Tracking COVID-19 as Cause of Death:
Global Estimates of Relative Severity

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ABSTRACT: Despite the rapid spread of the COVID-19 pandemic across countries, the global death toll remains highly concentrated in few high-income countries. Reported data suggests the developing world has been largely spared, yet a host of factors, not least demography, suggest that the observed discrepancy in the burden of mortality is likely significantly exaggerated. This paper tracks the severity implied by the reported data and relates it to pre-pandemic mortality patterns to get a feel for the discrepancies and inequalities. An indicator of "relative severity" is proposed to generate global comparisons across countries and over time. The methodology can be utilized to improve tracking systems and detect data anomalies that can then set the stage for further analysis. It should prove useful in getting a better grasp of the distribution and progression of the pandemic if or when the epicenters of the pandemic start shifting to the developing world.

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Keywords: Mortality; pandemic.

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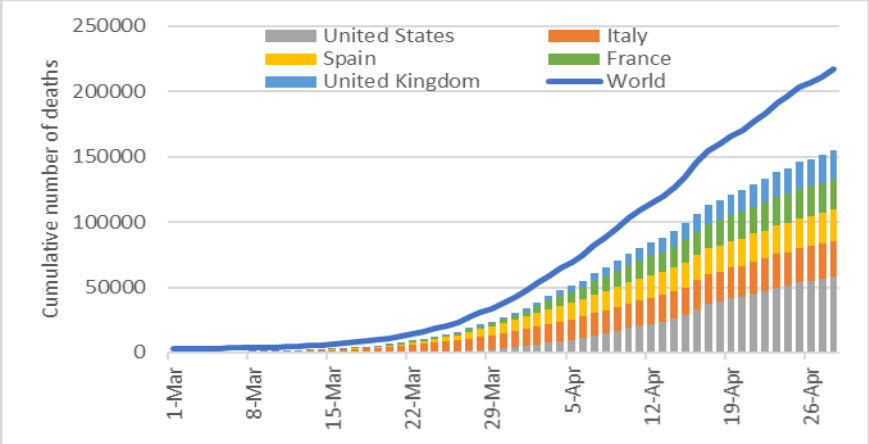
1. Introduction

Views about the severity of the COVID-19 outbreak have evolved considerably. The initial outbreak was thought to be confined to China. Soon it spread across Asia and then the rest of the world. In a matter of a few weeks, over 3.5 million people in 210 countries and territories became infected (Worldometer, 2020). The local outbreak became a full-scale pandemic, countries were locked down and the world collectively came to face the prospect of the worst economic downturn since the Great Depression (IMF, 2020).

Figure 1. COVID-19 Death Toll: World and Top Five Countries



Source: Johns Hopkins University.

Despite the rapid spread of the virus across countries, the global death toll has been astonishingly concentrated (Figure 1). Here's a striking statistic: as of April 30, the cut-off date for all data in this paper, five countries – the United States, Italy, UK, Spain and France – account for 70% of recorded deaths globally due to COVID-19 despite comprising only 7.5% of the global population. All high-income countries together represent 86% of COVID-related death. This leaves 14% for the developing world, which comprises about 85% of the global population (Table 1).

Within the developing world, there is huge concentration too (Table 1). Upper-middle income countries (UMICs) contribute 11.9% to global deaths, but lower-middle income and low-income countries (LMICs and LICs) contribute only 1.9% and 0.1%. In other words, the poorest countries (LMICs and LICs), which represent almost half of the global population, but only contribute 2% to the death toll of COVID-19.

2. The Unreal Dichotomy between High-Income and Developing Countries

For a disease that has spread so extensively and so rapidly, the patterns we observe in reported statistics make us wonder how unreal the dichotomy between high-income and developing countries could be. Crude death rates do not vary as dramatically across income classification categories as they do across individual countries. This implies, as shown also in Table 1, that the share in global death rates by income category closely mirrors the population shares. Not so for COVID-19, though.

Table 1. Distribution by Income Classification: COVID-19 Deaths, All-Cause Deaths and Total Population (percent)

		Balanced sample (160 countries)		Unbalanced sample (all countries)	
	Share in COVID-19 deaths	Share in expected deaths from all causes	Share in population	Share in expected deaths from all causes	Share in population
High income	86.0	18.1	15.7	18.6	16.2
Upper-middle income	11.9	34.5	36.0	32.7	34.1
Lower-middle income	1.9	38.9	40.1	38.3	39.7
Low income	0.1	8.5	8.1	10.6	10.0

