ASHOKA UNIVERSITY ECONOMICS
DISCUSSION PAPER NO. 43

The Inter-state Variation in Death from COVID-19 in India

November 2020

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The inter-state variation in death from Covid-19 in India

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Abstract

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 its states. This suggests that region-specific factors are likely to be relevant to the determination of this rate. In this paper we address this issue. The methodology used is rank correlation and regression analysis. A significant aspect of this study is the use of three different measures of the death rate in the empirical exercise. As there is a dispersion of wealth, reflected in per capita income, among the states of India we first studied the relationship between income and death from COVID-19. This revealed none, implying that wealth is not a shield against death from the disease. It led us to investigate the possible impact of public policy towards healthcare, notably expenditure on health and the presence of physical infrastructure in the public sector. 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. We interpret this 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. Our finding has an immediate implication for public policy towards COVID-19, not just in India but in all developing countries. It suggests that countries that fail to invest in a public health system even as they prioritize growth could end up jeopardizing their health security.

Keywords: COVID-19, public health policy, India, developing countries

JEL Codes: C80, I15, I18

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[1] Ashoka University and Indian Institute of Management Kozhikode, respectively. An earlier version of this paper was presented at the Society for Economic Research (SERI) Workshop on COVID-19 held online over September 18-19, 2020. We thank the organisers and participants in the workshop, in particular Bhaskar Dutta and Aditya Dar, for valuable comments. We have benefited from discussions with Gautam Menon, M.Suresh Babu, M. Parameswaran and above all Deepak Dayanithy. Finally, we acknowledge the role of Ashwini Deshpande in allowing us to make a correction when we discovered an error in a data source. Errors that may remain are our responsibility.

1. Introduction

The death rate from COVID-19 in India is relatively low in a global comparison[i]. 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 October 3, 2020 the range recorded for the case fatality rate was 3.8 percent while the median was 1.3 percent[ii]. 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 country-wide lockdown either in geographic coverage or duration. An inter-state 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. Attention has generally focused on the transmission of the disease across regions (Ghosh et al., 2020), reliability of the reported number of deaths (Chatterjee, 2020) and how some states have managed the epidemic (Chathukulam and Tharamangalam, forthcoming 2021). However, there is relatively little by way of economic analysis of the death rate across the country. 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 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 a valuable study it had come at a very early stage of the epidemic, 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.

2. Methodology

We follow a lead proposed by medical practitioners who view the impact of the epidemic 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 inter-state 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 inter-state 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.

2.1 Measuring the death rate 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 denominator 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 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 is 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 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 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 fifteen days prior to the date for which deaths are counted. The CFR computed for this study reflects this requirement (see Table A1 of the Appendix).

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 the cause of death (MCCD). This is to scale up the number of reported COVID-19 deaths by the inverse of the product

$$\frac{Registered\ Deaths}{Total\ Deaths} * \frac{MCCD}{Registered\ Deaths}$$

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. 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[iii].

We have computed DR(E) for all states and present it beside the Crude Death Rate for comparison (see Table A2 of the Appendix.). Note that the difference is considerable. For instance, the Estimated Death Rate exceeds the Crude Death Rate by a factor of 9 in Kerala[iv]. This appears implausibly high to us given that the surveillance of COVID 19 infection may be expected to be high there given the quality of governance[v]. And the resulting fatality the public health system of the state. 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.

The methodology we follow is to first investigate the rank correlation between the fatality rate and chosen variables and follow this up with a regression analysis. The software used is IBM *SPSS Statistics 25*.

