The Impact of Health Expenditure on COVID-19 mortality

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November 26, 2021

ABSTRACT

To be written.

Website: `https://ddtsvetkova.github.io/che-covid19/`

Contents

1 Introduction

In this project we aim to evaluate the degree to which health expenditure prevents deaths in the event of a global emergency such as the COVID-19 pandemic using multiple linear regression model. The relevance of the chosen research question is hard to understate. Indeed, it would be of interest for country-level and international policy-makers alike, as well as for the general public, to know whether spending on health is really worth it.

We use publicly available data in our calculations and control for a range of variables that may affect mortality from COVID-19, including measures of availability and quality of healthcare, public attitudes and behaviors during the pandemic, and several demographic characteristics. Full list of variables with their sources and intuition behind including them in the model is presented in Table A.1 in Appendix A. In short, *mortality* is the dependent variable, and *che* is the explanatory variable of interest. Along with *beds*, *doctors*, *nurses*, and *dghe*, it could indicate greater preparedness for the pandemic, better healthcare system, and as such, lower mortality. Higher measures of a country's citizens' behavior (*beh_.*), attitudes (*fob_.*), and government trust could also mean lower mortality from COVID-19, unlike higher shares of urban population (*urban*) and population over 65 (*pop65*), which might lead to increased mortality rates. Complete cases are available for 96 countries; the data are as recent as possible. Admittedly, there are still variables which could be further included in the model, but for which we were unable to find adequate data, for example, availability of training in medical emergency for medical personnel, quality of ambulance services, etc.

One concern would be inadvertently replicating existing research in both research question and methodology. To the best of our knowledge, there is no such issue with our current specifications. Khan et al., 2020,[5] despite an overlap in some (but not all) of the data, use negative binomial regression and put more of an emphasis on healthcare capacity. Oshunibi et al., 2021[6] use both linear and exponential models and analyze the impact of current health expenditure on the reproduction number R0 of COVID-19 instead of mortality rate. Kapitsinis, 2020[8] uses multiple linear regression but limits his sample to the regions of nine EU countries. Elola-Somoza et al., 2021[7] take into account only Spain and Europe and calculate only Pearson's correlation coefficient.

2 Exploratory data analysis

Now we turn to discussing the data collected in more detail. First, we describe data processing along with the features of the data themselves. Then, we look at how well this data can answer our research question.

2.1 Data

The data used in this project come from their respective sources (see Table A.1). Due to these sources being under the jurisdiction of separate entities, there was some mismatch in the country names and/or the list of countries available in different sources. When at all possible, the retrieved datasets were merged by three-letter country codes, otherwise the inconsistencies in country names were adjusted manually before merging. As noted also in Table A.1, the years selected were generally the latest available, with several notable conditions to their selection: (1) that the features of health systems were taken to be before the pandemic, even if more recent data were available (the reason being our focus on the pandemic preparedness rather than the pandemic response); (2) that several variables (e.g. *nurses*) consist of the latest observations for their respective countries (not necessarily of the same year), in the interest of maximizing the list of countries for which such information was obtainable.

Then, only complete observations were selected, and only those for which there were no less than 20 respondents in the Global Behaviors and Perceptions survey[2] (the prior aggregation of the data of this survey is detailed in Table A.1). The resulting dataset contains data on 60 countries.

2.2 Statistical Analysis

In order to make sense of possible outliers due to errors in variables one may look at descriptive statistics presented in Table A.2. For example, one can observe that domestic general government health expenditure (*dghe*) on average comprises more than half of current health expenditure; 52% of countries available procure medical devices at the national level (*procur*); the scores of the residents' behavior and attitudes are usually very high (possibly due to the respondents' exaggeration, which is not, however, the subject of this study), unlike the scores detailing the evaluation of government's response, etc. Generally, all variables are within their expected ranges.

Turning to the only categorical variable in our analysis *region*, it is easy to see that while only African region is absent from the analysis, there are very few observations in three of the remaining regions (Table A.3, Figures A.1-A.2). It is logical to aggregate them into *Other* (Table A.3). Still, the distribution of *mortality* varies depending on the category, as is evident from Figure A.2. By contrast, the medians of *mortality* distributions depending on the two values of the only binary variable *procur* seem close enough, though variances differ (Figure A.3).

The correlogram (Figure A.4) might well prove useful when trying to avoid the omitted variable bias during model specification. Extra attention should be paid to the first two rows of the matrix, which describe the variables that correlate with *mortality*, the dependent variable, and *che*, the variable of interest. As we face the trade-off between bias and variance of the coefficient of interest, we will likely include only some of the variables in our model, so having solid reasons to do so is a good thing. Another feature of note is a correlation of -1 between domestic private and government health expenditure (despite the supposed presence of external expenditures in current health spendings).

The scatterplots of all other variables against *mortality* (Figure A.5) paint an alarming picture in the sense that there is a very nebulous observable relationship, if at all. After deep contemplation, we presumed that the reason for this unobservability of linear, let alone nonlinear, relationship was the noise attributed to the small number of observations in our dataset (n=60). The only remedy for this is returning the data to the drawing board and reconstructing the dataset from scratch, trying to wrangle out more observations in the process.

It is important to keep in mind that while various sources provide similar lists of countries, the number of observations available varies. The cause of shrinking number of complete observations, therefore, is twofold: at least one of the 26 variables not having data for a country (causing the country to be omitted), and our selection of countries for which there were no less than 20 respondents in the Global Behaviors and Perceptions survey.[2] While the latter we believe to be reasonable, the former we can inspect closer, as we have plenty of variables. As a result of such an inspection, the variables causing the most "shrinking", namely *beds*, *tobacco*, and *procur* were got rid of, which increased the sample by more than 50% (n=96). At this point, the number of observations is greater than in Khan et al., 2020,[5] for example (they study 86 countries), which we deemed satisfactory.

We will now provide a short overview of the exploratory data analysis we repeated for the new sample. Judging by the descriptive statistics (Table A.4), all variables are again within their expected ranges. There are a few improvements in the new dataset, however: (1) there are now data on Africa available, completing the set of the WHO Regions (Table A.5, Figures A.6-A.7); (2) the correlogram yields more useful correlations (Figure A.8); as expected, there exists only imperfect multicollinearity between *dphe* and *dghe*; (3) the conclusions about the relationship between *mortality* and the explanatory variables, despite likely contradicting our expectations in some cases (Figures A.9-A.11), are expected to hold up better due to the asymptotic nature of various hypothesis tests. We plan to use the updated dataset from this point onwards.