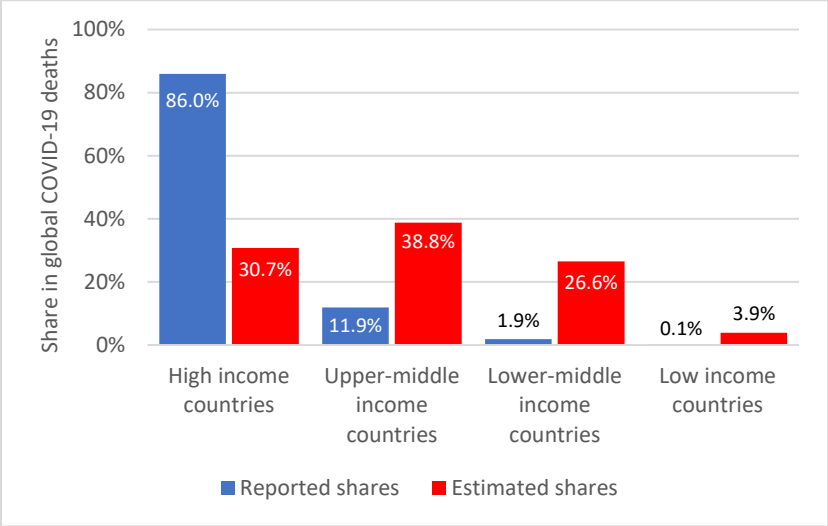
Source: Johns Hopkins University; World Health Organization; World Population Prospects.
Note: Deaths from all causes extrapolated to 2020 with 2016 crude mortality rate. COVID-19 data is reported for 160 countries, to which the balanced sample conforms. Unbalanced sample includes all countries of the world.

Of course, such comparisons are superficial because of the confounding role of demography (Ahmad and others, 2001). The world is undergoing intense demographic change which is reflected in an unprecedent diversity in age structure across the wide spectrum of the world's pre-, early-, late- and post-dividend countries (World Bank, 2016). While higher shares in elderly populations will bias the distribution of COVID-19 fatalities towards high-income countries, we should not forget that large segments of the developing world have been aging at breakneck speed. In absolute terms, the developing world has many more old people than the high-income countries together: their 70+ population is 1.8 times as large and their 60+ population is 2.4 times bigger.

What share in global COVID-19 mortality would developing countries be expected to claim then? To answer this question, let's conduct a thought experiment where we apply the observed infection and fatality patterns in the high-income world to the age distributions of the entire world. The population-level infection rate (PIR) and age-specific case fatality rates (CFRs) are likely mismeasured in the early stage of a pandemic. But their levels only affect total deaths and not the shares in global deaths if common PIR and CFR values are applied equally to all countries and the age distribution of infection and fatality is maintained constant.

In line with Beam and others (2020), we set the common PIR at an arbitrary 10 percent and assume that the patterns of Italy for the age-specific CFRs apply globally (Istituto Superiore di Sanità, 2020; data for March 30). We then calculate the expected lives lost across countries and income classifications and deduce from the totals the shares in global COVID-19 fatalities. For reasons explained later, this method will likely yield a "minimal" baseline in the sense that other factors will make it likely that developing countries will claim an even larger share.

Figure 2. Distribution of COVID-19 deaths by income classification:
Reported shares versus estimated shares imposing common patterns of infection and fatality on respective age distributions (percent)



Source: Johns Hopkins University; World Health Organization; World Population Prospects; Istituto Superiore di Sanità (2020).
Note: Population infection rate (PIR) is set at 10% and age-specific case fatality rates (CFR) of Italy as of Mar 30 are applied to all countries, consistent with Beam and others (2020). Levels of PIR and CFR affect total deaths but not the share in global deaths providing identical values are applied across countries and their age distribution is not changed. Reported data for 160 countries; estimates for the world.

As Figure 2 shows, demography does not explain the heavy concentration of COVID-19 fatalities in high-income countries—in fact, it contradicts it. If we were to properly account for age structure, the share of HICs in global COVID-related deaths would be three times lower than the reported data suggests (from 86% to 31%). The share of UMICs which have registered very rapid aging over the last few decades would more than triple (from 12% to 39%). Even more strikingly, the share of LMICs would rise by a factor of 14 (from 2% to 27%) and that of LICs by a factor of 39 (from 0.1% to 3.9%).

The slope of the J-shaped curve that characterizes the CFRs as we progress through the age cohorts will influence the results. The age-specific case fatality rates of Italy show a steep slope: 7% for those aged 60-69, 20% for the 70-79 cohort, and 28% for the 80-89 one (Belligoni, 2020). To check for robustness, we also made the calculations using China, South Korea and Spain for the base CFRs. If we were to use the CFRs of China, the HIC share would fall by 1.3 ppts compared to the 31% derived from the Italian data (Wu and McGoogan, 2020; data for February 11). If we used the CFRs of Spain, the HIC share would rise by 0.1 ppts (Spanish Ministry of Health, 2020; data for May 4). The CFRs of South Korea would yield an increase in the HIC share by 3 ppts (Korean Ministry of Health and Welfare, 2020; data for May 6).

These deviations are small – in fact they are minimal compared to the shortfall between the reported and estimates shares. The overall conclusion remains: demography does not explain the low shares of developing countries in the global death toll that is featured in the reported data.

Relative to Figure 2 as a baseline for further discussion, there are of course other factors at play. But these, as we will argue below, collectively do not offer convincing explanations of the shortfall between the reported and estimated shares. In fact, several of the factors discussed would further accentuate the drop of the HIC share.

