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Decoding India's Low Covid-19 Case Fatality Rate

Minu Philip[a], Debraj Ray[b,c] and S. Subramanian[d]*

[a]Department of Economics, New York University, New York, USA; [b]Department of Economics, New York University, New York, USA; [c]Department of Economics, University of Warwick, Coventry, UK; [d]Independent Researcher, Chennai, India

ABSTRACT

India's case fatality rate (CFR) under Covid-19 is strikingly low, around 1.7% at the time of writing. The world average rate is far higher. Several observers have noted that this difference is at least partly due to India's younger age distribution. We use age-specific fatality rates from 17 comparison countries, coupled with India's distribution of Covid-19 cases, to "predict" India's CFR. In most cases, those predictions yield even lower numbers, suggesting that India's CFR is, if anything, too high rather than too low. We supplement the analysis with a decomposition exercise, and we additionally account for time lags between case incidence and death for a more relevant perspective under a growing pandemic. Our exercise underscores the importance of careful measurement and interpretation of the data, and emphasises the dangers of a misplaced complacency that could arise from an exclusive concern with aggregate statistics such as the CFR.

KEYWORDS

Covid-19; Case fatality rate; Demographics; Public health; Cross-country comparisons; Age-specific mortality

1. Introduction

As of September 10, 2020, India has 4.5 million confirmed cases of Covid-19, with a death toll of over 76,000. Figure 1 plots the *case fatality rate* [CFR] in India, compared to the world (Panel A) and to selected countries (Panel B). Over the initial duration of this epidemic, India has hovered around a CFR of 3% or more, with a steady downward trend to around 1.7%. The world rate is far higher, trending down from a peak of over 7% to a current number around 3%. Several economically advanced countries are far higher still. Panel B of Figure 1 compares India to a number of other countries — these comparisons will recur throughout the paper. India is at or near the bottom of the case fatality heap. The end-August fatality rate of 1.8% compares favorably with countries such as the Netherlands (8.9%), Italy (13.2%), and Spain (6.3%).

Of course, CFRs are not to be confused with *infection* fatality rates, the latter being the true measure of mortality from the disease. But Covid-19 infection

CONTACT Minu Philip minu.philip@nyu.edu
*Formerly Professor at Madras Institute of Development Studies.

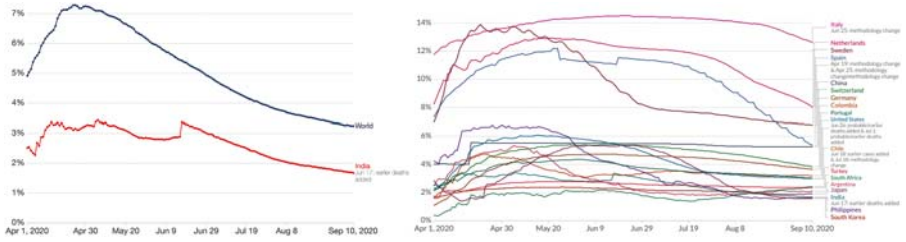

Figure 1. Case Fatality Rates for India and Selected Countries over Apr 01 – Sept 10, 2020. Source. Roser et al. (2020). (a) India and World. (b) India and Others.

rates are not known anywhere in the world, and in India they are currently the subject of considerable debate.[1] Therefore, at least for assessing trends and comparisons, we must currently make do with CFRs. And it is not a bad measure at all for this purpose, *provided that the absolute numbers are not interpreted literally*,[2] and are only used to make comparisons across countries and time; that too with a great deal of care.

Certainly, India's seeming robustness under this measure (compared to other countries) has not gone unnoticed. Government spokespersons have attributed it to "early identification and clinical management of cases." Prime Minister Modi, in a national address on July 26, 2020, while correctly emphasising the need to "remain vigilant," observed that "India's Covid-19 recovery rate is better than others. Our fatality rate is much less than most other countries."[3]

To move from a low CFR to an unqualified commendation of deliberate policy-induced recovery from the disease might (to put it mildly) overlook certain crucial aspects of demographic detail. That the age distribution within a country will influence the CFR for Covid-19 is widely known, with "younger countries" exhibiting lower CFRs simply on account of lower death rates among younger age groups. Many observers have pointed to the Indian age structure as a possible confounding variable in interpreting the aggregate CFR; see, for instance, Ray and Subramanian (2020) and Mukhopadhyay (2020) for India in particular, and Dudel et al. (2020) for other countries.[4]

We take this observation as a starting point, but seek a more precise *quantitative comparison* between India and other countries. Sections 2–4 deal with alternative approaches to this question, so as to provide an overall assessment of India's CFR.

One way of adjusting for age-distribution in a relatively young country is to ask what would happen to that country's overall CFR if it experienced age-specific CFRs similar to those in countries in which older cohorts account for a larger share of the population. In Section 2, we do this for India using a set of selected comparison countries and regions: the same set that appears in Figure 1. *A majority of these countries underpredict Indian rates in this exercise, even though their overall CFRs are far higher than that of India*.

With detailed age-specific data for both India and comparison countries, one can additionally decompose the differences in CFRs for a sharper description of

how the distribution of cases and deaths by age affects aggregate mortality statistics. The method is different from that in Section 2, in that it precisely separates the difference in CFR into two effects: one corresponding to case distribution (an "incidence effect"), and the other to age-specific fatality rates (the "fatality effect"). Our approach is based on Shorrocks (2013) and Kitagawa (1955), and corresponds closely to that taken by Dudel et al. (2020) to explain the observed cross-country variation in CFRs of selected countries; see Section 3 for details. We find that India's low CFR, while seemingly comparable (at least currently) to countries such as South Korea, masks significant differences in age-specific incidence and mortality burdens from those of South Korea, and only appears to be of comparable magnitude by a serendipitous opposition of these factors in the process of aggregation.

The preceding analysis is based on the presumption that current deaths divided by *current* cases is a good measure of case fatality. But this is problematic because there is a time-lag between the onset of infection and the date of death. Verity et al. (2020) report a mean duration of around 18 days from infection to death (conditional on death). It is unclear when such cases would be registered as "confirmed" — that would depend on the timing of testing — but in any event, cumulative deaths should be related to cumulative cases at some *anterior* date. This suggests that the contemporaneous CFR is an inaccurate reflection of the actual case mortality rate. A better approximation is the number of Covid deaths on a particular date divided by the number of Covid cases at some relevant anterior date. With cases mounting over time, the contemporaneous CFR will understate case fatality relative to this "lagged CFR." That would be true for all countries, but the extent of underestimation would be different for different countries because of inter-country variation in the rate of growth of cases. Section 4 undertakes a comparison of India with selected countries, while exploring the difference between contemporaneous and lagged CFRs. Using a three-week lag, the results are quite remarkable. For the overwhelming majority of countries that we consider, India's advantage in age-specific incidence is more than nullified by the higher age-specific mortality burdens.

We note that in making these comparisons, we have simply ignored the enormous problem of undercounting of Covid-19 deaths. Of course this matters, but even the *reported* deaths suffice to make our point.

To summarise: there are two potential sources of difficulty in simply accepting the case fatality rate, as it is usually reported, as a reliable indicator of cross-country comparison. (This is quite separate from the inadequacy of CFRs as a true measure of Covid-19 fatality, a well-known issue that we do not address here.) The first has to do with the failure of the measure to reflect the precise age-distribution of cases and deaths in each particular situation. The second has to do with the strong possibility that a lagged CFR is a more dependable indicator of case fatality than the customary contemporaneous CFR. Correcting

for these complications, as we shall see, leads to a picture of India's health-related capability in dealing with the Covid-19 epidemic which is altogether less flattering than what might otherwise appear to be the case. This is one more instance of the general proposition that careful measurement can make a difference to our assessment of actual country performance in the matter of human development and capabilities.

