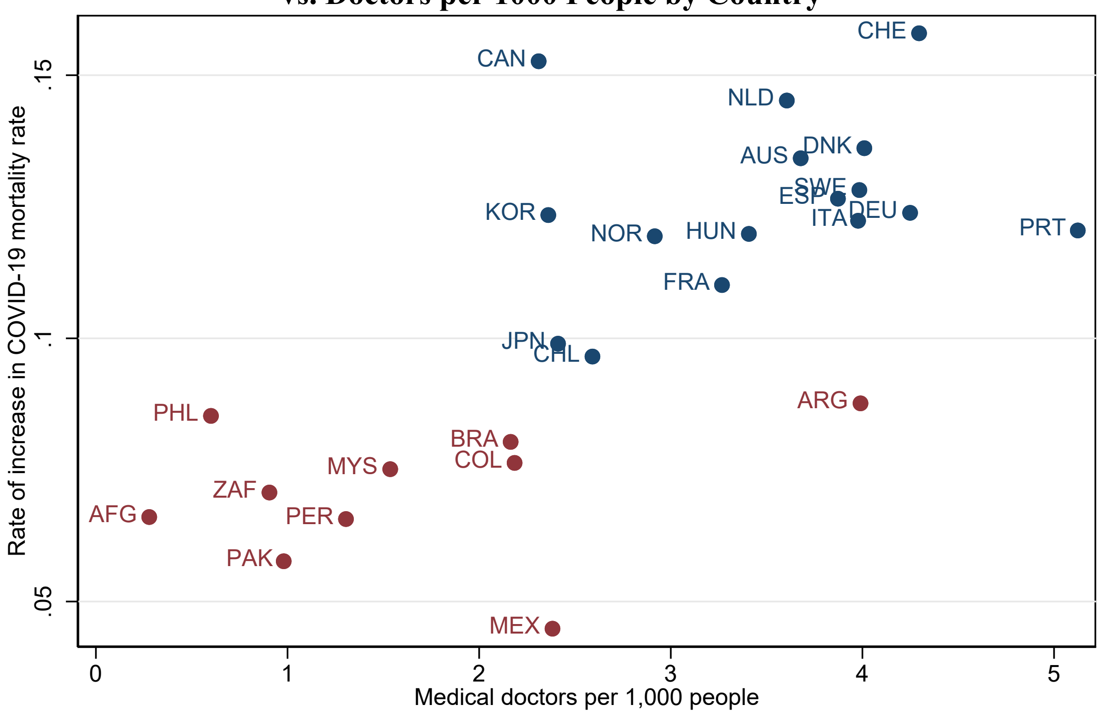


Figure 13: Rates of Increase per Year of Age in COVID-19 Mortality vs. Doctors per 1000 People by Country

