The Interstate Variation in Mortality from COVID-19 in India

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While the response to COVID-19 by the Government of India has been more or less uniform across the country, in that a lockdown was imposed throughout, the death rate has varied across the states. This suggests that region-specific factors are likely to be relevant to the determination of this rate. A significant aspect of this study is the use of three different measures of the death rate in the empirical exercise. This showed all three measures of the death rate to be strongly related to health expenditure as a share of the gross domestic product but hardly at all to public health infrastructure. This can be interpreted as a sign of the role of the public health system—comprising medical personnel, infrastructure and protocols—in the prevention of death, with health expenditure as a key determinant of its effectiveness. It has an implication for public policy beyond the immediate health emergency due to COVID-19.

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The death rate from COVID-19 in India is relatively low in a global comparison.[1] However, it is not widely known that there is a variation in this rate across the states of the country. In fact, it varies considerably. On 3 October 2020, the range recorded for the case fatality rate was 3.8% while the median was 1.3%.[2] This may be considered surprising, given that, at least in its initial phase, the lockdown has been quite uniform across the country, having been imposed by the central government. This had lasted from the last week of March to the last week of May amounting to a duration of about nine weeks. Since then, there have been total or partial—in the form of containment zones—lockdowns in the different states, but these do not amount to the same as the countrywide lockdown either in geographic coverage or duration. An interstate variation in the death rate does not necessarily imply that the initial lockdown had no effect but it does suggest that some state-specific factors could be responsible for it. In this paper, we explore likely such factors.

Writing on the topic of COVID-19 in India has appeared more in the media than in professional fora. This is understandable as there was need for immediate dissemination of data and some quick analysis based on it. However, there is relatively little by way of economic analysis of the death rate. A rare study in this vein is that of Chatterjee and Jain (2020) who aimed to establish the "state-level pattern of casualty" and explore "plausible reasons" for it. They argue for the adoption of an appropriate measure of the fatality rate and go on to compute it for the states of India, showing that a variation exists. They then plot this measure of fatality against the age profile of the population, the extent of testing, an indirect indicator of the public heath infrastructure and the practice of social distancing, respectively, and conclude that these are relevant to an explanation of the variation. While this being a valuable study, it had come at a very early stage of the pandemic, in April 2020, and the empirical strategy can be improved upon. We believe that our study constitutes an advance on both counts, while also providing a more granular picture.

Methodology

We follow a lead proposed by medical practitioners who view the impact of the pandemic as the outcome of the interaction between three elements, namely the agent or the virus, the host or the individual and the environment. This view has influenced our approach to the study of interstate variation in the death rate from COVID-19 as follows. We assume that the strain of the virus and that the attributes of the population, at least as far as susceptibility to death post-infection is concerned, are the same across the country. Where we believe that interstate differences do exist is in the environment defined by access to effective healthcare. In the context of a pandemic, effective healthcare is largely defined by the existence of a public health system. Given that health is a state subject according to the constitutional division of powers and responsibilities of the centre and the states in India, public policy towards health may be expected to vary. Our empirical investigation exploits this feature.

Measuring Mortality from COVID-19

The first task for a researcher studying death from any disease would be to decide on the measure of fatality to be adopted. In the case of a communicable disease spread by a virus, as COVID-19 is, the task is made particularly difficult. Two options are the infection fatality rate and the crude death rate. The first is the ratio of deaths to the number of infected persons. Assuming that deaths are properly counted, the issue becomes one of the denominators to be used. As testing the entire population is next to impossible for countries as large as India, a sero survey may be conducted to first establish the proportion of the population infected, and this information is used to get an estimate of the total number of infected persons. In the absence of sero surveys, the number of cases of infection detected through testing is usually taken as the denominator. This gives the case fatality rate (CFR). It is easy to see that, even when deaths are reported accurately, the CFR will reflect the progress made on testing the population for the existence of the virus. In a cross-section study such as the one we are undertaking here, if the actual cases of infection are the same but the rate of testing varies across units, this measure would show a higher death rate for those states in India that test less. We have some evidence that the extent of testing of the population varies between states, and over time within a state, leaving the CFR a less than ideal measure. Nevertheless, it is widely used globally and this leads us to retain it as a measure of the death rate in our investigation. We do, however, make an adjustment. Most often, the CFR is calculated as the number of deaths as a percentage of the number of confirmed cases of infection, both measured on the same date. This, however, is inappropriate as the incubation period of the virus is believed to be approximately two weeks. Now, the appropriate denominator is the number of confirmed cases of infection 15 days prior to the date for which deaths are counted. The CFR computed for this study reflects this requirement (Table A1, Appendix I, p 42).

This leaves the crude death rate, which we denote as DR(C), as an alternative measure of fatality. This measure is simply the ratio of deaths to the population. It would appear that this is a more straightforward measure than the CFR, cutting straight to the population, thus avoiding the need to count the cases of infection. However, while we have so far implicitly assumed in our discussion of the calculation of the CFR that deaths are properly counted, it need not be the case. It is well known that in India, not all deaths are registered with the civil authorities, and even when they are registered, the cause of death is not always medically certified. When this is so, the crude death rate will no longer suffice. Medical practitioners (Shewade and Parameswaran 2020) have proposed an adjustment to account for the under-reporting of death and incomplete medical certification of cause of death (MCCD). This is to scale up the number of reported COVID-19 deaths by the inverse of the product

$$\frac{\text{Registered Deaths}}{\text{Total Deaths}} \times \frac{\text{MCCD}}{\text{Registered Deaths}}.$$

While we see that this is an imaginative innovation in the context, we believe that the resulting figure, which we term the estimated death rate (DR[E]), should be treated with some caution. The main issue is that the adjustment assumes the same ratios (in the above product) for COVID-19 as for all other causes of death in India. This is questionable. Surveillance by both the government machinery and society during a pandemic very likely ensures that deaths from COVID-19 cannot evade medical certification or registration to the same extent as other cases of death.