2. Predicting Indian Mortality from Age-Specific CFRs of Other Countries

To fix some elementary ideas and notation: let f^c be the overall CFR in any country c, f_j^c the CFR in age-group j, and let w_j^c be the proportion of all cases in age-group j. Then, for any country,

$$f^c = \sum_{j=1}^{M} w_j^c f_j^c,$$

where M is the number of age groups. Begin by looking at India's weight distribution $\{w_j^I\}$, which marks the incidence of the disease across different age groups. Figure 2 displays information on the population distribution by age, the weight distribution by age, and the *impact ratios*, which we define to be w_j^c/n_j^c, where n_j^c is the population share in age group j for country c. These objects are displayed in Table 1. The first exercise that we conduct is to "predict" case fatality rates for India using age-specific data from a set of comparison countries, but using weights from *the case distribution pertaining to India*. The idea is to approximate how India would perform if it had the age-specific case fatality rates of these comparison countries. As it happens, our set of comparisons is perforce limited because information on cases and

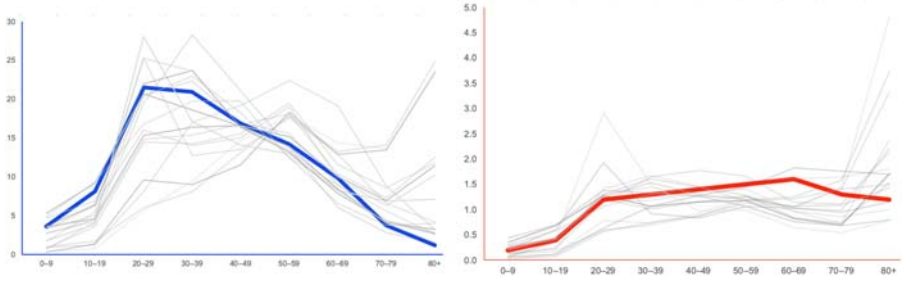

Figure 2. Distribution of Cases and Impact Ratios by Age for India and Selected Countries. For list of countries see text. Panel A shows the percentage of cases in each age group by country, Panel B plots the impact ratio by age, by country. A ratio greater than 1 indicates that the age group in question has been disproportionately hit relative to its population share. In each panel, India is shown in bold and comparison countries are as listed in Table 2. Sources. Case Distribution (see Table A1) and Population Distribution from *UN World Population Prospects* (United Nations, Department of Economic and Social Affairs, Population Division 2019). (a) Cases by Age. (b) Impact Ratios by Age.

Table 1. Case incidence, population distribution and impact ratios for India. Impact ratios show how different age-groups are affected relative to their population share.

	Age Group								
	0–9	10–19	20–29	30–39	40–49	50–59	60–69	70–79	80+
Case % [1]	3.6	8.1	21.5	21.0	16.8	14.2	9.9	3.8	1.2
Pop % [2]	17.0	18.3	17.4	15.6	12.3	9.3	6.3	2.8	1.0
Impact [1/2]	0.2	0.4	1.2	1.3	1.4	1.5	1.6	1.3	1.2

Sources. Case distribution from ICMR COVID Study Group et al. (2020) and population distribution from *UN World Population Prospects* (United Nations, Department of Economic and Social Affairs, Population Division 2019)

deaths by age is not easy to come by and needs to be extracted from individual country dashboards. Many countries do not provide those data or (as in the case of India) do so infrequently and irregularly via Ministerial decree. As of August 4, the Wikipedia website https://en.wikipedia.org/wiki/Coronavirus_disease_2019 lists 22 countries with age-specific, country-level mortality rates, of which we use fifteen: Argentina, Chile, China, Colombia, Germany (Bavaria), Italy, Japan, the Netherlands, the Philippines, Portugal, South Africa, South Korea, Spain, Sweden, and Switzerland. We add the State of California and Turkey for a total of seventeen comparison "countries."[5]

Figure 2(A) shows the percentage of Covid-19 cases by age group for India and the comparison countries, with the Indian line depicted in boldface. Relative to our comparison list — with the exception of other developing countries such as South Africa — India is demographically a very young country indeed. The burden of the Indian case distribution by age therefore sharply falls upon the younger age groups: the corresponding lines for several of the comparison countries are shifted to the right.

Panel B plots the impact ratio — the ratio of case incidence to population percentage by age, by country. A ratio greater than 1 indicates that the age group in question has been disproportionately hit relative to population size. India is shown in bold. For all countries, the impact ratios are smaller than one for the youngest age group, which is only to be expected: after all, the very youngest are relatively isolated from widespread, anonymous social interaction. But among working adult groups and relative to the comparison countries, India stands out in having a large impact ratio. These middle-aged and older working groups are not only those excessively represented in overall population (Panel B), they are also disproportionately *more* affected by Covid-19. In contrast, the Indian impact ratio is only slightly above 1 for the oldest age groups, while for many of the comparison countries, that impact ratio spikes upward quite dramatically. Taken together, these two features (population distribution and the distribution of impact ratios) create a substantial skew, at least in the *measured* incidence of Covid-19, among the younger age groups.[6] For the exact distributions of cases and deaths by age for our comparison countries, see Table A1 in the Appendix.

These distributions come from a variety of dates for different countries. Unfortunately, for countries for which age-based mortality data is taken from

data visualisation dashboards, previous information often disappears from the visualisation once updated, so that we typically have access to age-specific data at *one* date, that of the latest update. But there are exceptions. These exceptions suggest that barring the initial phases of the pandemic, the *distribution* of cases and deaths across ages appears to be reasonably stable. We explore this stability in Appendix A.3. That is not true of the age-specific mortality rates, which *do* change significantly over time. But the point is that the latter changes because there has been significant movement in the case-fatality rate over time, and not because the relative dispersion of cases or deaths has been changing. This feature will be exploited in the analysis below.

We can use India's case distribution information, along with the CFR patterns from comparison countries, to "predict" India's CFR were it to be driven by the age-specific rates in those countries, coupled with India's case distribution across ages (which mirrors Indian demographics). Table 2, which significantly extends Table 3 in Ray and Subramanian (2020), carries out these predictive exercises. Specifically, country c's prediction for India can be written as

$$\hat{f^{c,I}} = \sum_{j=1}^{M} w_j^I f_j^c,$$

where the weights are the Indian distribution of cases across the population.

India's latest CFR numbers stand at around 1.7%, but as Figure 1 also reveals, India's CFR has been around 3% for much of the period since the start of the pandemic, hitting 3.4% on June 17 as an adjustment of past deaths was made in

Table 2. Predicted Indian CFRs. Numbers in the first row report India's CFR for different dates. Subsequent rows report counterfactual CFR for India, predicted using age-specific CFRs of the respective comparison country and India's case distribution (Table 1). Underpredictions are in italics. Country-specific CFRs, as of July 30, are reported in bold for comparison.

		Predicted CFR at Various Dates				
	CFR Jul 30	June 20	July 10	July 30	Aug 20	Sept 10
India		**3.28**	**2.72**	**2.21**	**1.90**	**1.68**
China	**5.34**	*2.85*	2.84	2.78	2.73	2.73
S. Korea	**2.10**	*1.08*	*1.03*	*1.00*	*0.90*	*0.76*
Japan	**3.09**	*2.29*	*2.03*	*1.32*	*0.84*	*0.82*
Philippines	**2.30**	4.07	*2.61*	2.35	*1.65*	*1.67*
Netherlands	**11.45**	*2.46*	*2.42*	2.29	1.91	*1.61*
Italy	**14.24**	*3.18*	3.15	3.11	3.03	2.76
Spain	**9.96**	*2.44*	*2.37*	*2.11*	*1.62*	*1.14*
Bavaria	**5.16**	*1.94*	*1.92*	*1.87*	*1.76*	*1.57*
Sweden	**7.54**	*2.45*	*2.10*	*2.03*	1.90	1.83
Switzerland	**4.90**	*1.34*	*1.29*	*1.22*	*1.11*	*0.96*
S. Africa	**1.59**	*2.47*	*1.85*	*1.88*	2.46	2.79
Chile	**2.64**	*1.35*	*1.67*	*2.02*	2.08	2.10
Colombia	**3.42**	*2.89*	3.14	3.06	2.84	2.87
Argentina	**1.85**	*2.02*	*1.60*	*1.51*	*1.63*	1.71
Turkey	**2.47**	*2.11*	*2.01*	*1.97*	1.90	1.91
Portugal	**3.41**	*1.22*	*1.11*	*1.04*	*1.00*	*0.92*
California	**1.83**	*2.36*	*1.69*	*1.38*	*1.37*	*1.42*

Sources. Case and Death Distributions (Table A1) combined with CFRs from Roser et al. (2020) to calculate age-specific CFRs.

the database; then falling slowly. Depending on the dates for counterfactual prediction — we use five — we have different rates for India, which are described in Table 2. Countries that (age-adjusted with Indian weights) predict a lower CFR — relative to India's actual aggregate CFR — are shown in blue. Note that some country-level observations are mixed over time.