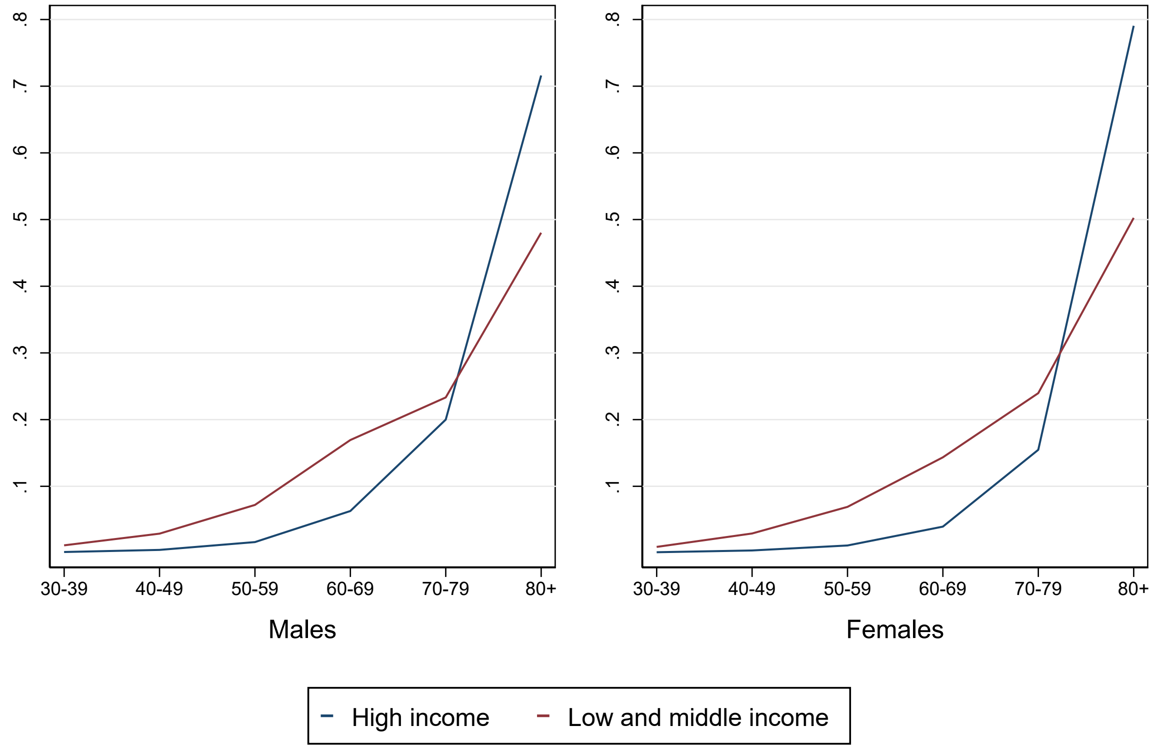


Note: Hospital bed and medical doctor data are from World Development Indicators. LMICs are shown in red and HMICs in blue.

6 Variation by Sex

COVID-19 mortality rates are higher for men than women. Of the 26 countries considered in the analysis in this paper, mortality data by both age group and sex were located for 21. The basic pattern of steeper age-mortality curves in high-income as compared to middle-income countries holds for men and women separately, as shown in Figure 14. Further figures with separate results for men and women are found in the Appendix.

Figure 14: Average Rates of Increase per Year of Age in COVID-19 Mortality by Sex



Note: See Appendix for data sources.

7 Conclusions

Among the 26 countries considered in this analysis, the observed age-mortality curves are notably flatter in middle-income countries as compared to high-income countries. This reflects some combination of differences in attribution of death to COVID-19, varying patterns of infection by age, and varying mortality rates by age among those infected. The findings from the analysis in this paper suggest the experience with COVID-19 in high-income countries may not be generalizable to middle- and low-income countries. Distinguishing between the various explanations should be a topic for further research.

One approach to considering these issues is by analyzing death on all-cause mortality during the COVID-19 period and making comparisons to previous years. Such an analysis of “excess mortality” by age group could contribute to an understanding of the extent to which the flatter age-mortality profile in middle-income countries is a real phenomenon rather than one generated by differences across countries in attribution. There are challenges in using excess mortality data, however. For developing countries, such data are typically available only with a long time lag, if at all, and currently such data are not available with an age breakdown for the COVID-19 period for any of the countries considered here. Excess mortality data are also challenging to interpret because the pandemic has both direct and indirect effects.

The analysis in this paper is also a reminder of the value of demographic data as a tool amidst the COVID-19 crisis. Governments have been widely varying in the extent to which they have been transparent with COVID-19 data. Some countries release only very limited data, while others make regularly updated microdata of cases and deaths available to the public. Countries that have been the most forthcoming with data have benefitted because wide scrutiny of the data has allowed deficiencies to be identified and corrected, and analysis by the broad research community has helped inform government responses. Greater data transparency should be encouraged as a public good to help the global community understand and better address the pandemic.

