International Journal of Disaster Risk Reduction 82 (2022) 103333

Contents lists available at ScienceDirect

International Journal of Disaster Risk Reduction

journal homepage: www.elsevier.com/locate/ijdrr

Statistical model for factors correlating with COVID-19 deaths

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A R T I C L E I N F O

Keywords:
COVID-19
Deaths
Country features
Containment measures
Linear mixed effect model

A B S T R A C T

Background: The COVID-19 pandemic has caused major disruption in societies globally. Our aim is to understand, what factors were associated with the impact of the pandemic on death rates. This will help countries to better prepare for and respond in future pandemics.
Methods: We modeled with a linear mixed effect model the impact of COVID-19 with the dependent variable "Daily mortality change" (DMC) with country features variables and intervention (containment measurement) data. We tested both country characteristics consisting of demographic, societal, health related, healthcare system specific, environmental and cultural feature as well as COVID-19 specific response in the form of social distancing interventions.
Results: A statistically significant country feature was Geert Hofstede's masculinity, i.e., the extent to which the use of force is endorsed socially, correlating positively with a higher DMC. The effects of different interventions were stronger that those of country features, particularly cancelling public events, controlling international travel and closing workplaces.
Conclusion: Social distancing interventions and the country feature: Geert Hofstede's masculinity dimension had a significant impact on COVID-19 mortality change. However other country features, such as development and population health did not show significance. Thus, the crises responders and scholars could revisit the concept and understanding of preparedness for and response to pandemics.

1. Introduction

The COVID-19 has spread almost everywhere with several millions of confirmed cases [1]. Several non-pharmaceutical interventions are introduced in several countries to slow down the course of the disease and maintain the capacity of healthcare. Understanding the effectiveness of different measures is important so that future pandemics can be fight against with at the lowest possible economic and social cost.

Researchers have published models and analyses for COVID-19 from different perspectives. One approach explores how countries were prepared for crises such as COVID-19 [2–4] or how to design strategies to cope with future pandemics in society [5–7]. Researchers have also explored the side effects of interventions, such as changes in mobility [8] or air pollution [9,10], and compared the first and second waves of COVID-19 in terms of deaths, confirmed cases and hospitalization [11,12]. Furthermore, several researchers have published models and analyses of impact of different factors or interventions on deaths and incidences [8,13–19]. In previous

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https://doi.org/10.1016/j.ijdrr.2022.103333
Received 24 May 2022; Received in revised form 20 September 2022; Accepted 26 September 2022
Available online 29 September 2022

studies, several country specific factors, such as healthcare system specific, environmental and cultural features, as well non-pharmaceutical measures, such as school and workplace closing, public events closing, restrictions on gatherings, stay at home orders, restrictions on internal movement, international travel controls and public info campaigns, are studied as predictive factors for modelling epidemic impact and country differences [8,14–16,20–26]. Many studies have concluded that the interventions and containment measures slow down the pandemic and seem to explain country differences in COVID-19 mortality [8,14–17,25,26]. Furthermore, Sorokowska et al. [22], found that interpersonal distances due to social norms and culture can affect the behaviour of the citizens which can influence the outcome of an epidemic. Similar findings could be detected for the impact of COVID-19 by Oksanen et al. [23] indicating that perceived sociability predicted higher COVID-19 mortality in 25 European countries during the first phase of the pandemic. Erman et al. [24] pointed out that cultural characteristics had previously been overlooked when explaining the impact of epidemics, and seem to play an important role in the outcome of COVID-19.

In this study we combine both country specific features and non-pharmaceutical interventions for modelling daily mortality change. Our aim was to understand, what country specific features and interventions are associated with the impact of the pandemic on death rates. The results of this study strengthen the understanding of behaviour of COVID-19 and support appropriate policy responses to cope with pandemic threats. It is important to understand which country specific features affect on the behaviour of COVID-19 and which non-pharmaceutical interventions are necessary to maintain control, because their large economic and social costs.

2. Materials and methods

We had three model types. The independent variables of the first model were country specific features. Our set of country specific features included demographics, societal, health related, healthcare system related, environmental and cultural factors of 33 countries. The independent variables of the second model were 11 non-pharmaceutical intervention categories. The independent variables of the third model were all individual interventions from different categories (Annex 2). For example, the category variable of school closures contained three individual variables that were “Recommend closing”, “Require closing (only some levels)" and “Require closing (all levels)".

2.1. Sample and data

In total 33 countries were included in the study. In the selected countries the epidemic started in the spring of 2020, and both country features and non-pharmacological intervention data were available from them. All included countries are presented in Table 1.

For the modelling, we utilized three types of data: country features data (cross-sectional), intervention data (time-series) and COVID-19 death data (time-series). The selection of the variables was grounded on previous academic publications on COVID-19 mortality [27,28] and potential risk factors identified in the H1N1 pandemic in 2009 [29,30].

Country features data was combined from several reliable public sources and represents data gathered and published 2017–2019. The majority of the used data came from the World Development Indicators (WDI) databank by the World Bank [31] as well as from the INFORM Epidemic Risk dataset [32].

Intervention data was assembled by The Blavatnik School of Government (OXFORD COVID-19 Government Response Tracker) [33]. The tracker collects information on several policy responses governments have taken, scores the stringency of these measures, and aggregates the scores into a stringency index.

COVID-19 death data was provided by Johns Hopkins University [34]. The death time-series in each country began from the first death and ended August 12, 2020 (Table 1).

2.2. Variables

Annex 1 (Table a) lists all country features variables used in this study. The country features variables are classified in the groups of

Table 1
Countries included in the study. Time-series in each country began from the first death and ended August 12, 2020.

Country	Abbreviation	Time series start/First death	Country	Abbreviation	Time series start/First death
Austria (EU)	AUT	March 12, 2020	Netherlands (EU)	NLD	March 6, 2020
Belgium (EU)	BEL	March 11, 2020	New Zealand	NZL	March 29, 2020
Bulgaria (EU)	BGR	March 11, 2020	Norway	NOR	March 14, 2020
Croatia (EU)	HRV	March 19, 2020	Poland (EU)	POL	March 12, 2020
Czechia (EU)	CZE	March 22, 2020	Portugal (EU)	PRT	March 17, 2020
Denmark (EU)	DNK	March 14, 2020	Romania (EU)	ROU	March 22, 2020
Estonia (EU)	EST	March 25, 2020	Serbia	SRB	March 20, 2020
Finland (EU)	FIN	March 21, 2020	Singapore	SGP	March 21, 2020
France (EU)	FRA	February 15, 2020	Slovenia (EU)	SVN	March 14, 2020
Germany (EU)	DEU	March 9, 2020	South Africa	ZAF	March 27, 2020
Greece (EU)	GRC	March 11, 2020	South Korea	KOR	February 20, 2020
Hungary (EU)	HUN	March 15, 2020	Spain (EU)	ESP	March 3, 2020
Ireland (EU)	IRL	March 11, 2020	Sweden (EU)	SWE	March 11, 2020
Israel	ISR	March 21, 2020	Switzerland	CHE	March 5, 2020
Italy (EU)	ITA	February 21, 2020	Ukraine	UKR	March 13, 2020
Japan	JPN	February 13, 2020	United Kingdom	GBR	March 6, 2020
Luxembourg (EU)	LUX	March 14, 2020			

demographics, societal, health related, healthcare system related, environmental and cultural. As different variables have different measurement scales, we applied Z-score transformation before modelling. Furthermore, Annex 1 (Table b) presents descriptive statistics of the country features variables for the countries of this study.

Annex 2 lists all individual non-pharmaceutical interventions used as predictive variables in this study. The interventions are classified in the groups of schools closing (c1), workplaces closing (c2), cancelling public events (c3), restrictions on gatherings (c4), closing public transport (c5), staying at home (c6), restrictions on internal movement (c7), international travel controls (c8), public info campaigns (h1), testing policy (h2) and contact tracing (h3). All interventions include daily information, e.g., is a particular measure either recommended or required. Closures and containments (c1 – c8) offer both country level and targeted (regional)

Table 2
Country features variable selection for multivariate modelling. Acronyms and data source of variables are reported in Annex 1.