3. Fatality, income and public health policy: an investigation

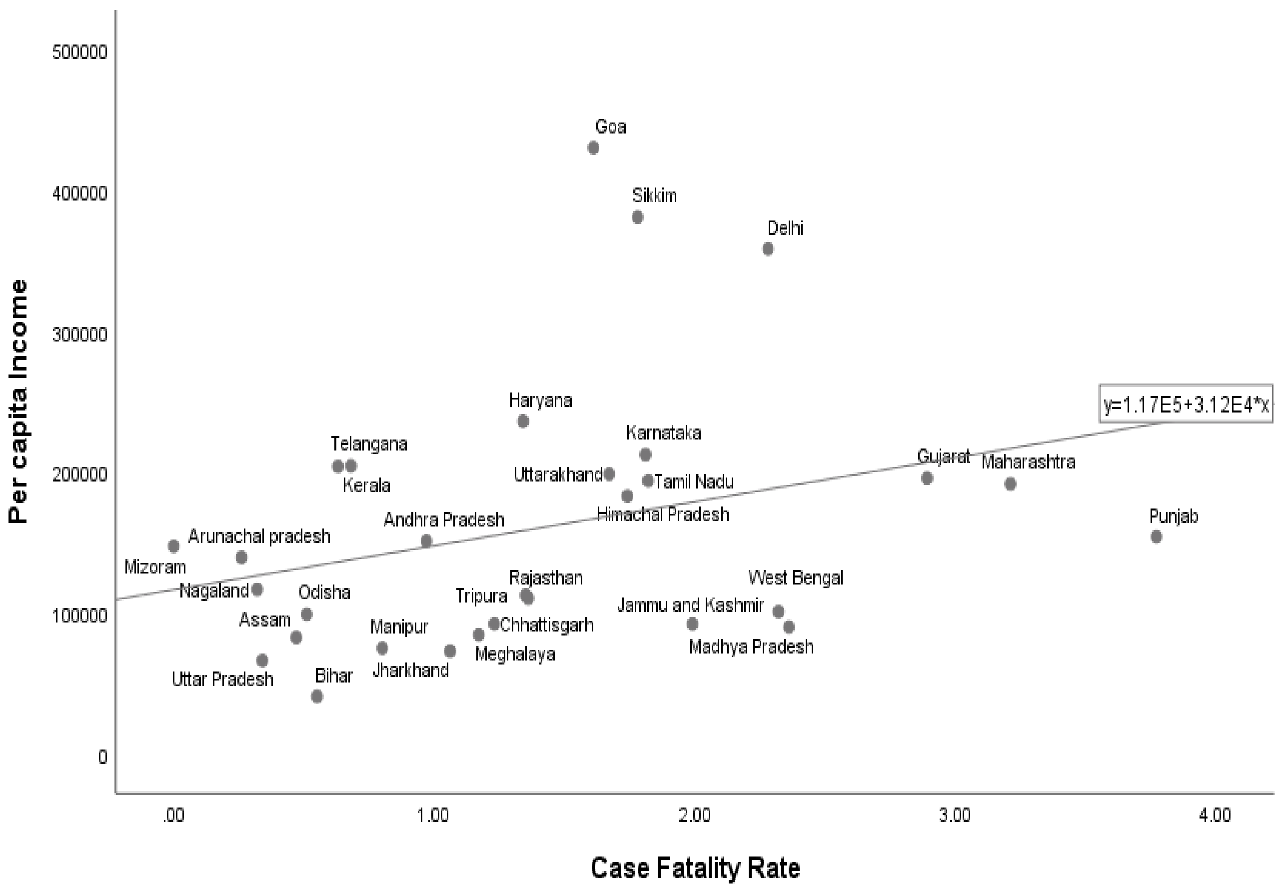
One of the first observations that may be made in a comparison of the states of India is that they display a substantial variation in per capita income. In fact, the dispersion in per capita income is almost as high as the case fatality rate[vi]. This led us to commence our empirical investigation of 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, 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.