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Appendix:

1. Table A1: Data Sources

Country	Fatalities	Sex	Data as of date	Source	Source URL	Description
Afghanistan	400	Yes	June 19, 2020	Ministry of Public Health	http://covid.moph-dw.org/#/	Afghanistan Ministry of Public Health maintains an online dashboard showing COVID-19 cases. Data for fatalities are provided by age groups and sex in a bar chart.
Argentina	568	No	May 28, 2020	Ministry of Health	https://www.argentina.gob.ar/salud/coronavirus-COVID-19/sala-situacion	Argentina Ministry of Health provides an online dashboard showing national epidemiological information of the COVID-19 situation. Deaths by age group are provided in chart form. Since June, age groups have changed to larger aggregates.
Australia	102	Yes	June 18, 2020	Department of Health	https://www.health.gov.au/news/health-alerts/novel-coronavirus-2019-ncov-health-alert/coronavirus-covid-19-current-situation-and-case-numbers	Australian Government Department of Health maintains a webpage showing the current situation nationwide. Fatalities by age groups and sex are provided in a bar chart, not including unknown fields.
Brazil	27,071	Yes	May 28, 2020	Civil Registry Offices of Brazil	https://transparencia.registrocivil.org.br/especial-covid	The Civil Registry Offices of Brazil maintains a dedicated page for COVID-19 showing death statistics, including a chart showing confirmed and suspected (aggregated) COVID-19 deaths by age group and sex. We set the date range up to June 19, 2020 for this use case.
Canada	7493	Yes	June 19, 2020	Government of Canada Statistics - Public Health Agency of Canada	https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1310077401&pickMembers%5B0%5D=1.1&pickMembers%5B1%5D=2.3&pickMembers	Detailed preliminary information on cases of COVID-19: 6 Dimensions (Aggregated data). Counts of fatalities provided by age groups and sex, including unknown fields.

					%5B2%5D=3.9	
Chile	4,000	No	June 19, 2020	Ministry of Health	https://www.gob.cl/coronavirus/cifrasoficiales/	Ministry of Health publishes daily reports (in PDF format, Spanish) on the COVID-19 situation. The report includes a section on patients who have died, including a table of the number of deaths by age groups. The age groupings follow standard 10-year intervals starting 40 years, and aggregates all deaths under 39 years. In June, a dashboard replaced the main page of the national situationer, including charts with downloadable data.
Colombia	1,950	Yes	June 18, 2020	Ministry of Information Technology and Communications	https://www.datos.gov.co/Salud-y-Protecci-n-Social/Casos-positivos-de-COVID-19-en-Colombia/gt2j-8ykr/data#Export	The Ministry of Information Technology and Communications of Colombia publishes metadata for positive cases of COVID-19 that is available for exporting (download). Case information includes variables on age, sex, and death. Historical data (previous days' metadata) are also provided.
Denmark	600	Yes	June 19, 2020	Statens Serum Institut	https://dc-covid.site.ined.fr/en/data/denmark/	Original source: Statens Serum Institut, from the Danish Civil Registration System (CPR) and the Cause of Death register. (Data obtained via the COVID-19 demography of deaths database. National Institute for Demographic Studies (INED) (distributor)). Deaths under 59 years are aggregated, and 10-year interval age groups are provided up to 90 years. Data provided by sex.
France	18,156	Yes	June 14, 2020	Public Health France	https://dc-covid.site.ined.fr/en/data/france/	Original source: Public Health France. (Data obtained via the COVID-19 demography of deaths database. National Institute for Demographic Studies (INED) (distributor)). Deaths are provided by 10-year age groups and sex.
Germany	8,851	Yes	June 18, 2020	Robert Koch-Institut	https://dc-covid.site.ined.fr/en/data/germany/	Original source: Robert Koch-Institut. (Data obtained via the COVID-19 demography of deaths database. National Institute for Demographic Studies (INED) (distributor)). Data include deaths occurred in hospitals or elsewhere, by 10-year age groups and sex.