There is also the suggestion that governments tend to manage numbers, encouraging the wrongful attribution of COVID-19 deaths to co-morbidities. However, it is not clear to us how this can be addressed with the data available in the public domain. On the whole question of under-reporting of deaths, it needs also to be noted that community health specialists have argued, in our view persuasively, that the view that deaths are systematically under-reported in India may be based more on predilection than facts.[3]

We have computed DR(E) for all states and present it beside the crude death rate for comparison in Table A2 of Appendix I (p 42). Note that the difference is considerable. For instance, the estimated death rate exceeds the crude death rate by a factor of nine in Kerala. This appears implausibly high to us, given that the surveillance of COVID-19 infection may be expected to be high there, considering the political awareness of the population. We also note the caution expressed by epidemiologists against the uncritical use of the estimated death rate as long as we do not find a surge in the disposal of bodies in the usual sites, namely cremation and burial grounds (Babu 2020). For this reason, in our empirical exercise, we worked with both the crude and the estimated death rates.

The coverage of this study is all of India except the union territories, which have been excluded because some of the necessary data was not available. All data used in this study were the most recent at the time of writing.

Fatality, Income and Public Health Policy

One of the first observations that may be made in a comparison of the states of India is that they display a substantial variation in per capita income. In fact, the dispersion in per capita income is almost as high as the case fatality rate.[4] This led us to commence our empirical investigation of the variation in fatality due to COVID-19 across India by studying its relationship to income. We next sought a role for public policy towards health measured by various indicators.

For the income of a state within India, we use its per capita state net domestic product in current rupees. When it comes to public policy on health, we treat it as having two components,

Figure 1: Case Fatality Rate and Per Capita Income

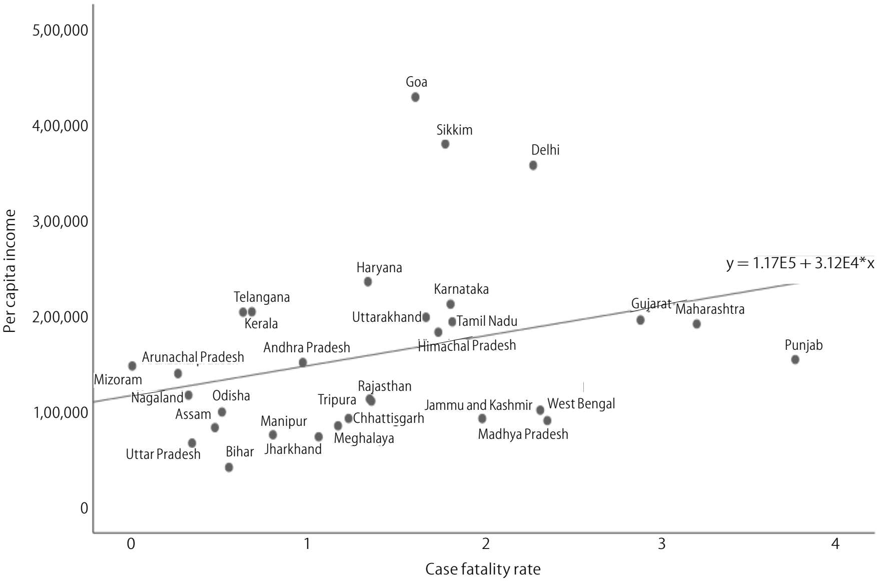
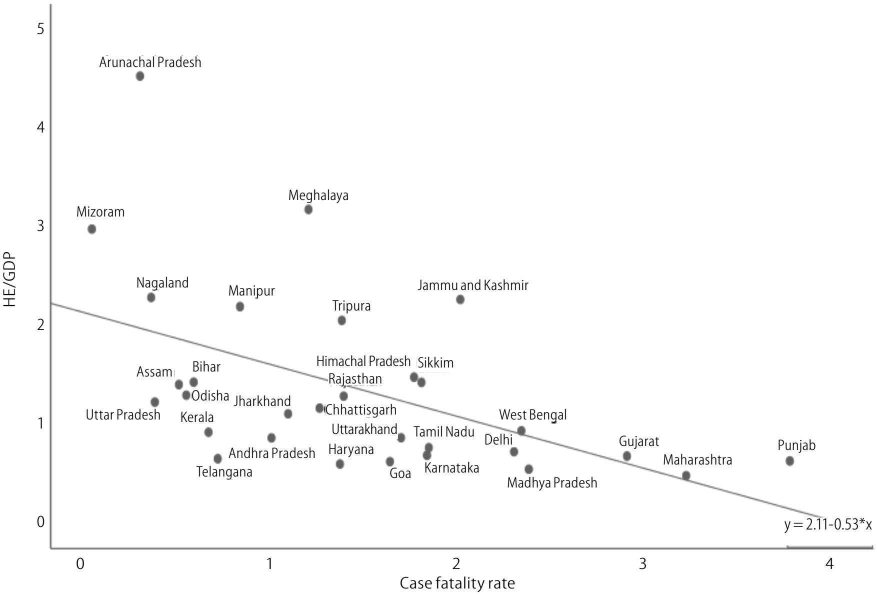


Figure 2: Case Fatality Rate and Public Health Expenditure as a Share of GDP



namely public spending on health and the health infrastructure in the public sector. Three indicators of the former are chosen in each category, namely public expenditure on health (HE) as a percentage of the state gross domestic product (GDP), per capita public expenditure on health and expenditure on health as a share of total public expenditure. As measures of the health infrastructure, we consider the population served by one bed, one hospital and one allopathic doctor, respectively, in the public sector.