3.1 Results

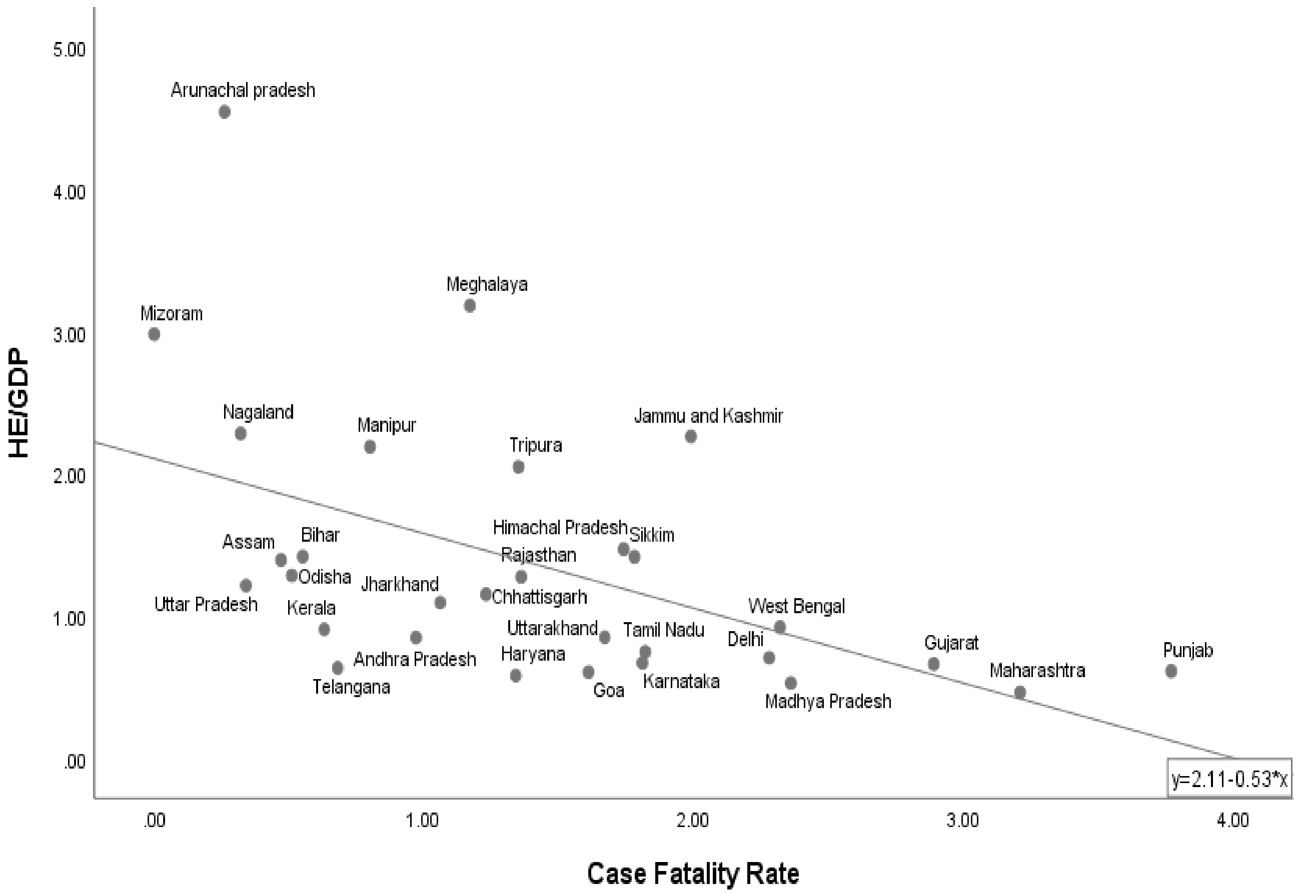
We started by checking for the relation between the case fatality rate (CFR) and income represented by per capita income. In the resulting scatter plot (Figure 1) the relationship is positive, with the richer states associated with a higher CFR. Clearly then, in India wealth is not a shield against COVID-19.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

Figure 1. Case fatality rate and per capita income



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.

Figure 2. **Case fatality rate and public health expenditure as a share of GDP**



We next investigated the rank correlation between the ranking of states according to fatality (CFR) and their ranking according to expenditure on health and their 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.

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 one Government Allopathic Doctor	Population served by one Government Hospital
CFR	Correlation coefficient	1.000	-.582**	-.049	.358	.067	.260
	Significance (2-tailed)	.	.001	.796	.052	.723	.165
	N	30	30	30	30	30	30

*** significant at the 0.01 level.*

The ranking of states on CFR is strongly correlated with their ranking on public expenditure on health. But there is no rank correlation between CFR and per capital 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, 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"[vii]. However, the containment of the pandemic and prevention of 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 very recent, i.e., as on October 3, 2020, the data on the indicators of health policy referred to earlier were available only as of 2018-19. Even though the lag is of a few months only, 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 was statistically significant in every regression. This led us to confine the subsequent testing to this indicator of public policy towards health alone. The results referred to but not presented here may be had from 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 2021) and the age profile of the population (Mallapaty, 2020; Bonanad et al., 2020) have been flagged as factors in the pandemic. 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.

Table 2. Regression analysis: Case Fatality Rate, income and public health policy

Model		Coefficients		t	Sig.
		B	Std. Error		
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				

Notes: *Dependent Variable is CFR; * P < 0.05, ** P < 0.01*

The regression results (Table 2), show 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.

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)	Correlation Coefficient	1.000	-.734**	-.282	.397*	.259	.479**
	Significance (2-tailed)	.	.000	.131	.030	.167	.007
	N	30	30	30	30	30	30

Notes: **significant at the 0.05 level, **significant at the 0.01 level*

We repeated the statistical exercises 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.

