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Time for bed(s): Hospital capacity and mortality from COVID-19

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Public response to rising deaths from COVID-19 was immediate and, in many cases, drastic, leading to substantial economic and institutional costs. In this paper, I focus on mortality from COVID-19. Using cross-country evidence and controlling for a variety of contributing factors, I find that increasing the number of hospital beds has a significant and quite substantial impact on mortality rates. Hospital beds likely capture the capacity of ICU, laboratories, and other hospital-related equipment. Facing a potential second or third wave of infection following an exit from lockdown policies, countries short on medical infrastructures should increase them immediately.

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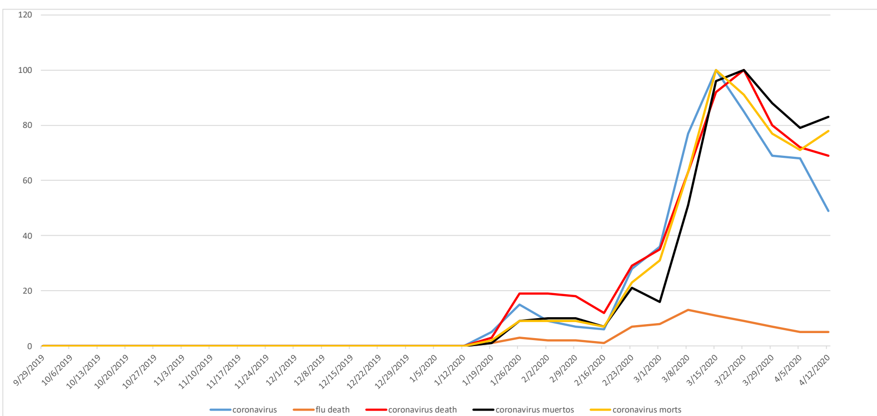
Introduction

As the COVID-19 was striking China in January 2020, most advanced Western economies exhibited complacency if not denial. By February 23rd, when Italy recorded its first deaths amid a rapid increase in cases, the government closed schools.[2] A week later, on February 28th, as deaths climbed to 20, Italy was the first European country to close workplaces. Media accounts suggest that policymakers reacted very strongly to fatality counts. In the U.K, with the Italian data available to policymakers, it wasn't until the first deaths on English soil that policy abruptly reversed course.[3] It seems that in weighing the economic cost of lockdowns, fatalities, rather than infections, played first fiddle. Case-fatality ratios became household expressions.

Figure 1

Public Interest in COVID-19 Deaths

(Google Trends: October 2019-April 2020)



Data from GoogleTrends on searches on the words: *coronavirus, coronavirus deaths*, in 3 major Western languages (**Figure 1**), exemplifies the rapidly rising public interest in coronavirus ***deaths***. It accelerated and peaked only when deaths hit close to home. Interestingly, the interest in deaths from COVID-19 is now relatively higher than the interest in the disease. As the economic toll of lockouts rises, the debate between those

[2] Data on policy response to COVID-19 us taken from Oxford University's policy response tracker. https://www.bsg.ox.ac.uk/research/research-projects/coronavirus-government-response-tracker

[3] For eample, see the denial by deputy chief medical officer on March 8th and the following day discussion in the media that already hints at reversal.

arguing for a faster resumption of economic activity and those in favor of continued lockdown centers on death rates. Some of the debate is focused on comparisons with mortality from seasonal flu and other respiratory illnesses.[4] However, ultimately, the fatality count is a significant factor in determining policy choices.

While epidemiologists and medical researchers are studying the factors that account for the death toll from the virus, the economists can test for contributing factors that can affect the policy discussion regarding the containment of the virus and its impact on the economy. In this paper, I focus on mortality from COVID-19. Using cross-country evidence and controlling for a variety of contributing factors, I find that increasing the number of hospital beds has a significant and quite substantial impact on mortality rates. Absent more detailed hospital infrastructure data, the number of beds likely captures also the availability of ICU units, testing facilities, laboratories, etc. This result substantiates a recent paper by Favero (2020) and the focus on hospital capacity constraints. Our analysis offers an interesting twist on the famous 'Reversal of Fortune' hypothesis (Acemoglu et al. 2002). In that paper, countries with higher mortality ended with inferior institutions. My findings suggest that countries that rank higher on the rule of law indices suffered more mortality, and countries with more effective governments had lower mortality.