The adjusted CFRs in Table 2 are quite remarkable, given that the actual CFRs for many of these countries far exceed those of India (Figure 1, Panel B). Countries such as the Netherlands or Spain have a CFR well in excess of 9%. Yet, once adjusted for the Indian case distribution, it becomes clear that India is no longer an outlier. While the reader is invited to go through the comparisons, we single out South Korea here, because age-*un*adjusted, the two CFRs are comparable as of July 30, 2020. And yet, once we adjust for differences in the demographic distribution, the South Korean rates translate into an aggregate CFR of merely 0.76%, far lower than India's CFR of around 1.68%.

There are over-predictors. Among them are Colombia, China, Turkey and Italy, the last of which comes as a bit of a (relative) surprise.[7] Compared to these countries, India's performance does not look as bad. We will revisit Table 2 with our study of lagged fatalities in Section 4. But even at this stage, it appears safe to dismiss as exaggeration the assertion that India's "fatality rate is much less than most other countries."

3. Decomposing Inter-Country Differences in Case Fatality Rates

3.1. A Decomposition

For a meaningful comparison of CFRs across two countries, we decompose the difference in CFRs into what may be called a *fatality effect* and a *case-incidence effect*. Let I stand for India, our country of interest, and let C be any comparison country. We "decompose" this difference into two terms, as follows:

$$\begin{aligned} f^c - f^I &= \frac{1}{2}(f^c - f^I) + \frac{1}{2}(f^c - f^I) \\ &= \frac{1}{2}(f^c - \sum_{j=1}^{M} w_j^I f_j^c + \sum_{j=1}^{M} w_j^c f_j^I - f^I) + \frac{1}{2}(f^c + \sum_{j=1}^{M} w_j^I f_j^c - \sum_{j=1}^{M} w_j^c f_j^I - f^I) \\ &= \frac{1}{2}\left[\sum_{j=1}^{M}(w_j^c - w_j^I)(f_j^c + f_j^I)\right] + \frac{1}{2}\left[(\sum_{j=1}^{M}(w_j^c + w_j^I)(f_j^c - f_j^I)\right] \\ &= \frac{1}{2}\left[\sum_{j=1}^{M}\Delta w_j(f_j^c + f_j^I)\right] + \frac{1}{2}\left[\sum_{j=1}^{M}(w_j^c + w_j^I)\Delta f_j\right], \end{aligned} \tag{1}$$

where $\Delta w_j = w_j^c - w_j^I$, and $\Delta f_j = f_j^c - f_j^I$. This decomposition is an instance of the *Shapley procedure* described by Shorrocks (2013), based on Shapley's (1953)

formulation of his celebrated "value" as a solution to allocation problems within a cooperative game. In the specific context of our paper, this approach coincides with a procedure advanced by Kitagawa (1955), which seeks to factorise the "difference between two rates" into its "component" parts (Preston, Heuveline, and Guillot 2001). Dudel et al. (2020) apply this procedure to differences in case fatality rates, as we do here. Note that this is an *exact* decomposition, that is, the relative contributions of the factors driving the change under examination add up to exactly 100% (without leaving behind any hard-to-interpret residual effects, such as the so-called "interaction" effect in "standard" decompositions).

The first component in the decomposition (1) is what we may call the *incidence effect*. It quantifies the difference in CFRs that would arise solely due to age-specific differences in case incidence rates under the hypothetical scenario that the countries share the average of their age-specific CFRs. This number will typically be positive if the comparison country is older, because older age groups are weighted by higher fatality rates and the comparison country will have more of such groups. The second component, which we call the *fatality effect*, quantifies the difference in CFRs that would arise solely due to differences in age-specific CFRs, in the hypothetical scenario that the countries share the average of their age-specific infection rates. This number would be negative if India's age-based fatality rate is higher than the corresponding age-based fatality rate for the comparison country, for most, if not all age groups.

The fatality effect is closely related to the analysis in Table 2, where we "predict" Indian CFR using *India's* case distribution, except that here we use as weights the *average* of the case distribution for India and the comparison country in question. Because the economically advanced countries among the latter group are more likely to have an older population, this tempers the prediction somewhat, and we expect milder effects compared to Table 2.

3.2. Decomposing India's CFR

The decomposition formula relies on more data than in Section 2; specifically, on the distribution of deaths by age for India, a statistic released sporadically by the Union Health Ministry and in age brackets that are both coarse and frustratingly non-comparable with those used for our comparison countries. The latest numbers are from a July 8 Press Release, with incidence for six age brackets. To maintain comparability, we've split these brackets into the nine brackets used so far, drawing on additional data with an interpolation procedure described in Appendix A.2; see Table 3.

Armed with the information here and invoking similar data for the comparison countries, we can set Equation (1) to work. Table 4 studies three dates over which the Indian CFR has progressively fallen (along with those of the comparison countries). For each of these dates and each comparison country, we report the CFR of the country, which — barring a few cases — significantly exceeds

Table 3. Case and Death Distribution by Age for India.

	Age Group								
	0–9	10–19	20–29	30–39	40–49	50–59	60–69	70–79	80+
Cases (%)	3.6	8.1	21.5	21.0	16.8	14.2	9.9	3.8	1.2
Deaths (%)	0.8	0.9	2.4	5.5	13.5	24.0	30.4	15.9	6.7

Sources. Case distribution from ICMR COVID Study Group et al. (2020) and death distribution interpolated using Indian Ministry of Health Press Release, July 08, 2020 (details in Appendix A.2).

those of India. The decomposition exercise then breaks up the difference between the Indian and comparison CFR into incidence and fatality effects, as described in (1). The CFR difference is the sum (accounting for positive and negative values) of the incidence and fatality effects.

Once again let's single out South Korea, given that its CFR on July 30 (2.1%) is comparable with that of India (2.2%). This comparability now appears clearly as the coincidental cancellation of two opposing forces. The incidence effect is positive, which isn't surprising given that South Korea has an older population. The fatality-weighted distribution of cases generates a higher fatality for South Korea on that score. But the fatality effect is negative — that is, the case-weighted distribution of fatalities generates a larger number for India. The two effects cancel, leaving them with comparable CFRs on the aggregate. The higher age-specific fatality rate, as indicated by the negative fatality effect, is suggestive of a relatively lower level of robustness of health in India, or a relatively lower level of robustness of treatment facilities, or both. If India and South Korea shared their age-specific CFRs, their average, South Korea's aggregate CFR would be higher than India's by close to one percentage point, a huge difference relative to their baseline CFRs. Alternatively, with the same case distribution, South Korea's CFR would be lower by slightly more than one percentage point, owing to its low age-specific CFRs.

The near-equivalence in the two CFRs is therefore a result of aggregation. The fatality effect goes against a favorable welfare interpretation for India. But India's particular pattern of the age-distribution of Covid-19 incidence masks that negative effect. The same pattern recurs for a number of other comparison countries, especially in the earlier months. To see this in a bit more detail, consider the data for September 10. Of the 17 comparison countries, 6 are ones for which the IE and the FE have opposing signs, and in all but one of these cases (S. Africa), the IE is positive and the FE negative. Of the remaining 11 cases, it is only in the case of the Philippines that both effects are negative; in 8 of the other 10 cases (that is, barring Chile and Colombia), both effects are positive, with the IE dominating the FE. In a majority of cases, therefore, it is the differential age-distribution of Covid cases that comes to India's rescue. Later, when we consider lagged CFRs (Table 6), these patterns acquire even greater clarity.

This decomposition analysis goes beyond our earlier comparisons in Table 2, in that it also includes the counterfactual when the CFRs are the same but case incidence isn't. Here, India's "advantage" of higher case incidence among the

Table 4. CFR-Difference Decomposition For India and Comparison Countries.