- Comorbidities which have been identified as elevating the CFRs are unlikely to solve the puzzle. A global meta-analysis of the role of prevalence of comorbidities highlights the importance of hypertension (21%), diabetes (10%), cardiovascular disease (8%) and respiratory system disease (1%) in severely infected patients (Yang and others, 2020). These co-morbidities should play an important role in the developing world, too. For example, of the 1.1 billion people with hypertension, two-thirds live in developing countries (WHO, 2019). Over the last decade, the number of cases and prevalence of diabetes has risen most quickly in the developing world (WHO, 2016b). Limited access to quality health care in developing countries would also mean that many ailments would be left untreated or undertreated, heightening vulnerability.

- There are environmental factors extrinsic to hosts such as population density and informality which will complicate physical distancing, raise the population-level infection rate and steepen the curve. Informal and self-employment will pose one challenge; urban density another one (La Porta and Shleifer, 2014). The latest estimates suggest that respectively 65% and 27% of urban populations in LICs and MICs live in slums. Flattening the curve will therefore be more difficult in many developing countries, meaning that pre-existing health capacity constraints will become more binding and result in greater case fatality.

Overshadowing all of the above is a lack of data quality in terms of accuracy, completeness, consistence, timeliness and validity. Where testing has been limited or untimely, data quality will suffer. The experience in high-income countries has illustrated that. Where vital statistics were poorly reported prior the pandemic, the problems will be even worse. For these reasons, the extreme discrepancy in the burden of COVID-19 mortality between high-income and developing regions must be overstated. We should expect a significant degree of inequality in the numbers just on account of demography alone – and in contrast to the popular perception that developing countries because of their age structure are "immune" to the disease.

To the extent that data quality is not the culprit, we should expect the number to catch up as the pandemic continues to work its way through the age distributions of the developing world. Developing countries may of course be at earlier stages of the pandemic compared to high-income countries. If that is true, it would likely offer only temporary respite as the disease is already reported to have travelled to more than 210 countries and territories. Moreover, because of the structural features highlighted before, developing countries would be expected to be less successful to contain the extent of contagion.

3. Tracking the Pandemic by Relative Severity

Correcting for data deficiencies in a globally consistent way is currently not possible. We are simply too early into this pandemic. The pandemic was declared only very recently – on March 11. Only just a month before, it was given a name.

What we can do now is track the reported data better. There is a dire need for global comparison across countries and over time. Spiky data in some countries, who revise methodologies for measuring COVID-19 infections and deaths, may suggest that excessively smooth paths elsewhere are suspicious. Differences in death rates between otherwise-similar countries could indicate distortions. Comparison across countries and over time is valuable: while it won't remedy the data problems, it will shed light on them.

Severity across Countries

To get a better grasp of the severity of the crisis, we conduct a global comparison of severity relative to the pre-pandemic mortality profile of individual countries. This approach has some advantages and complements other methods. The expression of mortality in relative terms speaks to the fact that countries may have adapted to their specific patterns of mortality. Deviations from this pattern may create pressure points, such as for example on the health system. Comparisons with previous patterns give a country-specific flavor of the severity of the COVID-19 pandemic, which could be used to corroborate realities on the ground.

As of end of April, 230 thousand lives have been lost due to COVID-19. That's roughly 1.5 times the number of deaths that we would expect to occur on an average prior to the pandemic. The death toll is expected to grow further. We know that is has been very unevenly distributed thus far. But how significant are the death toll numbers in relative terms across countries?