Results: We started by checking for the relation between the CFR and income represented by per capita income. In the resulting scatter plot (Figure 1), the relationship is positive, with the richer states associated with a higher CFR. Clearly then, in India, wealth is not a shield against COVID-19. Factors beyond income appear to matter for death from the disease, and it is to an investigation of this that we now turn.

The association between CFR and the first of the indicators of public expenditure on health mentioned above, namely public expenditure on health as a percentage of GDP, is presented in Figure 2. It shows a negative relationship. Unlike the relationship that obtains in Figure 1, this is intuitive in itself. Further, assuming that the distribution across the states of public expenditure on health in the year of our study represents a historical pattern, it is what we would expect. That is, states that have built up a public health capacity would be in a better position to avoid deaths from COVID-19.

We next investigated the rank correlation between the ranking of states according to fatality (CFR) and their ranking according to expenditure on health and health infrastructure. The Spearman's rho from this exercise is reported in Table 1. As there was no rank correlation detected between either expenditure on health as a share of total public expenditure or the population served by one hospital bed and any of the three measures of the death rate, the results obtained in this case are not reported henceforth.

The ranking of states on CFR is strongly correlated with their ranking on public expenditure on health as share of a state's gross domestic product (HE/GDP). But there is no rank correlation between CFR and per capita public expenditure on health or any of the indicators of public expenditure on health infrastructure in the public sector. We find it surprising that the size of the population served by one government doctor does not matter. However, the absence of a rank correlation between CFR and the availability of hospital beds need not be once we reflect upon a comment by a leading Indian medical practitioner that "Beds do not treat patients, health personnel do."[5] The containment of the pandemic and prevention of

Table 1: Rank Correlation—Case Fatality Rate, Income and Public Health Indicators

	Spearman's rho					
	CFR	HE/GDP	Per Capita Public Health Expenditure	Per Capita Income	Population Served by by One Government Allopathic Doctor	Population Served by One Government Hospital
CFR	1.000	-.582**	-.049	.358	.067	.260
Significance (2-tailed)	.	.001	.796	.052	.723	.165
N = 30						

** Significant at the 0.01 level.

death involves more than just treating patients at a late stage in hospitals. It is likely to be related as much to early identification through testing, contact tracing and quarantining. This requires a public health machinery, personnel beyond doctors and laboratories for testing. In the context, therefore, public expenditure on health may be a more relevant variable when it comes to avoiding death than the availability of medical infrastructure per se. Furthermore, if the variation in current public health expenditure figures represent a historical pattern, states with a higher ranking on this criterion are likely to have a more healthy population in general with a greater degree of resistance to the disease. Thus, while it is conceivable that in a country of India's size and diversity, the population of some states may be less prone to death from COVID-19, this could be due to immunity built by a public health system that includes primary healthcare, and not related to any genetic character of the population of those states.

We followed up the exercise reported so far with regression analysis. At the outset, we had to address a challenge posed by data availability. While the fatality data is for 2020, the data on the indicators of health policy referred to earlier were available only as of 2018–19. Even though the lag is not too long, relating the current death rate to lagged levels of health policy indicators may be considered less than ideal. The data constraint cannot be overcome; however, it can be an advantage from the econometric point of view. A lag removes the possibility of simultaneity, and implies that ordinary least squares estimation is sufficient. In the regression analysis, initially, each of the three measures of the death rate was regressed separately on each of the three indicators of public expenditure on health and each of the three indicators of the public health infrastructure. Only in a single case was a measure of expenditure other than expenditure as a share of GDP statistically significant and only once was any of the three indicators of health infrastructure statistically significant. On the other hand, the former variable was statistically significant in every regression. This led us to confine the subsequent statistical analysis to this indicator of public policy on health. The results referred to but not presented herein will be made available by the authors upon request.

The regression specification included three controls, namely population density, proportion of the population over 60 years of age and per capita income. Both population density (Coşkun et al forthcoming) and the age profile of the population (Mallapaty 2020; Bonanad et al 2020) have been flagged as factors responsible for the spread of COVID-19 and mortality due to it. Though we give them the same importance in our exercise, we would believe that it is the age profile that matters for death, population density is being a factor in the spread of the virus as social distancing becomes difficult in crowded areas. That is, while the elderly have been medically identified as more susceptible to death once they have contacted the disease, infection, though exacerbated by crowding, need not necessarily result in death.

The regression results (Table 2) show the CFR to be significantly inversely related to public health expenditure, even controlling for the age profile of the population and its density. It may be noted that neither control is significant, and that the coefficient on HE/GDP is relatively high.

We repeated the statistical exercises thus far for the other two measures of the death rate. There is very strong rank correlation (Table 3) between DR(C) and health expenditure as share of GDP, a positive correlation with income and, unlike in the case of CFR, the presence of doctors. In the regression (Table 4), it was found that while health expenditure is statistically significant when entered on its own, it is no longer so when controls are added.

Finally, when DR(E) was chosen as the measure of the death rate the results show an across-the-board improvement. Now, in the rank correlation exercise (Table 5, p 40), the death rate is related to both the measures of health spending and both the indicators of public health infrastructure. In the regression analysis (Table 6, p 40), health expenditure is statistically significant with and without controls.