	June 20				July 30				Sept 10			
Country	CFR	Diff	IE	FE	CFR	Diff	IE	FE	CFR	Diff	IE	FE
India	**3.28**	0.00	–	–	**2.21**	0.00	–	–	**1.68**	0.00	–	–
China	5.49	2.21	2.52	−0.31	5.34	3.13	2.09	1.04	5.25	3.57	1.88	1.69
South Korea	2.26	−1.02	1.24	−2.26	2.10	−0.11	0.99	−1.10	1.59	−0.09	0.75	−0.84
Japan	5.35	2.07	2.14	−0.07	3.09	0.88	1.29	−0.41	1.92	0.24	0.86	−0.62
Philippines	3.97	0.69	−0.08	0.78	2.30	0.09	−0.05	0.14	1.63	−0.05	−0.04	−0.02
Netherlands	12.30	9.02	7.83	1.19	11.45	9.24	6.54	2.70	8.04	6.36	4.71	1.65
Italy	14.52	11.24	8.78	2.46	14.24	12.03	7.65	4.37	12.63	10.95	6.53	4.42
Spain	11.52	8.24	7.54	0.70	9.97	7.76	5.95	1.81	5.36	3.68	3.65	0.03
Bavaria	5.37	2.09	2.82	−0.73	5.16	2.95	2.39	0.56	4.35	2.67	1.96	0.71
Sweden	9.12	5.84	4.74	1.10	7.54	5.33	3.71	1.63	6.80	5.12	3.21	1.91
Switzerland	5.37	2.09	3.53	−1.43	4.90	2.69	2.86	−0.16	3.84	2.16	2.21	−0.06
South Africa	2.09	−1.19	−0.35	−0.84	1.59	−0.62	−0.25	−0.36	2.36	0.68	−0.30	0.98
Chile**	1.77	−1.51	0.41	−1.92	2.64	0.43	0.44	−0.01	2.74	1.06	0.42	0.64
Colombia	3.23	−0.05	0.22	−0.27	3.42	1.21	0.22	1.00	3.21	1.53	0.20	1.33
Argentina	2.48	−0.80	0.31	−1.12	1.85	−0.36	0.23	−0.59	2.09	0.41	0.24	0.18
Turkey	2.65	−0.63	0.47	−1.10	2.47	0.26	0.39	−0.13	2.40	0.72	0.35	0.37
Portugal	3.97	0.69	2.57	−1.88	3.41	1.20	1.99	−0.79	3.00	1.32	1.66	−0.33
California	3.12	−0.16	0.51	−0.66	1.83	−0.38	0.31	−0.69	1.87	0.19	0.29	−0.10

Sources. Distribution of cases and deaths from Tables 3 and A1. These, along with overall CFRs from Roser et al. (2020), are combined and applied to the decomposition formula (1) to obtain Incidence Effects (IE) and Fatality Effects (FE).

young is not by virtue of its demographic characteristics alone. A quick recall of the population shares and case shares in Table 1, along with Panel B of Figure 2, reminds us that the caseload for the working-age population in India is higher than its population share. In contrast to most other countries with the highest impact ratio reserved for the oldest age group, it is the impact ratio for the middle-aged and older working population that is relatively high in India. While this helps attenuate India's CFR, it is certainly not desirable otherwise. *Why* that population is disproportionately affected requires an evaluation of exposure, prevalence of co-morbidities, or lifestyle choices such as smoking, etc., which is beyond the scope of the present exercise.

All in all, the recipe for a low aggregate CFR looks quite simple to implement: pick either an endowment of low age-specific CFRs, or a case distribution skewed towards low-CFR age groups. India's demographic structure generates an abundant supply of the second ingredient, amplified by its high impact ratios for working-age groups. (The same is true of South Africa, another young country.) In contrast, India appears to be lacking in the first ingredient: low age-specific CFRs.

Comparisons such as those between India and South Korea are not intended to verify the easily accessed fact that India has fared poorly in relation to a country which is an obvious outlier. Such comparisons would then add up to no more than an essentially trite exercise. Rather, the objective, at a general level, is to drive home the point that social indicators such as the aggregate CFR are essentially outcome-indicators, and that in certain cases, similar outcomes (as for India and South Korea) can display widely differing underlying processes that lead up to these outcomes. Similar observations have been made by Anderson and Ray (2010) and Jayaraj and Subramanian (2009) about the sex-ratio of a population, and by Kanbur and Mukherjee (2007) about poverty indices. This general point reinforces the specific desirability of guarding against misplaced complacency (or panic, as the case may be) that could arise from an exclusive concern with an aggregate statistic such as the CFR.

4. Growing Epidemics and Lagged Case Fatality Rates

When a SARS-CoV-2 infection ends in death, the mean duration from symptoms to death is around 2.5 weeks; see, for instance, Verity et al. (2020), who report a mean duration of around 18 days.[8] It is unclear when such cases would be registered as "confirmed" before the death occurs — that would depend on when testing occurs after the onset of symptoms — but it is likely that the cumulative deaths at any date should be related to cumulative cases at some anterior date, and not cumulative contemporaneous cases. Call this measure of case fatality the *lagged* case fatality rate, or LCFR.

Using case counts from January 30, 2020 to May 14, 2020, Mohanty et al. (2020) find that the 14-day LCFR for India is 8.01%, more than twice the contemporaneous CFR of 3.40% on May 14, 2020. But it is no surprise to learn that in societies with growing incidence (or expansion of testing), LCFR would significantly exceed CFR. That doesn't require us to calculate anything. A more interesting question emerges when we make comparisons across countries. *Every* LCFR would exceed its contemporaneous counterpart. The question is: by how much? It is easy to see that ceteris paribus, a country with a faster growth rate of confirmed cases would exhibit a higher *ratio* of LCFR to CFR. A bit more formally, if we denote the x-day growth rate of cases in country c by g^c, where x is a number that we would need to settle upon, then lagged fatality ϕ^c is connected to contemporaneous fatality f^c by the obvious identity:

$$\phi^c = f^c[1 + g^c].$$

4.1. The Prediction Exercise of Section 2 Revisited, with Lagged CFR

We revisit two exercises with lagged case fatality rates. The first is the prediction exercise from Table 2. That is, we use the same set of comparison countries to predict the case fatality rate for India using India's age distribution coupled with the age-specific fatality rates for those countries. But we now do so using lagged fatality rates. The following qualifications and remarks should be noted.

First, we'd like to use age-specific growth rates to achieve the correction, but this is data we do not have, so we apply the same growth rate in cases to all age groups within a country. Second, the growth rate — and consequently the predictions — will vary with the lag. Therefore, while we report 21-day lags, we explore a 14-day alternative in Appendix A.4. Third, the choice of calendar date will matter, as it will affect not just the values of India's case fatality rate, but also the rate of growth of cases. Therefore we conduct three exercises: for June 20, July 30 and Sept 10. As in Table 2, we hold fixed the *distribution* of cases and deaths across ages. (We again refer the reader to Appendix A.3 for the intertemporal stability of these distributions.) The age-specific lagged CFRs are generated from aggregate fatality rates applied to these distributions, and then used to make the Indian predictions. Finally, we reiterate that the *specific values* of the LCFRs, while potentially of interest, are problematic to interpret. We know they will go up with the lag, but their absolute magnitudes could reflect either changes in the progression of the epidemic, or the intensity of testing. Rather, all we do is explore what this does to the under- or over-prediction of India's correspondingly lagged rate.

Table 5 reports the results. Lagged CFRs are generally sizably larger than contemporaneous CFRs. The 21-day growth in cases in India was between

60–80%, which leads to higher (and probably more accurate) estimates of case fatalities; these are recorded in the first row of the table, along with the unlagged CFRs for easy comparison. The predicted rates from comparison countries are recorded in the rows below. For some countries like South Korea, Spain and Switzerland, the resulting changes are minimal, because there is a near-cessation of growth in new cases during this period. But more generally, there is a significant increase in under-prediction once the differential case growth is taken into account. For instance, Italy now switches from being an over-predictor of India's case fatality rate to being an under-predictor in most cases. The point is that Italian cases have grown slower than Indian cases during this time period, so India's effective case fatality rate is significantly higher than the rates in Table 2. The same switch also occurs for China at the earlier dates, and even at the latest date on record here, China remains comparable to India. The one country that appears to be doing distinctly worse is Colombia, which is also experiencing rapid growth in cases, and — at the later dates — is an over-predictor in both Tables 2 and 5.

4.2. The Decomposition Exercise of Section 3 Revisited, with Lagged CFR

Lagged CFRs can also be taken to the decomposition exercise of Section 3. We do so in Table 6. The structure is exactly the same as in Table 5. We study three dates — June 20, July 30 and Sept 10. This time we construct all case fatality

Table 5. Predicted Indian Lagged CFRs. Numbers in the first row report Indian LCFR for different dates and lags (14, 21 day). Subsequent rows record predictions from comparison countries. Underpredictions are in italics. Country-specific CFRs, as of July 30, are reported in bold for comparison.

