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Containing the COVID-19 Pandemic: What Determined the Speed of Government Interventions?

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Key Words: COVID-19 pandemic, government lockdown measures, speed of government interventions, health system capacity, time-to-event models.

JEL Classification: I18, H12, J18

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1 Introduction

Since the confirmation of the first COVID-19 case in China, the disease has spread to all countries in the world albeit at different points in time. In the absence of pharmaceutical interventions (vaccine and treatments), governments around the world have introduced a range of administrative measures to contain the spread of COVID-19. The speed of the government responses has varied widely across countries, with fast responses in a number of countries even before the first confirmed COVID-19 case and slower responses in other countries.

A number of research papers find that the speed with which governments implemented non-pharmaceutical interventions (NPIs) mattered for both health and economic outcomes. Demirgüç-Kunt et al. (2020) find that the COVID-19 mortality rate at the peak of the local outbreaks has been lower in countries that acted faster. Dergiades et al. (2020) use daily data on confirmed deaths in 32 countries from 1st January to 30th April 2020 and find that the greater the strength of government NPIs introduced at an early stage, the more effective NPIs were in slowing down or reversing the growth rate of COVID-19 related deaths. Pragyan et al. (2020) find that NPIs measures have been on average very effective in slowing down the pandemic and reducing the COVID-19 related mortality rate. The results indicate that the effects of the containment measures have been stronger in countries where these measures have been implemented faster and in countries having stronger health systems, larger shares of the elderly population, lower population density and in countries with a low temperature climate conditions.

While the existing evidence indicates that the speed with which the governments have implemented NPIs has mattered for both health and economic outcomes, to the best of our knowledge there has been no analysis on what factors determined the variation in the speed of government responses around the world. The aim of this paper is to contribute to filling this evidence gap by addressing the following two questions: (1) what factors influenced governments' decisions to start the implementation of NPIs to contain the COVID-19 pandemic? (2) what factors determined the speed with which government NPIs reached their highest level? In particular, we examine whether and to what extent the health system capacity and a range of other country-specific factors could explain how fast the governments introduced containment measures such as school closures, workplaces closures, public events cancelations, restrictions on gatherings, public transport restrictions, stay at home requirements, and domestic travel restrictions. To this purpose, we estimate time-to-event models and analyse daily data on confirmed COVID-19 cases and related deaths combined with information on containment measures available for 124 countries from 1st January to 15th July 2020.

Our work relates to a small but growing literature on the effectiveness of government NPIs to contain the COVID-19 pandemic (Demirgüç-Kunt et al. 2020; Dergiades et al. 2020; Flaxman et al. 2020; Hartl et al. 2020; Hsiang et al. 2020; Newbold et al. 2020).

Flaxman et al. (2020) examined the impact of NPIs in 11 European countries from the first confirmed case until 4th May 2020. They provide evidence showing that lockdown measures have been successful in reducing the transmission of COVID-19. Hartl et al. (2020) find that the implementation of containment measures in Germany on 13th and 20th March 2020 have reduced the growth rate of COVID-19 cases.

A second strand of research has analysed the effects of NPIs on a range of economic activity outcomes including output, electricity consumption and greenhouse gas emissions (Demirgüç-Kunt et al. 2020; Newbold et al. 2020). Newbold et al. (2020) examine the optimal duration and intensity of social distance measures. Dorn et al. (2020) estimate the cost of lockdown measures in a number of European countries.

Our results indicate that on average, other things being equal, governments in countries with a high intensity of confirmed COVID-19 cases were more likely to start lockdown measures faster and to reach the highest levels of containment interventions faster.[1] The start of the containment measures was more likely after the confirmation of the COVID-19 pandemic by the World Health Organisation (WHO). Further, the start of containment measures was earlier in countries with a weaker health system capacity and in countries with a larger share of elderly populations. However, the health system capacity and the share of old age populations did not influence the speed with which the containment measures reached their highest levels across the analysed countries. Smaller and more open economies were more likely to move faster to the highest level of containment measures.

The remainder of this paper is structured as follows. Section 2 presents the data used for this analysis and discusses patterns and trends of the government NPIs to contain the COVID-19 pandemic across countries. Section 3 presents the empirical strategy. Section 4 discusses the empirical results of baseline model specifications and a sensitivity analysis. Section 5 summarises the key findings and concludes.

[1] The level of government containment interventions is measured using data from the Oxford COVID-19 Government Response Tracker.

2 Data and Descriptive Analysis

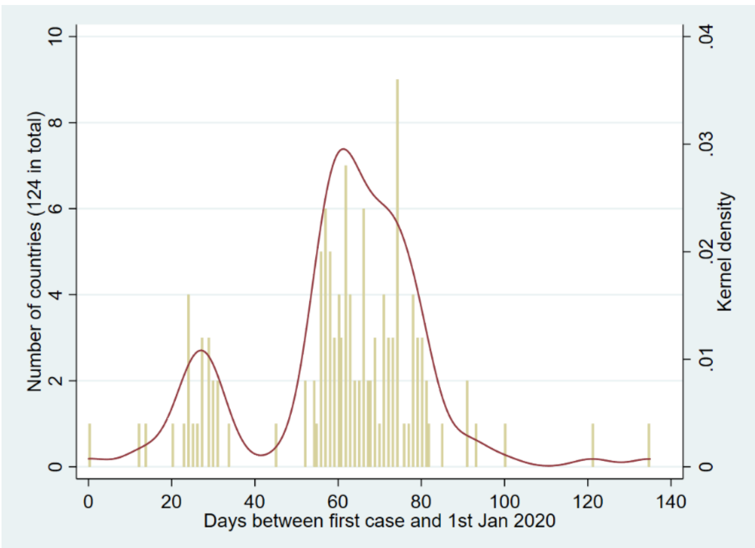
We analyse daily and annual data from a range of sources to examine factors that influence the speed of government interventions to contain the spread of COVID-19. Detailed descriptions of the variables used in the empirical analysis and the corresponding data sources are given in Table A1 in the Appendix.

2.1 Measuring the prevalence of COVID-19 across countries

We use daily data on confirmed COVID-19 cases and related deaths included in the Oxford COVID-19 Government Response Tracker for 124 countries from 1st January until 15th July 2020. Countries detected their first COVID-19 case at different points in time reflecting the spread of the virus.

Figure 1 illustrates the distribution of countries based on the date of the first confirmed COVID-19 case. A small group of countries have confirmed their first case very quickly, which was just around a month later since the 1st of January 2020. The majority of them confirmed the first case between 60 to 80 days after January 1st 2020. China had the first confirmed case before the 1st of January, which is before the start of the data set we analyse. This situation is shown as day 0 in Figure 1.