Factor	Estimate	P-value
Hci	−1.46	0.007 **
Pollution	1.36	0.014 *
unemployment	1.35	0.015 *
Gini	1.36	0.015 *
Hdi	−1.34	0.016 *
priv_share	1.29	0.020 *
Diabetes	1.27	0.024 *
Corruption	−1.25	0.025 *
vaccine_dpt	−1.23	0.027 *
gov_eff	−1.20	0.033 *
vaccine_measles	−1.18	0.038 *
blood_ab_plus	−1.11	0.043 *
life_exp	−1.14	0.047 *
blood_o_plus	1.07	0.058.
Nurses	−1.08	0.059.
hofstede_mas	1.01	0.072.
Arrivals	0.85	0.130
pop_urban	−0.87	0.131
Illnesses	0.87	0.135
Household	0.85	0.142
Physicians	−0.81	0.165
pop_gender	−0.76	0.194
women_labour	−0.71	0.223
Atms	0.69	0.229
blood_ab_minus	0.66	0.255
blood_b_plus	−0.64	0.270
Smoking	0.63	0.280
Bmi	0.59	0.314
Cholesterol	−0.59	0.320
Gdp	−0.57	0.334
blood_o_minus	0.51	0.381
hofstede_ltowvs	−0.51	0.382
pop_tot	0.47	0.418
hospital_beds	−0.47	0.423
hofstede_uai	0.44	0.452
blood_a_plus	−0.44	0.454
Alcohol	−0.43	0.468
hc_costs	−0.41	0.489
oop_hc	0.40	0.497
blood_a_minus	0.36	0.537
Internet	0.30	0.614
blood_pressure	0.24	0.687
mobile_subs	−0.19	0.754
hofstede_pdi	0.16	0.789
pop_density	−0.14	0.82
hc_costs_of_gdp	−0.13	0.823
hofstede_idv	0.05	0.939
blood_b_minus	0.01	0.984
services_of_empl	0.00	0.995

Significance at the 0.1%, 1%, 5% and 10% level is indicated by ***, **, * and., respectively.
Acronyms: hci = Human Capital Index, hdi = Human Development Index, priv_share = Domestic private health expenditure, vaccine_dpt = Immunization, DPT (% of children ages 12–23 months), gov_eff = Government Effectiveness, vaccine_measles = Immunization, measles (% of children ages 12–23 months), life_exp = Life expectancy at birth, total (years), ofstede_mas = Geert Hofstede's Masculinity, pop_urban = Population living in urban areas (%), pop_gender = Sex ratio at birth, atms = Automated teller machines, bmi = body mass index, gdp = Gross domestic product, ofstede_ltowvs = Geert Hofstede's Long term orientation, pop_tot = Population, total, ofstede_uai = Geert Hofstede's Uncertainty avoidance, hc_costs = Current health expenditure per capita, oop_hc = Out-of-pocket expenditure (% of current health expenditure), mobile_subs = Mobile cellular subscriptions per 100 people, Hofstede_pdi = Geert Hofstede's Power distance, pop_density = Population density, hc_costs_of_gdp = Current health expenditure (% of GDP), ofstede_idv = Geert Hofstede's Individualism, services_of_empl = Employment in services (% of total employment).

information on interventions. The stringency index with scale of 0–100 combines all 8 closures and containment interventions (c1 – c8) with the public info campaigns (h1), to create an approximation of the magnitude of each country's interventions on any given date.

The intervention time series for the modelling were constructed with an 18-day lead, as the results from Zhou et al. [35] and Verity et al. [36] stated that the median time from illness onset to death is 18 days. This means that intervention data starts 18 days prior to the mortality data.

In many previous studies, the number of infected people or mortality is used as the dependent variable. In this study, the dependent variable of the models was mortality. The reliability of mortality data is better compared to the number of infected people since the latter was affected by sampling bias due to the different testing protocols and capacity in each country, especially at the beginning of the pandemic [37]. At the time period of the data collection for this study (August 2020), the countries included in the study seem to have experienced the first wave of COVID-19 as the number of deaths increased rapidly around March 2020 and then started to decrease around May 2020. The change is not linear, and for that reason we processed the values of daily deaths to values of daily mortality change. First, daily death figures were made relative. Then the time series were smoothed with a 7-day (+-3 days) moving average. Finally, the relative percentage change was calculated from subsequent daily figures. As an end result, the daily mortality change (*DMC*) reflects the pace at which the death toll is either rising or decreasing, and provides a smoother data series compared to pure daily mortality figures.

2.3. Statistical analyses

We used linear mixed effect models [38] to identify factors associated with the number of deaths. Mixed effect models were chosen because they can handle repeated and correlated measurements, such as the country specific daily deaths. This is done by assuming different random intercept and/or slope for each country. One additional strength of the chosen method is its ability to deal with unbalanced panel data, allowing for all selected countries to be included in the study from the day of the first death in each country, until the data end August 12, 2020.

Correlation and variance inflation factor (VIF) analyses were used for eliminating collinearity of the variables selected for the multivariable models. The threshold values of correlation coefficient and VIF were 0.75 and 10 [39,40], respectively. If two variables correlated, the other variable was dropped from the multivariable models. The choice on which variable to be dropped was based on the variable's correlation to the remaining variables.

The model settings (e.g., random intercept and/or slope) were selected based on the model comparison tests. The utilized model includes only random intercept. Random slope was not included in the model based on AIC value test. In our models, random intercept means that each country has a different intercept value. That is, the model can be expressed as:

$$Y_{st} = \beta_{00} + \beta_{0s} + \beta_1 X_{st}$$

where Y_{st} is mortality change of day t from first death, β_{0s} is random effect (intercept) and X_{st} are fixed effects (independent variables) for country s. The tasks related to linear mixed effect modelling were performed using R language and the packages of stats, lme4 and pbkrtest [41,42].

We studied three model types: Model 1, Model 2a and Model 2b. The independent variables of Model 1 were the country features and stringency index. The country features were chosen from those that were statistically significant in univariate models controlled by the number of days from the first death in a specific country. Statistical significance was set at p-value of less than 0.1. The independent variables of Model 2a were intervention categories. The independent variables of Model 2b were independent interventions. All models were also controlled for the number of days from the first death. The dependent variable of the all models was daily mortality change.

Table 3
Linear mixed effect model estimates for country features.

Factor	Estimate	P-value
(Intercept)	26.14	<0.001 ***
Day	−0.09	<0.001 ***
Hofstede_mas	1.12	0.037 *
blood_ab_plus	−1.44	0.161
blood_o_plus	0.78	0.476
Corruption	0.35	0.774
Diabetes	0.90	0.174
Gini	−0.95	0.429
Hci	−0.98	0.367
vaccine_measles	0.14	0.876
Pollution	1.32	0.176
priv_share	0.51	0.570
unemployment	−0.42	0.598
Nurses	−0.31	0.691
vaccine_dpt	−0.47	0.557
stringency_index	−0.29	<0.001 ***
Marginal R^2/Conditional R^2	0.081/0.085	
F(15, 22.236) = 29.135	p < 0.000	

3. Results

3.1. Model 1: country features and stringency index

Table 2 presents the results of univariate models of country features presented in order according to p-values. According to the results, 16 country features had p-values less than 0.1 and were selected for correlation analysis. Correlation analysis reduced the number of variables to 13, dropping Human Development Index (*hdi*), Government Efficiency Index (*gov_eff*) and Life expectancy (life_exp). The correlation matrix of the selected variables is presented in Annex 3.

Model 1 answers the question which country features are associated with *DMC*, controlling for country-specific intervention actions with the stringency index. Table 3 presents the results of Model 1 ($R^2 = 0.085$, $F(15, 22.236) = 29.135$, $p < 0.000$). Of country features, *hofstede_mas* is statistically significant ($p < 0.05$). Geert Hofstede's masculinity, i.e., the extent to which the use of force is endorsed socially, correlates positively with the *DMC trend*: the higher the masculinity dimension, the higher increase or slower decrease in the daily mortality change. Estimates for all the other country features were insignificant. Both *day* and *stringency_index* showed statistically significant negative estimates ($p < 0.001$), meaning that higher stringency index and the passing of days both had a decreasing effect on *DMC*. It thus seems that apart from Hofstede's masculinity, interventions have had much greater effect on *DMC* over the country features.

3.2. Model 2a: intervention categories

Model 2a answers the question which intervention categories are associated with the *DMC*. Table 4 in Annex 6 presents the results of Model 2a ($R^2 = 0.091$, $F(12, 948.460) = 36.327$, $p < 0.000$). Based on the results, cancelling public events (c3_events_any_mes, est = −5.6, $p < 0.001$) seems to have the largest effect to lower DMC figures, followed by controlling international travel (c8_travelctrl_any_mes, est = −5.17, $p < 0.001$), closing workplaces (c2_work_any_mes, est = −5.12, $p < 0.001$) and closing schools (c1_school_any_mes, est = −3.00, $p = 0.038$), respectively. Furthermore, *day* has a negative and highly statistically significant coefficient ($p < 0.001$). On a 95% confidence level the other intervention categories do not seem to have effects on *DMC*.

3.3. Model 2b: intervention categories

Model 2b answers the question which individual interventions are associated with the *DMC*. Table 5 in Annex 6 presents the results of Model 2b ($R^2 = 0.095$, $F(30, 702.015) = 15.331$, $p < 0.000$). Based on the results, school closures (c1_school_req_all, est = −4.42, $p = 0.006$), cancelling public events (c3_events_rec, est = −5.16, $p = 0.001$; c3_events_req, est = −6.01, $p < 0.001$), recommending restricted internal movement (c7_movement_rec, est = −2.59, $p = 0.04$) and controlling international travel (c8_travelctrl_screening, est = −7.10, $p = 0.002$; c8_travelctrl_quarantine, est = −5.02, $p = 0.005$; c8_travelctrl_ban_high_risk, est = −6.47, $p < 0.001$; c8_travelctrl_total_closure, est = −6.98, $p < 0.001$) had statistically significant effect to lower DMC figures. Requiring all school levels to close seems to have been effective in reducing mortality. Cancelling public events, either recommending or requiring, as well as recommending restricted internal movement, seem to have both been highly effective in reducing mortality. In addition, all actions on international travel, such as screening, quarantine arrivals from high-risk regions, ban on high-risk regions or total border closure, seem to have had a strong decreasing effect on mortality.