		Predicted CFR for Different Date-Lag Combinations								
		June 20			July 30			Sept 10		
Country	CFR Jul 30	0	−14	−21	0	−14	−21	0	−14	−21
India		**3.28**	**5.47**	**7.45**	**2.21**	**3.61**	**4.56**	**1.68**	**2.27**	**2.65**
China	**5.34**	*2.85*	*2.86*	*2.87*	2.78	*2.84*	*2.85*	2.73	2.74	2.75
South Korea	**2.10**	*1.08*	*1.14*	*1.17*	*1.00*	*1.05*	*1.08*	*0.76*	*0.88*	*1.01*
Japan	**3.09**	*2.29*	*2.38*	*2.42*	*1.32*	*1.88*	*2.11*	*0.82*	*0.93*	*1.03*
Philippines	**2.30**	4.07	5.61	*6.96*	2.35	*3.42*	*3.99*	*1.67*	*2.02*	*2.35*
Netherlands	**11.45**	*2.46*	*2.58*	*2.64*	2.29	*2.40*	*2.42*	*1.61*	*1.83*	*1.93*
Italy	**14.24**	*3.18*	*3.22*	*3.26*	3.11	*3.16*	3.17	2.76	2.96	3.05
Spain	**9.96**	*2.44*	*2.49*	*2.51*	*2.11*	*2.33*	*2.38*	*1.14*	*1.47*	*1.67*
Bavaria	**5.16**	*1.94*	*1.96*	*1.98*	*1.87*	*1.91*	*1.93*	*1.57*	*1.70*	*1.77*
Sweden	**7.54**	*2.45*	*3.27*	*3.74*	*2.03*	*2.11*	*2.16*	1.83	*1.88*	*1.91*
Switzerland	**4.90**	*1.34*	*1.35*	*1.36*	*1.22*	*1.28*	*1.31*	*0.96*	*1.07*	*1.12*
South Africa	**1.59**	*2.47*	*4.98*	*7.40*	*1.88*	*2.85*	*3.95*	2.79	2.91	3.01
Chile	**2.64**	*1.35*	*2.56*	*3.46*	*2.02*	*2.21*	*2.34*	2.10	*2.23*	*2.30*
Colombia	**3.42**	*2.89*	*4.99*	*6.85*	3.06	5.12	6.57	2.87	3.44	3.93
Argentina	**1.85**	*2.02*	*3.81*	*5.19*	*1.51*	*2.45*	*3.14*	1.71	2.38	2.79
Turkey	**2.47**	*2.11*	*2.32*	*2.41*	*1.97*	*2.09*	*2.16*	1.91	*2.08*	*2.15*
Portugal	**3.41**	*1.22*	*1.38*	*1.46*	*1.04*	*1.11*	*1.18*	*0.92*	*1.01*	*1.04*
California	**1.83**	*2.36*	*3.20*	*3.76*	*1.38*	*1.87*	*2.25*	*1.42*	*1.54*	*1.63*

Sources. Case and Death Distributions (Table A1) combined with case and death counts from Roser et al. (2020).

Table 6. 21 day LCFR-Difference Decomposition For India and Comparison Countries.

	June 20				July 30				Sept 10			
Country	LCFR	Diff	IE	FE	LCFR	Diff	IE	FE	LCFR	Diff	IE	FE
India	**7.45**	0.00	–	–	**4.56**	0.00	–	–	**2.65**	0.00	–	–
China	5.51	−1.94	4.06	−6.00	5.48	0.92	2.99	−2.06	5.29	2.64	2.24	0.40
S. Korea	2.45	−5.00	2.12	−7.13	2.26	−2.30	1.50	−3.80	2.12	−0.53	1.08	−1.61
Japan	5.66	−1.79	3.00	−4.79	4.92	0.36	2.25	−1.89	2.40	−0.25	1.18	−1.42
Philippines	6.79	−0.66	−0.16	−0.49	3.90	−0.66	−0.10	−0.56	2.29	−0.36	−0.06	−0.30
Netherlands	13.18	5.73	11.90	−6.16	12.10	7.54	8.89	−1.35	9.68	7.03	6.22	0.81
Italy	14.88	7.43	12.88	−5.45	14.51	9.95	9.99	−0.04	13.94	11.29	7.95	3.34
Spain	11.84	4.39	11.49	−7.10	11.24	6.68	8.60	−1.92	7.86	5.21	5.52	−0.31
Bavaria	5.48	−1.97	4.27	−6.24	5.35	0.79	3.25	−2.46	4.89	2.24	2.45	−0.21
Sweden	13.90	6.45	8.29	−1.84	8.04	3.48	4.90	−1.42	7.11	4.46	3.74	0.72
Switzerland	5.45	−2.00	5.48	−7.47	5.25	0.69	4.07	−3.37	4.49	1.84	2.90	−1.06
S. Africa	6.26	−1.19	−0.94	−0.25	3.34	−1.22	−0.53	−0.69	2.54	−0.11	−0.36	0.26
Chile	4.52	−2.93	0.98	−3.92	3.06	−1.50	0.64	−2.13	3.00	0.35	0.51	−0.16
Colombia	7.66	0.21	0.53	−0.31	7.35	2.79	0.46	2.33	4.39	1.74	0.28	1.47
Argentina	6.36	−1.09	0.78	−1.87	3.84	−0.72	0.47	−1.19	3.42	0.77	0.38	0.39
Turkey	3.03	−4.42	0.77	−5.20	2.71	−1.85	0.56	−2.41	2.70	0.05	0.44	−0.39
Portugal	4.78	−2.67	4.38	−7.05	3.85	−0.71	3.00	−3.71	3.38	0.73	2.14	−1.40
California	4.97	−2.48	0.90	−3.38	2.97	−1.59	0.54	−2.13	2.15	−0.50	0.37	−0.86

Sources. Distribution of cases and deaths from Tables 3 and A1. These, along with total case and death counts from Roser et al. (2020) are combined and applied to the decomposition formula (1) to obtain Incidence Effects (IE) and Fatality Effects (FE).

rates using a 21-day lag, the idea being that deaths at day t are related to infection at day $t-18$ or thereabouts, and allowing for an additional "detection lag" of four days. (The findings are robust to different lags; see Table A2 in the Appendix for an example using 14-day lags).

The first column of numbers in this table lists lagged CFR by country, and the second column records the raw difference between the comparison country and India. Negative numbers indicate that the comparison country is "doing better" than India, either in the CFR itself or in terms of the fatality effect (or both). Compared to Table 5, India's aggregate LCFR now edges closer to the comparison countries just on account of the lag alone. This raw difference is broken up into an incidence and fatality effect, just as in in Table 2. Now there is a larger set of fatality effects that are negative, suggesting that once lagged fatalities are introduced, the average of age-specific fatalities — with weights equal to the average incidence of cases across India and the comparison country — is even less likely to be in India's favor.

5. Summary and Discussion

The Indian case fatality rate under Covid-19 is low relative to the world average and especially so relative to high-income countries. While these low rates have been cited as evidence for India's infrastructural resistance to the disease, it is a widely-held suspicion that India's age distribution (skewed in favor of the young) has something to do with it; see, for instance, Mukhopadhyay (2020) and Ray and Subramanian (2020). This paper provides precise quantitative confirmation of that suspicion by systematically comparing India to a set of comparison countries from over the world.

The findings in this paper confirm a reservation expressed by many researchers into Covid mortality: that when we fail to account for age-specific dispersion in the distribution of Covid-19 cases and deaths (which is the case with the CFR), this does make a difference to our assessment of how well or otherwise any given society has confronted the pandemic. The proposition is not just a matter of academic interest: it has implications for the assessment of both the intrinsic and comparative performance of countries in addressing the phenomenon of Covid mortality. Similar concerns might arise when studying the distribution of incidence across ethnic groups or gender, but of course we do not deal with that here.