Hungary	568	Yes	June 17, 2020	National government	https://koronavirus.gov.hu/	The Hungarian government has set up a website dedicated to COVID-19. Fatality data are provided in a table at the case level, including age, sex, and information on comorbidities.
Italy	33,309	Yes	June 18, 2020	Italian National Institute of Health	https://dc-covid.site.ined.fr/en/data/italy/	Original source: Italian National Institute of Health. (Data obtained via the COVID-19 demography of deaths database. National Institute for Demographic Studies (INED) (distributor)). Deaths are provided by 10-year age groups and sex.
Japan	586	No	May 29, 2020	Ministry of Health	https://toyokeizai.net/sp/visual/tko/covid19/en.html	The Ministry of Health, Labor and Welfare provides a dashboard showing nationwide statistics on the COVID-19 situation in Japan. Deaths by age group are presented in a chart, without sex. As of June 20, 2020, counts of deaths have been removed from the chart showing age groups.
Malaysia	121	Yes	June 19, 2020	Ministry of Health	https://en.wikipedia.org/wiki/COVID-19_pandemic_in_Malaysia	The Ministry of Health Malaysia maintains a web page showing limited statistics on the COVID-19 situation in the country. Additionally, MOH issues press statements on COVID-19 detailing cases of deaths. These have been collected by users of Wikipedia to provide a table on COVID-19 deaths by case, including age and sex.
Mexico	8,908	Yes	June 19, 2020	General Directorate of Epidemiology	https://www.gob.mx/salud/documentos/datos-abiertos-152127	The General Directorate of Epidemiology provides information regarding the cases associated with COVID-19 in Mexico in metadata form (archived daily; historical data available), including a data dictionary available for public download. Case data includes age and sex.
Netherlands	6,081	Yes	June 19, 2020	National Institute for Public Health and the Environment	https://dc-covid.site.ined.fr/en/data/netherlands/	Original source: National Institute for Public Health and the Environment. (Data obtained via the COVID-19 demography of deaths database. National Institute for Demographic Studies (INED) (distributor)). Deaths are published daily by 5-year age groups and sex.
Norway	244	Yes	June 19, 2020	Norwegian Institute of Public Health	https://dc-covid.site.ined.fr/en/data/norway/	Original source: Norwegian Institute of Public Health. (Data obtained via the COVID-19 demography of deaths database. National Institute for Demographic Studies (INED) (distributor)). Deaths are published

						daily by 10-year age groups and sex, however, deaths under age 40 are aggregated.
Pakistan	1,678	Yes	June 19, 2020	Government of Pakistan	http://covid.gov.pk/stats/pakistan	The Government of Pakistan maintains a dashboard for COVID-19. Death demographics (age group and sex) are provided in chart form showing percentages, including a category for miscellaneous ages for some cases.
Peru	7,641	Yes	June 19, 2020	Ministry of Health	https://covid19.minsa.gob.pe/sala_situacional.asp	Peru's Ministry of Health provides daily metadata of COVID-19 fatalities which include variables for age and sex, among other COVID-19-related data and statistics.
Philippines	1,116	Yes	June 18, 2020	Department of Health	https://bit.ly/DataDropPH	The Philippines' Department of Health shares to the public daily metadata of COVID-19 cases including variables for age, sex, and date of death.
Portugal	1,369	Yes	June 17, 2020	National Health Service-General Health Department	https://dc-covid.site.ined.fr/en/data/portugal/	Original source: National Health Service-General Health Department. (Data obtained via the COVID-19 demography of deaths database. National Institute for Demographic Studies (INED) (distributor)). Deaths are published daily by 10-year age groups and sex.
Republic of Korea	225	Yes	April 15, 2020	Korea Centers for Disease Control & Prevention	https://dc-covid.site.ined.fr/en/data/korea/	Original source: Korea Centers for Disease Control & Prevention. (Data obtained via the COVID-19 demography of deaths database. National Institute for Demographic Studies (INED) (distributor)). Deaths are published daily by 10-year age groups and sex.
South Africa	643	No	June 18, 2020	Department of Health	https://sacoronavirus.co.za/2020/05/30/update-on-covid-19-30th-may-2020/	Department of Health releases daily updates on COVID-19, including an age distribution of deaths. Sex data is not provided by age group.
Spain	20,536	Yes	May 21, 2020	Health Institute Carlos III	https://dc-covid.site.ined.fr/en/data/spain/	Original source: Health Institute Carlos III. (Data obtained via the COVID-19 demography of deaths database. National Institute for Demographic Studies (INED) (distributor)). Data include deaths occurred in hospitals or elsewhere, by 10-year age groups and sex.

