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Variability and strictness in COVID-19 government response: A macro-regional assessment☆

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ABSTRACT

We examine the effectiveness of non-pharmaceutical government interventions (NPIs) against COVID-19. In particular, we focus on the impact of strictness and variability in government interventions on the reproduction rate (R_t) and the number of new deaths (per million of inhabitants) in five different world regions (G7, G20, EU28, Central America and Asia). In line with existing evidence, we observe that more stringent and frequent NPIs contributed to slow down contagion. Unfortunately, no benefits in terms of mortality are found. In fact, with few exceptions, both strictness and variability in NPIs are associated with a rise in the number of new deaths. This evidence is observed to be stronger among advanced economies and over the second pandemic wave. Take together, our research findings advocate early and decisive implementation of NPIs, but gradual and staggered relaxation of NPIs when the pandemic appears to recede.

1. Introduction

The COVID-19 pandemic has become a major public health emergency of international concern with over 450 million of infected persons and 6 million of deaths in 225 countries across the globe. It has created an unprecedented economic, social and political upheaval, and it has pushed national healthcare systems to the brink of collapse, causing a persistent headache to healthcare professionals and experts. In this light, it is undeniable that the COVID-19 has attracted and is still attracting the interest of the world population and, more particularly, among scholars of a broad spectrum of scientific fields. To not surprise, "coronavirus" was the Google's most-searched word of 2020. Evidence of such interest lies in the mounting numbers of COVID-19-related scientific works, which grew at an average weekly rate above 20%, and as of March 21st, 2021 (i.e., 64 weeks after the beginning of the "COVID-19 era") amounted to 354.240. Notably, albeit unsurprisingly, a relatively large fraction (i.e., around 55%) of these studies belongs to the field of research "medical, health and biological sciences". A smaller space is instead occupied by work belonging to studies within the area "human society and economics" (i.e., around 9%) (see https://reports.dimensions.ai/covid-19/.)

Broadly, in this work we aim to contribute to the aforementioned different research fields by investigating the effectiveness of government policy responses to COVID-19. It is popularly known that countries around the world have implemented a range of non-pharmaceutical interventions (NPIs) in order to control the spread of the COVID-19 pandemic. However, a clear consensus on whether the deployed NPIs generated significant benefits in terms of reduced mortality risk has not yet been reached. For instance, Haug et al. (2020) provide an extensive analysis on the impact of more than 6000 individual NPIs on the reproduction rate (hereinafter R_t) of COVID-19 in 79 territories worldwide. They observe that no single NPI can decrease R_t below one. Actually, a combination of several NPIs seems to be needed to calm down the contagion. In this respect, Haug et al. (2020) show closing and restricting all those places where people gather for prolonged time (e.g., schools, businesses and bars) to be the most effective government interventions. Other effective, albeit less intrusive measures, are also found, i.e., cross-border travel restrictions and governmental support to vulnerable citizens and risk-communication strategies.

Using data on COVID-19 transmission in 41 countries for the period

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from January 2020 to May 2020, Brauner et al. (2020) also seek to evaluate the effectiveness of different NPIs (i.e., limiting gatherings to a) 1000 people or less, b) 100 people or less, c) 10 people or less, closures of businesses, schools, universities, as well as stay-at-home order) on reducing COVID-19 transmission. All NPIs collectively reduce R_t by 77%. Furthermore, Brauner et al. (2020) find that some NPIs tend to be more effective than others (e.g., businesses closures and gathering bans). Koh et al. (2020) evaluate the effectiveness of three different physical distancing measures (i.e., international travel controls, restrictions on mass gatherings, and lockdown-type measures) in mitigating the contagion risks. They focus on 142 countries and cover the period 01 January 2020–28 May 2020. Physical distancing measures – if implemented early – are found to be effective in reducing the R_t. In addition, recommended stay-at-home advisories and partial lockdowns are as effective as complete lockdowns in outbreak control. Hale et al. (2020b) examine whether more stringent governments interventions and the speed of their implementation affect the COVID-19-induced death rate. Rather than focusing on the country's different NPIs, they focus on the composite government indicator of NPIs (i.e., the Government Stringency Index) developed by Hale et al. (2020a) for the period 01 January 2020–27 May 2020. Standard cross-sectional regressions for a panel of 170 countries indicate that more stringent policies in the past (six--weeks) lead to a lower dead growth rate. Moreover, they show that delays in government responses lead to an acceleration of deaths. Fuller et al. (2021) make use instead of standard linear regressions to examine the link between mitigating policies and COVID-19-related mortality in 37 European countries during the first phase of the pandemic (i.e., 23 January 2020–30 June 2020). They observe that earlier implementation of stringent mitigation policies is key to prevent a widespread COVID-19 transmission and reduce the number of deaths. Therefore, countries that implement physical distancing measures earlier can expect to save thousands of lives relative to those countries that implemented similar measures, but later. The effects of NPIs on COVID-19 in Europe are also scrutinized by Flaxman et al. (2020). Specifically, they consider major interventions across 11 European countries for the period running from the start of the COVID-19 epidemics in February 2020 until May 2020. It is shown that major NPIs - and lockdowns in particular - have had a large effect on reducing transmission. Additional empirical evidence showing that NPIs have been associated with a decrease in the R_t can be found in Lai et al. (2020), Min et al. (2020) and Bo et al. (2021).