Our evaluation of India's experience suggests that the country's record is a good deal less flattering than a reliance solely on a measure of central tendency such as the case fatality rate would indicate. We've used age-specific fatality rates from comparison countries, coupled with India's distribution of Covid-19 cases (which mirrors India's demographic structure) to "predict" what India's CFR would be with those age-specific rates. In most cases, those

predictions are lower than India's actual performance, suggesting that India's CFR is, if anything, too high rather than too low. The general point, then, is to guard against misplaced complaisance (or panic, as the case may be) that could arise from an exclusive concern with the overall CFR, because crude aggregates often hide the fact that the news may be worse (or better, as the case may be) than it appears to be.

Our specific approach does not entirely rely on prediction. We supplement the prediction exercises by the application of a decomposition technique developed by Shorrocks (2013), the outcome of which coincides with a factorisation procedure advanced by Kitagawa (1955) for demographic contexts — one that has been employed to analyse differences in case fatality rates by Dudel et al. (2020), and in the present paper. While this approach needs access to more data that the prediction exercises do, it allows richer insights into cross-country CFR differences by breaking them up into estimates of age-based *incidence* and age-based *fatality*. In principle, this exercise could be applied not just across countries but over time, as the disease wears on and we have access to more data.

The analysis presented here also attempts to account for a specific epidemiological feature; namely, that there is a time lag between the occurrence of infection and the occurrence of death. Therefore, rapid growth in the number of cases will tend to depress the case-fatality rates if contemporaneous statistics of deaths and cases are employed in computing those rates. That in itself comes as no surprise. The question is how this affects cross-country comparisons. We return to both the prediction and decomposition exercises, this time with lagged CFR, and it turns out that India's relative performance generally worsens. Indeed, the gap between lagged CFR and the CFR is so striking that if we were to go by the conceptually more appropriate former measure, then there is no longer a "low" Indian Covid mortality rate asking to be decoded: it is, simply, large.

Whether for reasons of failure in accounting for age-distributions or time lags, India's Covid-19 experience does not imply successful management from the points of view of human development and capability achievement. At the very least, there is reason to believe that an undiscriminating employment of the raw CFR as an indicator of success deserves to be treated with some skepticism. It seems to be important to assert this when both objective appraisal and fair accountability are threatened by summary indicators of performance that are inadequate or misleading, and when such summary measures are employed to their advantage by politicians and policy-makers.

Finally, our concern endorses the call for the timely release of data beyond case and death counts. It is imperative that detailed data disaggregated by age and other relevant demographic attributes be collected, released, and placed in the public domain. This can only enable the scientific community at large to better assess the situation unfolding before us in this

unprecedented time, and to participate more meaningfully in the formulation, implementation, and monitoring of informed policies aimed at mitigation and containment.

Notes

1. Bhramar Mukherjee, in private communication, suggests a nationwide under-reporting factor of the order of 15–25, implying a current infected population of 30–50 million. See Bhattacharyya et al. (2020) for more details on the calculation of the under-reporting factor for India.
2. There are many reasons why the absolute values of CFRs have no obvious and natural meaning, some of which will play an unavoidable role in this paper.
3. The *Hindustan Times*, July 26, 2020; https://www.hindustantimes.com/india-news/pm-narendra-modi-s-67th-mann-ki-baat-address-to-nation-highlights/story-bXhnWiU1WElwNLFp0mpWRJ.html.
4. There are, of course, several other reasons for the CFR to vary across countries. Countries with higher testing rates will generally have lower CFRs — spotting more cases at an earlier and presumably milder stage. Moreover, CFRs will tend to trend down over time within the same country, as testing improves. Actually, India is pretty low on the world testing scale as measured by per-capita tests, so this logic suggests that its CFR should be higher, not lower. There are other ancillary issues, such as obvious caveats associated with using data from multiple sources, such as definitional differences in what constitutes a – "Covid-19 death." There is also the question of under-reporting (Pundir 2020; Thapar 2020; Chatterjee 2020), though this will affect both numerator and denominator in the CFR.
5. The remaining seven countries are Australia, Canada, Denmark, Finland, Israel, Mexico and Norway. Including them does not affect the analysis but lengthens the tables without much added insight.
6. It is possible that relative to the comparison countries, the old remain at home in India during their illness, and Covid deaths as well as cases are disproportionately undercounted among them.
7. The Italian comparison exhibits some contrast to Mukhopadhyay's (2020) analysis. He undertakes a similar exercise as in Table 2 using Italian data, and reports that: "[B]y multiplying Italy's age-specific CFR … to the age-specific number of cases in India, [we find that] [t]he estimated numbers of deaths that should have occurred, if the age-specific death rates of Italy were to prevail in India, is 535. The official number of deaths in India as of April 30 was actually twice that number, at 1074." We go some way towards a resolution of this difference in Section 4, though the disparity is still puzzling.
8. Based on a study of Chinese data by Yang et al. (2020), Wilson et al. (2020) conclude that "… a median of 13 days passed from pneumonia confirmation to death…"

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About the Authors

Minu Philip is a doctoral student in Economics at New York University. She completed her BA. (Hons.) in Economics from St. Stephen's College, Delhi and M.Sc. in Economics from Indira Gandhi Institute of Development Research, Mumbai. Her research interests include Applied Microeconomics and Development Economics.

Debraj Ray is Julius Silver Professor in the Faculty of Arts and Science and Professor of Economics at New York University. He received his BA from the University of Calcutta and his PhD in 1983 from Cornell University. He is a Fellow of the Econometric Society, a Guggenheim Fellow, and a Fellow of the American Academy of Arts and Sciences. He is on the Council of the Game Theory Society and the Board of Directors of the Bureau for Research in the Economic Analysis of Development (BREAD). He received the Dean's Award for Distinguished Teaching at Stanford and the Gittner Award for Teaching Excellence at Boston University. He holds an honorary degree from the University of Oslo, and was a Co-Editor of the American Economic Review between 2011 and 2020.

S. Subramanian is a former professor from the Madras Institute of Development Studies and a former National Fellow of the Indian Council of Social Science Research. He has research interests in aspects of social and economic measurement, collective choice theory, and development economics. He is a Fellow of the Human Development and Capability Association.

Appendix

A.1. Case and Death Distribution

All comparisons are made relative to 15 countries, plus Bavaria and California in place of Germany and the U.S., due to age classification of data. The distributions of cases and deaths are listed in Table A1.

Table A1. Case and Death Distributions for Comparison Countries. Dates are the latest for which we have data.

		Age Group								
		0–9	10–19	20–29	30–39	40–49	50–59	60–69	70–79	80+
China (11 Feb)	Cases (%)	0.9	1.2	8.1	17.0	19.2	22.4	19.2	8.8	3.2
	Deaths (%)	0.0	0.1	0.7	1.8	3.7	12.7	30.2	30.5	20.3
S. Korea (02 Aug)	Cases (%)	1.7	5.4	25.2	12.7	13.5	17.6	13.0	6.6	4.2
	Deaths (%)	0.0	0.0	0.0	0.7	1.0	5.3	13.6	29.9	49.5
Japan (29 Jul)	Cases (%)	1.8	3.8	28.1	17.1	14.1	13.0	8.2	6.9	7.1
	Deaths (%)	0.0	0.0	0.1	0.4	1.4	3.3	10.6	27.3	56.9
Philippines (02 Aug)	Cases (%)	2.7	4.5	25.2	23.7	16.4	13.4	8.6	4.0	1.5
	Deaths (%)	1.5	1.1	2.5	4.7	9.6	19.5	28.5	22.0	10.7
Netherlands (03 Jun)	Cases (%)	0.3	1.4	9.6	9.0	11.6	18.3	12.9	13.4	23.5
	Deaths (%)	0.0	0.0	0.1	0.2	0.5	2.4	8.2	26.9	61.8
Italy (21 Jul)	Cases (%)	1.0	1.7	6.0	8.1	13.1	17.8	13.2	14.1	24.9
	Deaths (%)	0.0	0.0	0.1	0.2	0.9	3.5	10.1	26.3	59.0
Spain (18 May)	Cases (%)	0.4	0.7	5.6	9.5	14.7	17.9	14.4	13.6	23.3
	Deaths (%)	0.0	0.0	0.1	0.3	1.1	3.2	8.8	24.1	62.3
Bavaria (02 Aug)	Cases (%)	3.2	6.3	16.1	14.0	15.1	19.1	9.8	6.3	10.3
	Deaths (%)	0.0	0.0	0.2	0.2	0.6	3.7	9.9	25.8	59.6
Sweden (02 Aug)	Cases (%)	0.6	4.2	14.8	15.4	16.7	18.1	10.4	7.3	12.5
	Deaths (%)	0.0	0.0	0.0	0.0	0.8	2.8	6.9	21.6	67.9
Switzerland (02 Aug)	Cases (%)	0.8	3.6	14.4	14.3	15.5	19.5	11.6	8.6	11.8
	Deaths (%)	0.1	0.0	0.0	0.3	0.4	2.4	7.6	20.3	69.0
S. Africa (28 May)	Cases (%)	2.8	4.2	19.5	28.3	21.1	13.8	6.1	2.8	1.5
	Deaths (%)	0.4	0.2	0.7	5.7	10.6	25.0	26.5	19.6	11.4
Chile* (02 Aug)	Cases (%)	3.3	5.0	20.6	22.3	17.0	15.6	9.0	4.5	2.8
	Deaths (%)	- - -	- - -	2.3	- - -	- - -	3.5	10.5	21.4	28.0	34.4
Colombia (30 Jul)	Cases (%)	3.7	6.4	21.9	23.7	16.4	13.2	7.9	4.2	2.7
	Deaths (%)	0.2	0.1	1.3	3.2	7.3	14.2	23.1	25.1	25.7
Argentina* (02 Aug)	Cases (%)	4.7	6.9	20.3	23.0	18.3	12.5	6.6	3.7	4.0
	Deaths (%)	0.2	0.2	0.8	2.1	5.0	9.8	17.9	24.5	39.6
Turkey* (18 Jun)	Cases (%)	4.8	9.3	16.8	19.8	19.8	12.4	9.0	5.6	2.6
	Deaths (%)	0.1	0.2	1.4	2.6	2.6	15.3	21.8	28.4	27.6
Portugal (02 Aug)	Cases (%)	3.6	4.6	15.3	16.4	16.6	15.1	10.0	6.9	11.4
	Deaths (%)	0.0	0.0	0.1	0.2	1.2	3.2	8.9	19.4	67.0
California* (17 Sept)	Cases (%)	5.3	9.1	20.7	18.6	16.5	13.9	8.4	4.1	3.2
	Deaths (%)	0.0	0.2	0.9	2.3	3.7	10.5	18.7	22.4	41.2