Sweden	5,053	No	June 18, 2020	National Board of Health and Welfare (NBHW)	https://dc-covid.site.ined.fr/en/data/sweden/	Original source: National Board of Health and Welfare. (Data obtained via the COVID-19 demography of deaths database. National Institute for Demographic Studies (INED) (distributor)). Data include deaths by 10-year age groups.
Switzerland	1678	Yes	June 18, 2020	Federal Office of Public Health	https://www.bag.admin.ch/bag/en/home/krankheiten/ausbrueche-epidemien-pandemien/aktuelle-ausbrueche-epidemien/novel-cov/situation-schweiz-und-international.html#-1199962081	FOPH website on the COVID-19 situation in Switzerland, providing data on epidemiological situation. Count of deaths by age groups and sex is provided.

2. Adjustment for 80+ Mortality

An adjustment is used for the COVID-19 mortality rate of the 80+ age group to account for the fact that the age structure of the 80+ population varies across countries. Low- and middle-income countries typically have younger populations overall, and the population of those age 80 and older is on average younger than in high-income countries. The adjustment is done with reference to a standard mortality schedule sM(x). United States all-cause mortality is used as the standard.

The indirect standardized 80+ mortality rate for each country *j*:

$$sM(80+, j) = \frac{\sum(sM(x) * N(x,j))}{\sum N(x,j)}$$

where *N(x,j)* is the count of people in the age group *x* to *x*=4 in country *j* (*x* = 80, 85, 90, 95).

The adjustment factor for country *j* is as follows:

$$\theta(j) = \frac{sM(80+,\text{USA})}{sM(80+,j)}$$

where sM(80+, USA) is the all-cause mortality rate for the 80+ age group in the standard.

This factor can be used to scale the observed COVID-19 mortality of the 80+ age group to adjust for age-structure effects:

$$adjM(80+,j)_{C19} = \theta(j) * \ obsM(80+,j)_{C19}$$

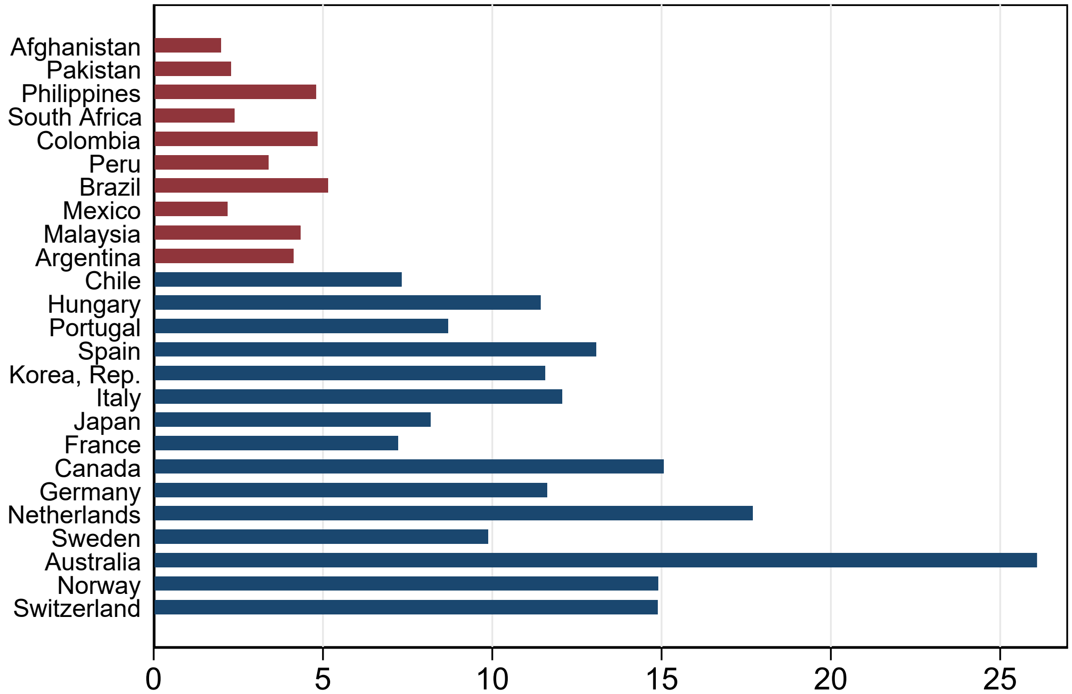
where $adjM(80+,j)_{C19}$is the adjusted COVID-19 mortality rate of the 80+ age group for country j and $obsM(80+,j)_{C19}$is the observed COVID-19 mortality rate of the 80+ age group for country j.