The policy implications of this paper are that increasing hospital capacity reduces mortality in cases of highly contagious diseases. The indirect economic benefit of hospital beds' capacity in these situations is to attenuate a costly policy response that could also affect future institutional quality.

Methodology

Deaths versus Cases

In this paper, I study deaths from COVID-19. There is an ongoing debate on whether we should look at cases or deaths from COVID-19. Most websites record both and provide case-fatality ratios and case-per-capita ratios but not per capita death ratios. Since testing rates differ from country to country, the use of case-fatality ratios could

[4]Financial times March 30 https://www.ft.com/content/f3796baf-e4f0-4862-8887-d09c7f706553. Washingtom Post, April 10, https://www.washingtonpost.com/politics/2020/04/10/not-that-bad-or-not-that-high-how-advocates-return-normal-misrepresent-coronavirus-deaths/.

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be misleading.[5] Arguably, the death count is more accurate. Moreover, for comparisons with past virus outbreaks, we can only use death rates as we do not have historical case data.

Mortality *rates* in country *i* (*Mi*) are a function of the incidence *rate* (*Ci*) times the case-fatality ratio:

$$(1) M_i = C_i * \left({}^{M_i}/_{C_i}\right)$$

The incidence of the disease is a function of variables that affect contagion. The case-fatality ratio is a function of variables that determine how deadly the disease is. Following the standard discussion in the medical research literature, two groups of factors affect contagion and mortality: natural and intervention. We can further classify natural causes as those affected by individual characteristics (age, general health condition, etc.) and environmental variables. Environmental variables include both the geographical environment (temperature, humidity, etc.') and the human environment (pollution, population density, norms of hygiene, etc.').

Research hypothesis:

The main hypothesis tested in this paper is whether *better* medical infrastructure, as captured by the number of hospital beds per capita (b_i), *reduces* the case-fatality ratio in country *i*.

Empirical strategy

Unlike the medical-research literature, I am not interested in determinants of *individual* mortality but rather in the macro case-fatality rate. I defend this approach on two grounds: a) given my research hypothesis, capacity constraints in hospitals create an *externality* to the individual probability of survival. b) in the absence of widespread daily testing, the policies applied were at the macro level as well. I, therefore, used cross country data for the latest mortality ratios (April 14, 2020).

At the macro level, it is difficult to distinguish between control variables that affect contagion and those that cause death. As we see in equation (1), the case fatality ratio

[5] See for example World Economic Forum, April 4, 2020 https://www.weforum.org/agenda/2020/04/we-could-be-vastly-overestimating-the-death-rate-for-covid-19-heres-why/

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is *endogenous*. Nevertheless, in what follows, I use a set of variables that are *exogenous* to both contagion and deaths. The model in its generalized form is:

$$(2) M_i = \boldsymbol{\beta X_i} + \boldsymbol{\gamma E_i} + \boldsymbol{\delta I_i} + \mu \boldsymbol{H_i} + \theta b_i + \tau \boldsymbol{T}_i$$

Where:

$\boldsymbol{X}$ is a vector of country-specific general controls.

$\boldsymbol{E}$ is a vector of country-specific economic controls.

$\boldsymbol{I}$ is a vector of country-specific institutional controls.

$\boldsymbol{H}$ is a vector of country-specific health system controls, excluding, $\boldsymbol{b}$**,** the number of beds per capita.

$\boldsymbol{T}$ is a vector of country-specific time controls.

The hypothesis to be tested is whether $\theta \neq 0$?