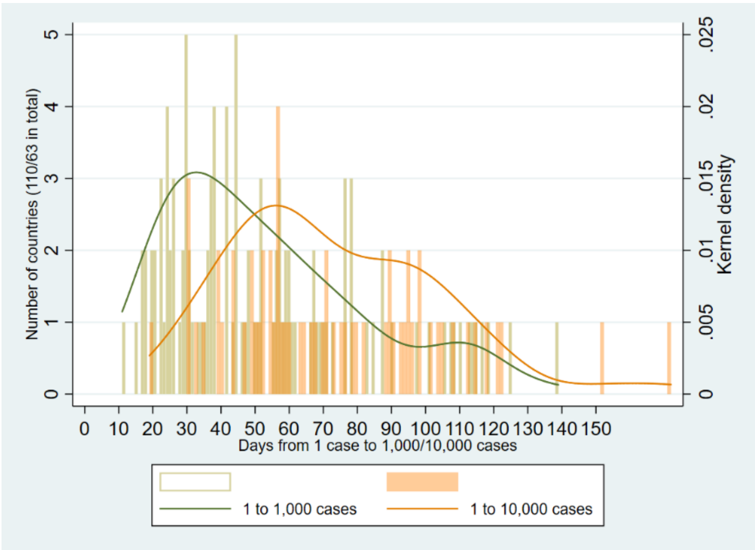
Figure 1. Days between the first confirmed case in each country and 1st January 2020



Source: Authors' elaboration based on data from the Oxford COVID-19 Government Response Tracker.

Once the first COVID-19 case was confirmed inside a country, the virus spread fast. As shown in Figure 2, most countries confirmed the first 1,000 cases around 30 days after the date when the first case was confirmed, while the total cases reached 10,000 after another 30 days. In this figure, countries that have a total case number less than 1,000 (or 10,000 in the latter one) are excluded, and as a consequence of this there are 110 (or 63 in the latter one) countries plotted in the figure.

Figure 2. How long it takes from the first confirmed case to 1,000/10,000 cases?



Source: Authors' elaboration based on data from the Oxford COVID-19 Government Response Tracker.

2.2 Measuring the speed of government interventions

To measure the speed of government interventions, we use daily data from the Oxford COVID-19 Government Response Tracker. The analysed data cover 124 countries over the period from 1st January until 15th July 2020.[2] We construct three measures of the speed of government interventions:

1) *the speed of starting government domestic lockdown measures from the first confirmed COVID-19 case***.** This is a binary variable that equals 1 when at least one of the following domestic lockdown measures were reported: school closures, workplaces closures, public events cancelations, restrictions on gatherings, public transport restrictions, stay at home requirements, and domestic travel restrictions;
2) *the speed of reaching the highest level of government response from the first confirmed COVID-19 case*. This is a binary variable that equals 1 when the country overall

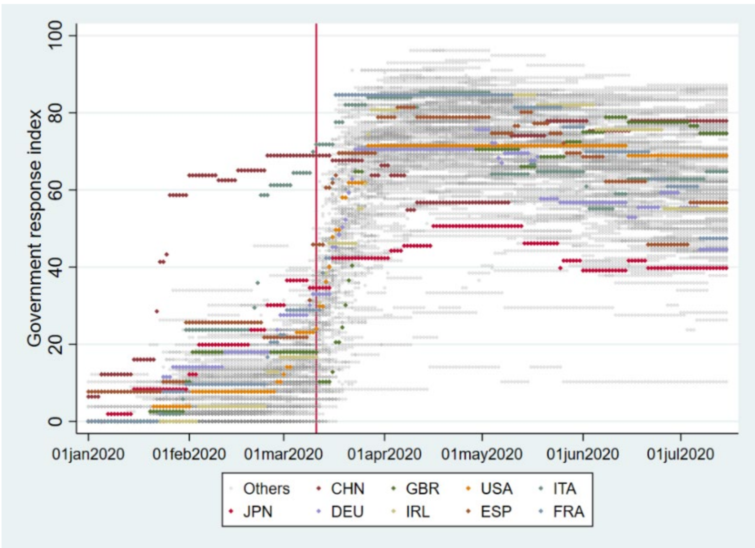
[2] The Oxford COVID-19 Government Response Tracker data set covers 177 countries. The lower number of countries included in our analysis is due to the fact that we only consider countries with reported COVID-19 cases and countries for which data on all variables is available.

Government Response Index is at its maximum value over the period 1st January to 15th July 2020;

3) *the speed of reaching the highest level of government response from the first COVID-19 related death.* This is a binary variable that equals 1 when the country overall Government Response Index is at its maximum value over the period 1st January to 15th July 2020.

Figure 3 shows the evolution of the overall Government Response Index since the 1st of January 2020 on the basis of the data provided by the Oxford Covid-19 Government Response Tracker. The red vertical line indicates the date when the WHO announced COVID-19 as a global pandemic (11th March 2020). As shown in Figure 3, most countries have started to respond to COVID-19 before the WHO global pandemic announcement, although with different restriction levels. Importantly, the WHO global pandemic announcement seems to have played a very big role in subsequent government responses, as almost all countries increased their restrictions level after the announcement. Further, Figure 3 shows that the highest level of restrictions (maximum overall Government Response Index) may also vary by country, as governments chose lockdown measures depending on their country-specific situation. Some countries have the maximum response index close to 100, while the maximum response index in other countries over the analysed period was around 60. Taking into account this country heterogeneity, we identify and use in the analysis the corresponding country-specific maximum Government Response Index.

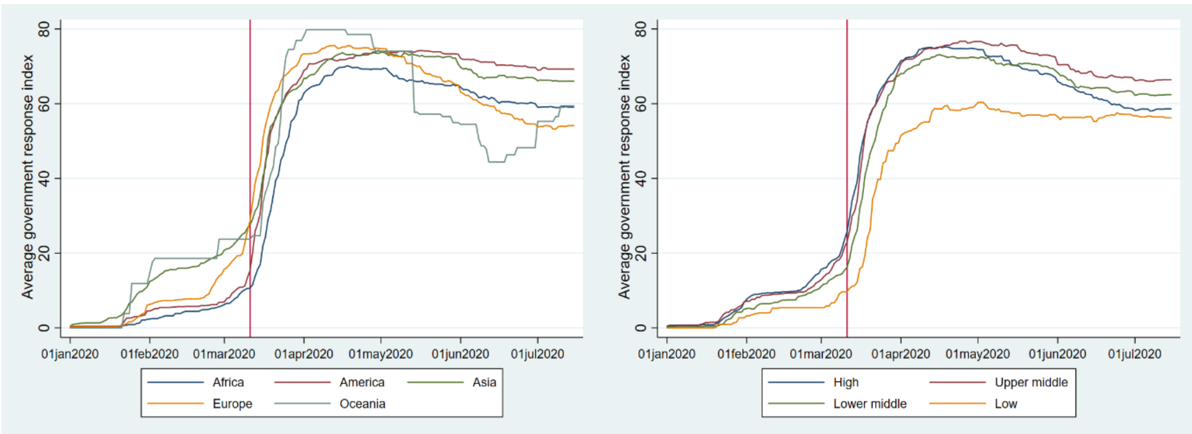
Figure 3. The evolution of the Government Response Index since 1st January 2020



Source: Authors' elaboration based on data from the Oxford COVID-19 Government Response Tracker.

In order to examine if government responses varied by continent or country income group,[3] Figure 4 plots the evolution of the Government Response Index averaged over countries in the same continent (shown in the left panel) or income group (right panel). This figure shows that countries in Asia and in Oceania started to respond quicker and had higher scores than countries in other continents before the WHO global pandemic announcement date. Countries in Oceania also relaxed their restrictions quicker (since May), but they reintroduced their restrictions in June. The right panel figure indicates that countries in the low-income group had relatively lower response scores than other countries, whereas countries in the middle income (upper middle or lower middle) group did not perform differently to those in the high-income group.