3. Additional Figures and Table

Table A2: Country Data

Country		Date of 100th death	Rate of increase by age of COVID-19 mortality	Rate of increase by age of all-cause mortality	Ratio of COVID-19 mortality ages 70-79 to ages 50-59	Ratio of all-cause mortality ages 70-79 to ages 50-59
Afghanistan	AFG	May 5, 2020	0.066	0.077	2.0	4.7
Argentina	ARG	May 5, 2020	0.088	0.085	4.1	4.9
Australia	AUS	June 5, 2020	0.134	0.096	26.1	6.2
Brazil	BRA	March 28, 2020	0.080	0.074	5.1	4.3
Canada	CAN	March 31, 2020	0.153	0.095	15.1	6.0
Chile	CHL	April 16, 2020	0.097	0.087	7.3	5.6
Colombia	COL	April 11, 2020	0.076	0.082	4.8	5.2
Denmark	DNK	April 1, 2020	0.136	0.095	N/A	5.6
France	FRA	March 15, 2020	0.110	0.086	7.2	4.0
Germany	DEU	March 24, 2020	0.124	0.093	11.6	5.4
Hungary	HUN	April 13, 2020	0.120	0.084	11.4	3.7
Italy	ITA	March 4, 2020	0.122	0.101	12.1	6.4
Japan	JPN	April 13, 2020	0.099	0.093	8.2	5.5
Malaysia	MYS	April 30, 2020	0.075	0.081	4.3	4.9
Mexico	MEX	April 6, 2020	0.045	0.076	2.2	4.5
Netherlands	NLD	March 20, 2020	0.145	0.100	17.7	6.6
Norway	NOR	April 8, 2020	0.119	0.100	14.9	6.4
Pakistan	PAK	April 15, 2020	0.058	0.083	2.3	5.3
Peru	PER	April 7, 2020	0.066	0.082	3.4	5.3
Philippines	PHL	April 2, 2020	0.085	0.072	4.8	3.7
Portugal	PRT	March 28, 2020	0.120	0.092	8.7	4.9
Republic of Korea	KOR	March 20, 2020	0.123	0.096	11.6	6.6
South Africa	ZAF	April 29, 2020	0.071	0.063	2.4	3.4
Spain	ESP	March 12, 2020	0.127	0.095	13.1	5.2
Sweden	SWE	March 25, 2020	0.128	0.103	9.9	6.8
Switzerland	CHE	March 25, 2020	0.158	0.101	14.9	6.1
Mean for high income countries			**0.126**	**0.095**	**12.6**	**5.7**
Mean for low and middle income countries			**0.071**	**0.077**	**3.5**	**4.6**

Figure A1: Ratio of COVID-19 Mortality Rate for Ages 70-79 to Rate for Ages 50-59



Source: Author's analysis. Countries are ranked by GDP per capita LMICs are shown in red and HMICs in blue.