3 Model Estimation

We will use multiple specifications in order to estimate the expected effect of a (hypothetical) change in current health expenditure (measured as a percentage of a country's GDP in 2018) on mortality from COVID-19 (measured as cumulative total per 100,000 population) in a country, holding all else constant. As there are numerous variables that potentially affect mortality and are correlated with the level of current health expenditure, it is necessary to include such control variables in the model to avoid omitted variable bias. For this reason our base specification includes *che* as well as the 6 control variables:

$$\begin{aligned} mortality = \beta_0 + \beta_1 \cdot che + \beta_2 \cdot pop65 + \beta_3 \cdot urban + \beta_4 \cdot doctors \\ + \beta_5 \cdot nurses + \beta_6 \cdot dghe + \beta_7 \cdot popdens + u \end{aligned}$$

The descriptions of the variables included can be found in Table A.1. The control variables are those which both economic intuition (occasionally shared by authors of the articles considered in Introduction) and significant correlation coefficients observed in data (Figure A.8) suggest as remedies to omitted variable bias.

We must also construct specifications which take into account regional variation as well as behavioral variables from the Global Behaviors and Perceptions survey,[2] some of which are clearly correlated with current health expenditure. Finally, nonlinear effects are always worth considering. It could be noted at the outset that both *mortality* and *che* (as well as several other variables measured as percentages) are already measured in relative terms; therefore, it makes no sense to take logarithms of them.

Table 1: OLS Regression results (n=96)

	Dependent variable:				
	mortality				
	(1)	(2)	(3)	(4)	(5)
che	12.060^{***}	6.468	0.623	-4.451	-19.426^{**}
	(2.992)	(4.319)	(6.196)	(7.279)	(9.694)
pop65		2.919	4.255	6.052^{*}	8.243^{**}
		(2.525)	(2.977)	(3.318)	(3.352)
urban		0.537	0.019	0.424	-0.346
		(0.755)	(0.683)	(0.738)	(0.761)
doctors		0.979	0.167	0.383	0.568
		(0.966)	(0.851)	(0.801)	(0.678)
nurses		-0.622^{**}	-0.415	-0.142	0.283
		(0.291)	(0.266)	(0.269)	(0.233)
dghe		0.377	0.196	-0.474	-0.351
		(0.602)	(0.527)	(0.601)	(0.547)
popdens		-0.018^{**}	-0.004	-0.008	-0.002
		(0.008)	(0.006)	(0.007)	(0.005)
region (base: Africa)					
Americas			138.996^{***}	109.000^{***}	69.798^{**}
			(41.076)	(39.809)	(31.886)
Eastern Mediterranean			37.900	-16.688	-30.269
			(32.463)	(40.335)	(26.359)
Europe			77.383^{**}	42.148	-11.910
			(37.860)	(43.650)	(42.038)
South-East Asia			-2.281	-35.179	-58.488
			(25.909)	(37.191)	(39.326)
Western Pacific			-36.447	-57.323	-87.725^{**}
			(35.140)	(38.304)	(35.681)

beh_stayhome				3.339*	3.769**
				(1.792)	(1.858)
beh_socgathering				$-$4.828**	$-$4.392**
				(2.184)	(2.232)
beh_distance				1.515	1.729
				(1.080)	(1.244)
beh_tellsymp				1.267	0.057
				(1.609)	(1.549)
beh_handwash				$-$4.285*	$-$4.426*
				(2.389)	(2.458)
fob_curfew				70.427	74.182
				(73.735)	(58.388)
incomelvl (base: LIC)					
LMC					$-$141.410**
					(58.606)
UMC					$-$73.648
					(69.091)
HIC					$-$40.095
					(77.346)
che × incomelvlLMC					25.838**
					(12.279)
che × incomelvlUMC					23.690**
					(11.772)
che × incomelvlHIC					8.988
					(9.929)
Observations	96	96	96	96	96

Note: *p<0.1; **p<0.05; ***p<0.01
Robust standard errors in parentheses

4 Results and Discussion

4.1 Multiple regression results

Table 1 summarises the results of OLS regressions of mortality on various sets of regressors, of which *che* is the regressor of interest. All the other regressors are controls used to minimize potential bias in the OLS estimator for the expected effect of current health expenditure before the pandemic on mortality, *ceteris paribus*. As such, the coefficients on control variables' being significantly different from zero is not our main concern. The effect of adding more (relevant) control variables on the value and significance of the coefficient on *che*, by contrast, interests us very much.

Consider regression (1). The estimated effect of *che* on mortality is, unexpectedly, positive and statistically significant at the 1% level. Recall that our intuition suggested that higher share of current health expenditure in GDP, translating into better quality of health systems, would in fact reduce(!) future mortality from COVID-19. Adding the controls included in our base specification (regression (2)), however, cuts that effect almost in half, rendering it insignificantly different from zero. Controlling for regional differences in current health expenditure (regression (3)) further reduces the absolute value of the coefficient of interest, though it remains positive. Regression (4), using behavioral variables that highly correlate with *che* and *mortality* as controls, shows a change in the sign of the coefficient on *che* to the one expected. This negative effect of current health expenditure on expected mortality, all else being equal, is still insignificantly different from zero.

There is a case to be made for the coefficient β_1 on *che* being overestimated. (It is overestimated to a lesser extent with the introduction of extra control variables, yet some overestimation may persist.) Suppose that the *mortality* numbers are affected by the quality of reporting cases and deaths, which developed countries might be able to track more accurately due to the superior quality of institutions. Suppose also that developed countries have higher shares of current health expenditure in GDP. If this is so, β_1 will be positively correlated with the error term, and hence upward biased. This is similar to the widely known models regressing wage on education (with unobserved ability).

One solution would be to use instrumental variables regression, but in our case, the quality of a country's institutions and/or the country's development is at least somewhat observable and can be approximated. The broad categories of *region* is a possible, yet imprecise, measure of development: e.g. the countries of Europe are known to vary in their levels of development. Instead, we use the World Bank country classification by income level as the simplest proxy for development (*incomelvl*). Table A.1 has been updated with the description of this new control variable; Table A.6 and Figures A.12-A.13 provide some exploratory data analysis, which, incidentally, supports the hypothesis that β_1 could be overestimated (see above).

Regression (5) incorporates a nonlinear effect into the model, namely the interaction of *che* and *incomelvl*, in addition to the linear effect of *incomelvl*. The resulting equation indicates that increasing the share of current health expenditures in GDP by 1 percentage point would reduce the expected mortality per 100,000 population by 19.426 in low income countries and by 10.438 in high income countries, all things being equal. By contrast, the absolute values of this effect in lower- and upper middle income countries are 6.412 and 4.264, respectively. To determine the significance levels, three additional Wald tests were carried out to test the hypothesis: "Holding all else constant, the effect of increasing the share of current health expenditures in GDP by 1 percentage point on mortality from COVID-19 in [insert income level] countries is significantly different from zero." (note that for low income countries, the coefficient is equal to the coefficient on *che*, so its significance can be inferred directly from Table 1). The results of the tests are summarized in Table 2.

Table 2: Hypothesis Tests Results

Income level	H_0	test	p-value	Conclusion
LIC	$che = 0$	z-test (two-sided)	0.0451	The effect is statistically significant at 5% level.
LMC	$che + che \times incomelvlLMC = 0$	Wald test	0.6143	The effect is statistically insignificantly different from zero.
UMC	$che + che \times incomelvlUMC = 0$	Wald test	0.7376	The effect is statistically insignificantly different from zero.
HIC	$che + che \times incomelvlHIC = 0$	Wald test	0.1064	The effect is statistically insignificantly different from zero, although close to being significant at the 10% level.