The other categories within Closures and Containment, i.e., closing workplaces (all c2), restricting gatherings (all c4), closing public transport (all c5) or setting curfews (all c6) did not show statistically significant association. In addition, all Public Health/ Health System interventions, such as COVID-19 information campaigns (all h1), testing (all h2) or tracing (all h3) did not show significance.

4. Discussion

The aim of this study was to examine why the COVID-19 epidemic expansion differed from one country to another. We tested both country characteristics consisting of demographic, societal, health related, healthcare system specific, environmental and cultural feature as well as COVID-19 specific response in the form of social distancing interventions.

We used mortality data instead of number of infected people since the latter can be influenced by sampling bias due to the different testing protocols and capacity in each country. Our data collection period coincides with the beginning of the pandemic, when testing capacity was very limited. Thus, the number of deaths is a more reliable and comparable measure across countries. Mortality data has also its limitations since the recording principles differ between healthcare systems and countries. Even though the number of deaths is an indirect indicator of the spread of the disease, during the time period prior to covid vaccines, there was a clear link between the number of positive cases, occurrence of severe disease form, and number of deaths per age group/risk group.

Of the country features, the only statistically significant country feature when controlling for the social distancing measures, was Geert Hofstede's masculinity, i.e., the extent to which the use of force is endorsed socially, correlated with higher *DMC*. Countries that show low masculinity according to Hofstede's dimensions are the Nordic countries and high in European countries like Hungary, Austria and Switzerland and relatively hight for United Kingdom. To understand why social endorsement of the use of force correlates with higher mortality in COVD-19 would require further research while keeping in mind that the other cultural dimension such as e.g., the dimension of power distance as well as individualism/collectivism did not show significant correlation with *DMC*. The finding could be analysed further in the light of other socio-economic factors such as e.g., political power since recent studied have found that e.g., countries led by women leaders have fared significantly better than those led by men when responding to the COVID-19 crisis [20].

Beyond the country features, specific intervention actions showed statistical significance and seem to have influenced the COVID-

19 country specific health impact, supporting previous research. Koh et al. [25] found that of different intervention types, border closures and lockdown-type measures have been most effective in outbreak control. However, based on their results, recommended stay-at-home advisories and partial lockdowns had to be implemented early to be effective. Friedson et al. [26] found that the full lockdown in California, US, remarkably reduced the number of COVID-19 cases in the following weeks. In this study the results showed that requiring all school levels to close, either recommending or requiring public events to be cancelled, recommending closing internal movement or restricting international travel in any fashion all had an effect to reduce mortality. The finding thus also supports the results of Deb et al. [43] that internal and international travel restrictions have been the most effective, and Keita [21] who found that more connected countries registered first cases significantly earlier than less connected countries. However, not all independent interventions seemed to have a significant effect, e.g., public transportation and introducing curfews, were not statistically significant, indicating that carefully chosen interventions can be as sufficient as a full lock-down.

The COVID-19 pandemic has showcased what preparedness in the global health system is. The features that are shown in this study to impact on the mortality are for example not related to the amount of health care resources. Our economic, social and political environments are linked and thus further studies could cluster countries as economic, social and political environments and investigate in how crises responders could best plan and prepare for pandemics in each specific environment.

There are a few limitations related to the modelling and variables. Many of the selected interventions were started at the same time (as seen in Annexes 3 and 4), making it difficult to separate the effects of distinct interventions. The selection of model variables is also important to take in consideration when analysing the results, particularly in the case of the novel COVID-19 context, as pointed out by Stojkoski et al. [28]. The models were sensitive for variable selection. We did not study interaction effects. It can be expected that there are interactions between the variables.

Further studies could be conducted to apply new methods to separate the effects of the concurrent interventions. The performance of the similar models can improve by adding interaction terms assuming that the sample size (number of countries) is high enough. Furthermore, more patient level clinical analyses are needed to study the effects of e.g., other diseases to COVID-19 vulnerability. In addition, recently interesting studies have been published considering also ethnicity [44], temperature [45], other climate conditions [46,47], and usage of masks [48].

Lastly, it should be noted that the data, and thus also the results, are valid only for the first wave of the COVID-19 epidemic. In future research, repeating the study with data from a longer time period when the total death toll is known, would improve the robustness of our results.

5. Conclusions

Social distancing interventions and the country feature Geert Hofstede's masculinity dimension had a significant impact on COVID-19 mortality change. However other country features, such as economic development and population health did not show significance. Clearly, based on our results, the effect of the non-pharmacological interventions overshadows that of country features. An interpretation of this is that regardless of population density, the level of preparedness of a country, or capability of the healthcare system, all countries had to resort to strict restrictions that closed down societies to cope with the pandemic. One implication is that the concept of prepress for and response to pandemics could be revisited in further research.

6. Key points

- Some country features had a significant association with COVID-19 mortality: Geert Hofstede's masculinity. These findings have an implication on the development of societies towards higher resilience when facing pandemics in the long run.
- Social distancing interventions had a significant impact on COVID-19 mortality change. More specifically, school closures, cancelling public events and controlling international travel were statistically significant. Other interventions, such as closing workplaces or public transportation and introducing curfews, were not statistically significant.
- Improving the access, reliability, precision and timeliness of the pandemic related data would help healthcare decision-makers model the spread of a pandemic faster and thus be able to take intervention decisions based on results

Statement of funding

This study has received within the HERoS project as part of the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003606.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data is publicly available.

Annexes.

Annex 1
Country features

a) Country features data		
Factor	Abbreviation	Source
Demographic		
Population blood groups, %: O+; A+; B+; AB+; O−; A−; B-, AB-	blood_o_plus; blood_a_plus; blood_b_plus; blood_ab_plus; blood_o_minus; blood_a_minus; blood_b_minus; blood_ab_minus	Several country-specific sources, see summary at Wikipedia[1]
Life expectancy at birth, total (years)	life_exp	WDI, 2017–2019
Population density (people per sq. km of land area)	pop_density	WDI, 2018–2019
Sex ratio at birth (male births per female births)	pop_gender	WDI, 2017–2019
Population, total	pop_tot	WDI, 2018–2019
Population living in urban areas (%)	pop_urban	INFORM, 2018
Societal		
International tourism, number of arrivals	arrivals	INFORM/World Bank, 2017
Automated teller machines (ATMs) (per 100 000 adults)	atms	WDI, 2017–2019
Corruption Perception Index	corruption	INFORM/Transparency International, 2019
GDP per capita (current US$)	gdp	WDI, 2018–2019
GINI index (World Bank estimate)	gini	WDI, 2012–2019, NZL: OECD 2014, SGP: CIA 2017
Government Effectiveness	gov_eff	INFORM/World Bank, 2018
Human Capital Index (HCI) (scale 0–1)	hci	WDI, 2017–2019
Human Development Index	hdi	INFORM, 2018
Household size	household	INFORM/UNDESA, 2006–2016, DNK: UN/Statistics of Denmark 2017, KOR: UN/DYB 2008, SWE: UN/Total Population Register 2015, CHE: UN/DYB 2000
Individuals using the Internet (% of population)	internet	INFORM/World Bank, 2017
Mobile cellular subscriptions per 100 people	mobile_subs	INFORM/World Bank, 2018
Employment in services (% of total employment) (modeled ILO estimate)	services_of_empl	WDI, 2019
Unemployment, total (% of total labor force) (modeled ILO estimate)	unemployment	WDI, 2019
Ratio of female to male labor force participation rate (%) (modeled ILO estimate)	women_labour	WDI, 2019
Health related		
Total alcohol consumption per capita (litres of pure alcohol, projected estimates, 15+ years of age)	alcohol	WDI, 2016–2019
Raised blood pressure (SBP $\geq$ 140 OR DBP $\geq$ 90) (age-standardized estimate)	blood_pressure	WHO, 2015
Mean BMI (kg/m2) (age-standardized estimate)	bmi	WHO, 2016
Raised total cholesterol ($\geq$5.0 mmol/L) (age-standardized estimate)	cholesterol	WHO, 2008
Diabetes prevalence (% of population ages 20 to 79)	diabetes	WDI, 2019
Mortality from CVD, cancer, diabetes or CRD between exact ages 30 and 70 (%)	illnesses	WDI, 2016–2019
Smoking prevalence, total (ages 15+)	smoking	WDI, 2016–2019
Immunization, DPT (% of children ages 12–23 months)	vaccine_dpt	WDI, 2018–2019
Immunization, measles (% of children ages 12–23 months)	vaccine_measles	WDI, 2018–2019
Healthcare system related		
Current health expenditure per capita (current US$)	hc_costs	WDI, 2016–2019
Current health expenditure (% of GDP)	hc_costs_of_gdp	WDI, 2016–2019
Hospital beds (per 1000 people)	hospital_beds	WDI, 2012–2019 NLD: World Bank 2009, ZAF: World Bank 2005
Nurses and midwives (per 1000 people)	nurses	WDI, 2014–2019
	oop_hc	WDI, 2016–2019

(*continued on next page*)