Figure 4. The evolution of the average Government Response Index by continent (left) and country income group (right) since 1st January 2020



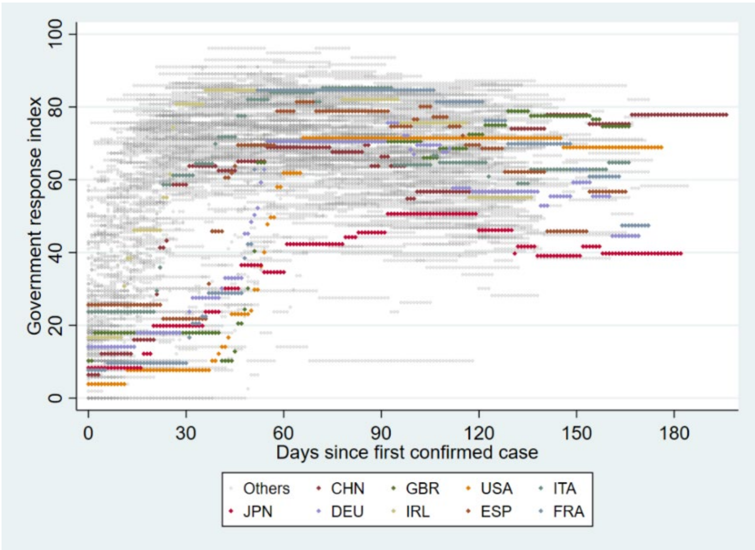
Source: Authors' elaboration based on data from the Oxford COVID-19 Government Response Tracker.

As the date when the first domestic COVID-19 case was detected vary across countries (as shown in Figure 1), the government responses might not have moved simultaneously, despite the fact that the WHO announcement had a strong influence. Figure 5 shows the evolution of the Government Response Index by country since the date when the first COVID-19 case was confirmed. It differs from Figure 3 in that this timeline no longer follows the calendar date. This figure shows clearly that the evolution of the government responses varied by country. Some countries responded fast and they intensified their measures within a month since the

[3] The grouping of countries by continent and by income group is taken from the World Bank data available at: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups.

first confirmed case, whereas it took other countries around 2 months to increase the level of lockdown restrictions.

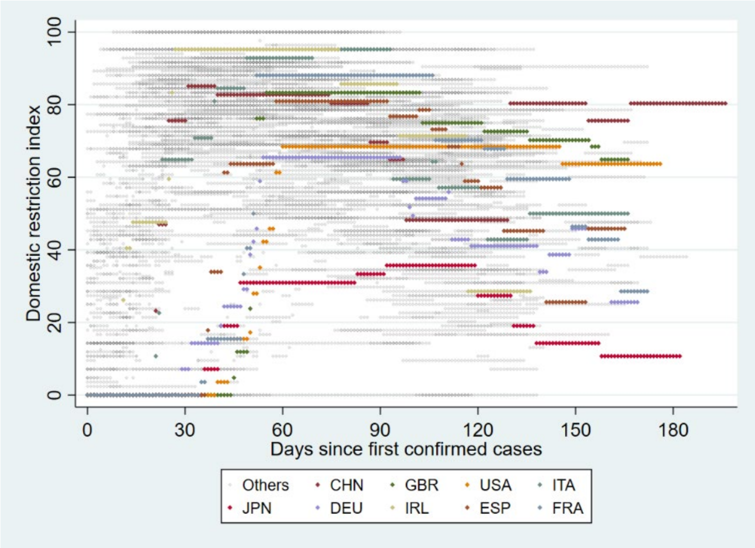
Figure 5. The evolution of the Government Response Index since the first confirmed COVID-19 case



Source: Authors' elaboration based on data from the Oxford COVID-19 Government Response Tracker.

Further, it is noteworthy that the Government Response Index has positive values for most countries on and before the first confirmed COVID-19 case. This is mainly because most countries have already introduced international travel restrictions (related to flights to and from China) as well as public information campaigns on Covid-19 before the first confirmed COVID-19 case. In order to examine how long it takes a government to start domestic lockdown measures, we compute a Domestic Lockdown Index based on the information provided in the Oxford Covid-19 Government Response Tracker for the all lockdown measures less those related to international travel. Figure 6 plots this index by country since the date of the first confirmed Covid-19 case in each country. This index evolves differently by country.

Figure 6. The evolution of government domestic lockdown measures

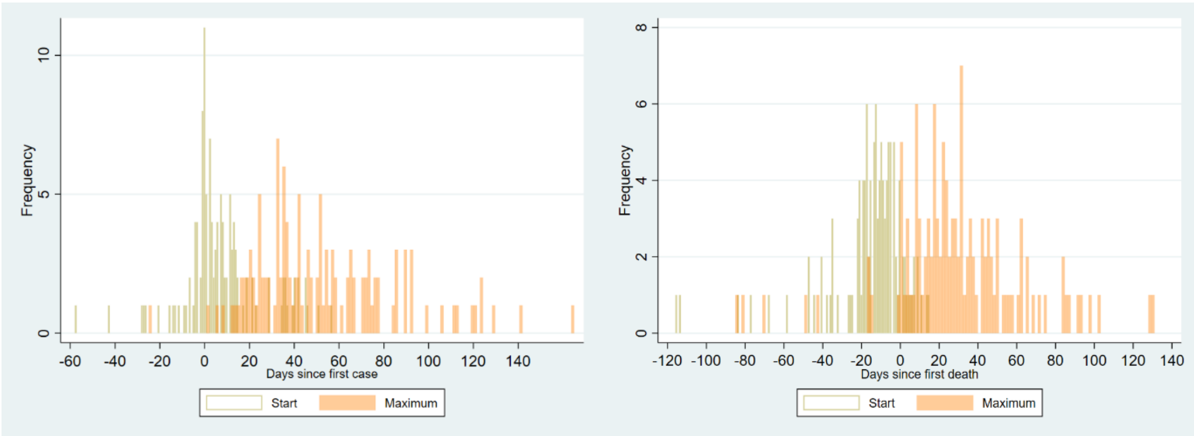


Source: Authors' elaboration based on data from the Oxford COVID-19 Government Response Tracker.

Although the dynamics of these scores for lockdown measures is interesting, the main focus of this paper is on the speed with which governments started domestic containment measures and on how fast these restrictions reached their highest level. To this purpose, we compute the difference in days between the date when a government started domestic lockdown restrictions (or the date when the Government Response Index reached its maximum value in that country) and the date when the first COVID-19 case was confirmed in that country. One may argue that the date of the first confirmed case may not be accurate given different testing capabilities. Therefore, as a robustness check, we also calculate the time difference with respect to the date when the first COVID-19 related death was confirmed.

Figure 7 plots the distribution of countries over the duration of the analysed period. On the left side, the duration is calculated based on the date of the first confirmed COVID-19 case. Both measures of duration, start of domestic response and maximum of response are reported. The distribution suggests that most countries have started to respond right after the first COVID-19 case was confirmed, and there are also countries that had started domestic lockdown restrictions before the first case. Moreover, while there is a fatter distribution of the speed with which a given country reached the maximum level of response, the peak is around 30-40 days. If we replace the date of the first confirmed case with the date of the first confirmed COVID-19 related death, we find that the majority of countries had already started domestic restrictions before the date of the first confirmed COVID-19 related death, and the response achieved their maximum value between 20 and 30 days. This figure is shown in the right panel.