Sources listed under Appendix A.5. *For Argentina, distribution of deaths is imputed using equivalent data on distribution of cases and age-specific CFRs. For Chile, age-specific CFR for age groups between 0–39 are assumed to be equal. Distributions for Turkey and California are interpolated (uniformly).

A.2. Interpolation of Distribution of Deaths Over 10-Year Age Groups

For the decomposition exercises undertaken in Sections 3 and 4, we use distributions of cases and deaths defined over 10-yr age brackets. For India, detailed age-specific information is hard to come by. To complement the available distribution of cases in India (as of April 30, 2020) defined over the narrow 10-year age brackets, we interpolate the density of deaths for 10-year brackets using the death distribution over 15-year age brackets made available by the Indian Government, as described below. Mohanty et al. (2020) report the distribution of cases and deaths as of 9 May, 2020 using *five*-year age brackets. Normally, this would suffice for our purposes. However, this distribution is based on a total of just 7191 cases and 511 deaths recorded in a crowd-sourced patient level database (Dashboard COVID19INDIA 2020). Wary of the possibility of it being from a non-random sample, we do not use it directly. However, we sparingly use the *relative* death rates across neighboring age groups in their data as a way of disaggregating the Ministry-issued data.

On July 08, 2020, the Indian Ministry of Health and Family Welfare provided a press release describing the distribution of Covid-19 deaths over six 15-yr age brackets: 0–14: 1%, 15–29: 3%, 30–44: 11%, 45–59: 32%, 60–74: 39% and 75+: 14%. Denoting I^n as the

set of n-year age groups, let the Ministry-provided distribution of deaths be $D_1{:}I^{15} \to [0, 100]$, and the distribution from Mohanty et al. (2020) be $D_2{:}I^5 \to [0, 100]$. We use D_2 to generate 10- and 15-year age distributions by simple aggregation:

$$D_2^m(i) = \sum_{k \in I^5 \mid k \subset i} D_2(k)$$

for $m \in \{10, 15\}$. We then apportion the relative weights from these distribution to the Ministry figures. Formally, define a matrix W of dimension $|I^{10}| \times |I^{15}|$ with a typical element w_{ij} given by

$$w_{ij} = \begin{cases} \dfrac{D_2^{10}(i)}{D_2^{15}(j)} & \text{if } i \subset j \\ 0 & \text{if } i \not\subset j \end{cases}$$

The interpolated density for 10-year age groups for the distribution of deaths based on D_1 is then given by $\tilde{D}_1^{10} = WD_1$. The distribution of deaths thus obtained is recorded in Table 3. We also interpolate the distribution of cases and deaths for Turkey and California, available over coarser age groups, into 10-yr brackets. Due to unavailability of any distribution over finer brackets, we interpolate uniformly. Here, a typical element w_{ij} of the weighting matrix W is the ratio of the measures of intervals i and j if $i \subset j$, and 0 otherwise.

A.3. Stability of Distribution of Cases and Deaths

Figures A1–A4 plot the age distributions of cases and deaths for select countries as obtained at different points in time. These countries are distinguished by the fact that we were able to obtain distributions of cases and deaths over 10-year age groups for several dates spanning a few months. Panel (a) graphs the age distributions of cases and Panel (b) graphs the age distributions of deaths. The graph depicted in boldface in each figure represents the latest distribution used for our analysis and listed under Table A1, while the distributions as of previous dates are depicted in grey.

As is apparent from the uncannily coinciding curves, barring initial phases of the pandemic, the distribution of cases and deaths have been largely stable over time. (This assumes, of course, that the relevant dashboards have been fully updated and no other procedure is being followed.)

We recognise that these countries are neither representative of the developing countries in our comparison pool nor of countries with a younger demographic structure, such as Argentina, Colombia, India and South Africa. However, they do reflect a heterogeneous

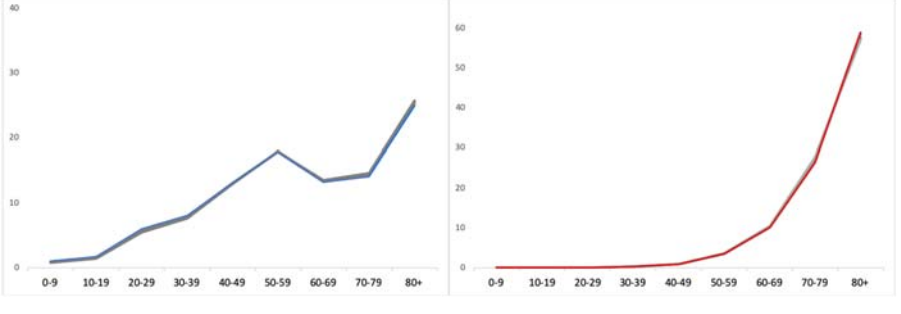

Figure A1. Italy. Panels (a) and (b) plot the age distribution of cases and deaths, respectively, for the dates 21 July, 30 June, 09 June, 20 May and 14 May 2020.

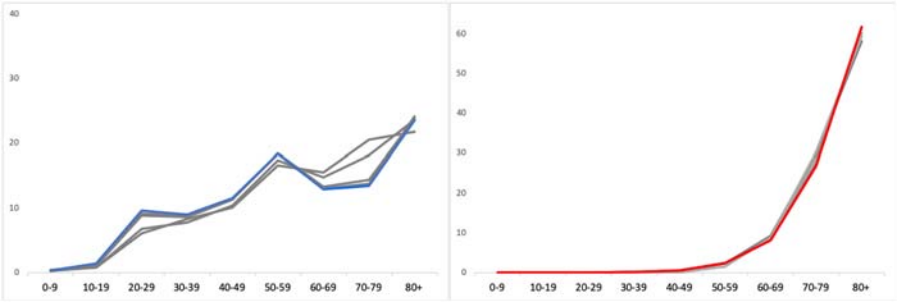

Figure A2. Netherlands. Panels (a) and (b) plot the age distribution of cases and deaths, respectively, for the dates 03 June, 20 May, 01 May, 10 April and 30 March 2020.labelnether

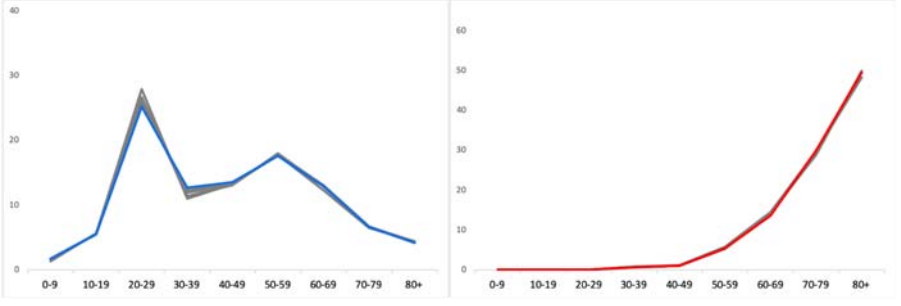

Figure A3. South Korea. Panels (a) and (b) plot the age distribution of cases and deaths, respectively, for the dates 02 August, 20 July, 10 July, 20 June and 20 May 2020.