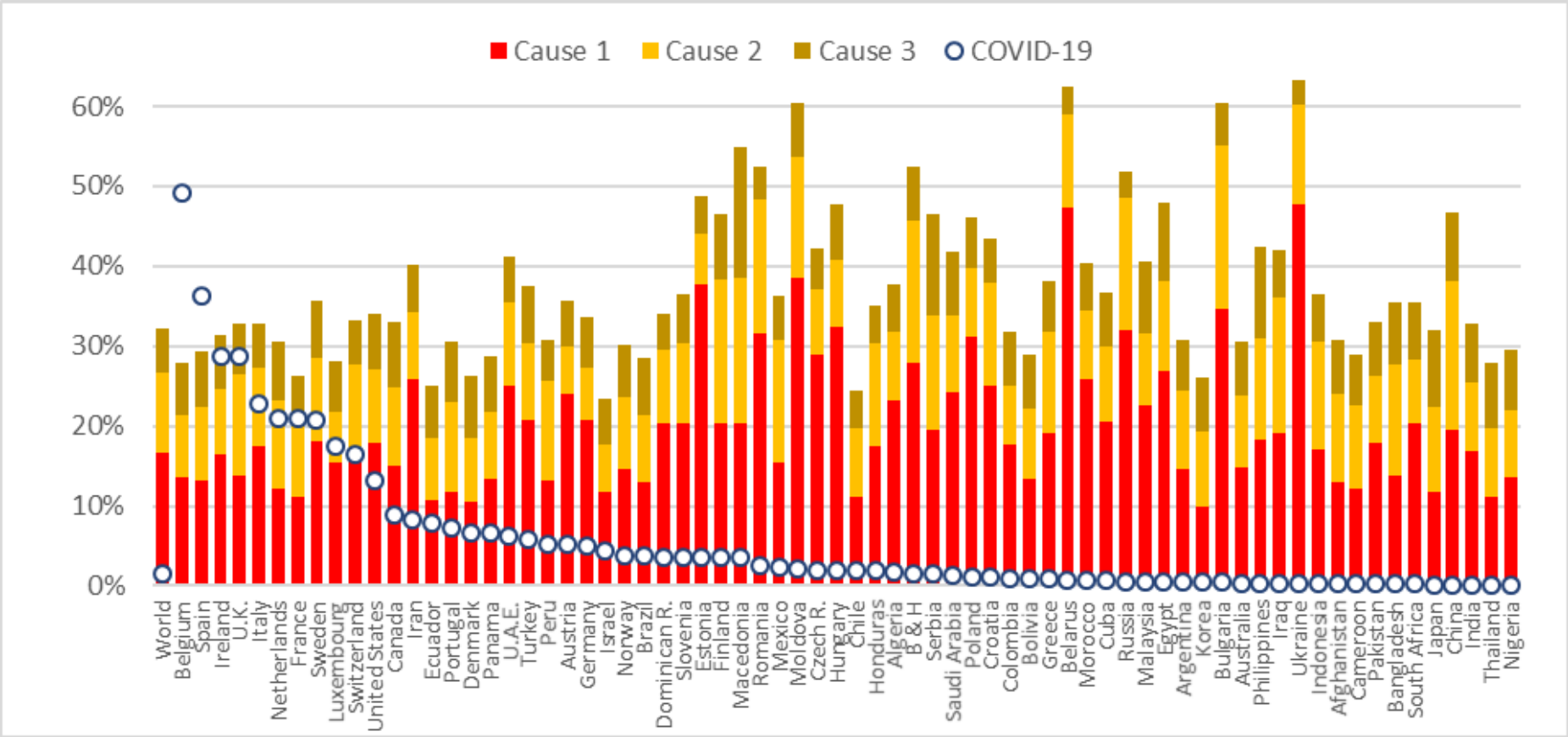
Figure 3 tracks what we call the "cumulative severity ratio" (the dot in the figure). This variable is the ratio of (1) the total deaths attributed to COVID-19 over the length of the period since the outbreak in the country (which differs across countries) to (2) the expected total deaths from all causes under the counterfactual assumption that the pandemic had not taken place over a base period of the same length. This number can be compared easily with the proportionate mortality rates of the most common diseases of a country (the stacked bars).

The data is based on the WHO's latest International Classification of Diseases (ICD-10) as of 2016 (WHO, 2016a). We use throughout this base year throughout the calculations in this paper to ensure consistency with the 2016 Global Health Estimates, which give us comprehensive information about the distribution of cause of death across countries (WHO, 2018a; 2018b; 2020). We apply the 2016 distribution to the proportionate mortality rates for the country-specific top three causes of deaths drawn from 123 disease families. We have data for 160 countries but remove, without loss of generality, the countries where the death toll as of April 30 was below 50 deaths. This results in a sample of 70.

Figure 3 puts a dimension on the COVID-19 crisis through the lens of country-specific mortality profiles. Here are some key take-aways:

- Countries that exceed the first cause of death:
    - **Belgium and Spain**: highest severity of the death toll in the world, exceeding their first, second and third causes of death in the base year.
    - **Ireland, United Kingdom, France** + Belgium and Spain**:** exceeding their first and second most common causes of death.
    - **Italy, Luxembourg, Netherlands, Sweden** + Ireland, United Kingdom, France, Belgium and Spain: exceeding their first cause of death.

Figure 3. The Distribution of Severity: Cumulative Severity of COVID-19 and Proportionate Mortality from Top Causes (percent)

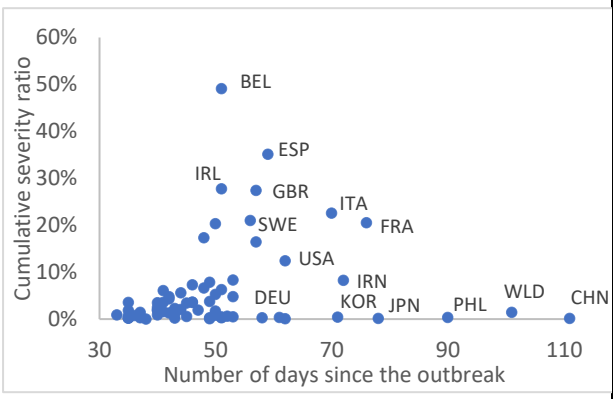


Source: Johns Hopkins University; World Health Organization.

- Countries that exceed the second or third causes of death:
    - **Ecuador, Switzerland, United States** + Italy, Luxembourg, Netherlands, Sweden, Ireland, United Kingdom, France, Belgium and Spain: exceeding the second cause of death
    - **Canada, Iran, United Arab Emirates, Peru** + Ecuador, Switzerland, United States, Italy, Luxembourg, the Netherlands, Sweden, Ireland, United Kingdom, France, Belgium and Spain: exceeding the third cause of death.