Annex 1 (*continued*)

a) Country features data

Factor	Abbreviation	Source
Demographic		
Out-of-pocket expenditure (% of current health expenditure)		
Physicians (per 1000 people)	physicians	WDI, 2014–2019
Domestic private health expenditure (% of current health expenditure)	priv_share	WDI, 2016–2019
Environmental		
PM2.5 air pollution, mean annual exposure (micrograms per cubic meter)	pollution	WDI, 2017–2019
Cultural		
Geert Hofstede's 6-D Model: Power distance; Individualism; Masculinity; Uncertainty avoidance; Long term orientation[2]	hofstede_pdi; hofstede_idv; hofstede_mas; hofstede_uai; hofstede_ltowvs	Geert Hofstede, 2020

1Wikipedia. Blood type distribution by country. https://en.wikipedia.org/wiki/Blood_type_distribution_by_country.
2Note: Geert Hofstede's 6th dimension, indulgence, not available for all countries studied and thus not included.

b) Descriptive statistics of the country features

	AUT	BEL	BGR	HRV	CZE	DNK	EST	FIN	FRA	DEU	GRC
alcohol	11.60	12.10	12.70	8.90	14.40	10.40	11.60	10.70	12.60	13.40	10.40
arrivals	29 460 000	8385 000	8883 000	15 593 000	10 160 000	11 743 000	3245 000	3180 000	86 861 000	37 452 000	27 194 000
atms	168.89	87.45	92.89	147.65	57.09	47.90	68.14	34.84	98.30	118.22	62.34
blood_a_minus	0.07	0.06	0.07	0.06	0.06	0.07	0.05	0.06	0.07	0.06	0.05
blood_a_plus	0.37	0.34	0.37	0.36	0.36	0.37	0.31	0.35	0.37	0.37	0.33
blood_ab_minus	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
blood_ab_plus	0.05	0.04	0.07	0.05	0.07	0.04	0.06	0.07	0.03	0.04	0.04
blood_b_minus	0.02	0.02	0.02	0.03	0.03	0.02	0.03	0.02	0.01	0.02	0.02
blood_b_plus	0.12	0.09	0.13	0.15	0.15	0.08	0.21	0.16	0.09	0.09	0.11
blood_o_minus	0.06	0.07	0.05	0.05	0.05	0.06	0.04	0.05	0.06	0.06	0.07
blood_o_plus	0.30	0.38	0.28	0.29	0.27	0.35	0.30	0.28	0.36	0.35	0.37
blood_pressure	21.00	17.50	28.40	32.40	27.90	20.60	27.40	19.40	22.00	19.90	19.10
bmi	25.60	26.10	26.40	27.40	27.10	25.30	26.40	25.90	25.00	26.60	27.10
cholesterol	59.70	62.40	49.90	49.80	53.90	65.20	56.70	59.00	62.00	65.60	48.20
corruption	77.00	75.00	43.00	47.00	56.00	87.00	74.00	86.00	69.00	80.00	48.00
diabetes	6.60	4.60	6.00	5.40	7.00	8.30	4.20	5.60	4.80	10.40	4.70
gdp	51 462	47 519	9273	14 910	23 079	61 350	23 266	50 152	41 464	47 603	20 324
gini	29.70	27.40	40.40	30.40	24.90	28.70	30.40	27.40	31.60	31.90	34.40
gov_eff	1.45	1.17	0.27	0.46	0.92	1.87	1.19	1.98	1.48	1.62	0.34
hc_costs	4688	4149	612	884	1322	5566	1185	4117	4263	4714	1511
hc_costs_of_gdp	10.44	10.04	8.23	7.18	7.15	10.35	6.68	9.49	11.54	11.14	8.45
hci	0.79	0.76	0.68	0.72	0.78	0.77	0.75	0.81	0.77	0.80	0.68
hdi	0.91	0.92	0.82	0.84	0.89	0.93	0.88	0.93	0.89	0.94	0.87
hofstede_pdi	11.0	65.0	70.0	73.0	57.0	18.0	40.0	33.0	68.0	35.0	60.0
hofstede_idv	55.0	75.0	30.0	33.0	58.0	74.0	60.0	63.0	71.0	67.0	35.0
hofstede_mas	79.0	54.0	40.0	40.0	57.0	16.0	30.0	26.0	43.0	66.0	57.0
hofstede_uai	70.0	94.0	85.0	80.0	74.0	23.0	60.0	59.0	86.0	65.0	112.0
hofstede_ltowvs	60.0	82.0	69.0	58.0	70.0	35.0	82.0	38.0	63.0	83.0	45.0
hospital_beds	7.60	6.20	6.80	5.60	6.50	2.50	5.00	4.40	6.50	8.30	4.30
household	2.27	2.36	2.34	2.80	2.40	2.10	2.30	2.07	2.26	2.14	2.56
illnesses	11.40	11.40	23.60	16.70	15.00	11.30	17.00	10.20	10.60	12.10	12.40
internet	87.94	87.68	63.41	67.10	78.72	97.10	88.10	80.50	48.05	34.67	55.86
life_exp	81.64	81.44	74.81	77.83	79.48	81.00	77.64	81.43	82.52	80.99	81.39
mobile_subs	123.54	99.70	118.94	105.58	119.11	125.12	145.44	129.47	108.36	129.32	115.67
nurses	8.18	11.10	5.30	8.11	8.41	10.30	6.45	14.72	9.69	13.20	3.37
oop_hc	18.92	15.86	47.95	15.36	15.02	13.71	22.69	20.35	9.76	12.41	34.34
physicians	5.14	3.32	3.99	3.00	4.31	4.46	3.47	3.81	3.23	4.21	4.59
pollution	12.48	12.89	19.15	17.90	16.07	10.03	6.73	5.86	11.81	12.03	16.22
pop_density	107.21	377.21	64.70	73.08	137.60	138.07	30.39	18.16	122.34	237.37	83.22
pop_gender	1.06	1.05	1.06	1.06	1.06	1.06	1.07	1.05	1.05	1.05	1.07
pop_tot	8847 037	11 422 068	7024 216	4089 400	10 625 695	5797 446	1320 884	5518 050	66 987 244	82 927 922	10 727 668
pop_urban	58.30	98.00	75.01	56.95	73.79	87.87	68.88	85.38	80.44	77.31	79.06
priv_share	27.49	15.89	49.44	21.75	18.12	15.88	24.37	22.64	17.10	15.33	39.00
services_of_empl	71.67	78.40	63.44	67.02	59.58	79.37	66.91	74.50	77.28	71.86	72.88
smoking	29.60	28.20	37.00	37.00	34.30	19.10	31.30	20.40	32.70	30.60	43.40
unemployment	4.64	6.44	4.82	7.77	2.47	4.83	5.88	7.25	9.10	3.20	18.08
vaccine_dpt	85.00	98.00	92.00	93.00	96.00	97.00	92.00	91.00	96.00	93.00	99.00