Figure 7. How long does it take for governments to start domestic response / highest level of restrictions compared to first conirmed COVID-19 case (left) and first related death (right)?



Source: Authors' elaboration based on data from the Oxford COVID-19 Government Response Tracker.

Since the hazard rate model employed in our econometric analysis only allows for positive values of the analysed time-to-event duration, we only investigate the duration from the first confirmed COVID-19 case and the start of domestic lockdown restrictions. Further, in the case of the speed with which government responses reached their highest level, we use the time-to event duration from both the date of the first confirmed COVID-19 case and the date of the first confirmed COVID-19 related death.

2.3 Country-specific characteristics

To identify and quantify the effects of factors likely to influence the speed of government interventions, we use a range of country-specific indicators such as the health system capacity, demographic characteristics, economic size, trade openness, and GDP per capita growth. Table 1 reports summary statistics of these indicators together with summary statistics for the variables measuring the prevalence of COVID-19 and of the variables measuring the speed of government interventions. Pair-wise correlations of the country-specific characteristics are reported in Table A2 in the Appendix.

Table 1. Summary statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
COVID-related variables					
From first case to the start of intervention					
Start response	1,445	0.06	0.24	0	1
Cumulative cases (CC), in log	1,445	-8.56	2.35	-14.66	-0.82
New cases (NC), in log	1,220	-10.22	2.29	-16.24	-3.33
Pandemic indicator	1,445	0.15	0.36	0.00	1
From first case to maximum of intervention					
Maximum response	6,629	0.02	0.13	0	1
Cumulative cases (CC), in log	6,629	-5.00	3.41	-16.07	2.67
New cases (NC), in log	6,300	-7.17	2.89	-16.24	-0.61
From first death to maximum of intervention					
Maximum response	4,006	0.03	0.16	0	1
Cumulative cases (CC), in log	4,006	-3.18	2.56	-11.93	2.67
New cases (NC), in log	3,956	-5.91	2.36	-14.74	-0.61
Country specific characteristics					
Health related					
Health system capacity	124	27.91	21.29	0.50	77.10
Demography related					
Old population (percent)	124	14.17	8.75	2.80	34.01
Total population (log)	124	16.38	1.61	11.49	21.08
Economic performance					
GDP (log)	124	25.29	1.89	21.19	30.67
Trade openness	124	57.58	9.02	34.78	88.67
GDP per capita growth (percent)	124	1.75	3.03	-17.35	9.71

Source: Authors' own calculations.

3 Empirical Strategy

We use time-to-event econometric models to examine factors that influence the speed of governments' responses to the spread of COVID-19. In the first set of models, we define the event as the start of a government's domestic response after the date when the first case was confirmed in that country. In the second set of models, we define the event to occur when a government reached the maximum level of all restrictions relative to the date of the first confirmed case. Although the response score can go up to 100 by definition, we allow the maximum level of a government response to vary across countries since each country may decide on reaching its highest level based on its own country-specific situation. Therefore, we define the highest level of government containment measures as the maximum response score a country had before the 15th of July 2020, the end of the data set we are using. Furthermore, as a robustness check, we re-estimate the second set of models for the time window after the date of the first confirmed death. We do not do the same for the first set of models as the majority of countries had already started domestic restrictions before the date when the first death in that country was confirmed.

Our empirical strategy is based on a hazard rate model with a complementary log-log link. Let $\lambda_j(\tau)$ be a continuous time hazard (the conditional probability of the occurrence of the event) that each country j has at time τ. Assume that $\lambda_j(\tau)$ is given by a proportional form as follows:

$$\lambda_j(\tau) = \lambda_0(\tau) exp\left(X_j(\tau)'\beta + Z_j'\gamma\right) \tag{1}$$

where $\lambda_0(\tau)$ is the baseline hazard, $X_j(\tau)$ are time varying country-specific covariates and Z_j are time-irrelevant country characteristics. Since the data is at daily frequency, we can generate a discrete time variable *t* based on the continuous time variable τ which belongs to the bounded intervals $[0, \tau_1), [\tau_1, \tau_2), \dots, [\tau_{t-1}, \tau_t), \dots, [\tau_l, \infty)$. For each country, $t = 0$ represents the date when the first COVID-19 case (or COVID-19 related death) was confirmed. The probability of event occurrence λ_{jt} in country j in day t conditional on no occurrence previously is described by the following equation:

$$\lambda_{jt} = \Pr\left[\tau_{t-1} \leq T_j < \tau_t \middle| T_j \geq \tau_{t-1}\right] = 1 - exp\{-exp\left(X_j(\tau)'\beta + Z_j'\gamma + \alpha(t)\right)\} \tag{2}$$

where $\alpha(t)$ is the duration variable that captures the baseline hazard $\log\left(-log(1 - \lambda_{0t})\right)$. The duration variable can be non-parametric if to each time t a dummy variable is assigned. However, in order to show the trend of the baseline hazard over time and to simplify the model, we assume it has a linear form, μt. We tested other polynomial forms with quadratic or cubic terms and the non-parametric specification, and the results remain qualitatively the same. Further, if we let $y_{jt} = log\left(-log\left(1 - \lambda_{jt}\right)\right)$, equation (2) can be expressed as follows:

$$y_{jt} = X_{jt}'\beta + Z_j'\gamma + \mu t \tag{3}$$

In our model specification, the most important time varying covariate of a country j, X_{jt} is the number of confirmed COVID-19 cases, which is measured either as cumulative cases or newly confirmed cases of the previous week. We also include in the model specification an indicator of the WHO pandemic announcement, which takes the value of 1 for the days after 11th March 2020 in models estimating the hazard of the start of domestic restrictions. However, this variable is excluded from the models for estimating maximum government response, as all countries implemented the highest level of restrictions after the pandemic announcement so that its effect cannot be identified.

The time invariant country fixed covariates Z_j include explanatory variables that relate to a country's health system capacity, demography, economic performance and geographic location. Although some of these variables may change over time, they are updated on a yearly basis, and hence remain unchanged for the period covered by our analysis. The country-specific variables included across all model specifications are the following: health system capacity, old age population, GDP, trade openness, GDP per capita growth and dummy variables for countries' continent location. In addition, we control for country income group. Detailed descriptions of the variables used in the analysis and their data sources are given in Table A1 in the Appendix.

Most country-specific time invariant variables included in the regressions are exogenous as they are based on economic and social data prior to the emergence of COVID-19. The only variable that may be endogenous is the number of confirmed cases (either new cases or cumulative cases), which is affected by government restrictions. For example, in the first set of models that estimate the speed with which government introduced domestic containment measures, the number of confirmed COVID-19 cases might be influenced by other restrictions that were launched before domestic restrictions such as bans on international travel, or information campaigns on COVID-19. In the second set of models that estimate the speed of reaching the highest level of government intervention, the number of confirmed cases might be influenced by earlier lower level interventions.

To alleviate this concern, we compute the number of confirmed cases as average over the previous seven days with respect to government restrictions. Assuming that the effect of government lockdown measures on the number of confirmed cases takes place with a delay, there should be no simultaneity in the model specifications. Second, although confirmed cases are likely to be influenced by earlier government restrictions, it is more likely that earlier restrictions would influence later decisions on containment measures through the number of COVID-19 cases. Thus, early restrictions are unlikely to be a confounding factor in the model specifications.