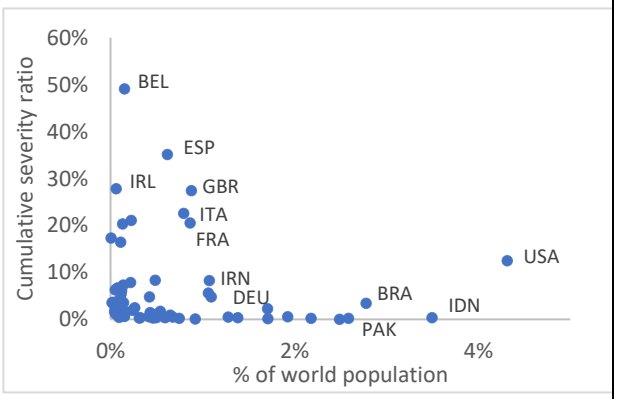
- Identification of causes of death:
    - **High-income countries**: virtually all countries are HICs, for which the typical top causes of deaths are: ischaemic heart disease, stroke and Alzheimer disease along with other dementias.
    - **Upper-middle income countries:** only 3 developing countries stand out: Ecuador, Iran and Peru. For Ecuador, the top three causes are ischaemic heart disease, diabetes and stroke; for Iran: ischaemic heart disease, stroke and road injury; for Peru: lower respiratory infections, ischaemic heart disease and stroke.

Figure 4. Severity against Length of Outbreak



Source: Johns Hopkins University; World Health Organization

Figure 5. Severity against Population Size



Source: Johns Hopkins University; World Health Organization

The severity of the mortality burden has so far been poorly correlated with the length of the outbreak (Figure 4). China, Philippines and Japan started the period (over which the pandemic manifested itself locally) earlier than others, but their measures of cumulative severity were in fact lower than most countries that came later. Among second-wave countries, there is a large discrepancy between the few that top the chart and the vast majority of other countries with much lower cumulative severity ratios.

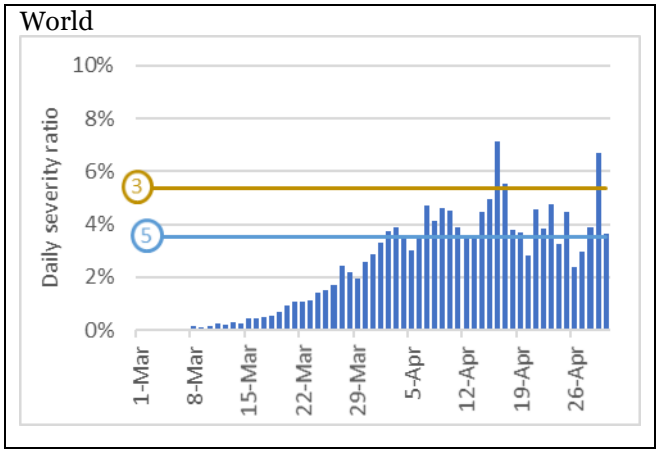
Countries with large populations seem to have experienced lower severity (Figure 5). The data is choppy, but larger countries tend to have lower numbers. Among the 12 with 100+ million people, China and India (not shown in the figure) have severity ratios of 0.2 and 0.1% whereas others in this category are well below 1% except for the US (12%), Brazil (3%) and Mexico (2%). Such numbers could rise significantly at subnational levels if the outbreak is concentrated at lower levels of aggregation—think of China versus Hubei (Fenz and Kharas, 2020). Among countries with smaller populations, the severity ratios appear to be much more spread out.

Severity over Time

To examine the progression of severity over time, we switch from cumulative to daily measures. The daily numbers are calculated by comparing COVID-related deaths and baseline deaths for all or top causes is made with respect to the period of one single day. The discrete daily data shows significant noise, but it allows us to examine patterns related to the speed and sustained strength of the progression of the pandemic at the country level. The raw data also allows us to make inferences about sudden adjustments due to the statistical methods and other one-off country-specific factors.

The global numbers in Figure 6 illustrate the steady rise in daily severity, up through mid-April. Around end-March, COVID-related deaths exceeded the total number of daily deaths from Alzheimer – the top fifth cause of death globally. The daily additions continued to rise through middle of April when they started to exceed the global third cause of death, which is chronic obstructive pulmonary disease.

Figure 6. The Global Progression of Severity: Daily Severity from COVID-19 and Proportionate Mortality by Top Cause (percent)