Data

While data on the COVID-19 cases and deaths is available for almost all countries, the controls used below limit the set of countries used to 66 in the smallest sample. The small sample is biased towards more advanced economies, for which more data is available. However, the more advanced economies, for now, have more significant exposure to COVID-19.[6]

Country specific control variables: Since the spread of a COVID-19 is believed to be dependent on weather conditions, I control for countries' geographical location by including their latitude and longitude position. Mortality from COVID-19 is concentrated among the elderly, I, therefore, use as controls the share of the population above the age of 80. Another factor that could affect contagion is urbanization. Therefore, I also control for the percent of the population living in urban areas. Since there could be other country-specific variables that affect mortality from flu viruses, such as pollution, hygiene norms, etc., I use as controls, the death rate from influenza from 2018. As argued above, I cannot distinguish between the effect of these variables on contagion and their effect on deaths. For example, weather can affect the spread of the virus, but also the vulnerability of those who catch it. The variation in countries'

[6] A short appendix details the data sources used.

historical death rates from the flu reflects both the rates of contagion and case-fatality rates, etc. Nevertheless, all these are *exogenous* to COVID-19 death rates.

Economic Controls: I used GDP per capita as a proxy for the population's well being, education, etc. that could contribute to either contagion and/or death rates. I used the degree of country openness to trade as a proxy for exposure to imported COVID-19.

Institutional controls: The media has argued that institutional variables can account for the spread of COVID 19 – for example, the reluctance of Western democracies to close borders between them, the success of authoritarian regimes in enforcing lockdowns, etc. I, therefore, control for several commonly used institutional indices, such as the rule of law, protection of private property rights, effectiveness of the government, etc. I also control for 'neo-liberal' inclined governments by using government spending to GDP ratio. Again, media accounts suggest that more market-oriented economies tended to postpone the imposition of restrictions.

Health system controls: I used the health expenditure to GDP ratio and the number of physicians per capita and, more important as we shall see, the number of beds per capita. Ideally, given that acute COVID-19 treatment requires ICU units and ventilators, I would have liked to have more detailed cross-country data on additional medical infrastructure variables. I assume that there is a positive correlation between these additional variables and hospital beds. In the estimation, I also used the number of beds squared to reflect possible nonlinearities in hospital size.

Time controls: since COVID-19 did not hit all countries at once and since death rates are rising over time, I included a time control – counting the number of days since the first recorded death. Since some countries instituted measures to contain the spread of COVID-19 – to 'flatten the curve,' I also included a control variable that measures the time elapsed since the introduction of these measures.

Estimation and results

Basic specifications

We begin with a simple specification that allows us to use data from 94 countries. The specification includes the geographical setting – latitude, longitude, the 2018 death rate from influenza, the percent of the urban population, and the percent of the population

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above 80.[7] I also control, as in all regressions, for the time elapsed since the first death from COVID-19 was recorded in a country. All regressions were estimated as a cross-country regression using least squares with errors clustered by World Bank country groupings.

We can see (**Table 1**, column 1), that this simple specification can account for almost 60 percent of the variation in death rates in our broad sample. Analytical plots (**Figures 3a-3b**) show that the equation is well behaved and that given the higher share of elderly in the economy, Italy and Spain and Belgium that recorded high mortality rates, have higher mortality then their demographics imply. Japan, on the other hand, stands as an outlier with low death rates given its demographics. The coefficient of the percent of urbanization is positive but not significant. As we shall soon see, controlling for additional variables, the positive effect of urbanization on mortality is reversed. We can also see, (**Table 1**, column 2), that when we decrease the sample to 66 countries for which we have all data, the results remain unchanged.

The effect of economic activity

I next introduce economic controls: GDP per capita and the degree of openness of the economy. The results (**Table 1** column 3) show that countries with higher GDP per capita and a higher degree of openness to trade are subject to higher death rates. It is likely that higher death rates in advanced economies are caused by greater contagion rather than by higher case-fatality ratios. Note that when including economic activity controls the sign of the coefficient of the degree of urbanization is now negative. We interpret this result as suggesting that for a given (a higher) rate of contagion in advanced economies, case-fatality ratios are lower in more urbanized economies due to better medical infrastructure. Our findings below on health infrastructure confirm this hypothesis.