4 Results

4.1 What determined the start of government domestic interventions?

Table 2 shows the estimated effects of factors influencing the speed with which governments implemented domestic restrictions to reduce the spread of the COVID-19 pandemic. The domestic restrictions considered are the following: school closures, workplaces closures, public events cancelations, restrictions on gatherings, public transport restrictions, stay at home requirements, domestic travel restrictions.

Columns (1) and (2) show the baseline estimates while columns (3) and (4) control for the country income groups. On average, other things being equal, countries with a higher intensity of confirmed COVID-19 cases, with a lower capacity of the health system in terms of human resources and facilties, and countries with a higher share of old age populations were more likely to implement domestic restrictions faster. The implied marginal effects indicate that a doubling of the average intensity of the cumulative confirmed COVID-19 cases over a period of seven days (an increase by 100%) increases the probability of government domestic containment measures by 1 percentage point. A similar increase in the average intensity of new daily confirmed COVID-19 cases increases the probability of government responses by 1.3 percentage points. The WHO confrmation of the COVID-19 pandemic has also accelerated the start of government restrictions of domestic activities. The results indicate that the introduction of containment measures after the WHO pandemic anouncement were more likely by 16 percentage points compared to the introduction of such measures before the pandemic announcement. Further, when we control for the income group, the results in columns (3) and (4) indicate that countries with a higher GDP per capita growth were more likely to implement containment measures faster.

Table 2. Determinants of governments' decision to start domestic restrictions, all countries

	(1) CC	(2) NC	(3) CC	(4) NC
Confirmed COVID cases	0.270***	0.321***	0.254**	0.345***
	(0.087)	(0.081)	(0.109)	(0.091)
Health system capacity	-0.030***	-0.031***	-0.032***	-0.032***
	(0.009)	(0.009)	(0.009)	(0.009)
Pandemic indicator	2.072***	2.012***	2.054***	2.029***
	(0.240)	(0.229)	(0.251)	(0.229)
Old age population	0.052**	0.052**	0.056**	0.061**
	(0.023)	(0.021)	(0.026)	(0.024)
GDP	0.100	0.147	0.072	0.153
	(0.107)	(0.106)	(0.103)	(0.100)
Trade openness	-0.011	-0.022	-0.013	-0.017
	(0.017)	(0.016)	(0.020)	(0.018)
GDP per capita growth	-0.085	-0.071	-0.103*	-0.104**
	(0.052)	(0.049)	(0.059)	(0.053)
Upper middle income			0.449	0.621
			(0.478)	(0.411)
Lower middle income			-0.349	0.206
			(0.728)	(0.613)
Low income			0.338	0.908
			(1.037)	(0.865)
Time Trend	-0.033***	-0.027***	-0.026**	-0.026***
	(0.012)	(0.010)	(0.012)	(0.010)
Constant	-2.098	-1.786	-1.341	-2.341
	(2.405)	(2.391)	(2.507)	(2.411)
Marginal effects $\partial\lambda/\partial X$ (selected variables)				
Confirmed COVID cases	0.0102***	0.0130***	0.0094**	0.0135***
	(0.0031)	(0.0029)	(0.0039)	(0.0033)
Health sector capacity	-0.0011***	-0.0013***	-0.0012***	-0.0013***
	(0.0003)	(0.0004)	(0.0003)	(0.0003)
Pandemic indicator	0.1620***	0.1564***	0.1561***	0.1539***
	(0.0302)	(0.0276)	(0.0322)	(0.0277)
Old age population	0.0020**	0.0021***	0.0021**	0.0024***
	(0.0008)	(0.0008)	(0.0009)	(0.0009)
Observations	1,445	1,220	1,445	1,220
Log likelihood	-276.1	-252.7	-273.4	-250.8
Countries	90	87	90	87

Notes: Continent dummies are included in all models with Africa as the reference category. Robust standard errors are clustered by country and are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

4.2 What determined the speed of reaching the highest level of containment measures?

We further examined the influence of the same health related and other country-specific factors on reaching the highest level of containment measures. As a reference point, firstly we consider the date of the first confirmed COVID-19 case and secondly the date of the first confirmed COVID-19 related death.

Table 3 shows the estimated efffects of factors likely to influence the speed with which government containment measures were introduced since the first confirmed COVID-19 case reached the highest intensity level. The results indicate that a higher intensity of confirmed COVID-19 cases increased the probability of reaching the highest level of containment measures faster. While the health sector capacity and the share of old age population did not have significant effects, smaller countries in terms of their economic size and more open economies were more likley to reach the highest level of containment measures faster.

Table 4 reports the estimated effects of factors likely to influence the speed with which government containment measures introduced since the first confirmed death reached the highest intensity level. The results are qualitatively similar with the results reported in Table 3.

Table 3. Determinants of reaching the highest level of government interventions since the first confirmed COVID-19 case, all countries

	(1) CC	(2) NC	(3) CC	(4) NC
Confirmed COVID cases	0.280***	0.204***	0.285***	0.206***
	(0.050)	(0.051)	(0.056)	(0.054)
Health system capacity	0.004	0.006	0.004	0.005
	(0.007)	(0.007)	(0.008)	(0.007)
Old age population	0.067	0.647	0.665	0.996
	(2.248)	(2.121)	(2.282)	(2.096)
GDP	-0.234***	-0.277***	-0.218***	-0.257***
	(0.072)	(0.070)	(0.075)	(0.072)
Trade openness	-0.043***	-0.044***	-0.042***	-0.045***
	(0.013)	(0.012)	(0.013)	(0.013)
GDP per capita growth	0.048	0.056	0.042	0.052
	(0.044)	(0.044)	(0.045)	(0.047)
Upper middle income			0.024	-0.051
			(0.257)	(0.249)
Lower middle income			0.044	-0.026
			(0.371)	(0.346)
Low income			0.344	0.273
			(0.506)	(0.501)
Time Trend	0.011***	0.021***	0.011**	0.021***
	(0.004)	(0.003)	(0.004)	(0.004)
Constant	5.005***	5.772***	4.479**	5.313***
	(1.687)	(1.553)	(1.812)	(1.701)
Marginal effects $\partial\lambda/\partial X$ (selected variables)				
Confirmed COVID cases	0.0029***	0.0024***	0.0029***	0.0025***
	(0.0005)	(0.0006)	(0.0006)	(0.0007)
GDP	-0.0024***	-0.0033***	-0.0022***	-0.0031***
	(0.0007)	(0.0008)	(0.0007)	(0.0008)
Trade openness	-0.0004***	-0.0005***	-0.0004***	-0.0005***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Observations	6,629	6,300	6,629	6,300
Log likelihood	-556.2	-550.4	-555.8	-550
Countries	123	121	123	121

Notes: Continent dummies are included in all models with Africa as the reference category. Robust standard errors are clustered by country and are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4. Determinants of reaching the highest level of government interventions since the first confirmed COVID-19 related death, all countries