We found that greater proportion of health expenditure may reduce mortality in low income countries. This is a step up from our results in regressions (1)-(4), yet this verdict is a tentative one due to the few low income countries included in the sample. The effect of current health expenditure on expected mortality in middle- and high income countries, all else being equal, remains insignificant.

4.2 Discussion of internal and external validity

There is limited opportunity to analyze the **external validity** of this study due to the nature of the objects studied (countries of the world). Two things can be done, however. First, we can replicate regressions (1)-(3) on the larger sample of 160 countries. Regressions (4)-(5) are impossible to replicate, as they use behavioral variables as controls, which in turn rely on the number of participants of the Global Behaviors and Perceptions survey[2] in each country being no smaller than 20. Nevertheless, if the results of regressions (1)-(3) for the larger sample are similar enough to the results presented in Table 1, we could theorize that the results of (4)-(5) would also be similar, were the data on behavioral variables available. Indeed, Table 3 demonstrates a similar pattern of estimates of the coefficient on *che* for a wider "population" of countries. This significantly boosts our confidence in the external validity of our study.

Second, it is possible to compare our results to those obtained by Khan et al., 2020,[5] whose paper is plausibly the closest in terms of themes and variables discussed to this study. The authors report a surprising finding of a significant positive relationship between national expenditure on healthcare and COVID-19 fatalities. This finding resembles the result of regression (1); we found the relationship to be positive in the regressions (2) and (3) as well. It is possible that the authors did not adequately address the upward bias in the coefficient on current health expenditure, as it was not their main variable of interest. All in all, this may be a further indirect argument in favour of external validity.

Table 3: OLS Regression results (n=160)

	Dependent variable:		
	mortality		
	(1)	(2)	(3)
che	10.475***	2.538	0.985
	(2.642)	(2.207)	(2.085)
pop65		5.677***	4.398**
		(1.989)	(1.798)
urban		0.771*	0.466
		(0.425)	(0.405)
doctors		0.727	−0.237
		(0.751)	(0.737)
nurses		−0.487*	−0.396*
		(0.252)	(0.239)
dghe		0.321	0.464
		(0.304)	(0.306)
popdens		−0.019***	−0.008*
		(0.005)	(0.005)
region (base: Africa)			
Americas			97.138***
			(26.916)
Eastern Mediterranean			30.730**
			(15.455)
Europe			77.697***
			(26.378)
South-East Asia			7.412
			(15.139)
Western Pacific			−26.567*
			(14.525)

Observations	160	160	160
Note:			*p<0.1; **p<0.05; ***p<0.01 Robust standard errors in parentheses

Turning to the **internal validity**, we will discuss each possible threat in turn.

1. **Omitted variable bias.** The multiple regressions discussed above control for a wide range of country-level characteristics reflecting the availability and quality of healthcare, public attitudes and behaviors during the pandemic, geographical, demographic and economic influences. Admittedly, there still could be some variables omitted, e.g. availability of training in medical emergency for medical personnel, quality of ambulance services, etc., in which case some omitted variable bias would remain. There are two ways in which this study can be built upon in the future: first, a more sensitive measure of a country's development (and the quality of its records) may be applied; second, something may be done in the interest of further eliminating endogeneity in the variable of interest *che*: for instance, pandemic response by the government (e.g. "*che* post-pandemic") may be correlated with *che* and affect mortality (and even suffer from simultaneous causality). The last reasoning, however, puts us in the territory of dealing with time series and is beyond the scope of this study.

2. **Misspecification of the functional form.** There is no evidence of a glaring misspecification of the functional form that we can think of (especially considering the already relative nature of many variables included in the model). Further functional form analysis could conceivably be carried out in the future.

3. **Errors in variables.** It is rather likely that the quality of reporting COVID-19 cases and fatalities varies across countries. One could hope, however, that there is less ambiguity in calculating the number of fatalities than in determining the number of cases, which is why *mortality* was chosen as the dependent variable. Another measurement error could arise in the responses to the Global Behaviors and Perceptions survey[2] if people had opted to not tell the truth.

4. **Sample selection.** We can assuredly say that there was no biased sample selection on our part, as we strived to include as many countries as possible (the sample was constrained mostly by the availability of data). The most obvious source of sample selection bias would be the sampling methodology of the Global Behaviors and Perceptions survey:[2] people who willingly participated in the online survey could have been more concerned

about COVID-19 or have had better access to the Internet than the general population. Sample selection could also arise if the data missing from other sources were missing systemically for some countries due to conflict, lack of statistical capacity, or other nonrandom reasons. As such, we must advise caution when generalizing our findings.

5. **Simultaneous causality.** In principle, there should be little to no simultaneous causality, for while the data on *mortality* are rather recent, the data on most other variables (and specifically *che*) were collected before the pandemic even started.

6. **Heteroskedasticity and correlation of the error term across observations.** All the errors in this study are heteroskedasticity robust; the sampling, however, was not random (the data were collected for all countries, not counting other sampling issues discussed above), so there might be some degree of correlation of the regression errors across observations, especially for adjacent countries, despite our controlling for geographical influences via *region*.

5 Conclusion

This paper adds to the (rather sparse at the time of writing) body of literature studying the role of increased national spending on health in alleviating some of the adverse outcomes of the COVID-19 pandemic. It demonstrates that an increase in the share of current health expenditures in GDP by 1 percentage point would have decreased mortality per 100,000 population in a low income country by 19.426 in the event of a global emergency such as the COVID-19 pandemic, *ceteris paribus*. This effect for middle- and high income countries is not as significant.

The answer to our research question and the policy implication combined, therefore, is that spending on health can save lives. A cautious reader, however, might take this result with a grain of salt for reasons outlined in subsection 4.2.

6 Teamwork evaluation

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Appendix A

Table A.1: Variables and Definitions

Variable	Definition	Type	Intuition	Source
mortality	Deaths - cumulative total per 100,000 population (Retrieved 13.10.2021)	continuous	Dependent variable.	WHO Coronavirus (COVID-19) Dashboard
che	Level of current health expenditure expressed as a percentage of GDP. (2018). Estimates of current health expenditures include healthcare goods and services consumed during each year. This indicator does not include capital health expenditures such as buildings, machinery, IT and stocks of vaccines for emergency or outbreaks.	continuous (between 0 and 100)	Variable of interest. As it is the source of financing for the country's health system, higher health expenditure could mean better health system, greater preparedness for the pandemic, and consequently, lower mortality.	World Bank Open Data
beds	Hospital beds (per 1,000 people). (2017)	continuous	More beds could mean greater preparedness for the pandemic (and lower mortality). It is likely both to be correlated with che and have an effect on mortality.	
pop65	Population ages 65 and above (% of total population). (2019). Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship.	continuous (between 0 and 100)	As elderly people face a greater risk of severe COVID-19 cases and comorbidities,[9] greater proportion of people over 65 could mean greater mortality rates.	