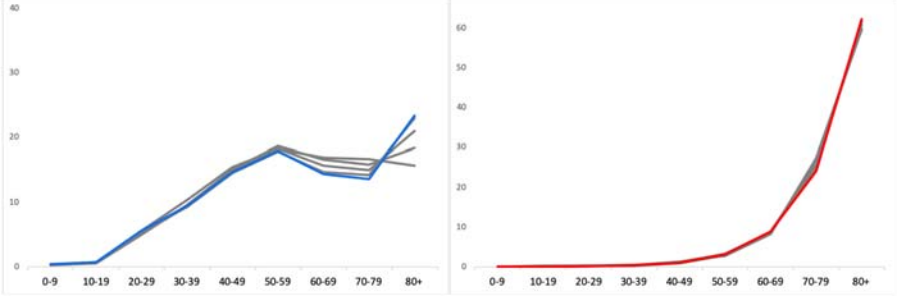

Figure A4. Spain. Panels (a) and (b) plot the age distribution of cases and deaths, respectively, for the dates 18 May, 30 April, 20 April, 10 April and 30 March 2020.

variety of Covid-19 experiences. Additionally, the dates over which we have plotted the distributions span a considerably large period of the epidemiological phase thus far. While at one level, this stability is not surprising, that could change with qualitatively different testing regimes, differences in response to mitigation strategies, exposure to risk stemming from a change in lockdown policy, and so on.

A.4. Decomposition with 14-Day Lagged CFR

Table A2 repeats the decomposition exercise of Section 3 using 14-day lagged CFRs.

Table A2. 14 day LCFR - Difference Decomposition For India and Comparison Countries.

	June 20				July 30				Sept 10			
Country	LCFR	Diff	IE	FE	LCFR	Diff	IE	FE	LCFR	Diff	IE	FE
India	**5.47**	0.00	–	–	**3.61**	0.00	–	–	**2.27**	0.00	–	–
China	5.51	0.04	3.33	−3.30	5.47	1.86	2.64	−0.78	5.27	3.00	2.10	0.90
S. Korea	2.39	−3.08	1.71	−4.80	2.20	−1.41	1.30	−2.70	1.85	−0.42	0.94	−1.35
Japan	5.57	0.10	2.61	−2.51	4.38	0.77	1.92	−1.15	2.17	−0.10	1.04	−1.14
Philippines	5.48	0.01	−0.13	0.14	3.33	−0.28	−0.08	−0.20	1.97	−0.30	−0.05	−0.25
Netherlands	12.90	7.43	10.02	−2.60	11.98	8.37	8.00	0.37	9.17	6.90	5.68	1.22
Italy	14.74	9.27	10.95	−1.68	14.43	10.82	9.06	1.76	13.55	11.28	7.44	3.84
Spain	11.74	6.27	9.63	−3.37	10.99	7.38	7.63	−0.26	6.91	4.64	4.80	−0.15
Bavaria	5.42	−0.05	3.58	−3.63	5.29	1.68	2.91	−1.23	4.71	2.44	2.27	0.17
Sweden	12.14	6.67	6.80	−0.12	7.83	4.22	4.42	−0.20	6.98	4.71	3.53	1.19
Switzerland	5.44	−0.03	4.56	−4.59	5.15	1.54	3.59	−2.05	4.28	2.01	2.65	−0.64
S. Africa	4.22	−1.25	−0.66	−0.60	2.41	−1.20	−0.40	−0.80	2.46	0.19	−0.34	0.53
Chile	3.34	−2.13	0.73	−2.86	2.89	−0.72	0.56	−1.28	2.91	0.64	0.48	0.16
Colombia	5.58	0.11	0.38	−0.27	5.72	2.11	0.36	1.75	3.85	1.58	0.23	1.35
Argentina	4.66	−0.81	0.57	−1.38	2.99	−0.62	0.37	−0.98	2.91	0.64	0.33	0.31
Turkey	2.91	−2.56	0.64	−3.20	2.62	−0.99	0.49	−1.48	2.60	0.33	0.41	−0.07
Portugal	4.50	−0.97	3.56	−4.53	3.64	0.03	2.58	−2.55	3.29	1.02	1.97	−0.95
California	4.24	−1.23	0.73	−1.97	2.47	−1.14	0.44	−1.58	2.03	−0.24	0.34	−0.57

Sources. Distribution of cases and deaths from Tables 3 and A1. These, along with total case and death counts from Roser et al. (2020) are combined and applied to the decomposition formula (1) to obtain Incidence Effects (IE) and Fatality Effects (FE).

The 14-day LCFRs reported in the first column are lower than the 21-day LCFRs reported in Table 6, for obvious reasons. For countries such as India, Colombia and Argentina with higher growth rate of cases, the difference between the 14-day and 21-day LCFR is sizable in contrast to countries such as South Korea and Japan which have low case growth.

Despite this relative edge in depressed fatality ratios, India still fares poorly relative to several countries in the matter of age-specific mortality, lending support to the inferences made previously on the basis of Table 6.

A.5. Data Sources

Table A3 lists the papers, situation reports and various national dashboards from which we have obtained the data on distributions of cases and deaths recorded in Table A1.

Table A3. List of Data Sources for Distribution of Cases and Deaths reported under Table A1.

Country	Data	Sources
India	Distribution of Cases	ICMR COVID Study Group et al. (2020)
	Distribution of Deaths	Ministry Press Release - Times of India (Dey 2020)
China	Distribution of Cases & Deaths	Novel Coronavirus Pneumonia Emergency Response Epidemiology Team (2020)
South Korea	Distribution of Cases & Deaths	Korean Center for Disease Control and Prevention (2020)
Japan	Distribution of Cases & Deaths	Toyo Keizai Online https://toyokeizai.net/sp/visual/tko/covid19/en
Philippines	Distribution of Cases & Deaths	https://www.doh.gov.ph/covid19tracker
Netherlands	Distribution of Cases & Deaths	National Institute for Public Health and the Environment (2020)
Italy	Distribution of Cases & Deaths	Istituto Superiore di Sanità (2020)
Spain	Distribution of Cases & Deaths	Ministerio de Sanidad, Consumo y Bienestar Social (2020)
Bavaria	Distribution of Cases & Deaths	Bavarian Health and Food Safety Authority (2020)
Bavaria	Counts of Cases & Deaths	Robert Koch Institute (2020)
Sweden	Distribution of Cases & Deaths	https://experience.arcgis.com/experience/09f821667ce64bf7be6f9f87457ed9aa
Switzerland	Distribution of Cases & Deaths	https://datawrapper.dwcdn.net/IJC8v/144/
South Africa	Distribution of Cases & Deaths	Department of Health, Republic of South Africa (2020)
Chile	Distribution of Cases & Deaths	https://www.gob.cl/coronavirus/cifrasoficiales/
Colombia	Distribution of Cases & Deaths	https://www.ins.gov.co/Noticias/Paginas/Coronavirus.aspx
Argentina	Distribution of Cases & Deaths	https://www.argentina.gob.ar/salud/coronavirus-COVID-19/sala-situacion
Turkey	Distribution of Cases & Deaths	Ministry of Health, Republic of Turkey (2020)
Portugal	Distribution of Cases & Deaths	Ministry of Health, Portugese Republic (2020)
California	Distribution of Cases & Deaths	California Department of Public Health (2020)
California	Counts of Cases & Deaths	https://www.worldometers.info/coronavirus/usa/california/