Table 4. Regression analysis: Crude Death Rate - DR(C) - income and public health policy

Model		Coefficients		t	Sig.
		B	Std. Error		
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				

Notes: *Dependent Variable is DR(C); * P < 0.05, ** P < 0.01*

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) 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) health expenditure is statistically significant with and without controls.

Table 5. Rank Correlation: Estimated Death Rate – DR(E) - and public health indicators

Spearman's rho								
Model		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)	Correlation Coefficient	1.000	-.566**	-.414*	.186	.508**	.445*
	Significance (2-tailed)	.	.001	.023	.326	.004	.014
	N	30	30	30	30	30	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		t	Sig.
		B	Std. Error		
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				

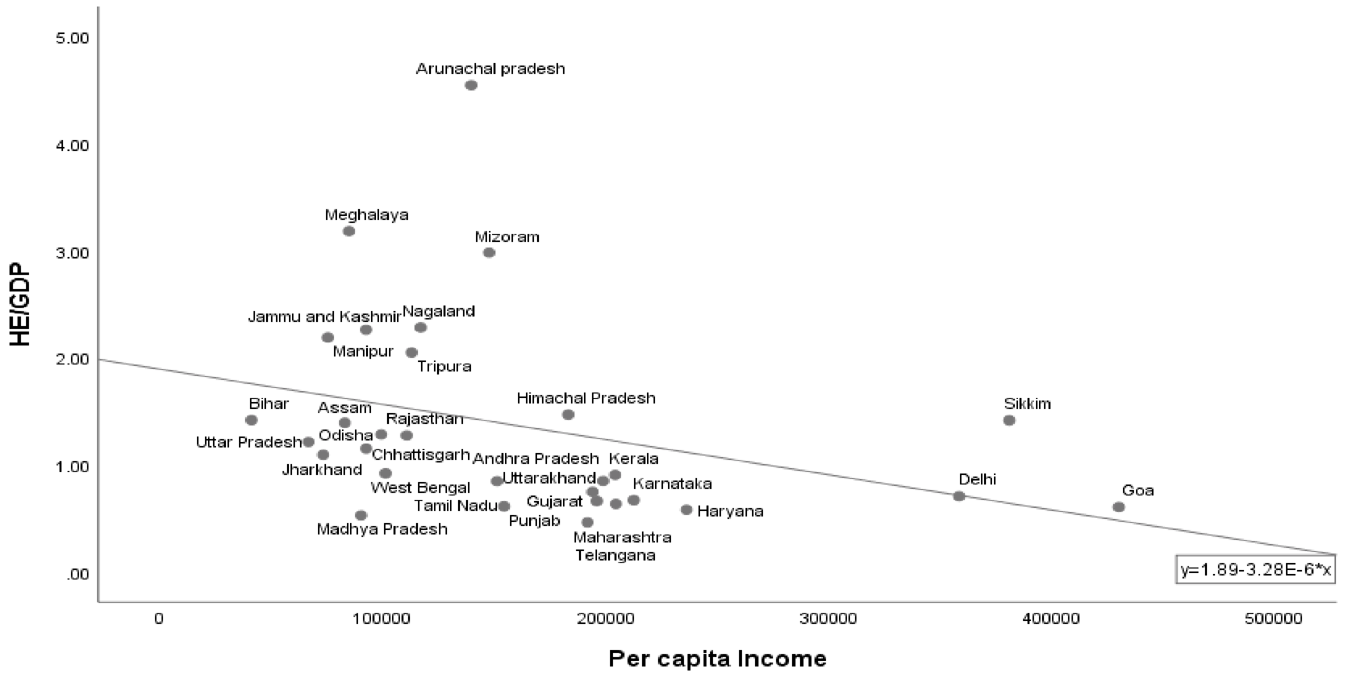
Notes: *Dependent Variable is DR(E);* P < 0.05, ** P < 0.01*

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 (see 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 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).

4. 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, i.e., public expenditure as a percentage of state GDP is inversely related to per capita income. This may be seen in Figure 3 below. Thus, the positive relationship between fatality and per capita income may be judged a statistical artifact, being the reflection of the negative relationship between per capita income and public health expenditure across units. However, the related finding that the richer states of India spend relatively less on health is a reality not generally known.

Figure 3. Per capita income and public health expenditure as a share of GDP



5. A detour

5.1 Northeastern 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 northeastern 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 case fatality rate as it measures fatality among the infected. Moreover, it may be noted that the infection rate is not particularly low in the northeast. Of the six states considered here, in mid-September 2020, four had an infection rate, i.e., 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 northeastern states beyond that has been provided in this study is actually needed. The six northeastern states in our sample are among the top seven states of India when it comes to expenditure on health as share of the state gross domestic product (see Figure 2).