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	AUT	BEL	BGR	HRV	CZE	DNK	EST	FIN	FRA	DEU	GRC
vaccine_measles	94.00	96.00	93.00	93.00	96.00	95.00	87.00	96.00	90.00	97.00	97.00
women_labour	83.39	81.64	80.37	78.81	76.86	88.07	80.49	88.51	84.10	83.65	74.82
	HUN	**IRL**	**ISR**	**ITA**	**JPN**	**LUX**	**NLD**	**NZL**	**NOR**	**POL**	**PRT**
alcohol	11.40	13.00	3.80	7.50	8.00	13.00	8.70	10.70	7.50	11.60	12.30
arrivals	5650 000	10 338 000	3613 000	58 253 000	28 691 000	1046 000	17 924 000	3555 000	6252 000	18 258 000	15 432 000
atms	60.52	79.14	128.07	91.14	127.59	117.40	41.15	64.66	34.55	70.78	165.69
blood_a_minus	0.07	0.05	0.04	0.06	0.00	0.06	0.07	0.06	0.07	0.06	0.07
blood_a_plus	0.33	0.26	0.34	0.36	0.40	0.37	0.35	0.32	0.42	0.32	0.40
blood_ab_minus	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
blood_ab_plus	0.08	0.02	0.07	0.03	0.10	0.04	0.03	0.03	0.03	0.07	0.03
blood_b_minus	0.03	0.02	0.02	0.02	0.00	0.02	0.01	0.02	0.01	0.02	0.01
blood_b_plus	0.16	0.09	0.17	0.08	0.20	0.09	0.07	0.09	0.07	0.15	0.07
blood_o_minus	0.05	0.08	0.03	0.07	0.00	0.06	0.08	0.09	0.06	0.06	0.06
blood_o_plus	0.27	0.47	0.32	0.39	0.30	0.35	0.40	0.38	0.33	0.31	0.36
blood_pressure	30.00	19.70	16.60	21.20	17.60	21.90	18.70	16.20	19.70	28.70	24.40
bmi	27.30	27.50	27.30	25.60	22.70	26.30	25.60	28.00	26.70	26.70	25.60
cholesterol	55.20	62.60	53.50	62.20	57.10	66.90	60.50	56.20	61.90	57.10	55.90
corruption	44.00	74.00	60.00	53.00	73.00	80.00	82.00	87.00	84.00	58.00	62.00
diabetes	6.90	3.20	9.70	5.00	5.60	5.00	5.40	6.20	5.30	6.10	9.80
gdp	16 162	78 806	41 715	34 483	39 290	116 640	53 024	41 945	81 697	15 421	23 408
gini	30.60	32.80	39.00	35.90	32.90	34.90	28.50	34.90	27.00	29.70	33.80
gov_eff	0.49	1.42	1.21	0.41	1.68	1.78	1.85	1.67	1.89	0.66	1.21
hc_costs	943	4759	2837	2739	4233	6271	4742	3745	7478	809	1801
hc_costs_of_gdp	7.36	7.38	7.31	8.94	10.93	6.16	10.36	9.22	10.50	6.52	9.08
hci	0.70	0.81	0.76	0.77	0.84	0.69	0.80	0.77	0.77	0.75	0.78
hdi	0.84	0.94	0.91	0.88	0.91	0.91	0.93	0.92	0.95	0.87	0.85
hofstede_pdi	46.0	28.0	13.0	50.0	54.0	40.0	38.0	22.0	31.0	68.0	63.0
hofstede_idv	80.0	70.0	54.0	76.0	46.0	60.0	80.0	79.0	69.0	60.0	27.0
hofstede_mas	88.0	68.0	47.0	70.0	95.0	50.0	14.0	58.0	8.0	64.0	31.0
hofstede_uai	82.0	35.0	81.0	75.0	92.0	70.0	53.0	49.0	50.0	93.0	104.0
hofstede_ltowvs	58.0	24.0	38.0	61.0	88.0	64.0	67.0	33.0	35.0	38.0	28.0
hospital_beds	7.00	2.80	3.10	3.40	13.40	4.80	4.70	2.80	3.90	6.50	3.40
household	2.60	2.81	3.14	2.40	2.42	2.41	2.23	2.70	2.22	2.82	2.66
illnesses	23.00	10.30	9.60	9.50	8.40	10.00	11.20	10.10	9.20	18.70	11.10
internet	98.24	81.58	61.30	44.37	62.30	9.80	88.47	24.57	15.51	94.29	63.75
life_exp	76.06	81.96	82.60	83.24	84.10	82.69	81.56	81.66	82.51	77.85	81.12
mobile_subs	103.45	103.17	127.66	137.47	141.41	132.16	123.73	134.93	107.17	134.75	115.63
nurses	6.64	14.29	5.20	5.87	11.52	12.35	11.10	10.96	18.12	5.72	6.37
oop_hc	29.70	12.99	22.97	23.11	13.45	11.23	11.45	13.58	14.52	22.94	27.75
physicians	3.23	3.09	3.22	4.09	2.41	3.03	3.51	3.03	4.63	2.40	3.34
pollution	15.93	8.21	21.38	16.75	11.70	10.36	12.03	5.96	6.96	20.88	8.16
pop_density	107.91	70.45	410.53	205.45	347.07	250.09	511.46	18.55	14.55	124.04	112.24
pop_gender	1.06	1.06	1.05	1.06	1.06	1.05	1.05	1.06	1.06	1.06	1.06
pop_tot	9768 785	4853 506	8883 800	60 431 283	126 529 100	607 728	17 231 017	4885 500	5314 336	37 978 548	10 281 762
pop_urban	71.35	63.17	92.42	70.44	91.62	90.98	91.49	86.54	82.25	60.06	65.21
priv_share	34.14	27.93	35.97	25.54	16.41	17.63	19.02	21.35	14.87	30.12	33.65
services_of_empl	63.89	76.75	81.81	70.66	72.24	88.24	81.63	73.50	78.89	58.61	69.32
smoking	30.60	24.30	25.20	23.70	22.10	23.50	25.80	16.00	20.20	28.00	22.70
unemployment	3.46	5.28	3.93	9.22	2.41	5.41	3.76	4.81	3.97	3.27	6.13
vaccine_dpt	99.00	94.00	98.00	95.00	99.00	99.00	93.00	93.00	96.00	95.00	99.00
vaccine_measles	99.00	92.00	98.00	93.00	97.00	99.00	93.00	92.00	96.00	93.00	99.00
women_labour	74.54	81.16	85.84	68.71	72.96	85.54	84.43	85.37	90.52	74.68	83.98
	ROU	SRB	SGP	SVN	ZAF	KOR	ESP	SWE	CHE	UKR	GBR
alcohol	12.70	11.10	2.00	12.60	9.30	10.20	10.00	9.20	11.50	8.60	11.50
arrivals	10 926 000	1497 000	13 903 000	3586 000	10 285 000	13 336 000	81 786 000	7054 000	9889 000	14 230 000	37 651 000
atms	64.49	48.75	66.46	90.03	66.66	272.82	108.58	32.01	99.19	97.36	115.67
blood_a_minus	0.07	0.07	0.00	0.07	0.05	0.00	0.07	0.07	0.07	0.06	0.07
blood_a_plus	0.37	0.35	0.24	0.33	0.32	0.34	0.36	0.37	0.38	0.34	0.32
blood_ab_minus	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01
blood_ab_plus	0.07	0.04	0.06	0.06	0.03	0.11	0.03	0.05	0.04	0.05	0.03
blood_b_minus	0.02	0.02	0.00	0.03	0.02	0.00	0.02	0.02	0.01	0.02	0.02
blood_b_plus	0.14	0.13	0.25	0.12	0.12	0.27	0.08	0.10	0.08	0.15	0.08
blood_o_minus	0.05	0.06	0.01	0.07	0.06	0.00	0.09	0.06	0.06	0.05	0.09
blood_o_plus	0.28	0.32	0.45	0.31	0.39	0.28	0.35	0.32	0.35	0.32	0.38
blood_pressure	30.00	29.50	14.60	30.50	26.90	11.00	19.20	19.30	18.00	27.10	15.20
bmi	26.90	26.10	23.60	26.60	27.30	23.80	25.90	26.00	25.20	26.60	27.10

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	ROU	SRB	SGP	SVN	ZAF	KOR	ESP	SWE	CHE	UKR	GBR
cholesterol	45.80	49.80	57.50	56.30	35.50	42.50	56.10	51.80	59.20	44.40	63.40
corruption	44.00	39.00	85.00	60.00	44.00	59.00	62.00	85.00	85.00	30.00	77.00
diabetes	6.90	9.00	5.50	5.90	12.70	6.90	6.90	4.80	5.70	6.10	3.90
gdp	12 301	7247	64 582	26 124	6374	31 363	30 371	54 608	82 797	3095	42 944
gini	36.00	36.20	45.90	24.20	63.00	31.60	34.70	28.80	32.70	26.10	34.80
gov_eff	−0.25	0.11	2.23	1.13	0.34	1.18	1.00	1.83	2.04	−0.42	1.34
hc_costs	476	494	2462	1834	428	2044	2390	5711	9836	141	3958
hc_costs_of_gdp	4.98	9.14	4.47	8.47	8.11	7.34	8.97	10.93	12.25	6.73	9.76
hci	0.60	0.76	0.88	0.79	0.41	0.85	0.74	0.80	0.77	0.65	0.78
hdi	0.82	0.80	0.93	0.90	0.70	0.91	0.89	0.94	0.95	0.75	0.92
hofstede_pdi	90.0	86.0	74.0	71.0	49.0	60.0	57.0	31.0	34.0	92.0	35.0
hofstede_idv	30.0	25.0	20.0	27.0	65.0	18.0	51.0	71.0	68.0	25.0	89.0
hofstede_mas	42.0	43.0	48.0	19.0	63.0	39.0	42.0	5.0	70.0	27.0	66.0
hofstede_uai	90.0	92.0	8.0	88.0	49.0	85.0	86.0	29.0	58.0	95.0	35.0
hofstede_ltowvs	52.0	52.0	72.0	49.0	34.0	100.0	48.0	53.0	74.0	86.0	51.0
hospital_beds	6.30	5.70	2.40	4.60	2.80	11.50	3.00	2.60	4.70	8.80	2.80
household	2.88	2.88	3.29	2.47	3.38	3.90	2.69	2.20	2.20	2.46	2.35
illnesses	21.40	19.10	9.30	12.70	26.20	7.80	9.90	9.10	8.60	24.70	10.90
internet	20.00	11.77	78.89	1.88	84.60	98.00	28.00	93.71	31.87	53.00	94.78
life_exp	75.31	76.09	82.90	81.18	63.54	82.63	83.33	82.31	83.60	71.78	81.16
mobile_subs	116.25	95.78	148.82	118.67	159.93	129.67	115.99	126.83	126.77	127.75	118.37
nurses	6.10	6.12	7.21	9.68	3.52	6.97	5.53	11.54	17.28	7.06	8.29
oop_hc	20.75	40.50	31.17	12.00	7.75	33.31	23.83	15.24	29.56	54.34	15.12
physicians	2.26	3.13	2.31	3.00	0.91	2.37	4.07	5.40	4.24	3.01	2.81
pollution	14.61	24.73	19.08	16.02	25.10	25.04	9.70	6.18	10.30	20.31	10.47
pop_density	84.64	79.83	7953.00	102.64	47.63	529.65	93.53	25.00	215.52	77.03	274.83
pop_gender	1.06	1.07	1.07	1.06	1.03	1.06	1.06	1.06	1.05	1.06	1.05
pop_tot	19 473 936	6982 084	5638 676	2067 372	57 779 622	51 635 256	46 723 749	10 183 175	8516 543	44 622 516	66 488 991
pop_urban	54.00	56.09	100.00	54.54	66.36	81.46	80.32	87.43	73.80	69.35	83.40
priv_share	21.81	41.85	45.47	27.71	44.27	40.85	28.76	16.49	37.22	56.76	19.76
services_of_empl	47.55	57.96	83.02	61.68	71.73	70.48	76.02	80.39	76.80	60.53	80.89
smoking	29.70	38.90	16.50	22.50	20.30	23.30	29.30	18.80	25.70	28.90	22.30
unemployment	4.16	13.51	3.62	5.50	27.32	3.71	14.70	6.84	4.87	9.31	3.81
vaccine_dpt	86.00	96.00	96.00	93.00	74.00	98.00	93.00	97.00	96.00	50.00	94.00
vaccine_measles	90.00	92.00	95.00	93.00	70.00	98.00	97.00	97.00	96.00	91.00	92.00
women_labour	70.75	75.34	79.34	85.30	77.92	71.94	81.79	90.53	84.78	74.20	84.39