Variable	Definition	Type	Intuition	Source
popdens	Population density (people per sq. km of land area). (2019).	continuous	Higher population density could mean greater risk of contagion, more COVID-19 cases and greater mortality.	
urban	Urban population (% of total population). (2019). Urban population refers to people living in urban areas as defined by national statistical offices. The data are collected and smoothed by United Nations Population Division.	continuous (between 0 and 100)	People in cities may face higher risk of contagion (and higher mortality) due to population density; however, people in rural areas are more vulnerable in terms of access to timely healthcare.	
dphe	Domestic private health expenditure (% of current health expenditure). (2018). Domestic private sources include funds from households, corporations and non-profit organizations. Such expenditures can be either prepaid to voluntary health insurance or paid directly to healthcare providers.	continuous (between 0 and 100)	Private health expenditure making up a relatively large share of current expenditure (and government health expenditure making up a small share) could mean that a lot of health expenses households have to cover out-of pocket; i.e. not many health services are guaranteed by the government. That is, there are barriers to health care access, and preparedness for the pandemic is relatively low.	

Variable	Definition	Type	Intuition	Source
dghe	Domestic general government health expenditure (% of current health expenditure) (2018).	continuous (between 0 and 100)	See above. The third category in current health expenditure is external expenditure.	
tobacco	Prevalence of current tobacco use (% of adults) (2018).	continuous (between 0 and 100)	As tobacco is a well-recognized cause of severe COVID-19 cases,[10] higher prevalence of tobacco use could mean higher mortality.	
procur	Procurement of medical devices carried out at the national level (Latest year).	binary (Yes=1, No=0)	A measure of quality of the national health system. Probably countries that procure medical devices at the national level are better prepared for the pandemic.	The Global Health Observatory Indicators
doctors	Medical doctors (per 10,000) (Latest year).	continuous	A measure of health system capacity. More doctors could mean more adequate care and less fatalities.	
nurses	Nursing and midwifery personnel (per 10,000) (Latest year).	continuous	A measure of health system capacity. More nurses could mean more adequate care and less fatalities.	

Variable	Definition	Type	Intuition	Source
Global Behaviors and Perceptions in the COVID-19 Pandemic				
beh_ stayhome	Question asked to individuals in spring of 2020 was: "To what extent do the following statements describe your behavior for the past week? [0 = Does not apply at all; 100 = Applies very much] I stayed at home. We took the average of responses by country and selected countries with no less than 20 respondents.	continuous (between 0 and 100)	The success of emergency measures taken depends on the nation's attitudes and behaviors; the better people followed recommendations, the less people could have died from COVID-19.	Global Behaviors and Perceptions in the COVID-19 Pandemic
beh_ socgathering	...I did not attend social gatherings.	continuous (between 0 and 100)		
beh_ distance	...I kept a distance of at least two meters to other people.	continuous (between 0 and 100)		
beh_ tellsymp	...If I had exhibited symptoms of sickness, I would have immediately informed the people around me.	continuous (between 0 and 100)		
beh_ handwash	...I washed my hands more frequently than the month before	continuous (between 0 and 100)		

Variable	Definition	Type	Intuition	Source
fob_social	"What do you think: should people in your country cancel their participation at social gatherings because of the coronavirus right now? [No = 0; Yes = 1]" We took the average of responses by country (getting the percentage of people who said Yes) and selected countries with no less than 20 respondents.	continuous (between 0 and 1)	Another way to look not on people's actions, but on their beliefs on whether recommendations are reasonable or not.	
fob_handshake	"What do you think: should people in your country not shake other people's hands because of the coronavirus right now? [No = 0; Yes = 1]"	continuous (between 0 and 1)		
fob_stores	"What do you think: should all shops in your country other than particularly important ones, such as supermarkets, pharmacies, post offices, and gas stations, be closed because of the coronavirus right now? [No = 0; Yes = 1]"	continuous (between 0 and 1)		
fob_curfew	"What do you think: should there be a general curfew in your country (with the exception of grocery shopping, necessary family trips, and the commute to work) because of the coronavirus right now? [No = 0; Yes = 1]"	continuous (between 0 and 1)		

Variable	Definition	Type	Intuition	Source
perceived reaction_ d	"Do you think the reaction of your country's government to the current coronavirus outbreak is appropriate, too extreme, or not sufficient? [5-point scale; 1 = The reaction is much too extreme; 2 = The reaction is somewhat too extreme; 3 = The reaction is appropriate; 4 = The reaction is somewhat insufficient; 5 = The reaction is not at all sufficient]" We converted the categorical variable into binary (4,5 = 1, 1,2,3 = 0) and aggregated as before.	continuous (between 0 and 1)	Stronger civil responsibility and trust in the government's actions of the populace when emergency measures are taken could mean less deaths from COVID-19.	
govtrust_ d	How much do you trust your country's government to take care of its citizens? [5-point scale; 1 = Strongly distrust; 2 = Somewhat distrust; 3 = Neither trust nordistrust; 4 = Somewhat trust; 5 = Strongly trust] Aggregated as above.	continuous (between 0 and 1)		
govfact_ d	How factually truthful do you think your country's government has been about the coronavirus outbreak? [5-point scale; 1 = Very untruthful; 2 = Somewhat untruthful; 3 = Neither truthful nor untruthful; 4 = Somewhat truthful; 5 = Very truthful]	continuous (between 0 and 1)		

Variable	Definition	Type	Intuition	Source
perceived effective ness_d	What do you think: How effective are social distancing measures (e.g., through a general curfew) to slow down the spread of the coronavirus? [5-point scale; 1 = Not at all effective; 2 = Not effective; 3 = Neither effective nor ineffective; 4 = Effective; 5 = Very effective]	continuous (between 0 and 1)		
region	WHO Region (Americas, Europe, Western Pacific, Eastern Mediterranean, South-East Asia, Africa)	categorical	Extra control variable to account for geographical influences.	WHO Coronavirus (COVID-19) Dashboard
population	Total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship. (2019). The values shown are midyear estimates.	continuous	Extra control variable to help with the relative data described above (percentages, etc.)	World Bank Open Data
incomelvl	Economies are divided among income groups according to 2019 gross national income (GNI) per capita, calculated using the World Bank Atlas method. (2019). The groups are: low income (LIC), $\leq$ \$1,035; lower middle income (LMC), \$1,036 - 4,045; upper middle income (UMC), \$4,046 - 12,535; and high income (HIC), $\geq$ \$12,536.	categorical	Extra control variable to approximate the countries' level of development.	World Bank DataBank[11]

Table A.2: Descriptive Statistics (n=60)