Table 2: Regression Analysis—Case Fatality Rate, Income and Public Health Policy

	Model	Coefficients B	Coefficients Std Error	T	Sig
1	Constant	2.101	.262	8.024	.000
	HE/GDP	-.506	.159	-3.184	.004**
	OLS, N = 30, adjusted R-squared = .240				
2	Constant	2.213	1.257	1.760	.091
	HE/GDP	-.512	.241	-2.119	.044*
	Population density	9.487E-6	.000	.106	.916
	Population over 60 (%)	-.043	.124	-.351	.728
	Per capita income	1.504E-6	.000	.784	.440
	OLS, N = 30, adjusted R-squared = .176				

Dependent variable is CFR; * P < 0.05, ** P < 0.01.

Table 3: Rank Correlation—Crude Death Rate (DR[C]) and Public Health Indicators

	Spearman's rho DR(C)	HE/GDP	Per Capita Public Health Expenditure	Per Capita Income	Population Served by One Government Allopathic Doctor	Population Served by One Government Hospital
DR (C)	1.000	-.734**	-.282	.397*	.259	.479**
Significance (2-tailed)	.	.000	.131	.030	.167	.007
N = 30						

* Significant at the 0.05 level, ** Significant at the 0.01 level.

Table 4: Regression Analysis—Crude Death Rate (DR[C]), Income and Public Health Policy

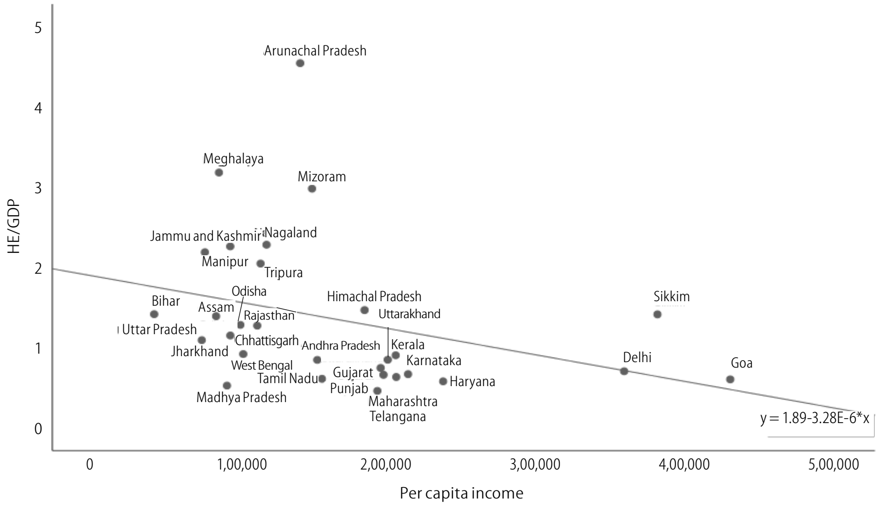
	Model	Coefficients B	Coefficients Std Error	T	Sig
1	Constant	61.808	14.014	4.410	.000
	HE/GDP	-20.683	8.504	-2.432	.022*
	OLS, N = 30, adjusted R-squared = .145				
2	Constant	8.467	53.446	.158	.875
	HE/GDP	-10.177	10.265	-.991	.331
	Population density	.012	.004	3.119	.005**
	Population over 60 (%)	2.081	5.251	.396	.695
	Per capita income	8.372E-5	.000	1.026	.315
	OLS, N = 30, adjusted R-squared = .417				

Dependent variable is DR(C); * P < 0.05, ** P < 0.01.

We conclude with the following observations on our findings. First, it may be noted that income is statistically significant in only one out of the total of six instances of correlation and regression exercises undertaken, and in this case, its association with the death rate is positive (Table 3). Clearly, income has not played a direct role in the prevention of death from COVID-19 in India. On this front, it is public expenditure on health that has made the difference. Our results are broadly in consonance with the views of other researchers in the field. Kandel et al (2020) have developed an operational response index, which measures the capacity to provide health security to a society. In this index, they include the capacities to detect a health risk early, respond to it medically and to finance the associated operations (which they term the "enabling function"). Then, the chief scientist of the World Health Organization has observed that

> Of the lessons I have learned over the last nine or ten months, the most important one is the significance of investing in public health and primary healthcare. Countries that invested in primary healthcare over the past decade or two are reaping the benefits now. (Swaminathan 2020)

Figure 3: Per Capita Income and Public Health Expenditure as a Share of GDP



Income and the Death Rate, Once Again

As we found that fatality is positively related to per capita income when the regression is run without controls (Figure 1), we chose to investigate this result further. We discovered that the relationship between per capita income and public expenditure on health is actually negative, that is, public expenditure as a percentage of state GDP is inversely related to per capita income. This may be seen in Figure 3. Thus, the positive relationship between fatality and per capita income may be judged a statistical artefact, being the reflection of the negative relationship between per capita income and public health expenditure across units. The related finding that the richer states of India spend relatively less on health is a reality not generally known.

Table 5: Rank Correlation—Estimated Death Rate (DR[E]) and Public Health Indicators

Model	Spearman's rho DR(E)	HE/GDP	Per Capita Public Health Expenditure	Per Capita Income	Population Served by One Government Allopathic Doctor	Population Served by One Government Hospital
DR(E)	1.000	-.566**	-.414*	.186	.508**	.445*
Significance (2-tailed)	.	.001	.023	.326	.004	.014
N = 30						

* Significant at 0.05 level, ** Significant at the 0.01 level.

Table 6: Regression Analysis—Estimated Death Rate (DR[E]), Income and Public Health Policy

	Model	Coefficients B	Coefficients Std Error	T	Sig
1	Constant	506.337	78.444	6.455	.000
	HE/GDP	-129.421	47.600	-2.719	.011*
	OLS, N = 30, adjusted R-squared = .181				
2	Constant	722.659	377.585	1.914	.067
	HE/GDP	-161.023	72.520	-2.220	.036*
	Population density	.000	.027	-.018	.986
	Population over 60 (%)	-13.677	37.099	-.369	.715
	Per capita income	.000	.001	-.664	.512
	OLS, N = 30, adjusted R-squared = .110				

Dependent variable is DR(E); * P < 0.05, ** P < 0.01.