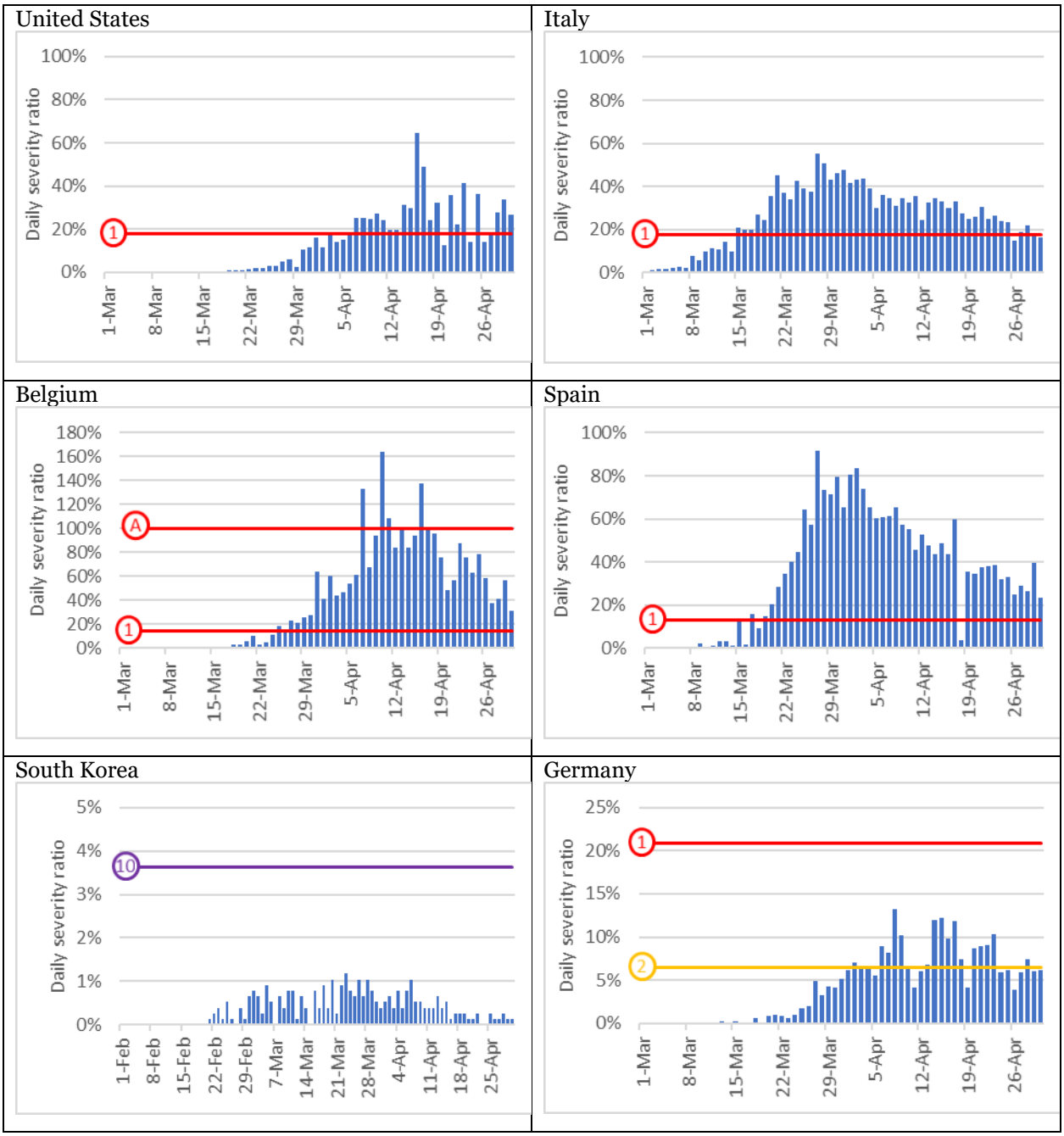


Source: Johns Hopkins University; World Health Organization.
Note: Bars represent nth cause of death, where n is circled number.

Next we consider the progression at the level of individual countries. We start with a selection of high-income countries (Figure 7):

- **Italy and United States:** the pandemic manifested itself earlier in Italy than the US. Severity in Italy reached around 50% at its peak, but it is now levelling off to around 20%. The US has registered a significant rise in the death toll. Like Italy, it has sustained an excess over the first cause of death for several weeks now.
- **Belgium and Spain:** both countries top the ranking in cumulative severity terms and we can see why given the rapid rise and sustained elevated levels of daily severity. Belgium exceeded all causes of death on a number of days, whereas both Belgium and Spain exceeded the first cause of death during most the period.
- **South Korea and Germany:** both countries are hailed as success stories in the fight against the disease. The plot of daily severity data helps us again see why, while also point to important differences. Korea managed to suppress the disease well below its 10th cause of death. Germany managed to keep the numbers below the 2nd cause of death.

Figure 7. The Progression of Severity among Select High-Income Countries:
Daily Severity from COVID-19 and Proportionate Mortality by Top Cause (percent)