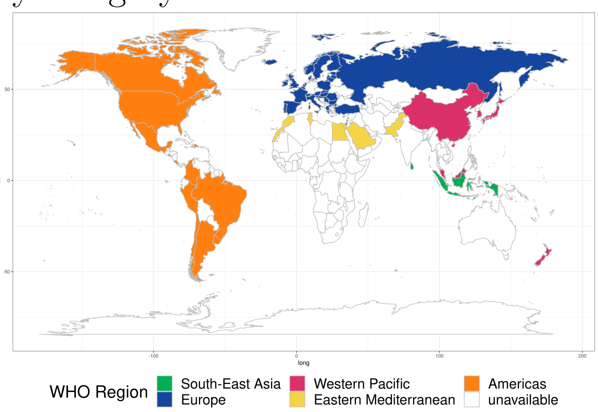
variable	**mean**	**sd**	**min**	**Q1**	**median**	**Q3**	**max**
mortality	134.62	106.71	0.39	50.64	125.66	204.73	605.68
che	7.62	2.58	2.50	5.69	7.54	9.26	16.89
beds	3.87	2.51	0.63	2.20	3.12	5.13	13.05
pop65	14.78	5.96	1.52	9.13	15.59	19.76	28.00
popdens	296.44	1043.79	3.58	34.63	99.85	218.33	8044.53
urban	75.39	16.11	18.59	66.55	79.73	87.03	100.00
dphe	35.83	14.43	13.67	25.91	34.44	48.15	70.60
dghe	63.96	14.56	28.73	51.75	64.81	74.09	85.32
tobacco	24.25	8.77	7.90	18.32	23.50	28.88	44.70
procur	0.52	0.50	0.00	0.00	1.00	1.00	1.00
doctors	33.81	16.05	4.65	23.62	32.37	43.60	80.13
nurses	69.25	50.03	2.80	26.46	61.65	102.38	216.70
beh_stayhome	83.46	7.33	58.68	81.24	84.83	87.91	94.41
beh_socgathering	92.33	4.99	75.30	90.95	94.35	95.56	99.00
beh_distance	78.76	9.12	47.87	74.07	81.32	85.27	90.56
beh_tellsymp	92.85	4.28	78.45	92.82	94.26	95.09	97.72
beh_handwash	91.69	2.83	83.72	90.47	92.06	93.75	96.57
fob_social	0.98	0.04	0.79	0.98	0.99	0.99	1.00
fob_handshake	0.97	0.04	0.74	0.96	0.98	0.99	1.00
fob_stores	0.81	0.17	0.20	0.77	0.87	0.91	0.97
fob_curfew	0.71	0.19	0.16	0.59	0.74	0.88	0.99
perceivedreaction_d	0.40	0.23	0.00	0.23	0.36	0.56	0.91
govtrust_d	0.57	0.24	0.09	0.38	0.58	0.80	0.96
govfact_d	0.63	0.24	0.09	0.49	0.71	0.82	0.98
perceivedeffectiveness_d	0.89	0.05	0.70	0.85	0.90	0.93	0.97
population (mln.)	64.587	187.688	0.361	5.428	10.730	47.935	1397.715

Table A.3: *region*: № of observations by category

	region	№ of obs.
1	Americas	12
2	Eastern Mediterranean	7
3	Europe	33
4	South-East Asia	2
5	Western Pacific	6

	region	№ of obs.
1	Americas	12
2	Europe	33
3	Other	15

Figure A.1: *region*: Countries available by category



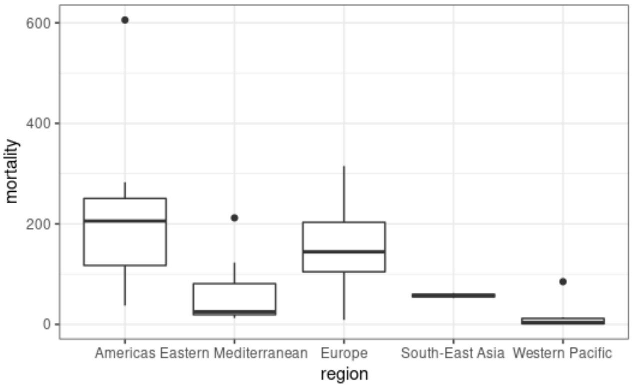


Figure A.2: *mortality* distributions by WHO Region

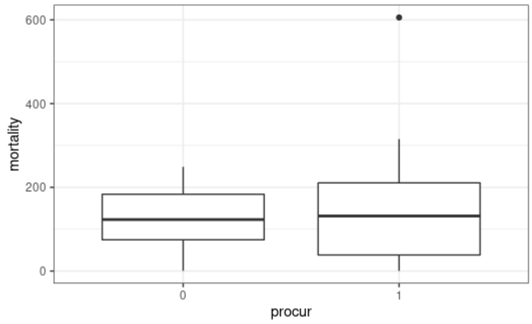


Figure A.3: *mortality* distributions by Procurement of medical devices carried out at the national level (1=Yes, 0=No)