A Detour

North-eastern India: The results obtained in this study cast light on a pattern that has been flagged in the public discussion in India. It has been pointed out that the north-eastern states of India have turned in very low fatality rates, and there has been some speculation as to what accounts for this. Among the suggestions that have been made are that their population enjoys a special immunity and that the region has been less exposed to contagion than the rest of India. The latter is not relevant in the context of the CFR as it measures fatality among the infected. Moreover, it may be noted that the infection rate is not particularly low in the North East. Of the six states considered here, in mid-September 2020, four had an infection rate, that is, confirmed cases to population, very close to or above the national median (calculated from data in Table A1). Our study cannot address the first of the above claims as it would require medical expertise. However, it can be seen that no additional explanation for the death rates in India's north-eastern states beyond that has been provided in this study is actually needed. The six north-eastern states in our sample are among the top seven states of India when it comes to expenditure on health as share of the state GDP (Figure 2).

South Asia: As a concluding exercise, we chose to test our principal finding that the varying death rate from COVID-19 across India is inversely related to public expenditure on health in a wider field, namely South Asia. The death rate chosen was CFR on 3 October 2020. An unmistakable pattern emerged when the relevant data were assembled. Mere viewing of the data was sufficient to recognise a strong inverse relationship between the ranking of the countries according to the death rate and their ranking according to public health expenditure as a percentage of the GDP. This was confirmed by a rank correlation coefficient (Spearman's rho) of -.83. A second feature of South Asia is that health expenditure and per capita income are positively related, with a Spearman's rho of .75. It suggests that the case of health expenditure varying inversely with income may be peculiar to India, the country's comparatively greater size also allowing for greater variation within it. The findings from this detour to South Asia as a whole gives credence to our explanation of the varying death rate within India.

Table 7: Fatality from COVID-19 in South Asia

Country	CFR	GDP per Capita (current $)	Public Health Expenditure as % of GDP
Afghanistan	3.75	556.30	0.60
Pakistan	2.13	1464.99	0.92
India	1.90	1981.65	0.96
Bangladesh	1.53	1563.91	0.38
Nepal	0.84	911.44	1.24
Sri Lanka	0.40	4077.04	1.64
Maldives	0.36	9540.63	6.45
Bhutan	0.00	3286.57	2.37

Case fatality rate = Total deaths(t)/Total cases(t-15); t = 3 October 2020.
Source: COVID-19 data is from www.ourworldindata.org, GDP per capita and General Government Expenditure on Health is from the World Bank. See data sources in Appendix II (p 43) for details.

A Missing Factor

We have been unable to incorporate two actions that could have a role in averting fatality. These are the response of the public health system and the behaviour of the civilian population in the presence of the virus. Take the former first. Coordination between the branches of the public health machinery is required for testing, contact tracing and quarantining of the infected, and managing the hospitalisation of the severe cases. Where this coordination is absent or even limited, the presence of infrastructure is neutralised. Timely transportation is one such aspect that can determine whether a patient survives or not. For instance, ventilators are not available in all hospitals of India even as they are crucial at the final stages of COVID-19 which strikes at the respiratory system. Reaching patients in an advanced stage of the disease to the relevant hospital is a challenge, requiring coordination. The efficacy of the response of a state's public health system is tested during a pandemic. We know that not all states of Indian show the same capacity to govern the system, which can contribute to the death rate varying across them. The second response that could be important in determining the death rate is the response of the civilian population to the pandemic. The spread of the virus is also related to the behaviour adopted by the population. Where social distancing, hand hygiene and mask-wearing is strictly adhered to, the extent of the spread is reduced. This requires a disciplined population. In a democracy where top-down measures cannot be sustained for long, whether a population adheres to the requisite discipline may be expected to depend upon the degree of trust in the state and a general public spiritedness that induces socially responsible behaviour. We believe that these elements vary across India's states, with an implication for the spread of the virus and the resulting deaths.

As of now, there is no data that can be used to objectively quantify, or can even rank, the response of the public health system or social behaviour of the civilian population to the pandemic in the states of India. Under the circumstances, an approach would be to undertake case studies of individual states.

Conclusions and Policy Implications

We set out to provide an answer to the considerable dispersion in fatality due to COVID-19 among India's states. Finding that this cannot be explained by income differentials, we investigated whether the dispersion can be explained by public policy towards health. For identification, aspects of the latter were placed in two bins, namely expenditure and infrastructure. Three indicators were chosen under each category. In statistical exercises that included computing the rank correlation and regression analysis, we found that each of the three measures of fatality that we use show a relationship with at least one indicator of expenditure or infrastructure, respectively. However, avoidance of fatality was found to be more closely related to public health expenditure than to infrastructure. This leads us to conclude that healthcare is more than just hospitals, implying that the public health system needs to be taken as a whole when evaluating its effectiveness in disease control. For instance, primary healthcare may be important in the prevention of deaths from COVID-19 as it contributes to the building of the immune system of the population. How exactly healthcare is related to public expenditure on health and whether primary healthcare actually matters require further study. However, it would be reasonable to assume that a sufficiently high public health expenditure in relation to GDP is necessary for an effective public health system.