	(1) CC	(2) NC	(3) CC	(4) NC
Confirmed COVID cases	0.192***	0.150***	0.164**	0.118**
	(0.064)	(0.057)	(0.070)	(0.059)
Health system capacity	0.008	0.009	0.006	0.006
	(0.007)	(0.007)	(0.007)	(0.007)
Old age population	1.475	2.229	0.705	1.065
	(2.014)	(1.965)	(2.069)	(2.030)
GDP	-0.236***	-0.270***	-0.246***	-0.280***
	(0.074)	(0.070)	(0.076)	(0.071)
Trade openness	-0.036***	-0.037***	-0.040***	-0.042***
	(0.014)	(0.014)	(0.013)	(0.014)
GDP per capita growth	0.037	0.041	0.041	0.047
	(0.045)	(0.045)	(0.046)	(0.046)
Upper middle income			-0.323	-0.431*
			(0.273)	(0.260)
Lower middle income			-0.206	-0.410
			(0.393)	(0.360)
Low income			-0.445	-0.641
			(0.545)	(0.534)
Time Trend	0.011**	0.018***	0.013***	0.019***
	(0.004)	(0.003)	(0.005)	(0.004)
Constant	4.296**	5.089***	4.825**	5.894***
	(1.757)	(1.733)	(1.875)	(1.821)
Marginal effects $\partial\lambda/\partial X$ (selected variables)				
Confirmed COVID cases	0.0043***	0.0035***	0.0037**	0.0027**
	(0.0014)	(0.0013)	(0.0015)	(0.0013)
GDP	-0.0053***	-0.0062***	-0.0055***	-0.0064***
	(0.0015)	(0.0015)	(0.0015)	(0.0015)
Trade openness	-0.0008***	-0.0008***	-0.0009***	-0.0010***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Observations	4,006	3,956	4,006	3,956
Log likelihood	-486.7	-486.4	-486.1	-485.4
Countries	111	111	111	111

Notes: Continent dummies are included in all models with Africa as the reference category. Robust standard errors are clustered by country and are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

4.3 Sensitivity Analysis

The results of our analysis might be driven by large countries. To check the robustness of our results to such potential outliers, we re-estimate the model specifications first without China and second without the US. The results of these robustness checks are reported in Tables A3-A8 in the Appendix. These results are qualitatively similar to the results obtained with all countries shown in Tables 2-4.

An additional econometric issue might be a potential correlation between the date of the first confirmed COVID-19 case and the quality of the health system in a given country. In countries with a health system of higher quality the first COVID-19 case might have been detected earlier than in countries with a health system of lower quality. Governments in countries with a lower health system capacity might have introduced containment measures earlier being aware of the possible lagged detection of COVID-19 cases. This omitted variable might affect the effect of the health system capacity on the speed with which governments introduced NPIs. To account for this potential bias, we added in the model specifications a variable measuring the country-specific capacity of health systems to detect and report early epidemics of potential international concern.[4] The data is taken from the 2019 Global Health Security Index. The inclusion of this additional variable does not change the sign and significance of the health system capacity. The estimated average effects of the capacity of health systems to detect and report early epidemic of international concern are negative but not statistically significant. Taken together these results[5] indicate that the effect of the health system capacity on the speed with which government introduced NPIs to contain the spread of COVID-19 stands.

[4] This variable is a country score ranging from 0 to 100. The country score is computed as a weighted average of a range of indicators that assess laboratory systems; real-time surveillance and reporting; epidemiology workforce; and data integration between the human, animal, and environmental health sectors.

[5] These results are available from the authors upon request.

5 Conclusions

This paper contributes to the recent literature on the effectiveness of government interventions to contain the spread of COVID-19. We build on and extend the previous research by examining the speed with which governments introduced containment measures such as school closures, workplaces closures, public events cancelations, restrictions on gatherings, public transport restrictions, stay at home requirements, and domestic travel restrictions. To this purpose, we address two questions: (1) what factors influenced the governments' decisions to start the implementation of lockdown measures?; and (2) what factors determined the speed with which government lockdown measures reached their highest level?

We estimate time-to-event models and analyse daily data on COVID-19 confirmed cases and related deaths combined with information on containment measures available for 124 countries from 1st January to 15th July 2020. Further, we combine these data with country-level data on the health system capacity and a range of other indicators such as demographic characteristics, economic size, income per capita, economic growth, trade openness, and geographical location.

We construct three measures to capture the speed of such interventions: (1) the time from the first confirmed COVID-19 case until the start of lockdown measures; (2) the time from the first confirmed COVID-19 case until the highest level of lockdown measures; and (3) the time from the first confirmed COVID-19 related death until the highest level of lockdown measures.

Our results indicate that the speed of government interventions was strongly determined by the intensity of confirmed COVID-19 cases. The start of government lockdown measures was more likely after the confirmation of the COVID-19 pandemic by the WHO. In countries with a weaker health system capacity, and in countries with a larger share of elderly populations, governments were more likely to start containment measures faster. However, the health system capacity and the share of the elderly populations did not appear to influence the speed with which government responses reached the highest level. Government responses were more likely to reach their highest levels in smaller and more open economies. This result might reflect a higher capacity in smaller open economies to react to external shocks.

Taken together, our results suggest that boosting the health system capacity would be important to avoid costly lockdown measures aimed at containing a pandemic. Further research on factors influencing government responses to the COVID-19 pandemic could shed more light on the optimal mix and timing of containment measures.

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Appendix

Table A1. Variables description and data sources

Variable	Description	Data source
Government interventions		
Government response index	Composite index ranging from 0 to 100 measuring the level of government responses to COVID-19	Oxford COVID-19 Government Response Tracker. www.bsg.ox.ac.uk/covidtracker
Start of government domestic restrictions	Binary variable indicating the start of domestic restrictions. It is equal to 1 for values of domestic lockdown measures greater than 0.	Authors' own computation based on Oxford COVID-19 Government Response Tracker
Maximum level of government response	Binary variable measuring the highest level of restrictions. It equals to 1 if a country's government response index reached its maximum value (before the 15^{th} of July 2020).	Authors' own computation based on Oxford COVID-19 Government Response Tracker
Health related		
Cumulative confirmed COVID-19 cases	Average cumulative cases over the previous 7 days per 1000 inhabitants (in log)	Authors' own calculation based on Oxford COVID-19 Government Response Tracker
New confirmed COVID-19 cases	New cases: rolling average of daily new cases over the previous 7 days per 1000 inhabitants (in log)	Authors' own calculations based on Oxford COVID-19 Government Response Tracker.
Pandemic indicator	Binary variable equal to 1 after the WHO pandemic announcement (11 March 2020)	
Health system capacity	Country score ranging from 0 (the lowest) to 100 (the highest) based on data on available human resources and facilities capacities in clinics, hospitals and community care centres.	2019 Global Health Security Index (GHS). The Economist Intelligent Unit. Available at: https://www.ghsindex.org
Early detection and reporting of epidemics of international concern	Country score ranging from 0 (the least favourable) to 100 (the most favourable) based on indicators a range of indicators that assess laboratory systems; real-time surveillance and reporting; epidemiology workforce; and data integration between the human, animal, and environmental health sectors.	2019 Global Health Security Index (GHS), The Economist Intelligence Unit. Available at: https://www.ghsindex.org

Demography related		
Old age population	The share of population aged 60 and over in the total population, 2019 (in percent).	UNCTAD Statistics. https://unctadstat.unctad.org
Total population	Total population in 2019	UNCTAD Statistics. https://unctadstat.unctad.org
Economic performance		
GDP	Gross domestic product in millions of US dollars in constant (2015) price, 2018 (in log).	UNCTAD Statistics. https://unctadstat.unctad.org
Trade openness	Country score in 2019 ranging from 0 (least open) to 100 (most open).	World Economic Forum. Available: http://reports.weforum.org/global-competitiveness-report-2019/downloads/
GDP per capita growth	Annual average growth rates of gross domestic product per capita over 2013 – 2018 (in percent).	UNCTAD Statistics.
Country income group	Dummy variables: 1 = high income countries; 2 = upper middle income countries; 3 = lower middle income countries; 4 = low income countries	2020 World Bank Country and Lending Groups. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups

Table A2. Pair-wise correlations between country-specific variables

	Health sector capacity	The share of old age population	GDP	Trade openness	GDP per capita growth
Health system capacity	1.000				
The share of old age population	0.611	1.000			
GDP	0.611	0.450	1.000		
Trade openness	0.505	0.435	0.345	1.000	
GDP per capita growth	0.119	0.225	0.030	0.137	1.000

Source: Authors' own calculations.