Effect of quality of institutions

The long term effect of institutions is captured by GDP per Capita, Urbanization, and longevity (Aecmoglu et al. 2002). Media accounts alluded to the weakness of Western democracies, open societies, in dealing with COVID-19 because of reluctance to restrict

[7] Controlling for the normal death rate from influenza reduces significantly the sample size. However, omitting it would bias our results as it

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movement and monitor citizens. The inclusion of institutional quality variables confirms (**Table 1** col. 4.) some of the assertions in the media. Institutional variables that are related to upholding the rule of law, allowing for voice and accountability, are associated with higher rates of mortality from COVID. In contrast, institutions that capture political stability, quality of regulation, and government effectiveness are associated with lower mortality rates. However, given that the coefficients are measured at the mean of the institutional variables, there is no real constraint to increase government effectiveness without having to lower civil liberties.

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Health infrastructure

Geographic, economic, and institutional factors account for a substantial proportion of the variation in death rates in our sample. I end the analysis with the introduction of health infrastructure as captured by the number of beds per 1000 residents and the number of physicians per 1000. **Table1**, column 5, reports the preferred specification that uses the number of beds squared (accounting for non-linearities in hospital infrastructure). We can readily see that a more abundant supply of hospital beds reduces mortality significantly (Fisher et al. 2000).

Figure 3c shows that the results are not driven by outliers. **Figure 3d** shows the added value plot of the number of beds. The effect of the number of physicians per capita was insignificant (Appendix table col 5). Hospital bed capacity is also related to the supply of other components of medical infrastructures, such as ICU units, testing, and laboratory facilities.

Controlling for other covariates, the number of available beds can account for most of the differences in death rates between Italy or Spain and Japan (**Figure 3d**). One source of concern is the statistic influence of Japan on the coefficient on the number of beds. Dropping Japan from the regression reduces the coefficient, but it remains highly significant and substantial (see **Appendix Figure**). Note that the coefficient on urbanization declines and becomes insignificant. This result suggests that before introducing the supply of hospital beds, the urbanization variable captured the higher and often better quality supply of medical care in large cities.

The introduction of the number of beds variables affects the coefficient on the percent of people above 80 significantly. This is because there is a high correlation (0.56) between the number of beds and the share of the elderly population. In a regression of the number of beds on the percentage of the population above 80 (available from the author upon request), we find that Japan is an outlier with a very high ratio of beds to the elderly, whereas, ***tragically***, Italy and Spain are opposite outliers with a low number of beds. As it happens, COVID-19, which affects mainly the elderly, hit the Achilles heel of those countries' medical systems.

How substantial is the impact of the supply of hospital beds on the death rate from COVID-19? A useful example is to take the death rate in Italy, one of the countries with the highest number of deaths and the lowest supply of beds (**Figure** 2b). Using the

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coefficient estimate on the number of beds squared shows us that, other things equal, if Italy had the same number of beds per capita as Japan, the number of deaths would have been reduced to Japanese levels – a few hundred. If we exclude Japan, an outlier in the number of beds per capita (**Appendix** table col 4), we get a reduction of deaths to about 3,600 people (given death rates at the time of writing this paper).

Table 1

Dependent variable: Log COVID-19 deaths per capita

	(1)	(2)	(3)	(4)	(5)	(6)
Log flu deaths per capita	0.316*	0.381*	0.371**	0.246*	0.282*	0.260*
	(0.137)	(0.171)	(0.098)	(0.104)	(0.124)	(0.122)
Perecent above 80	21.365**	15.935**	10.477*	12.326**	32.295***	27.007**
	(5.951)	(5.843)	(4.813)	(4.155)	(4.142)	(8.549)
Percent urban	0.469	1.335	-0.816**	-0.416*	-0.186	-0.022
	(0.953)	(1.011)	(0.275)	(0.201)	(0.500)	(0.628)
Log GDP per capita			0.897***	1.171***	1.060***	0.904**
			(0.216)	(0.141)	(0.178)	(0.302)
Imports to GDP			0.769***	1.935**	1.413*	1.521*
			(0.119)	(0.557)	(0.662)	(0.735)
Voice and Accountability				0.638**	0.449**	0.374*
				(0.161)	(0.127)	(0.177)
Government Effectiveness				-0.534	-0.787	-0.822
				(0.548)	(0.585)	(0.494)
Rule of Law				1.248***	0.766*	0.711**
				(0.209)	(0.316)	(0.223)
Regulatory Quality				-1.275***	-0.755***	-0.700***
				(0.240)	(0.085)	(0.161)
Political Stability				-0.738	-0.335	-0.282
				(0.388)	(0.286)	(0.229)
Control of Corruption				0.255	0.255	0.501
				(0.293)	(0.388)	(0.386)
Beds per 1000 squared					-0.024***	-0.022***
					(0.004)	(0.004)
Obs.	94	66	66	66	66	66
R-squared	0.596	0.615	0.673	0.729	0.790	0.809
Time Effects	yes	yes	yes	Yes	yes	yes
Geo position	yes	yes	yes	Yes	yes	yes
COVID-19 Mitigation						yes