A secondary finding of our study is that wealth measured by per capita income has not served to prevent deaths from COVID-19 in India. We are able to account for this statistical relationship by showing that the statewise expenditure on health as a share of the GDP is inversely related to per capita income. Now the uncomfortable conclusion must be that some of India's richer states have chosen not to spend on public health commensurate with their economic capacity.

The policy implications of our study are immediate. As health is a state subject in India, the states would have to do much more than they have done in the past. This study implies that some of them have the capacity to do so as the richer states spend relatively less of their GDP on health. As they have experienced a higher death rate, they would now have to revise their public expenditure pattern. For some time into the future, expenditure on health should take precedence over almost all other items in the budget of the state governments, that is, health expenditure needs to be prioritised. We further submit that these findings have an international relevance, especially for developing countries. It is understandable that poor countries try to get rich, and quickly. However, if they do so at the cost of neglecting the health of their populations, they will remain vulnerable to death from disease.

Finally, we are aware that as the virus progresses, some of the results presented here may alter. At the same time, this analysis of the mortality data took place six months into the pandemic in India. This should have been long enough for a pattern to have emerged, allowing for conclusions to be drawn on the role of the public health system. Moreover, when, at the end of the pandemic, a study of the factors preventing mortality from COVID-19 is undertaken, this one could serve as a template.

NOTES

1 See https://www.worldometers.info/coronavirus/#countries, viewed on 13 October 2020.
2 See Table A1 of Appendix I for the data used.
3 See Kurian (2020) for the view that deaths may be under-reported and that this cannot be assumed, respectively.
4 The coefficient of variation is .65 and .59 for the case fatality rate per capita income, respectively. See Table A1 and Table A3 (p 43) in Appendix I for the data used.
5 Devi Prasad Shetty, interview on New Delhi Television (NDTV), 2 October 2020.

REFERENCES

Babu, G (2020): "The Challenges in Counting the Dead," *Hindu*, 14 August, https://www.thehindu.com/opinion/lead/the-challenges-in-counting-the-dead/article32347217.ece.

Bonanad, C, S García-Blas, F Tarazona-Santabalbina, J Sanchis, V Bertomeu-González, L Fácila, A Ariza, J Núñez and A Cordero (2020): "The Effect of Age on Mortality in Patients with COVID-19: A Meta-Analysis with 611,583 Subjects," *Journal of the American Medical Directors Association*, Vol 21, No 7, pp 915–18, https://doi.org/10.1016/j.jamda.2020.05.045.

Chatterjee, T and R Jain (2020): "Is Covid-19 Equally Deadly Across all States? A Preliminary Examination," *Ideas for India*, 28 April, https://www.ideasforindia.in/topics/macroeconomics/is-covid-19-equally-deadly-across-all-states-a-preliminary-examination.html.

Kurian, O C (2020): "Counting Deaths and Feeling Bad: COVID-19 as Spectator Sport," *Observer Research Foundation*, 20 July, https://www.orfonline.org/expert-speak/counting-deaths-and-feeling-bad/.

Coşkun, H, N Yıldırım and S Gündüz (forthcoming, 2021): "The Spread of COVID-19 Virus through Population Density and Wind in Turkey Cities," *Science of the Total Environment*, Vol 751, 141663, https://doi.org/10.1016/j.scitotenv.2020.141663.

Shewade, D and G Parameswaran (2020): "COVID-19 Deaths May be Higher than Reported," *Hindu*, 10 August, https://www.thehindu.com/opinion/op-ed/covid-19-deaths-are-not-as-low-as-reported/article32310814.ece.

Ghosh, P, R Ghosh and B Chakraborty (2020): "COVID-19 in India: Statewise Analysis and Prediction," *JMIR Public Health and Surveillance*, Vol 6, No 3, p e20341, https://doi.org/10.2196/20341.

Kandel, N, S Chungong, A Omaar and J Xing (2020): "Health Security Capacities in the Context of COVID-19 Outbreak: An Analysis of International Health Regulations Annual Report Data from 182 Countries," *Lancet*, Vol 395, No 10229, pp 1047–53, https://doi.org/10.1016/s0140-6736(20)30553-5.

Mallapaty, S (2020): "The Coronavirus Is Most Deadly If You Are Older and Male—New Data Reveal the Risks," *Nature*, Vol 585, No 7823, pp 16–17, https://doi.org/10.1038/d41586-020-02483-2.

Swaminathan, S (2020): "The Many Lessons from COVID-19," *Hindu*, 27 October, https://www.thehindu.com/opinion/op-ed/the-many-lessons-from-covid-19/article32947329.ece.

Appendix I: Data

Table A1: The Case Fatality Rate on 3 October

States	Total Confirmed (as on 19 September 2020)	Deaths (as on 3 October 2020)	CFR (%)
Punjab	92,833	3501	3.77
Maharashtra	11,67,496	37,480	3.21
Gujarat	1,20,336	3,475	2.89
Madhya Pradesh	1,00,458	2,372	2.36
West Bengal	2,18,772	5,070	2.32
Delhi	2,38,828	5,438	2.28
Jammu and Kashmir	61,041	1,212	1.99
Tamil Nadu	5,30,908	9,653	1.82
Karnataka	5,02,982	9,119	1.81
Sikkim	2,303	41	1.78
Himachal Pradesh	11,622	202	1.74
Uttarakhand	38,007	636	1.67
Goa	27,379	442	1.61
Rajasthan	1,11,290	1,516	1.36
Tripura	21,484	289	1.35
Haryana	1,06,261	1,425	1.34
Chhattisgarh	81,617	1,002	1.23
Meghalaya	4,445	52	1.17
Jharkhand	68,578	729	1.06
Andhra Pradesh	6,09,558	5,900	0.97
Manipur	8,607	69	0.8
Telangana	1,69,169	1,153	0.68
Kerala	1,26,381	791	0.63
Bihar	1,65,218	910	0.55
Odisha	1,71,341	875	0.51
Assam	1,52,858	721	0.47
Uttar Pradesh	3,42,788	1,153	0.34
Nagaland	5,357	17	0.32
Arunachal Pradesh	7,005	18	0.26
Mizoram	1,548	0	0

Case fatality rate = Total deaths(t)/Total confirmed(t-15), accordingly confirmed COVID-19 figures are as on 19 September 2020 and deaths as on 3 October 2020.
Source: COVID-19 data is from www.MyGov.in. See the data sources in Appendix II for details.