Figure A2: COVID-19 Mortality Rates by Age Group and Country, by Sex

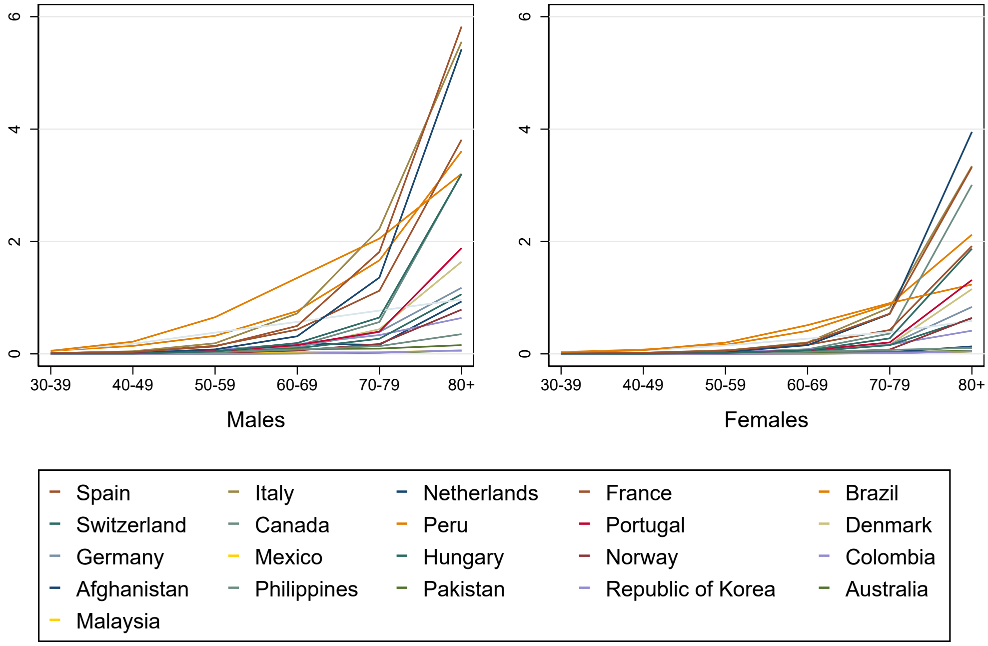


Figure A3: Normalized COVID-19 Mortality Rates by Age Group and Country, by Sex

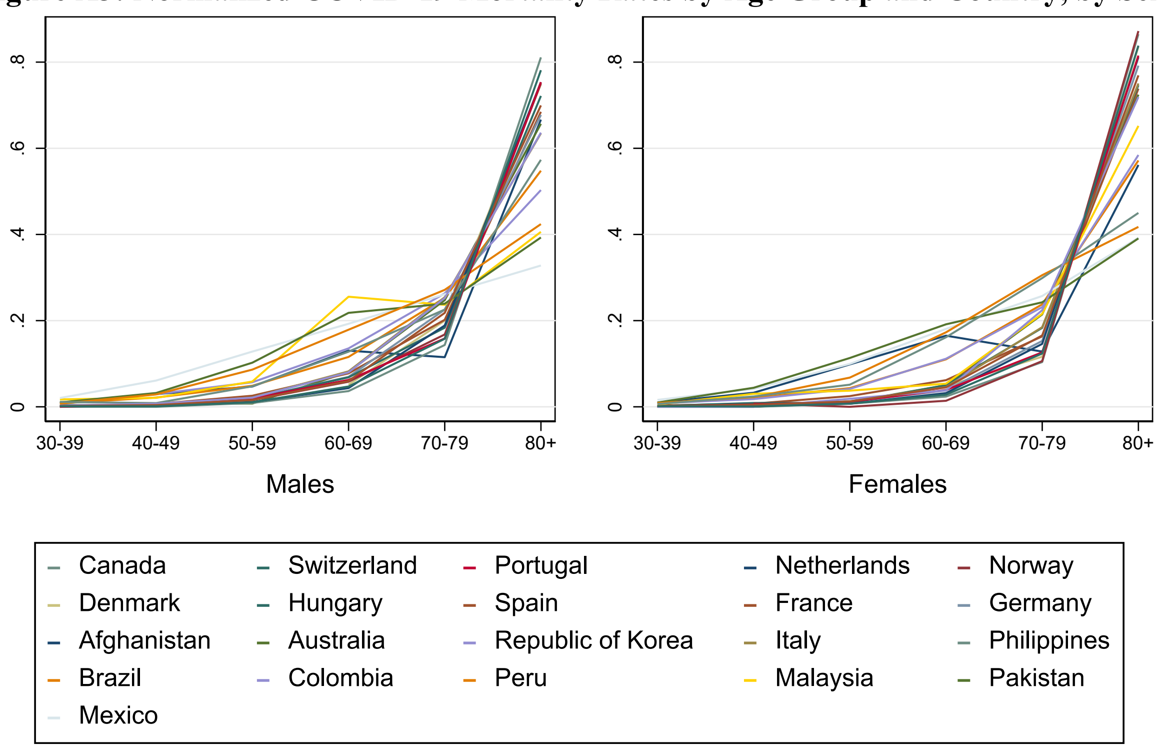