Notes: Data sources see data appendix. All regressions were estimated with errors clustered by the World Bank region classification.
Standard errors are in parenthesis
*** *p*<0.01, ** *p*<0.05, * *p*<0.1

Mitigation efforts.

Many countries launched a variety of COVID mitigation policies. These are tracked by Oxford University's policy response tracker. Albeit the short time that elapsed since their introduction, I controlled for the time elapsed, the squared time, and the index of the stringency of the measures. The results (**Table1** col 6) did not change significantly. Moreover, these controls are determined simultaneously with mortality rates (Jones et

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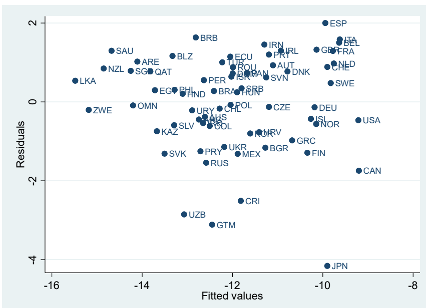
al., 2020). Owing to their small marginal contribution to the explanatory power and the simultaneity issues, I leave them for Appendix regressions.

Figure 3

Fitted versus residual plot **Added value plot**

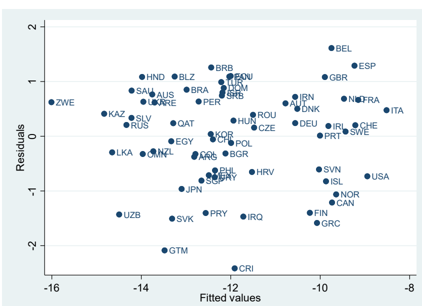
Percent above 80 on COVID-19 mortality rates

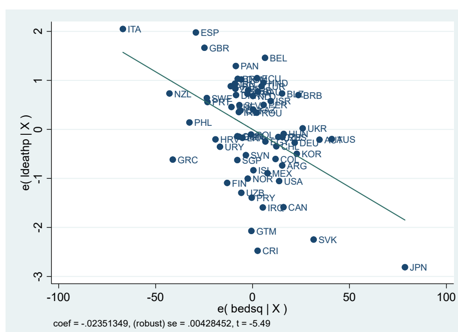
a **b**



c **d**

Beds squared per capita on COVID-19 mortality rates





Notes: panels **a** and **b** based on column 2 in Table 1. Panels **c** and **d** based on column 5 in Table 1.

Discussion and policy implications

Since the pandemic is recent and its global spread is still in process, the conclusions from data available at the time of writing this note should be taken with more than the usual caveats. Nevertheless, our regressions confirm that death rates from COVID-19 are higher in advanced and open economies suggesting higher degrees of contagion due to more contact and travel. The results also suggest that controlling for income per