Table A3. Determinants of governments' decisions to start domestic restrictions, all countries without China

	(1) CC	(2) NC	(3) CC	(4) NC
Confirmed COVID cases	0.265***	0.311***	0.249**	0.334***
	(0.088)	(0.081)	(0.111)	(0.091)
Health system capacity	-0.029***	-0.031***	-0.032***	-0.032***
	(0.009)	(0.009)	(0.009)	(0.009)
Pandemic indicator	2.078***	2.022***	2.062***	2.040***
	(0.242)	(0.229)	(0.252)	(0.229)
Old age population	0.053**	0.053**	0.056**	0.060**
	(0.024)	(0.022)	(0.026)	(0.024)
GDP	0.088	0.131	0.066	0.143
	(0.119)	(0.117)	(0.121)	(0.114)
Trade openness	-0.011	-0.021	-0.013	-0.017
	(0.017)	(0.016)	(0.020)	(0.018)
GDP per capita growth	-0.090	-0.079	-0.104	-0.105*
	(0.057)	(0.053)	(0.064)	(0.057)
Upper middle income			0.432	0.590
			(0.487)	(0.415)
Lower middle income			-0.359	0.167
			(0.732)	(0.611)
Low income			0.316	0.851
			(1.039)	(0.864)
America	-0.660	-0.551	-0.827*	-0.663
	(0.450)	(0.406)	(0.468)	(0.437)
Asia	0.217	0.545	0.097	0.598
	(0.375)	(0.382)	(0.408)	(0.410)
Europe	-0.047	-0.053	-0.074	0.039
	(0.516)	(0.513)	(0.546)	(0.529)
Oceania	-0.645	-0.259	-0.628	-0.193
	(0.546)	(0.531)	(0.565)	(0.545)
Time Trend	-0.033***	-0.027***	-0.026**	-0.026**
	(0.012)	(0.011)	(0.013)	(0.010)
Constant	-1.867	-1.542	-1.237	-2.180
	(2.657)	(2.579)	(2.906)	(2.717)
Observations	1,423	1,205	1,423	1,205
Log likelihood	-272	-249.4	-269.4	-247.6
Countries	89	86	89	86

Notes: Robust standard errors in parentheses, errors are clustered by country. *** p<0.01, ** p<0.05, * p<0.1.

Table A4. Determinants of governments' decisions to start domestic restrictions, all countries without the USA

	(1) CC	(2) NC	(3) CC	(4) NC
Confirmed COVID cases	0.267***	0.320***	0.259**	0.354***
	(0.088)	(0.083)	(0.111)	(0.095)
Health system capacity	-0.030***	-0.032***	-0.032***	-0.033***
	(0.009)	(0.009)	(0.009)	(0.009)
Pandemic indicator	2.096***	2.041***	2.079***	2.068***
	(0.239)	(0.228)	(0.249)	(0.226)
Old age population	0.052**	0.052**	0.057**	0.062**
	(0.024)	(0.022)	(0.027)	(0.024)
GDP	0.085	0.132	0.062	0.143
	(0.106)	(0.106)	(0.104)	(0.100)
Trade openness	-0.011	-0.022	-0.011	-0.015
	(0.017)	(0.016)	(0.020)	(0.018)
GDP per capita growth	-0.088*	-0.075	-0.109*	-0.111**
	(0.053)	(0.050)	(0.059)	(0.053)
Upper middle income			0.524	0.714*
			(0.474)	(0.406)
Lower middle income			-0.249	0.323
			(0.714)	(0.604)
Low income			0.420	1.010
			(1.028)	(0.860)
America	-0.686	-0.576	-0.868*	-0.703
	(0.462)	(0.415)	(0.478)	(0.444)
Asia	0.265	0.609	0.156	0.697*
	(0.373)	(0.385)	(0.398)	(0.401)
Europe	-0.000	-0.016	-0.002	0.111
	(0.515)	(0.515)	(0.541)	(0.521)
Oceania	-0.598	-0.191	-0.567	-0.097
	(0.552)	(0.537)	(0.571)	(0.544)
Time Trend	-0.034***	-0.028***	-0.027**	-0.028***
	(0.012)	(0.011)	(0.012)	(0.010)
Constant	-1.794	-1.455	-1.249	-2.224
	(2.406)	(2.395)	(2.516)	(2.425)
Observations	1,404	1,179	1,404	1,179
Log likelihood	-270.9	-247.5	-268	-245.4
Countries	89	86	89	86

Notes: Robust standard errors in parentheses, errors are clustered by country. *** p<0.01, ** p<0.05, * p<0.1.

Table A5. Determinants of reaching the highest level of government domestic interventions since the first confirmed case, all countries without China

	(1) CC	(2) NC	(3) CC	(4) NC
Confirmed COVID cases	0.283***	0.213***	0.288***	0.217***
	(0.050)	(0.053)	(0.056)	(0.057)
Health system capacity	0.003	0.005	0.003	0.005
	(0.007)	(0.007)	(0.007)	(0.007)
Old age population	0.193	0.633	0.939	1.090
	(2.179)	(2.094)	(2.185)	(2.067)
GDP	-0.209***	-0.265***	-0.190**	-0.245***
	(0.075)	(0.072)	(0.075)	(0.073)
Trade openness	-0.044***	-0.045***	-0.043***	-0.045***
	(0.013)	(0.012)	(0.014)	(0.013)
GDP per capita growth	0.056	0.057	0.052	0.053
	(0.046)	(0.045)	(0.048)	(0.048)
Upper middle income			0.076	-0.020
			(0.255)	(0.248)
Lower middle income			0.035	0.004
			(0.384)	(0.354)
Low income			0.382	0.318
			(0.510)	(0.503)
America	-0.118	0.032	-0.177	0.000
	(0.330)	(0.345)	(0.357)	(0.376)
Asia	-0.092	0.035	-0.119	0.036
	(0.287)	(0.289)	(0.298)	(0.296)
Europe	-0.438	-0.292	-0.521	-0.321
	(0.453)	(0.464)	(0.452)	(0.459)
Oceania	-0.241	-0.122	-0.315	-0.150
	(0.883)	(0.869)	(0.883)	(0.873)
Time Trend	0.011***	0.020***	0.010**	0.020***
	(0.004)	(0.003)	(0.005)	(0.004)
Constant	4.466**	5.620***	3.872**	5.090***
	(1.745)	(1.659)	(1.812)	(1.750)
Observations	6,487	6,165	6,487	6,165
Log likelihood	-550.6	-545.2	-550.1	-544.7
Countries	122	120	122	120

Notes: Robust standard errors in parentheses, errors are clustered by country. *** p<0.01, ** p<0.05, * p<0.1.