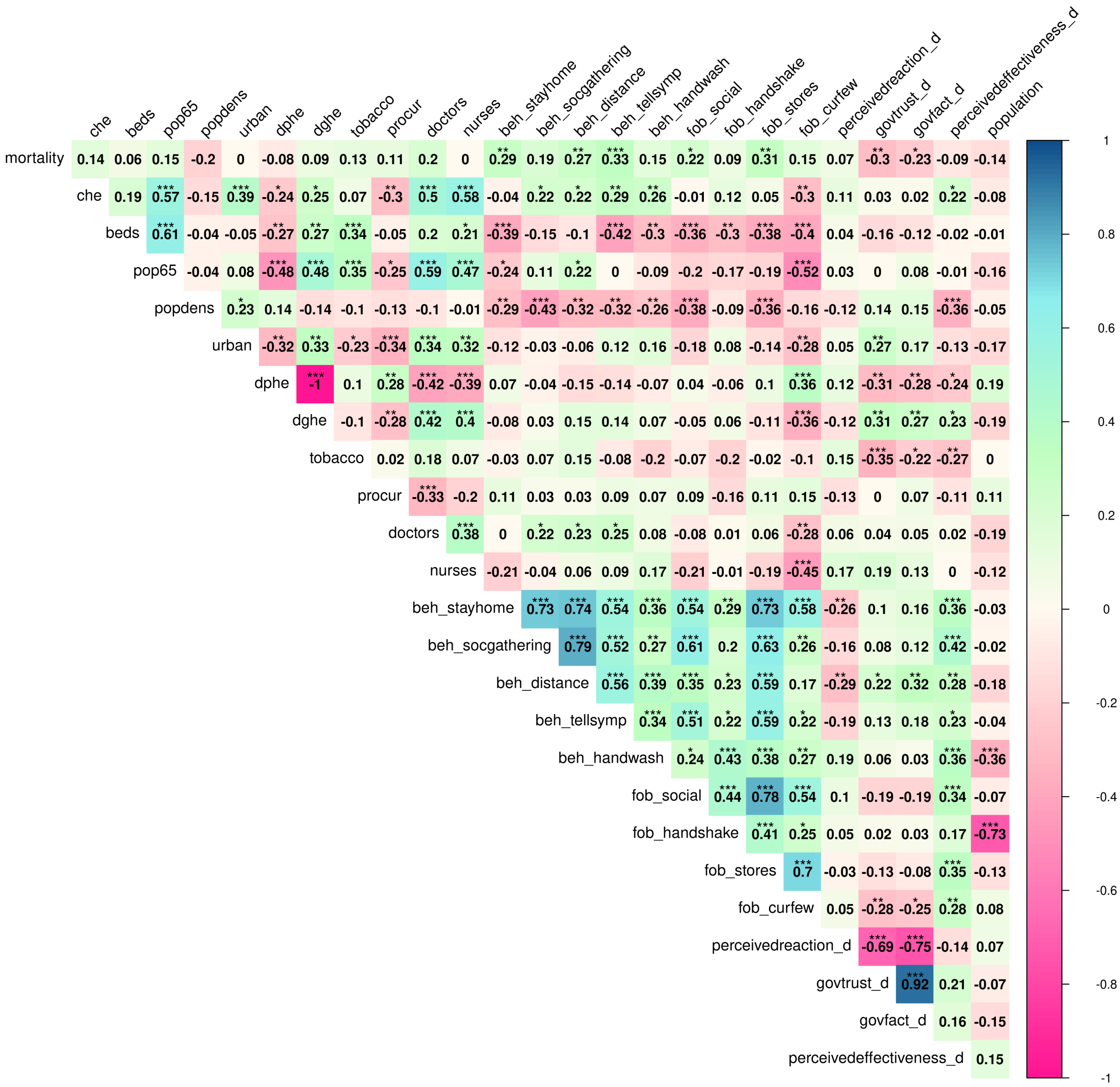


Figure A.4: Correlogram of numeric variables. (*, **, and *** mean that correlation is different from 0 at 0.1, 0.05, and 0.01 levels respectively)

Figure A.5: *mortality* vs each numerical variable

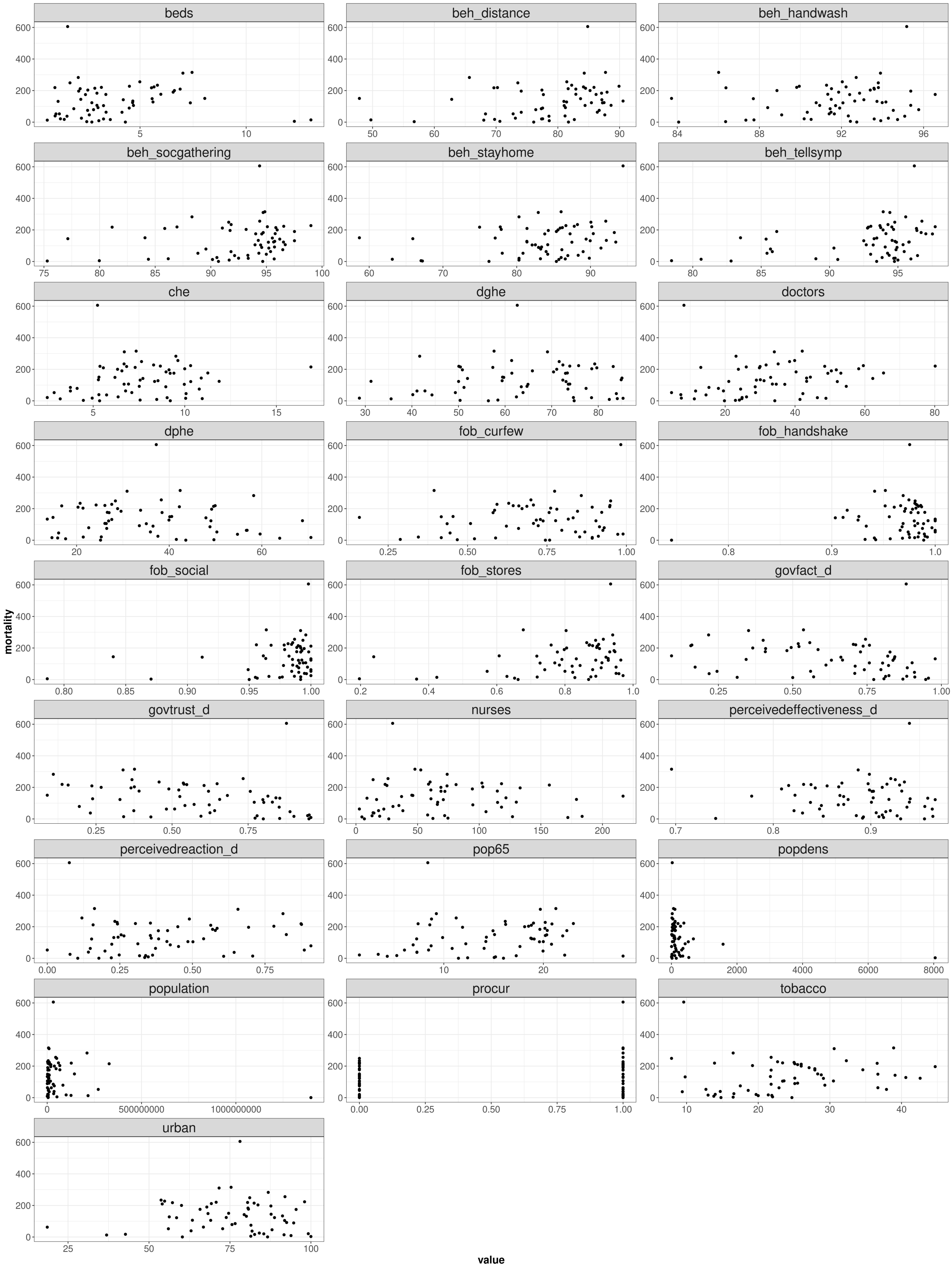


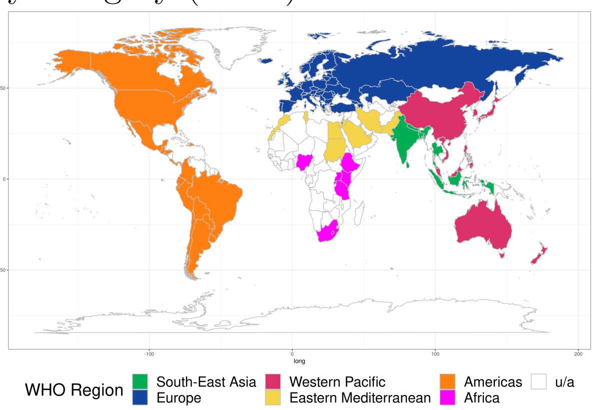
Table A.4: Descriptive Statistics (n=96)