Annex 2
Interventions, based on the Oxford COVID-19 Government Response Tracker

Intervention category	Intervention	Abbreviation
School closing	Recommend closing	c1_school_rec
School closing	Require closing (only some levels or categories, e.g. just high school, or just public schools)	c1_shool_req_some
School closing	Require closing (all levels)	c1_school_req_all
Workplace closing	Recommend closing (or work from home)	c2_work_rec
Workplace closing	Require closing (or work from home) for some sectors or categories of workers	c2_work_req_some
Workplace closing	Require closing (or work from home) all-but-essential workplaces (e.g. grocery stores, doctors)	c2_work_req_all
Cancel public events	Recommend cancelling	c3_events_rec
Cancel public events	Require cancelling	c3_events_req
Restrictions on gatherings	Restrictions on very large gatherings (the limit is above 1000 people)	c4_gatherings_1000plus
Restrictions on gatherings	Restrictions on gatherings between 100–1000 people	c4_gatherings_100_1000
Restrictions on gatherings	Restrictions on gatherings between 10 and 100 people	c4_gatherings_10_100
Restrictions on gatherings	Restrictions on gatherings of less than 10 people	c4_gatherings_10minus
Close public transport	Recommend closing (or significantly reduce volume/route/means of transport available)	c5_transport_rec
Close public transport	Require closing (or prohibit most citizens from using it)	c5_transport_req
Stay at home	Recommend not leaving house	c6_curfew_rec
Stay at home	Require not leaving house with exceptions for daily exercise, grocery shopping, and 'essential' trips	c6_curfew_req_loose
Stay at home	Require not leaving the house with minimal exceptions (e.g. allowed to leave only once every few days, or only one person can leave at a time, etc.)	c6_curfew_req_strict
Restrictions on internal movement	Recommend closing (or significantly reduce volume/route/means of transport)	c7_movement_rec
Restrictions on internal movement	Require closing (or prohibit most people from using it)	c7_movement_req
International travel controls	Screening	c8_travelctrl_screening
International travel controls	Quarantine arrivals from high-risk regions	c8_travelctrl_quarantine
International travel controls	Ban on high-risk regions	c8_travelctrl_ban_high_risk

(*continued on next page*)

Annex 2 (*continued*)

Intervention category	Intervention	Abbreviation
International travel controls	Total border closure	c8_travelctrl_total_closure
Public info campaigns	Public officials urging caution about COVID-19	h1_campaigns_individual
Public info campaigns	Coordinated public information campaign (e.g. across traditional and social media)	h1_campaigns_coordinated
Testing policy	Only those who both (a) have symptoms AND (b) meet specific criteria (e.g. key workers, admitted to hospital, came into contact with a known case, returned from overseas)	h2_testing_criteria
Testing policy	Testing of anyone showing COVID-19 symptoms	h2_testing_symptoms
Testing policy	Open public testing (e.g. "drive through" testing available to asymptomatic people)	h2_testing_open
Contact tracing	Limited contact tracing - not done for all cases	h3_tracing_limited
Contact tracing	Comprehensive contact tracing - done for all cases	h3_tracing_comprehensive
	Stringency index combining the info from C1–C8 and H1 on scale 0-100	stringency_index

Annex 3
Correlation table of selected country features

	blood_ab_plus	blood_o_plus	corruption	diabetes	gini	hci	hofstede_mas	nurses	pollution	priv_share	unemployment	vaccine_dpt
blood_ab_plus	1.00											
blood_o_plus	−0.72	1.00										
corruption	−0.21	0.34	1.00									
diabetes	0.04	−0.13	−0.29	1.00								
gini	−0.15	0.36	−0.22	0.49	1.00							
hci	0.17	0.07	0.58	−0.42	−0.56	1.00						
hofstede_mas	0.13	0.09	−0.13	0.05	0.28	−0.06	1.00					
life_exp												
nurses	−0.17	0.14	0.71	−0.33	−0.43	0.42	−0.14	1.00				
pollution	0.35	−0.16	−0.72	0.42	0.42	−0.35	0.18	−0.63	1.00			
priv_share	0.17	0.01	−0.60	0.27	0.44	−0.33	0.07	−0.52	0.66	1.00		
unemployment	−0.39	0.23	−0.42	0.36	0.59	−0.68	0.00	−0.43	0.31	0.37	1.00	
vaccine_dpt	0.09	0.05	0.42	−0.18	−0.14	0.53	0.11	0.19	−0.26	−0.47	−0.34	1.00
vaccine_measles	0.24	−0.19	0.28	−0.29	−0.62	0.70	−0.03	0.30	−0.29	−0.23	−0.62	0.53

Annex 4
Days between first start of different interventions, in categories

	Intervention	N	Avg 1st executed	1	2	3	4	5	6	7	8	9	10
1	c1_school_any_mes	33	11 March										
2	c2_work_any_mes	33	14 March	-3									
3	c3_events_any_mes	33	7 March	4	7								
4	c4_gatherings_any_mes	32	15 March	-4	-1	-8							
5	c5_transport_any_mes	23	19 March	-8	-6	-13	-4						
6	c6_curfew_any_mes	31	17 March	-6	-3	-10	-2	3					
7	c7_movement_any_mes	33	15 March	-4	-1	-8	0	5	2				
8	c8_travelctrl_any_mes	32	24 February	16	19	12	20	24	22	20			
9	h1_campaigns_any_mes	33	11 February	29	32	25	33	37	35	33	13		
10	h2_testing_any_policy	33	18 February	22	25	18	26	30	28	26	6	-7	
11	h3_tracing_any_tracing	32	26 February	15	17	10	19	23	20	18	-2	-15	-8

Annex 5
Days between first start of different interventions, independently

	Intervention	N	Avg 1st executed	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	c1_school_rec	12	29 May																												
2	c1_shool_req_some	28	7 May	21																											
3	c1_school_req_all	29	14 March	75	54																										
4	c2_work_rec	25	14 April	45	23	-31																									
5	c2_work_req_some	29	7 April	52	30	-24	7																								
6	c2_work_req_all	20	22 March	68	47	-8	23	16																							
7	c3_events_rec	20	23 April	36	14	-40	-9	-16	-32																						
8	c3_events_req	30	11 March	78	57	3	34	27	10	43																					
9	c4_gatherings_1000plus	9	20 April	39	17	-37	-6	-13	-29	3	-40																				
10	c4_gatherings_100_1000	23	23 April	36	15	-40	-9	-16	-32	0	-42	-3																			
11	c4_gatherings_10_100	23	29 April	30	9	-46	-15	-22	-38	-6	-48	-9	-6																		
12	c4_gatherings_10minus	27	20 March	69	48	-6	25	18	2	34	-9	31	33	39																	
13	c5_transport_rec	19	28 March	61	40	-14	17	9	-7	25	-17	22	25	31	-8																
14	c5_transport_req	7	24 March	65	44	-10	21	14	-2	30	-13	27	30	35	-4	4															
15	c6_curfew_rec	28	11 April	48	26	-28	3	-4	-20	12	-31	9	12	18	-22	-13	-18														
16	c6_curfew_req_loose	23	22 March	68	47	-8	23	16	0	32	-10	29	32	38	-1	7	3	20													