5.2 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 October 3, 2020. An unmistakable pattern emerged when the relevant data were assembled. Mere viewing of the data was sufficient to recognize 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 gross domestic product. 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 US $)	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

Notes: *Case Fatality Rate = Total Deaths(t)/Total Cases(t-15); t = October 3, 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 the Data Source in Appendix for details.*

6. 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. Co-ordination between the branches of the public health machinery is required for testing, contact tracing and quarantining of the infected, and managing the hospitalization of the severe cases. Where this co-ordination is absent or even limited the presence of infrastructure is neutralized. 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 an epidemic. 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 epidemic. 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 which induces socially responsible behavior. 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 epidemic in the thirty states of India. Under the circumstances, an approach would be undertake case studies of individual states.

7. Conclusion and policy implications

We set out to provide an answer to the wide 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 health by the states is shown to be inversely related to their wealth measured in of per capita income. The prevent deaths from COVID-19 in India. We are able to explain this finding statistically. The expenditure on uncomfortable conclusion must then be that some of India's richer states have chosen not to spend on public health commensurate with their 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 i.e., health expenditure needs to be prioritized. 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 takes place eight six months into the epidemic 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.

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Appendix

I. Data

1. The Case Fatality Rate on October 3

Table A1

State	Total Confirmed (as on 19.09.20)	Deaths (as on 03.10.20)	Case Fatality Rate
Punjab	92833	3501	3.77
Maharashtra	1167496	37480	3.21
Gujarat	120336	3475	2.89
Madhya Pradesh	100458	2372	2.36
West Bengal	218772	5070	2.32
Delhi	238828	5438	2.28
Jammu and Kashmir	61041	1212	1.99
Tamil Nadu	530908	9653	1.82
Karnataka	502982	9119	1.81
Sikkim	2303	41	1.78
Himachal Pradesh	11622	202	1.74
Uttarakhand	38007	636	1.67
Goa	27379	442	1.61
Rajasthan	111290	1516	1.36
Tripura	21484	289	1.35
Haryana	106261	1425	1.34
Chhattisgarh	81617	1002	1.23
Meghalaya	4445	52	1.17
Jharkhand	68578	729	1.06
Andhra Pradesh	609558	5900	0.97
Manipur	8607	69	0.8
Telangana	169169	1153	0.68
Kerala	126381	791	0.63
Bihar	165218	910	0.55
Odisha	171341	875	0.51
Assam	152858	721	0.47
Uttar Pradesh	342788	1153	0.34
Nagaland	5357	17	0.32
Arunachal	7005	18	0.26
Mizoram	1548	0	0

Notes: *Case Fatality Rate = Total Deaths(t)/Total Confirmed(t-15), accordingly confirmed COVID-19 figures are as on September 19, 2020 and deaths as on October 3, 2020.*

Source: *COVID-19 data is from www.MyGov.in. See the Data Source for details*

2. The Crude Death Rate - DR(C) - and the Estimated Death Rate - DR(E)

Table A2

State	Deaths (as on 03.10.20)	DR(C) Per million	Multiplication factor	Multiplication factor*Deaths	Projected Population 2020	DR(E) per million
Andhra Pradesh	5900	65	7.09	41831	90949000	460
Assam	721	21	4.79	3454	33856000	102
Bihar	910	8	42.5	38675	108372000	357
Goa	442	204	1	442	2170000	204
Gujarat	3475	53	4.78	16611	65532000	253
Haryana	1425	49	6.13	8735	29002000	301
Himachal Pradesh	202	28	8.22	1660	7311000	227
Karnataka	9119	142	3.29	30002	64410000	466
Madhya Pradesh	2372	29	13.5	32022	82134000	390
Maharashtra	37480	298	2.61	97823	125711000	778
Odisha	875	20	8.55	7481	43762000	171
Rajasthan	1516	20	7.76	11764	76759000	153
Telangana	1153	29	5.22	6019	39362732	153
Uttar Pradesh	1153	5	19.12	22045	231425000	95
Uttarakhand	636	58	19.92	12669	11029000	1149
Arunachal	18	13	5.04	91	1367000	66
Chhattisgarh	1002	37	6.17	6182	27066000	228
Delhi	5438	228	1.65	8973	23818000	377
Jammu and Kashmir	1212	94	1.58	1915	12888000	149
Jharkhand	729	21	38.76	28256	35278000	801
Kerala	791	22	9.01	7127	36410000	196
Meghalaya	52	18	2.75	143	2887000	50
Mizoram	0	0	1.83	0	1106000	0
Manipur	69	26	4.83	333	2698000	124
Nagaland	17	7	66.94	1138	2477000	459
Punjab	3501	116	6.37	22301	30101000	741
Sikkim	41	61	2.3	94	673000	140
Tamil Nadu	9653	137	2.31	22298	70617000	316
Tripura	289	73	4.67	1350	3983000	339
West Bengal	5070	144	8.38	42487	96633000	440