variable	**mean**	**sd**	**min**	**Q1**	**median**	**Q3**	**max**
mortality	118.11	101.07	0.39	30.93	105.14	184.11	605.68
che	7.00	2.52	2.34	5.28	6.88	8.66	16.89
pop65	12.20	6.67	1.16	6.43	12.11	18.75	28.00
popdens	268.42	856.98	3.30	46.36	100.05	220.68	8044.53
urban	68.47	20.49	17.31	57.00	71.19	83.75	100.00
dphe	39.80	16.24	11.96	26.60	39.48	49.72	77.27
dghe	57.86	18.33	14.87	45.25	59.59	73.16	88.04
doctors	27.95	17.93	0.60	12.66	26.29	40.52	80.13
nurses	58.15	46.94	2.80	19.03	51.52	74.27	216.70
beh_stayhome	82.68	8.71	48.36	79.06	84.24	88.50	95.72
beh_socgathering	91.26	5.79	70.30	88.16	93.19	95.55	99.30
beh_distance	76.33	9.91	47.87	69.79	77.60	84.31	92.07
beh_tellsymp	92.31	4.67	78.45	90.60	93.77	95.01	99.29
beh_handwash	91.49	3.29	80.60	90.18	91.97	93.75	97.92
fob_social	0.98	0.03	0.79	0.98	0.99	0.99	1.00
fob_handshake	0.96	0.04	0.66	0.96	0.97	0.98	1.00
fob_stores	0.81	0.14	0.20	0.78	0.86	0.90	0.97
fob_curfew	0.75	0.18	0.16	0.65	0.78	0.89	1.00
perceivedreaction_d	0.40	0.24	0.00	0.21	0.37	0.56	0.95
govtrust_d	0.54	0.25	0.04	0.37	0.52	0.77	0.96
govfact_d	0.60	0.24	0.09	0.40	0.65	0.80	0.98
perceivedeffectiveness_d	0.87	0.07	0.62	0.84	0.89	0.92	1.00
population (mln.)	69.54	201.818	0.361	5.658	12.161	53.932	1397.715

Table A.5: *region*: № of observations by category (n=96)

	region	№ of obs.
1	Africa	7
2	Americas	18
3	Eastern Mediterranean	13
4	Europe	43
5	South-East Asia	6
6	Western Pacific	9

Figure A.6: *region*: Countries available by category (n=96)



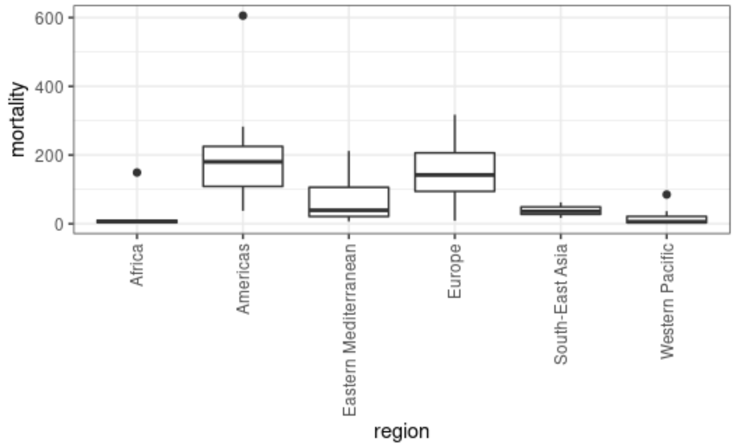


Figure A.7: *mortality* distributions by WHO Region (n=96)