Table A6. Determinants of reaching the highest level of government domestic interventions since the first confirmed case, all countries without the USA

	(1) CC	(2) NC	(3) CC	(4) NC
Confirmed COVID cases	0.281***	0.201***	0.285***	0.202***
	(0.051)	(0.051)	(0.057)	(0.055)
Health system capacity	0.003	0.006	0.003	0.005
	(0.007)	(0.007)	(0.007)	(0.007)
Old age population	-0.009	0.598	0.559	0.900
	(2.310)	(2.176)	(2.349)	(2.155)
GDP	-0.248***	-0.291***	-0.233***	-0.273***
	(0.072)	(0.070)	(0.074)	(0.071)
Trade openness	-0.044***	-0.044***	-0.043***	-0.045***
	(0.013)	(0.012)	(0.013)	(0.013)
GDP per capita growth	0.046	0.053	0.040	0.049
	(0.044)	(0.045)	(0.046)	(0.047)
Upper middle income			0.033	-0.051
			(0.256)	(0.249)
Lower middle income			0.029	-0.047
			(0.371)	(0.346)
Low income			0.311	0.234
			(0.507)	(0.499)
America	-0.136	0.026	-0.176	-0.007
	(0.337)	(0.351)	(0.363)	(0.382)
Asia	-0.085	0.066	-0.104	0.063
	(0.289)	(0.291)	(0.298)	(0.296)
Europe	-0.361	-0.236	-0.415	-0.258
	(0.471)	(0.478)	(0.464)	(0.469)
Oceania	-0.162	-0.126	-0.219	-0.154
	(0.892)	(0.874)	(0.891)	(0.877)
Time Trend	0.012***	0.021***	0.011**	0.021***
	(0.004)	(0.003)	(0.005)	(0.004)
Constant	5.373***	6.108***	4.910***	5.711***
	(1.677)	(1.554)	(1.789)	(1.697)
Observations	6,562	6,233	6,562	6,233
Log likelihood	-551.4	-545.8	-551	-545.5
Countries	122	120	122	120

Notes: Robust standard errors in parentheses, errors are clustered by country. *** p<0.01, ** p<0.05, * p<0.1.

Table A7. Determinants of reaching the highest level of government domestic interventions since the first confirmed death, all countries without China

	(1) CC	(2) NC	(3) CC	(4) NC	(5) CC	(6) NC
Confirmed COVID cases	0.176***	0.133**	0.147**	0.096	0.137**	0.087
	(0.062)	(0.065)	(0.070)	(0.069)	(0.068)	(0.070)
Health system capacity	0.007	0.009	0.005	0.006	0.009	0.010
	(0.007)	(0.007)	(0.007)	(0.007)	(0.011)	(0.011)
Old age population	1.826	2.318	1.113	1.199	1.216	1.233
	(1.859)	(1.879)	(1.912)	(1.939)	(1.940)	(1.993)
GDP	-0.200***	-0.242***	-0.214***	-0.253***	-0.211***	-0.250***
	(0.074)	(0.069)	(0.075)	(0.070)	(0.076)	(0.073)
Trade openness	-0.039***	-0.037***	-0.043***	-0.043***	-0.042***	-0.042***
	(0.014)	(0.013)	(0.014)	(0.014)	(0.015)	(0.016)
GDP per capita growth	0.056	0.052	0.062	0.062	0.063	0.064
	(0.047)	(0.046)	(0.048)	(0.048)	(0.048)	(0.049)
Upper middle income			-0.275	-0.407	-0.014	-0.141
			(0.273)	(0.262)	(0.537)	(0.540)
Lower middle income			-0.309	-0.505	-0.016	-0.067
			(0.418)	(0.395)	(0.723)	(0.711)
Low income			-0.459	-0.665	-0.856	-1.047
			(0.555)	(0.541)	(0.847)	(0.806)
					(0.055)	(0.050)
America	0.160	0.177	0.183	0.178	0.252	0.288
	(0.325)	(0.329)	(0.347)	(0.341)	(0.392)	(0.391)
Asia	0.355	0.416	0.406	0.458	0.369	0.436
	(0.339)	(0.337)	(0.333)	(0.328)	(0.354)	(0.349)
Europe	-0.228	-0.201	-0.161	-0.135	-0.175	-0.114
	(0.434)	(0.436)	(0.436)	(0.431)	(0.472)	(0.476)
Oceania	-0.287	-0.237	-0.283	-0.288	-0.434	-0.449
	(0.943)	(0.964)	(0.973)	(0.993)	(0.984)	(1.008)
Time Trend	0.013***	0.018***	0.015***	0.020***	0.016***	0.021***
	(0.005)	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)
Constant	3.382**	4.284**	4.091**	5.155***	3.768**	4.689**
	(1.717)	(1.746)	(1.819)	(1.787)	(1.879)	(1.895)
Observations	3,874	3,829	3,874	3,829	3,874	3,829
Log likelihood	-480.1	-480.4	-479.7	-479.5	-478.7	-478.2
Countries	110	110	110	110	110	110

Notes: Robust standard errors in parentheses, errors are clustered by country. *** p<0.01, ** p<0.05, * p<0.1.

Table A8. Determinants of reaching the highest level of government domestic interventions since the first confirmed death, all countries without the USA

	(1) CC	(2) NC	(3) CC	(4) NC
Confirmed COVID cases	0.189***	0.144**	0.159**	0.111*
	(0.065)	(0.058)	(0.071)	(0.059)
Health system capacity	0.008	0.009	0.006	0.006
	(0.007)	(0.007)	(0.007)	(0.007)
Old age population	1.439	2.190	0.598	0.943
	(2.077)	(2.017)	(2.130)	(2.079)
GDP	-0.252***	-0.285***	-0.265***	-0.299***
	(0.074)	(0.070)	(0.075)	(0.071)
Trade openness	-0.037***	-0.037***	-0.040***	-0.042***
	(0.014)	(0.014)	(0.013)	(0.014)
GDP per capita growth	0.034	0.038	0.040	0.046
	(0.045)	(0.045)	(0.047)	(0.047)
Upper middle income			-0.331	-0.444*
			(0.274)	(0.261)
Lower middle income			-0.238	-0.442
			(0.393)	(0.360)
Low income			-0.507	-0.704
			(0.546)	(0.535)
America	0.086	0.114	0.180	0.162
	(0.326)	(0.328)	(0.353)	(0.348)
Asia	0.282	0.388	0.402	0.471
	(0.350)	(0.348)	(0.339)	(0.335)
Europe	-0.176	-0.175	-0.023	-0.043
	(0.463)	(0.455)	(0.457)	(0.448)
Oceania	-0.152	-0.124	-0.086	-0.096
	(0.944)	(0.933)	(0.966)	(0.942)
Time Trend	0.012***	0.018***	0.014***	0.020***
	(0.004)	(0.004)	(0.005)	(0.004)
Constant	4.694***	5.446***	5.341***	6.367***
	(1.761)	(1.753)	(1.848)	(1.816)
Observations	3,979	3,929	3,979	3,929
Log likelihood	-482	-481.8	-481.4	-480.6
Countries	110	110	110	110

Notes: Robust standard errors in parentheses, errors are clustered by country. *** p<0.01, ** p<0.05, * p<0.1.