Notes: *Deaths are as on October 3.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.*

3. Public expenditure on health

Table A3

State	HE/GDP	Health Expenditure/Total Expenditure	Per capita Public Health Expenditure	Per capita Income (in Rupees)
Andhra Pradesh	0.85	4.51	825	151173
Assam	1.39	6.46	1400	82837
Bihar	1.42	4.73	689	40982
Goa	0.61	3.71	2269	430081
Gujarat	0.66	5.49	1555	195845
Haryana	0.58	3.63	1420	236147
Himachal Pradesh	1.47	5.72	3106	183108
Karnataka	0.67	4.42	1494	212477
Madhya Pradesh	0.53	2.35	548	90165
Maharashtra	0.47	3.91	1058	191736
Odisha	1.29	5.00	1322	99196
Rajasthan	1.28	5.80	1584	110606
Telangana	0.64	3.42	1536	204488
Uttar Pradesh	1.22	4.63	805	66512
Uttarakhand	0.85	4.30	1925	198738
Arunachal	4.54	7.69	8334	139588
Chhattisgarh	1.15	5.03	1418	92413
Delhi	0.71	11.88	2440	358430
Jammu and Kashmir	2.26	4.39	2786	92347
Jharkhand	1.10	5.15	978	73155
Kerala	0.91	5.91	1969	204105
Meghalaya	3.18	2.05	3762	84725
Mizoram	2.98	6.03	5364	147602
Manipur	2.19	4.19	2306	75226
Nagaland	2.28	4.97	2564	116882
Punjab	0.62	2.77	1095	154313
Sikkim	1.42	7.17	6165	380926
Tamil Nadu	0.75	5.14	1783	193964
Tripura	2.05	7.36	2615	112849
West Bengal	0.92	4.27	2807	101138

Notes: *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 for more details*

4. Public Health Infrastructure

Table A4

State	Population served by one Government Allopathic Doctor	Population served by one Government Hospital	Population served by one Government Hospital Bed
Andhra Pradesh	17538	347640	3876
Assam	5453	27052	1935
Bihar	38034	92582	9104
Goa	3211	48093	687
Gujarat	11730	146626	3184
Haryana	10792	42295	2514
Himachal Pradesh	4750	8996	581
Karnataka	12571	22321	910
Madhya Pradesh	17446	172133	2573
Maharashtra	17609	172892	2389
Odisha	10031	23883	2329
Rajasthan	10362	26275	1591
Telangana	8490	40560	1668
Uttar Pradesh	20907	48507	2948
Uttarakhand	8100	23667	1279
Arunachal	2443	6151	558
Chhattisgarh	16290	123776	2814
Delhi	2469	206633	924
Jammu and Kashmir	3121	88566	1737
Jharkhand	19232	62132	3198
Kerala	6883	28173	949
Meghalaya	4841	18038	635
Mizoram	2483	12056	543
Manipur	2408	88200	1854
Nagaland	7319	67500	1293
Punjab	8894	43438	1652
Sikkim	2463	20000	423
Tamil Nadu	9684	57557	903
Tripura	3110	25038	882
West Bengal	10945	61707	1230

Notes: *Government hospitals include Central Government, State Government and Local Government*.

Source*: National Health Profile Report 2019, Government of India*

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Endnotes

[i] See https://www.worldometers.info/coronavirus/#countries; accessed on 13.10.2020.

[ii] See Table A1 of the Appendix for the data used.

[iii] See Slater and Masih (2020) and Kurian (2020) for the view that deaths may be under-reported and that this cannot be assumed, respectively.

[iv] See Table A1 of the Appendix.

[v] See Chathukulam and Tharamangalam (2020).

[vi] The coefficient of variation is .65 and .59 for the case fatality rate per capita income, respectively. See Tables A1 and A3 in Appendix for the data used.

[vii] Dr. Devi Shetty, interview on New Delhi Television (NDTV), October 2, 2020.