17	**c7_movement_rec**	26	31 March	58	37	-17	14	7	-9	23	-20	20	22	28	-11	-3	-7	11	-10												
18	**c7_movement_req**	21	23 March	66	45	-9	22	15	-2	31	-12	28	30	36	-3	5	1	19	-2	8											
19	**c8_travelctrl_screening**	17	29 February	89	68	14	45	37	21	53	11	51	53	59	20	28	24	41	21	31	23										
20	**c8_travelctrl_quarantine**	15	15 April	44	23	-32	-1	-8	-24	8	-34	5	8	14	-26	-17	-22	-4	-24	-14	-22	-45									
21	**c8_travelctrl_ban_high_risk**	29	15 March	75	54	-1	30	23	7	39	-3	36	39	45	6	14	9	27	7	17	9	-14	31								
22	**c8_travelctrl_total_closure**	18	20 March	70	49	-6	25	18	2	34	-8	31	34	40	1	9	4	22	2	12	4	-19	26	-5							
23	**h1_campaigns_individual**	11	3 February	115	94	40	71	64	48	80	37	77	80	85	46	54	50	68	48	57	49	26	72	41	46						
24	**h1_campaigns_coordinated**	33	18 February	100	79	25	56	48	32	64	22	62	64	70	31	39	35	53	32	42	34	11	56	25	30	-15					
25	**h2_testing_criteria**	31	18 February	101	80	25	56	49	33	65	23	62	65	71	32	40	36	53	33	33	35	12	57	26	31	-15	1				
26	**h2_testing_symptoms**	27	12 April	46	25	-29	2	-5	-21	11	-32	8	11	16	-23	-15	-19	-1	-21	-12	-20	-43	3	-28	-23	-69	-54	-54			
27	**h2_testing_open**	11	6 May	23	2	-53	-22	-29	-45	-13	-55	-16	-13	-7	-46	-38	-43	-25	-45	-35	-43	-66	-21	-52	-47	-93	-77	-78	-24		
28	**h3_tracing_limited**	19	7 March	83	62	7	38	31	15	47	5	44	47	53	13	22	17	35	15	24	16	-6	39	8	13	-33	-17	-18	36	60	
29	**h3_tracing_comprehensive**	29	13 March	77	56	1	32	25	9	41	-1	38	41	47	8	16	11	29	9	19	11	-12	33	2	7	-39	-23	-24	30	54	-6

Annex 6: Linear mixed effect model estimates for interventions

Table 4
Linear mixed effect model estimates for intervention categories

Factor	Estimate	Confidence interval (95%)	P-value
(Intercept)	23.54	17.48–29.61	<0.001 ***
Day	−0.05	−0.07–−0.03	<0.001 ***
c1_school_any_mes	−3.00	−5.83–−0.17	0.038 *
c2_work_any_mes	−5.12	−7.91–−2.34	<0.001 ***
c3_events_any_mes	−5.60	−8.43–−2.78	<0.001 ***
c4_gatherings_any_mes	−1.57	−4.25–1.10	0.248
c5_transport_any_mes	−1.06	−3.21–1.08	0.332
c6_curfew_any_mes	−1.53	−3.82–0.77	0.192

(continued on next page)

Table 4 (*continued*)

Factor	Estimate	Confidence interval (95%)	P-value
c7_movement_any_mes	−2.06	−4.32–0.20	0.074
c8_travelctrl_any_mes	−5.17	−8.01–−2.33	<0.001 ***
h1_campaigns_any_mes	0.83	−5.12–6.77	0.786
h2_testing_any_policy	0.55	−4.06–5.16	0.815
h3_tracing_any_tracing	1.72	−1.18–4.61	0.246
Marginal R^2/Conditional R^2	0.083/0.091		
F(12, 948.460) = 36.327	$p < 0.000$		

Significance at the 0.1%, 1%, 5% and 10% level is indicated by ***, **, * and., respectively.

Table 5
Linear mixed effect model estimates for independent interventions

Factor	Estimate	Confidence interval (95%)	P-value
(Intercept)	23.66	18.28–29.05	<0.001 ***
Day	−0.10	−0.13–−0.08	<0.001 ***
c1_school_rec	−0.68	−4.17–2.81	0.703
c1_shool_req_some	−2.32	−4.96–0.33	0.086
c1_school_req_all	−4.42	−7.56–−1.27	0.006 **
c2_work_rec	−1.92	−4.94–1.10	0.213
c2_work_req_some	−0.91	−3.78–1.97	0.537
c2_work_req_all	−3.17	−7.00–0.66	0.105
c3_events_rec	−5.16	−8.21–−2.10	0.001 **
c3_events_req	−6.01	−8.81–−3.22	<0.001 ***
c4_gatherings_1000plus	1.62	−2.73–5.98	0.465
c4_gatherings_100_1000	1.94	−1.05–4.93	0.204
c4_gatherings_10_100	0.70	−2.30–3.70	0.646
c4_gatherings_10minus	−2.7	−6.01–0.61	0.110
c5_transport_rec	−1.46	−3.78–0.86	0.217
c5_transport_req	−0.15	−4.09–3.79	0.939
c6_curfew_rec	0.01	−2.39–2.41	0.995
c6_curfew_req_loose	−1.19	−4.13–1.75	0.428
c7_movement_rec	−2.59	−5.06–−0.12	0.040 *
c7_movement_req	0.16	−2.74–3.06	0.914
c8_travelctrl_screening	−7.10	−11.68–−2.52	0.002 **
c8_travelctrl_quarantine	−5.02	−8.54–−1.51	0.005 **
c8_travelctrl_ban_high_risk	−6.47	−9.47–−3.47	<0.001 ***
c8_travelctrl_total_closure	−6.98	−10.34–−3.62	<0.001 ***
h1_campaigns_individual	2.35	−10.16–14.85	0.713
h1_campaigns_coordinated	0.12	−5.39–5.63	0.965
h2_testing_criteria	1.41	−3.39–6.21	0.564
h2_testing_symptoms	−0.12	−5.20–4.96	0.963
h2_testing_open	1.55	−4.02–7.12	0.585
h3_tracing_limited	0.70	−2.70–4.09	0.687
h3_tracing_comprehensive	2.45	−0.75–5.66	0.133
Marginal R^2/Conditional R^2	0.087/0.095		
F(12, 948.460) = 36.327	$p < 0.000$		

Significance at the 0.1%, 1%, 5% and 10% level is indicated by ***, **, * and., respectively.

References

[1] Johns Hopkins Coronavirus Resource Center CSSE, COVID-19 Dashboard, 2021. https://coronavirus.jhu.edu/map.html.

[2] M. Coccia, Preparedness of countries to face COVID-19 pandemic crisis: strategic positioning and factors supporting effective strategies of prevention of pandemic threats, Environ. Res. 203 (2022), 111678, https://doi.org/10.1016/j.envres.2021.111678.

[3] I. Benati, M. Coccia, Global analysis of timely COVID-19 vaccinations: improving governance to reinforce response policies for pandemic crises, International Journal of Health Governance (2022), https://doi.org/10.1108/IJHG-07-2021-0072.

[4] M. Coccia, Improving preparedness for next pandemics: max level of COVID-19 vaccinations without social impositions to design effective health policy and avoid flawed democracies, Environ. Res. (2022), 113566, https://doi.org/10.1016/j.envres.2022.113566.

[5] M. Coccia, Pandemic prevention: lessons from COVID-19, Encyclopedia 1 (2) (2021) 36, https://doi.org/10.3390/encyclopedia1020036.

[6] M. Coccia, High health expenditures and low exposure of population to air pollution as critical factors that can reduce fatality rate in COVID-19 pandemic crisis: a global analysis, Environ. Res. 199 (2021), 111339, https://doi.org/10.1016/j.envres.2021.111339.

[7] S. Chirumbolo, S. Pandolfi, L. Valdenassi, Seasonality of COVID-19 deaths. Did social restrictions and vaccination actually impact the official reported dynamic of COVID-19 pandemic in Italy? Environ. Res. 212 (2022), 113229 https://doi.org/10.1016/j.envres.2022.113229, 2022.

[8] Y.M. Htun, T.T. Win, N.H. Shan, Z.T. Winn, K.S. Thu, N.L. Maung, K.M. Tun, Impact of containment measures on community mobility, daily confirmed cases, and mortality in the third wave of COVID-19 epidemic in Myanmar, Trop. Med. Health 50 (23) (2022) 1–8, https://doi.org/10.1186/s41182-022-00413-8.

[9] R. Schneider, P. Masselot, A.M. Vicedo-Cabrera, F. Sera, M. Blangiardo, C. Forlani, A. Gasparrini, Differential impact of government lockdown policies on reducing air pollution levels and related mortality in Europe, Sci. Rep. 12 (726) (2022) 1–13, https://doi.org/10.1038/s41598-021-04277-6.

[10] X. Lian, J. Huang, R. Huang, C. Liu, L. Wang, T. Zhang, Impact of City Lockdown on the Air Quality of COVID-19-Hit of Wuhan City, vol. 742, Science of the Total Environment, 2020, 140556, 0.1016/j.scitotenv.2020.140556.