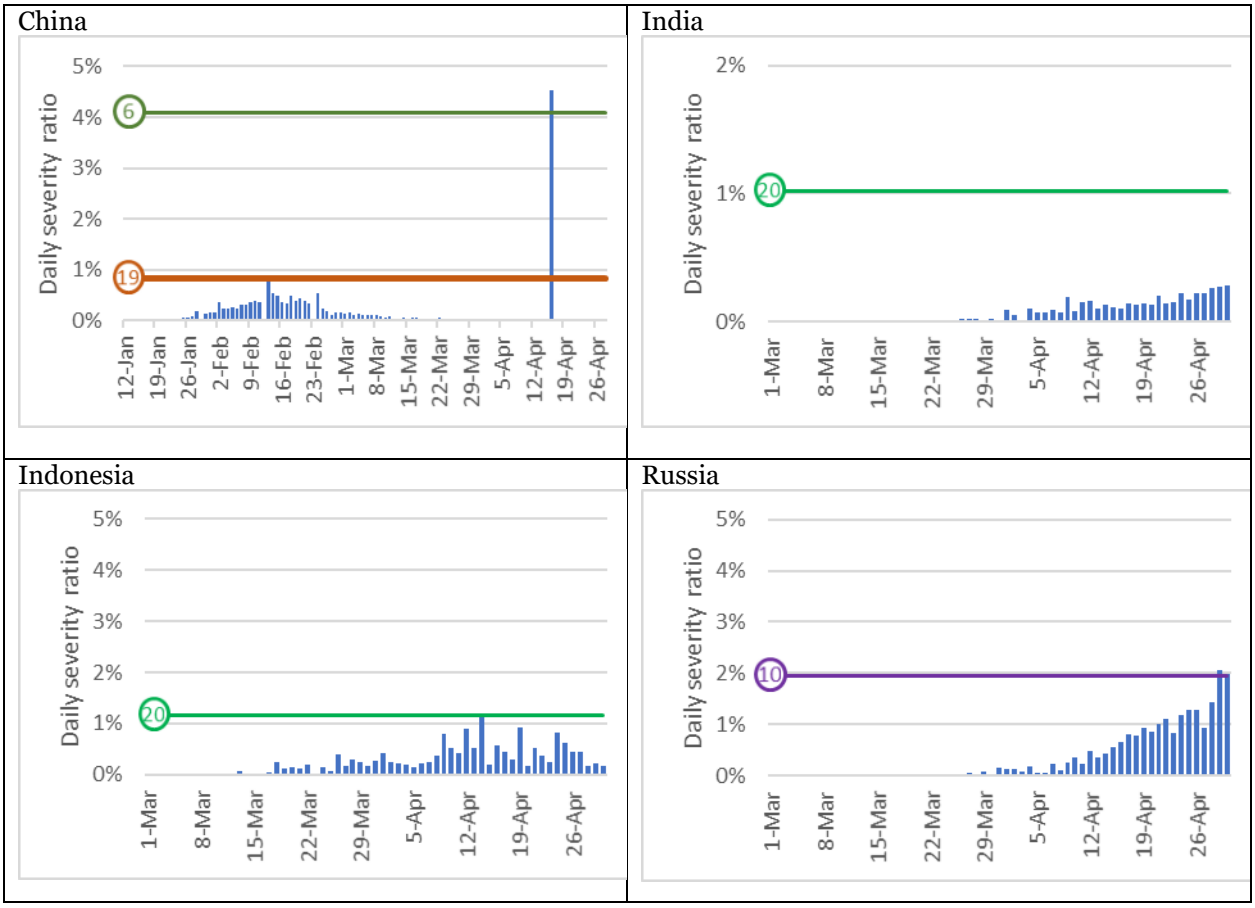


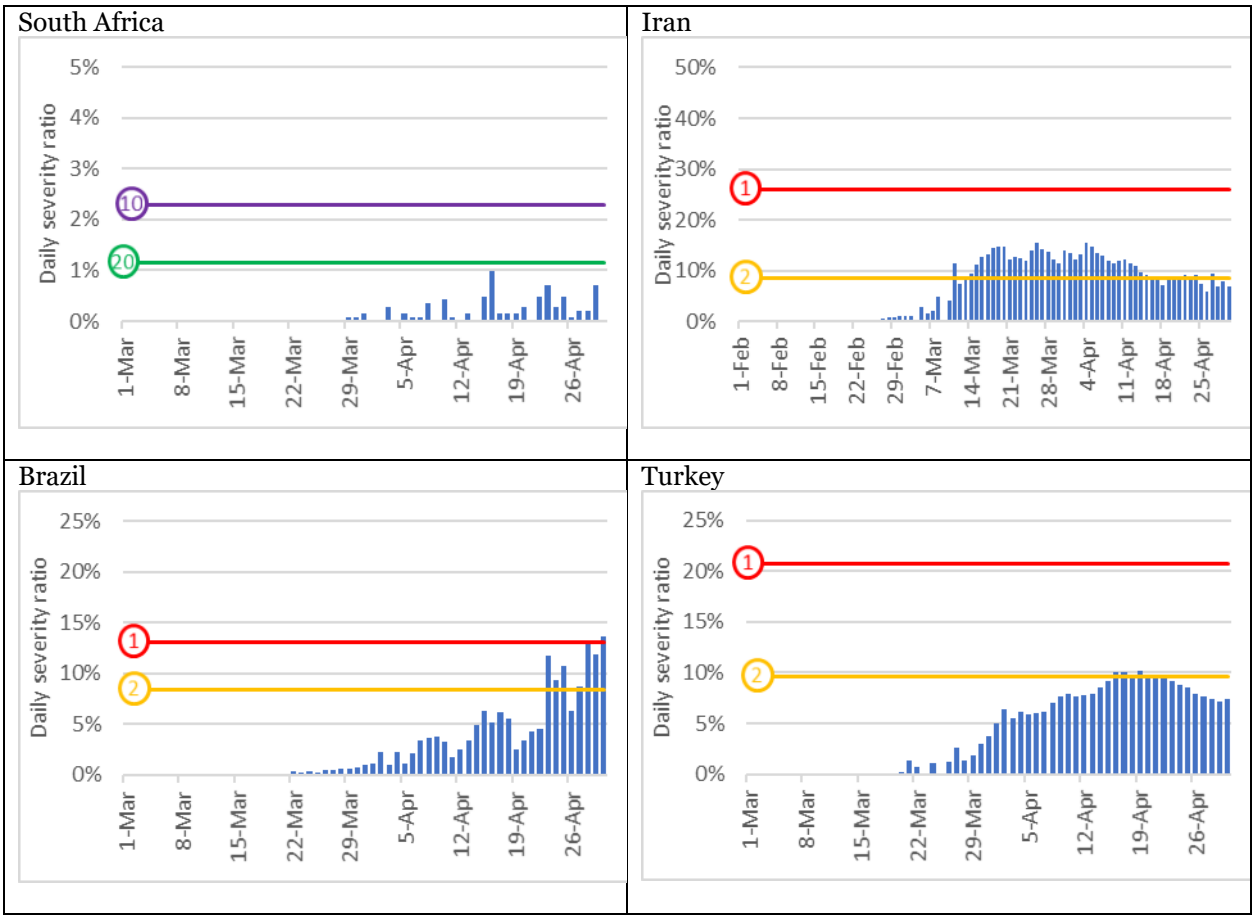
Source: Johns Hopkins University; World Health Organization.
Note: Bars represent nth cause of death, where 'n' is circled number. A circled 'a' represents all causes of death.