Table A2: The Crude Death Rate (DR[C]) and the Estimated Death Rate (DR[E])

States	Deaths (as on 3 October 2020)	DR(C) per Million	Multiplication Factor	Multiplication Factor* Deaths	Projected Population 2020	DR(E) per Million
Andhra Pradesh	5,900	65	7.09	41,831	9,09,49,000	460
Assam	721	21	4.79	3,454	3,38,56,000	102
Bihar	910	8	42.5	38,675	10,83,72,000	357
Goa	442	204	1	442	21,70,000	204
Gujarat	3,475	53	4.78	16,611	6,55,32,000	253
Haryana	1,425	49	6.13	8,735	2,90,02,000	301
Himachal Pradesh	202	28	8.22	1,660	73,11,000	227
Karnataka	9,119	142	3.29	30,002	6,44,10,000	466
Madhya Pradesh	2,372	29	13.5	32,022	8,21,34,000	390
Maharashtra	37,480	298	2.61	97,823	12,57,11,000	778
Odisha	875	20	8.55	7,481	4,37,62,000	171
Rajasthan	1,516	20	7.76	11,764	7,67,59,000	153
Telangana	1,153	29	5.22	6,019	3,93,62,732	153
Uttar Pradesh	1,153	5	19.12	22,045	23,14,25,000	95
Uttarakhand	636	58	19.92	12,669	1,10,29,000	1149
Arunachal Pradesh	18	13	5.04	91	13,67,000	66
Chhattisgarh	1,002	37	6.17	6,182	2,70,66,000	228
Delhi	5,438	228	1.65	8,973	2,38,18,000	377
Jammu and Kashmir	1,212	94	1.58	1,915	1,28,88,000	149
Jharkhand	729	21	38.76	28,256	3,52,78,000	801
Kerala	791	22	9.01	7,127	3,64,10,000	196
Meghalaya	52	18	2.75	143	28,87,000	50
Mizoram	0	0	1.83	0	11,06,000	0
Manipur	69	26	4.83	333	26,98,000	124
Nagaland	17	7	66.94	1,138	24,77,000	459
Punjab	3,501	116	6.37	22,301	3,01,01,000	741
Sikkim	41	61	2.3	94	6,73,000	140
Tamil Nadu	9,653	137	2.31	22,298	7,06,17,000	316
Tripura	289	73	4.67	1,350	39,83,000	339
West Bengal	5,070	144	8.38	42,487	9,66,33,000	440

Deaths are as on 3 October.The multiplication factor, being the adjustment made to the reported deaths, is discussed in Section 2.1 above.
Source: Multiplication factor is from Shewade and Parameswaran (2020), https://docs.google.com/spreadsheets/d/1SBy8j_aQbJw2HNddoPoxReC6EadtQJ8SAoEsSlgNvu8/edit#gid=0.

Table A3: Public Expenditure on Health

States	HE/GDP	Health Expenditure/ Total Expenditure	Per Capita Public Health Expenditure	Per Capita Income (₹)
Andhra Pradesh	0.85	4.51	825	1,51,173
Assam	1.39	6.46	1,400	82,837
Bihar	1.42	4.73	689	40,982
Goa	0.61	3.71	2,269	4,30,081
Gujarat	0.66	5.49	1,555	1,95,845
Haryana	0.58	3.63	1,420	2,36,147
Himachal Pradesh	1.47	5.72	3,106	1,83,108
Karnataka	0.67	4.42	1,494	2,12,477
Madhya Pradesh	0.53	2.35	548	90,165
Maharashtra	0.47	3.91	1,058	1,91,736
Odisha	1.29	5.00	1,322	99,196
Rajasthan	1.28	5.80	1,584	1,10,606
Telangana	0.64	3.42	1,536	2,04,488
Uttar Pradesh	1.22	4.63	805	66,512
Uttarakhand	0.85	4.30	1,925	1,98,738
Arunachal Pradesh	4.54	7.69	8,334	1,39,588
Chhattisgarh	1.15	5.03	1,418	92,413
Delhi	0.71	11.88	2,440	3,58,430
Jammu and Kashmir	2.26	4.39	2,786	92,347
Jharkhand	1.10	5.15	978	73,155
Kerala	0.91	5.91	1,969	2,04,105
Meghalaya	3.18	2.05	3,762	84,725
Mizoram	2.98	6.03	5,364	1,47,602
Manipur	2.19	4.19	2,306	75,226
Nagaland	2.28	4.97	2,564	1,16,882
Punjab	0.62	2.77	1,095	1,54,313
Sikkim	1.42	7.17	6,165	3,80,926
Tamil Nadu	0.75	5.14	1,783	1,93,964
Tripura	2.05	7.36	2,615	1,12,849
West Bengal	0.92	4.27	2,807	1,01,138

Per capita income is for the year 2018-19. "Health expenditure" is expenditure on "Health and Family Welfare." For Madhya Pradesh and Nagaland it is on "Health" alone.
Source: From www.mospi.gov.in and www.prsindia.org. See data source s in Appendix II for more details.