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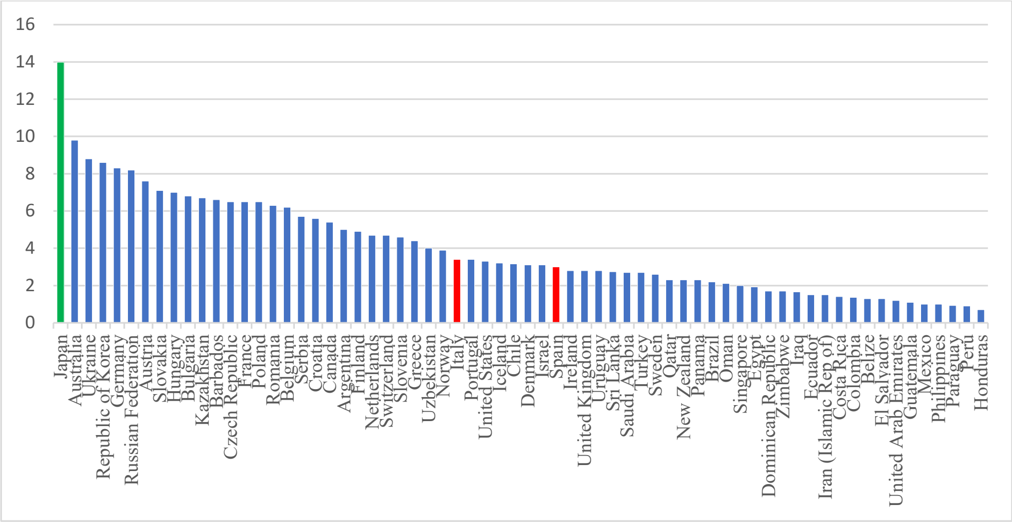
capita, countries that rank higher in indices of the rule of law and property rights protection exhibit higher death rates, and countries with more efficient and stable governments exhibit lower death rates. The degree of government spending in the economy, as a proxy of a greater or smaller degree of redistribution policies, does not seem to have an impact on death rates (**Appendix Table**). On a more positive note, our findings suggest that other things equal, living in an urban environment, saves lives – mainly by providing access to medical facilities.

Mitigation policies seem to have been, to a large extent, endogenous to rising deaths than preventive, and their impact on death rates is yet insignificant. However, due to the substantial lags between the imposition of restrictions, their effect on contagion, and ultimately deaths, these results should be taken with a grain of salt.

Figure 3

Hospital beds per 1000 people



Note: For countries used in the regression analysis.
Source: World bank [Hospital beds per 1000 people]

The most important empirical finding is the large and significant role played by hospital beds capacity on death rates. Our findings echo horror accounts from the heavily affected regions in Italy and Spain. Our results show that hospital capacity is crucial in reducing the deaths of infected people. It can also indirectly reduce contagion by removing infected people from their home surroundings to hospitals. A smaller supply of hospital beds leads to higher mortality rates that induce governments to take more stringent closure measures that have greater economic costs. Higher mortality could also affect consumer confidence, bring about panic-driven decisions that also affect the economy adversely.

Our analysis has a clear policy implication – to increase hospital capacity. Given our findings that the disease affects more wealthy economies, it seems that these economies can afford the cost of increasing the supply. Of course, the economic costs of hospital beds' shortages are more significant for wealthier economies.

An interesting parallel between COVID-19 and "reversal of fortune" (Acemoglu et al. (2002)) can be drawn. In that seminal paper, more advanced and urbanized economies in 1500 were more prone to deaths from Malaria and Yellow Fever. It seems that COVID-19 similarily affects the more advanced economies. In the historical setting, settler mortality led to the adoption of inferior institutions that did not uphold the rule of law and offered weaker protection of property rights. Inferior institutions led to slower rates of economic growth that persist to this day in many of the affected areas. Some policy reactions to COVID-19, such as sending the military to enforce lockdown in Italy and more tracking and monitoring in more authoritarian regimes, may have similar consequences as in the historical 'settler mortality' environment– to weaken the institutions that contributed to economic growth.

While the pandemic could be short-lived, institutional responses to it could be long-lived. Investment in medical capacity becomes, therefore, even more crucial. Increasing hospital capacity, availability of testing, and protective equipment does not only save lives but may also save us from long-term consequences of taking measures that affect institutional quality. In the likely event of a second or even third wave of the pandemic, countries in need of medical capacity should start doing so with no delay.