[11] M. Coccia, The impact of first and second wave of the COVID-19 pandemic in society: comparative analysis to support control measures to cope with negative effects of future infectious diseases, Environ. Res. 197 (2021), 111099, https://doi.org/10.1016/j.envres.2021.111099.
[12] M. Coccia, COVID-19 pandemic over 2020 (with lockdowns) and 2021 (with vaccinations): similar effects for seasonality and environmental factors, Environ. Res. 208 (2022), 112711, https://doi.org/10.1016/j.envres.2022.112711.
[13] B. Seligman, M. Ferranna, D.E. Bloom, Social determinants of mortality from COVID-19: a simulation study using NHANES, PLoS Med. 18 (12) (2021), e1003490, https://doi.org/10.1371/journal.pmed.1003888.
[14] A. Rangachev, G.K. Marinov, M. Mladenov, The demographic and geographic impact of the COVID pandemic in Bulgaria and Eastern Europe in 2020, Sci. Rep. 12 (2022) 6333, https://doi.org/10.1038/s41598-022-09790-w.
[15] N. Askitas, K. Tatsiramos, B. Verheyden, Estimating worldwide effects of non-pharmaceutical interventions on COVID-19 incidence and population mobility patterns using a multiple-event study, Sci. Rep. 11 (2021) 1972, https://doi.org/10.1038/s41598-021-81442-x.
[16] S. Flaxman, S. Mishra, A. Gandy, H.J.T. Unwin, T.A. Mellan, H. Coupland, S. Bhatt, Estimating the effects of non-pharmaceutical interventions on COVID-19 in Europe, Nature 584 (7820) (2020) 257–261, https://doi.org/10.1038/s41586-020-2405-7.
[17] L. Cuéllar, I. Torres, E. Romero-Severson, R. Mahesh, N. Ortega, S. Pungitore, N. Hengartner, Assessing the impact of human mobility to predict regional excess death in Ecuador, Sci. Rep. 12 (2022) 370, https://doi.org/10.1038/s41598-021-03926-0.
[18] J. Huang, X. Liu, L. Zhang, Y. Zhao, D. Wang, J. Gao, C. Liu, The oscillation-outbreaks characteristic of the COVID-19 pandemic, Natl. Sci. Rev. 8 (8) (2021) nwab100, https://doi.org/10.1093/nsr/nwab100.
[19] J. Huang, L. Zhang, X. Liu, Y. Wei, C. Liu, X. Lian, T. Zhang, Global prediction system for COVID-19 pandemic, Sci. Bull. 65 (22) (2020) 1884–1887, https://doi.org/10.1016/j.scib.2020.08.002.
[20] L. Coscieme, L. Fioramonti, L.F. Mortensen, K.E. Pickett, I. Kubiszewski, H. Lovins, R. Wilkinson, Women in power: female leadership and public health outcomes during the COVID-19 pandemic, medRxiv (2020), https://doi.org/10.1101/2020.07.13.20152397.
[21] S. Keita, Air passenger mobility, travel restrictions, and the transmission of the covid-19 pandemic between countries, Covid Economics 9 (2020) 77–96.
[22] A. Sorokowska, P. Sorokowski, P. Hilpert, K. Cantarero, T. Frackowiak, K. Ahmadi, S. Blumen, Preferred interpersonal distances: a global comparison, J. Cross Cult. Psychol. 48 (4) (2017) 577–592, https://doi.org/10.1177/002202211769803.
[23] A. Oksanen, M. Kaakinen, R. Latikka, I. Savolainen, N. Savela, A. Koivula, Regulation and trust: 3-month follow-up study on COVID-19 mortality in 25 European countries, JMIR Public Health Surveill 6 (2) (2020), e19218, https://doi.org/10.2196/19218.
[24] A. Erman, M. Medeiros, Exploring the impact of cultural variability on COVID-19-related mortality: a meta-analytic approach, Research Square (2020), https://doi.org/10.21203/rs.3.rs-39104/v1.
[25] W.C. Koh, L. Naing, J. Wong, Estimating the impact of physical distancing measures in containing COVID-19: an empirical analysis, Int. J. Infect. Dis. 100 (2020) 42–49, https://doi.org/10.1016/j.ijid.2020.08.026, 2020.
[26] A. Friedson, D. McNichols, J. Sabia, D. Dave, Did California's shelter-in-place order work? Early Coronavirus-Related Public Health Effects (2020) https://doi.org/10.2139/ssrn.3584923. SSRN.
[27] R. Chaudhry, G. Dranitsaris, T. Mubashir, J. Bartoszko, S. Riazi, A country level analysis measuring the impact of government actions, country preparedness and socioeconomic factors on COVID-19 mortality and related health outcomes, EclinicalMedicine 25 (2020), 100464, https://doi.org/10.1016/j.eclinm.2020.100464.
[28] V. Stojkoski, Z. Utkovski, P. Jolakoski, D. Tevdovski, L. Kocarev, The Socio-Economic Determinants of the Coronavirus Disease (COVID-19) Pandemic, 2020 arXiv preprint arXiv:2004.07947.
[29] K.F. Morales, J. Paget, P. Spreeuwenberg, Possible explanations for why some countries were harder hit by the pandemic influenza virus in 2009–a global mortality impact modeling study, BMC Infect. Dis. 17 (1) (2017) 1–12, 0.1186/s12879-017-2730-0.
[30] G. Nikolopoulos, P. Bagos, T. Lytras, S. Bonovas, An ecological study of the determinants of differences in 2009 pandemic influenza mortality rates between countries in Europe, PLoS One 6 (5) (2011), e19432, https://doi.org/10.1371/journal.pone.0019432.
[31] The World Bank, World development indicators, Available from: https://databank.worldbank.org/source/world-development-indicators A. (Accessed 9 April 2020). Accessed.
[32] INFORM., INFORM, Epidemic risk, Available from: https://data.humdata.org/dataset/inform-epidemic-risk. (Accessed 14 April 2020). Accessed.
[33] Thomas Hale, Sam Webster, Anna Petherick, Toby Phillips, Beatriz Kira, Oxford COVID-19 Government Response Tracker, Blavatnik School of Government, 2020. Available from: https://data.humdata.org/dataset/oxford-covid-19-government-response-tracker.
[34] Johns Hopkins University. Novel coronavirus (COVID-19) cases data. Available from: https://data.humdata.org/dataset/novel-coronavirus-2019-ncov-cases.
[35] F. Zhou, T. Yu, R. Du, G. Fan, Y. Liu, Z. Liu, J. Xiang, Y. Wang, B. Song, X. Gu, L. Guan, Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study, Lancet 395 (10229) (2020) 10–14, https://doi.org/10.1016/S0140-6736(20)30566-3, 1062.
[36] R. Verity, L.C. Okell, I. Dorigatti, P. Winskill, C. Whittaker, N. Imai, A. Dighe, Estimates of the severity of coronavirus disease 2019: a model-based analysis, Lancet Infect. Dis. 20 (6) (2020) 669–677, https://doi.org/10.1016/S1473-3099(20)30243-7.
[37] F.P. Havers, C. Reed, T. Lim, J.M. Montgomery, J.D. Klena, A.J. Hall, A.M. Fry, D.L. Cannon, C.F. Chiang, A. Gibbons, I. Krapiunaya, Seroprevalence of antibodies to SARS-CoV-2 in 10 sites in the United States, March 23-May 12, 2020, JAMA Intern. Med. 180 (12) (2020) 1576, https://doi.org/10.1001/jamainternmed.2020.4130.
[38] Andrzej Gałecki, Tomasz Burzykowski, Linear Mixed-Effects Models Using R: A Step-by-step Approach, Springer-Verlag New York, 2013, https://doi.org/10.1007/978-1-4614-3900-4.
[39] E. Vittinghoff, D.V. Glidden, S.C. Shiboski, C.E. McCulloch, Regression Methods in Biostatistics: Linear, Logistic, Survival, and Repeated Measures Models, second ed., Springer, 2012, p. 509.
[40] G. James, D. Witten, T. Hastie, R. Tibshirani, An Introduction to Statistical Learning: with Applications in R, first ed., Springer, 2013. Corr 7th printing 2017.
[41] D. Bates, M. Mächler, B. Bolker, S. Walker, Fitting linear mixed-effects models using lme4, J. Stat. Software 67 (1) (2015) 1–48, https://doi.org/10.18637/jss.v067.i01.
[42] U. Halekoh, S. Højsgaard, A kenward-roger approximation and parametric bootstrap methods for tests in linear mixed models - the R package pbkrtest, J. Stat. Software 58 (10) (2014) 1–30, https://doi.org/10.18637/jss.v059.i09.
[43] P. Deb, D. Furceri, J.D. Ostry, N. Tawk, The effect of containment measures on the COVID-19 pandemic, IMF Work Pap 20 (159) (2020).
[44] E.J. Williamson, A.J. Walker, K. Bhaskaran, S. Bacon, C. Bates, C.E. Morton, J. Cockburn, Factors associated with COVID-19-related death using OpenSAFELY, Nature 584 (7821) (2020) 430–436, https://doi.org/10.1038/s41586-020-2521-4.
[45] M.F. Bashir, B. Ma, B. Komal, M.A. Bashir, D. Tan, M. Bashir, Correlation between climate indicators and COVID-19 pandemic in New York, USA, Sci. Total Environ. 728 (138835) (2020), 138835, https://doi.org/10.1016/j.scitotenv.2020.138835.
[46] Y. Ma, Y. Zhao, J. Liu, X. He, B. Wang, S. Fu, B. Luo, Effects of temperature variation and humidity on the death of COVID-19 in Wuhan, China, Sci. Total Environ. 724 (2020), 138226, https://doi.org/10.1016/j.scitotenv.2020.138226.
[47] B. Chen, H. Liang, X. Yuan, Y. Hu, M. Xu, Y. Zhao, X. Zhu, Roles of meteorological conditions in COVID-19 transmission on a worldwide scale, medRxiv (2020), https://doi.org/10.1101/2020.03.16.20037168.
[48] S.E. Eikenberry, M. Mancuso, E. Iboi, T. Phan, K. Eikenberry, Y. Kuang, E. Kostelich, A.B. Gumel, To mask or not to mask: modeling the potential for face mask use by the general public to curtail the COVID-19 pandemic, Infect Dis Model 5 (2020) 293–308, https://doi.org/10.1016/j.idm.2020.04.001.