The patterns among developing countries are generally more muted (Figure 8):

- **China and India:** the reported data suggests that COVID-19 has remained well suppressed in the country *as a whole* (as noted earlier, a more disaggregated analysis will paint a different picture). The pandemic started in China, but severity at the level of the entire country remained well below the 19th cause of death, except for the brief spike mid-April. The official data suggests India is growing steadily from a low base, but severity has been limited thus far, again for the country as a whole.
- **Indonesia, Russia and South Africa:** similar patterns are observed for these countries, except for Russia where the disease has approached the 2% mark and the threshold of the 10th cause of death.
- **Iran:** the outbreak has been much more significant in Iran. The daily additions have been sustained for a long period and they have consistently exceed the 2nd cause of death.
- **Brazil and Turkey:** the increase has been rapid in these countries. But where Brazil seems to continue its steady rise, Turkey appears to be beyond the peak based on the reported data. Turkey managed to keep the numbers below the 2nd cause of death, while Brazil recently broke the 1st cause of death threshold.

Figure 8. The Progression of Severity among Selected Developing Countries:
Daily Severity from COVID-19 and Proportionate Mortality by Top Cause (percent)





Source: Johns Hopkins University; World Health Organization.
Note: Bars represent n^{th} cause of death, where 'n' is circled number.

4. COVID, Quo Vadis?

In which direction will the burden of COVID-19 mortality travel as we look to the future? Will new epicenters emerge outside of the high-income world? Is this just the beginning for the poorer countries?

While these questions are hard to answer, this paper has argued that the observed concentration in reported mortality data should be considerably overestimated given their demographic profile as well as other host-specific and environmental factors. Developing countries may of course be at earlier stages of the pandemic compared to high-income countries. If true, this would indicate only temporary respite as the virus has already travelled to more than 210 countries and territories and structural features of developing countries may make them more susceptible to contagion.

To the extent that data quality is not at play, we should expect developing countries to catch up with and overtake high-income countries as the pandemic continues to work its way through the age distributions of the developing world. COVID-19 has been described as a heat-seeking missile speeding toward the most vulnerable in society. That metaphor applies not just to the

vulnerable in the rich world; the vulnerable in the rest of the world are not more immune. They may actually be easier targets.

Data quality will remain a key challenge going forward. The need for adequate measurement and reporting cannot be emphasized enough. We see that high-income countries are grappling with these issues. Even if total deaths may be measured with more precision than infections, especially in HICs, there is significant evidence that COVID-19 deaths are being misattributed to other causes of death (The Economist, 2020b). By some estimates, reported death rates in selected countries could be underestimated by 60%, which would of course imply a significant increase in the already considerable severity of the mortality burden in those countries (Financial Times, 2020a).

Some countries, like Belgium, have introduced corrective measures to aggressively include deaths occurring in elderly-care homes based on symptoms shown and contacts made even if there was not a confirmed infection (Bloomberg, 2020). While this may help explain why Belgium has the highest level of severity globally, it at the same time raises suspicion of the data of many other countries.

Measures of cumulative and daily severity provide valuable comparative perspectives that help the distribution and progress of the pandemic relative to pre-existing mortality patterns. The estimates presented in this paper relied on reported data, both to illustrate the method and to call into question the sheer dichotomy between the high-income and developing worlds. These differences can be analyzed at a more granular level by monitoring anomalies over time and dissimilarities between countries that cannot be easily explained by other factors.

The method also lends itself to the use of dashboards that provide progressive layers of granularity in many possible dimensions, such as age-cohort, co-morbidity patterns, socioeconomic group or subnational geography. Together these techniques should enable us to put into sharped focus how the severity of the pandemic is evolving across a wide spectrum of countries, including those in the developing world.

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