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Appendix

Data:

Countries (*countries* dropped from the final sample because of missing data in *italics*):

Albania, Argentina, *Armenia*, Australia, Austria, *Azerbaijan*, Barbados, *Belarus*, Belgium, Belize, *Bosnia and Herzegovina*, Brazil, Bulgaria, Canada, Chile, Colombia, Costa Rica, Croatia, *Cuba*, *Cyprus*, Czech Republic, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, *Estonia*, Finland, France, *Georgia*, Germany, Greece, Guatemala, *Guyana*, *Haiti*, Honduras, *Hong Kong SAR*, Hungary, Iceland, Iran (Islamic Rep of), Iraq, Ireland, Israel, Italy, *Jamaica*, Japan, Kazakhstan, *Kuwait*, *Kyrgyzstan*, *Latvia*, *Lithuania*, *Luxembourg*, Mexico, *Montenegro*, *Morocco*, Netherlands, New Zealand, Norway, Oman, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Republic of Korea, *Republic of Moldova*, Romania, Russian Federation, Saudi Arabia, Serbia, Singapore, Slovakia, Slovenia, *South Africa*, Spain, Sri Lanka, Sweden, Switzerland, *Syrian Arab Republic*, *TFYR Macedonia*, *Thailand*, *Tunisia*, Turkey, Ukraine, United Arab Emirates, United Kingdom, United States, Uruguay, Uzbekistan, *Venezuela (Bolivarian Republic of)*, *West Bank and Gaza*, Zimbabwe.

Sources:

COVID-19 mortality data: COVID-19 Dashboard by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU) (April 14th, 2020)

GDP per capita at PPP, Imports as a percent of GDP, Urbanization rate, Percent of government expenditures of GDP, Hospital beds per 1000 people, Physicians per 1000 people: World Bank database

Population and population 80 years and above: United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects, 2019, Online Edition. Rev. 1.

Mortality from Influenza: WHO Causes of death database.

Institutional quality indices: World Bank Governance Indicators.

Mitigation policies, timing, and stringency: Oxford University's policy response tracker.

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Table Appendix
Dependent variable: Log COVID-19 deaths per capita

	(1)	(2)	(3)	(4)	(5)
Log flu deaths per capita	0.285***	0.107	0.248*	0.297*	0.260
	(0.048)	(0.092)	(0.101)	(0.136)	(0.177)
Perecent above 80	14.541**	8.303	10.579**	34.584***	21.193**
	(5.277)	(6.174)	(3.155)	(5.649)	(6.662)
Percent urban	-1.409*	-1.092	-0.676	0.097	-0.417
	(0.682)	(0.823)	(0.420)	(0.329)	(0.731)
Log GDP per capita	0.754***	0.700*	1.184***	0.968***	0.912
	(0.128)	(0.337)	(0.119)	(0.154)	(0.480)
Imports to GDP	-0.080	0.365	1.922**	1.373*	1.580
		(0.365)	(0.582)	(0.580)	(0.797)
Voice and Accountability		0.694*	0.601***	0.273*	0.311
		(0.337)	(0.127)	(0.133)	(0.280)
Government Effectiveness		-0.117	-0.477	-0.818	-0.882
		(0.623)	(0.558)	(0.607)	(0.682)
Rule of Law		0.593**	1.198***	0.848*	0.707*
		(0.192)	(0.225)	(0.370)	(0.297)
Regulatory Quality		-0.885**	-1.208***	-0.720***	-0.525**
		(0.326)	(0.227)	(0.104)	(0.184)
Political Stability		-0.512	-0.699	-0.331	-0.240
		(0.321)	(0.387)	(0.257)	(0.281)
Control of Corruption		0.354	0.193	0.299	0.379
		(0.377)	(0.236)	(0.290)	(0.304)
G to GDP		1.071	2.308		2.955
		(3.268)	(3.175)		(4.288)
Beds per 1000 squared				-0.017***	-0.022***
				(0.004)	(0.003)
Doctors per 1000					0.073
					(0.092)
Health expen. to GDP					0.037
					(0.136)
Obs.	91	90	66	65	66
R-squared	0.635	0.682	0.730	0.796	0.813
Time Effects	yes	yes	yes	yes	yes
Geo position	yes	yes	yes	yes	yes
COVID-19 Mitigation					yes

Figure Appendix
Added value plot of beds squared per capita on COVID-19 mortality rates
Table Appendix, column (4), excluding Japan