Figure A4: Rate of Increase per Year of Age in COVID-19 Mortality Rate by Country

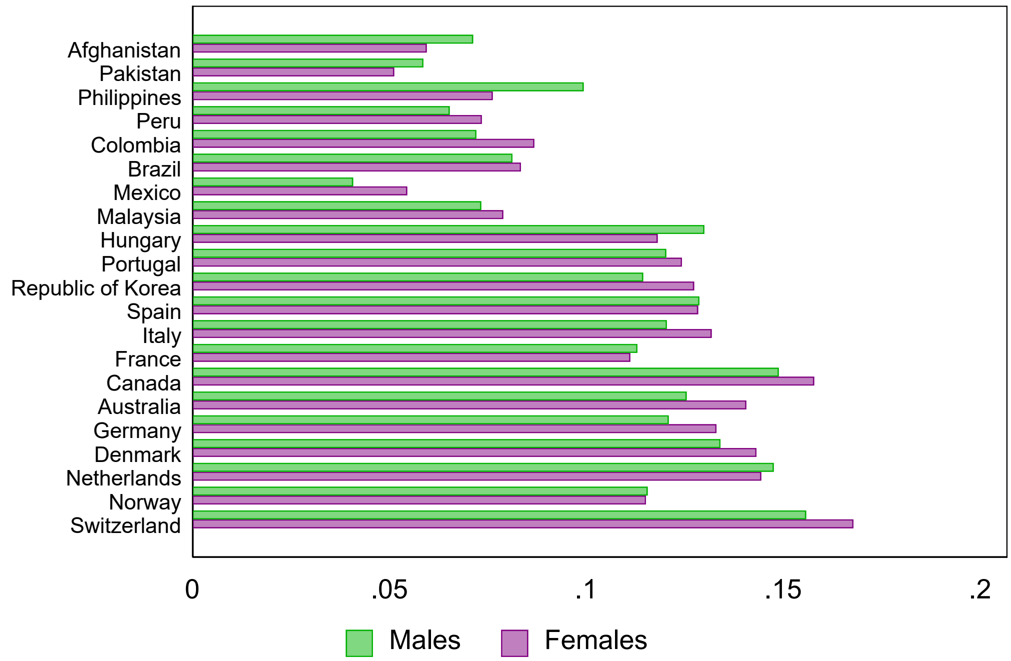


Figure A5: Rates of Increase per Year of Age in COVID-19 Mortality vs. GDP per Capita by Country and Sex