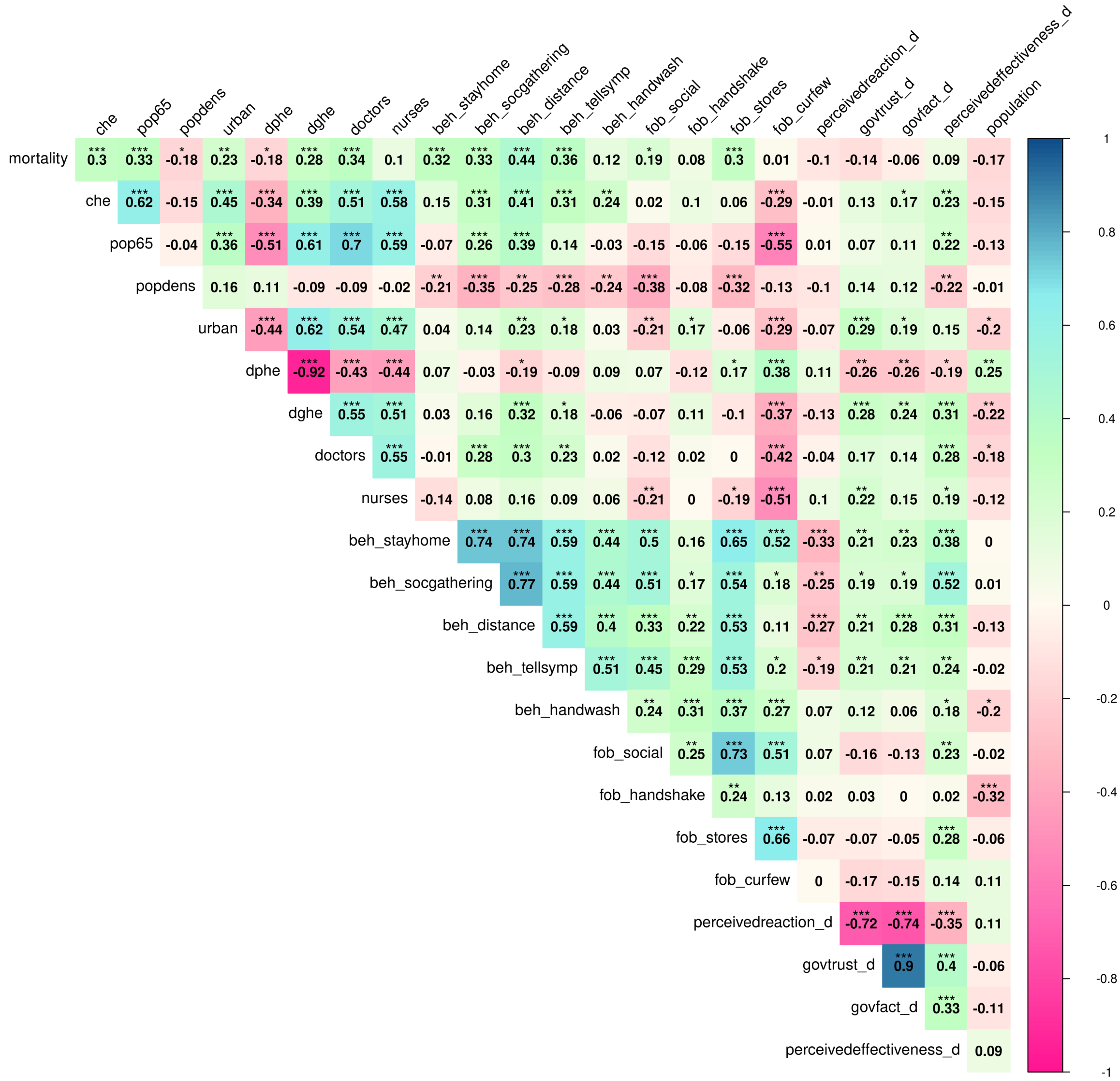
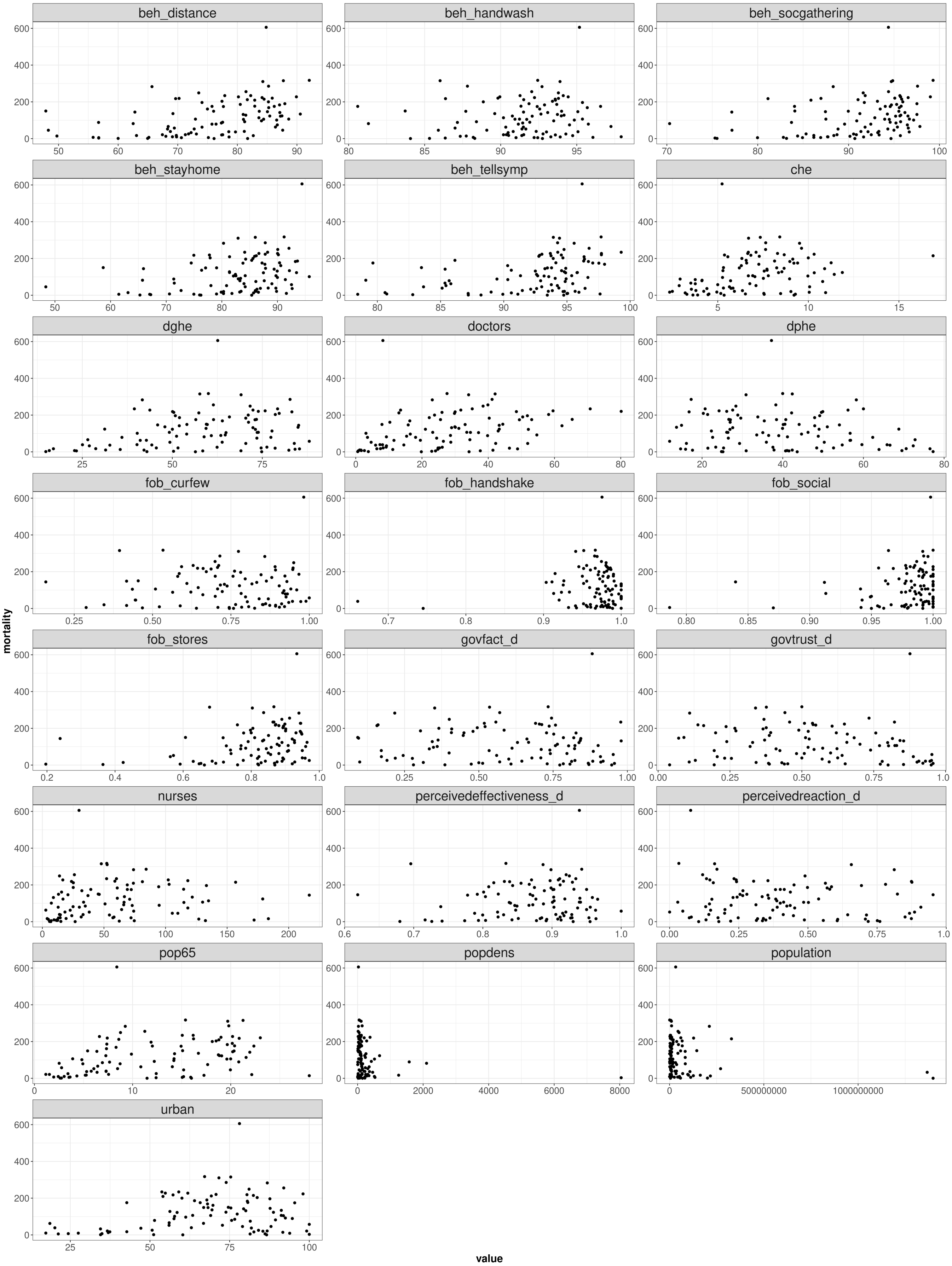


Figure A.8: Correlogram of numeric variables (n=96). (*, **, and *** mean that correlation is different from 0 at 0.1, 0.05, and 0.01 levels respectively)

Figure A.9: *mortality* vs each numerical variable (n=96)



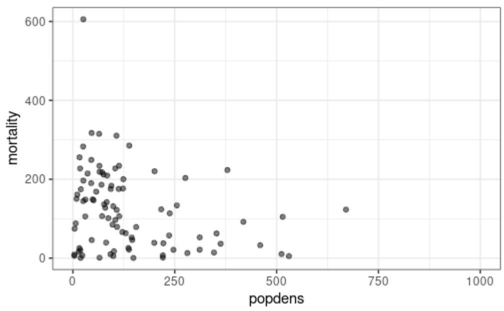


Figure A.10: *mortality* vs. population density (over a limited range of density) (n=96)

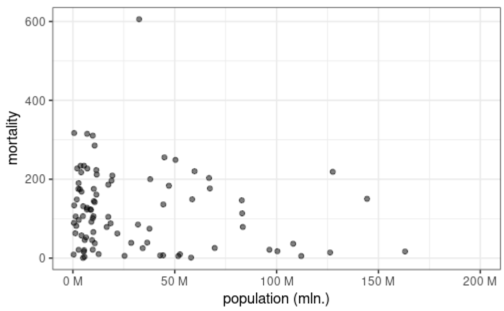


Figure A.11: *mortality* vs. population (over a limited range of population) (n=96)

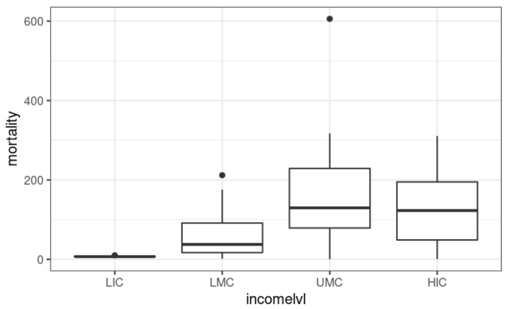


Figure A.12: *mortality* distributions by income level

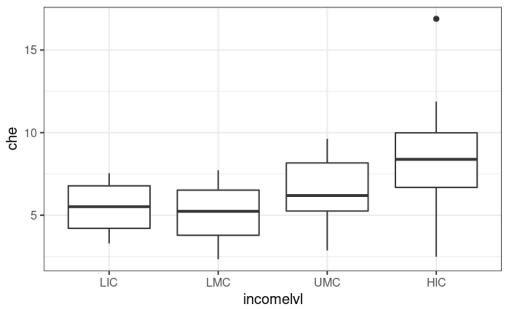


Figure A.13: *che* distributions by income level

Table A.6: *incomelvl*: № of observations by category (n=96)

	incomelvl	№ of obs.
1	LIC	4
2	LMC	18
3	UMC	28
4	HIC	46

Appendix B

Relevant R code is available here: `https://ddtsvetkova.github.io/che-covid19/code.html`