Table A4: Public Health Infrastructure

States	Population Served by One Government Allopathic Doctor	Population Served by One Government Hospital	Population Served by One Government Hospital Bed
Andhra Pradesh	17,538	3,47,640	3,876
Assam	5,453	27,052	1,935
Bihar	38,034	92,582	9,104
Goa	3,211	48,093	687
Gujarat	11,730	1,46,626	3,184
Haryana	10,792	42,295	2,514
Himachal Pradesh	4,750	8,996	581
Karnataka	12,571	22,321	910
Madhya Pradesh	17,446	1,72,133	2,573
Maharashtra	17,609	1,72,892	2,389
Odisha	10,031	23,883	2,329
Rajasthan	10,362	26,275	1,591
Telangana	8,490	40,560	1,668
Uttar Pradesh	20,907	48,507	2,948
Uttarakhand	8,100	23,667	1,279
Arunachal Pradesh	2,443	6,151	558
Chhattisgarh	16,290	1,23,776	2,814
Delhi	2,469	2,06,633	924
Jammu and Kashmir	3,121	88,566	1,737
Jharkhand	19,232	62,132	3,198
Kerala	6,883	28,173	949
Meghalaya	4,841	18,038	635
Mizoram	2,483	12,056	543
Manipur	2,408	88,200	1,854
Nagaland	7,319	67,500	1,293
Punjab	8,894	43,438	1,652
Sikkim	2,463	20,000	423
Tamil Nadu	9,684	57,557	903
Tripura	3,110	25,038	882
West Bengal	10,945	61,707	1,230

Government hospitals include central government, state government and local government.
Source: National Health Profile Report 2019, Government of India.

Appendix II: Data Sources

COVID-19: Cases and Deaths

Coronavirus Source Data (4 October 2020): "Our World in Data," https://ourworldindata.org/coronavirus-source-data.

COVID-19 State-wise status (19 September 2020): "MyGov.In," https://www.mygov.in/corona-data/covid19-statewise-status

Income (GDP) and Public Expenditure on Health

Annual Financial Statement 2020–21 (2020a): "Government of Sikkim," http://www.sikkim-fred.gov.in/Budget_2020-21/Documents/AFS2020-21/AFS%20Disbursement.pdf.

— (2020b): "Government of Nagaland," http://finance.nagaland.gov.in/subpageframe.aspx?val=933.

— (February 2020c): "Government of Manipur," https://manipur.gov.in/wp-content/uploads/2020/02/afs20-21.pdf.

Comptroller and Auditor General of India (2019): "CAG Audit Report on State Finances-Sikkim," https://cag.gov.in/en/sites/default/files/audit_report_files/Report_No_1_of_2019_State_Finances_Government_of_Sikkim.pdf.

Department of Finance (February 2020): "Manipur Budget at a Glance 2020–21," Government of Manipur, https://manipur.gov.in/wp-content/uploads/2020/02/bag-20-21.pdf.

— (2020a): "Annual Financial Statement 2020–21," Government of Meghalaya,"http://megfinance.gov.in/budget_documents/2020-2021/others/financial_statement.pdf.

— (2020b): "Budget at a Glance 2020–21," Government of Tripura, https://finance.tripura.gov.in/sites/default/files/Budget%20At%20A%20Glance%202020-21.pdf.

— (2020c): "Statements Under the Nagaland FRBM Act, 2005," Government of Nagaland, http://finance.nagaland.gov.in/subpageframe.aspx?val=939.

— (February 2020d): "Budget at a Glance 2020–21," Government of Goa, http://goabudget.gov.in/assets/documents/2020-21/budget_glance.pdf.

Department of Finance Planning and Investment (March 2020): Statement Laid Before Assembly as Required under FRBM Act 2006, Government of Arunachal Pradesh, http://www.arunachalbudget.in/docs/fiscal.pdf.

Macro Economic Framework Statement 2020–21 (February 2020): Government of Mizoram, https://finance.mizoram.gov.in/uploads/attachments/f1e5a1604562454cfd3608615df862ca/macro-economic-framework-2020-21.pdf

Ministry of Statistics and Program Implementation (7 October 2020): "State Domestic Products and Other Aggregates, 2011–2012 series [Dataset]," Directorate of Economics and Statistics of Respective State Governments, http://www.mospi.gov.in/data.

PRS India, Analysis of State Budgets, PRS Legislative Research, retrieved 7 September 2020, from https://www.prsindia.org/parliamenttrack/budgets/state?field_state_tid=All&field_session_year_value[value]&page=1.

World Bank, Domestic General Government Health Expenditure (% of GDP) | Data [Dataset]: World Health Organization Global Health Expenditure database, https://data.worldbank.org/indicator/SH.XPD.GHED.GD.ZS.

World Bank, GDP per capita (current US$) | Data [Dataset], World Bank national accounts data. https://data.worldbank.org/indicator/NY.GDP.PCAP.CD.

Public Health Infrastructure

Central Bureau of Health Intelligence (2019): National Health Profile 2019 (No 14), Government of India, http://www.cbhidghs.nic.in/showfile.php?lid=1147.

Population

Ministry of Statistics and Programme Implementation (February 2016): "Elderly in India Report 2016," Government of India, http://mospi.nic.in/sites/default/files/publication_reports/ElderlyinIndia_2016.pdf.

Office of the Registrar General and Census Commissioner (2011): "Census 2011, Density of Population," Government of India, https://censusindia.gov.in/2011-prov-results/data_files/india/Final_PPT_2011chapter7.pdf.

Telangana Population (no date): http://www.Populationu.com/, Retrieved 8 September 2020, from http://www.populationu.com/in/telangana-population.