It is worth noting that the existing body of studies sheds lights on the *benefits* of government responses to COVID-19 pandemic that seek to defy COVID-19. However, this body of research overlooks the flipside of the coin, the risk and uncertainty surrounding the communication, implementation, trust and behavioral change in response to public policies. To the best of our knowledge, this is the first study that evaluates the effects of the *risk* or *uncertainty* of such public policies on the death and reproduction rates. This effects risk and uncertainty are driven by the following views (please see Section 2): public health transparency view, public health trust view, decisive leadership view, and behavioral public response view. These highlight the complexity in the public response to government health policies that seek to control the spread of the COVID-19 pandemic. Such public response can vary significantly across countries, and can be driven by the aforementioned catalysts or inhibitors that governments, public health authorities and research think tanks are typically unable to observe, measure and/or control for. In this sense, our regional approach to research into the effectiveness of government policies across the globe allows us to uncover a wealth of heterogeneous insights. It should be noted that our approach is not slanted towards a particular or binary stand in terms of the effectiveness of government health policies. Instead, our study is frankly agnostic, empirical and exploratory. Equipped with a rigorous methodology, we seek to document both the desired and undesired public health policy outcomes. The extent to which governments can anticipate such undesired public health policy outcomes and act preemptively can save human lives.

To sum up, our main contribution is that we account for the risk and uncertainty in the government offensive launched against COVID-19 and its related impact on the reproduction rate and mortality risk. With this last test, we attempt to evaluate the government's frenzy in a) introducing new NPIs frequently and/or at short notice, given its initial failure in controlling the virus transmission, and/or b) relaxing existing NPIs frequently and/or at short notice.

Our second contribution is that we estimate the effects of rising stringency in combined psychical distancing measures – measured by means of the Oxford COVID-19 Government Response Tracker (COVID-19 GRT) – on COVID-19 mortality and contagion risk. Our analysis, however, departs from the aforementioned empirical works in several ways. First, we abstract from studying the effectiveness of individual NPIs as, for instance, in Haug et al. (2020) and Brauner et al. (2020). We instead rely on a single composite indicator of government NPIs, i.e, COVID-19 GRT.

Our third contribution is that we compare the effectiveness of government interventions across different world regions (i.e., G7, G20, EU28, Asia and Central America) departing thus from the study of a unique global and homogeneous effect, which can potentially disguise regional differences. This allows us to shed light on the potential cross-country heterogeneity in the effectiveness of government interventions and, more importantly, to infer differences in the effectiveness of government interventions across countries that adopted similar measures and collected and processed data similarly. As aforementioned, the effectiveness is conditioned on a country's broadly defined cultural context, which comprises accurate, reliable and up-to-date information of the spread of the pandemic, the extent to which the government is trusted, the capacity of enforcement of government policies, as well as the behavioral public response. In this respect, we follow Wong et al. (2020) who recommend the need of additional analyses aimed at evaluating the effectiveness of NPIs in different countries.

Our fourth contribution is that our analysis does not focus only on the first phase of the pandemics but extends to February 2021, which allows us to compare the effectiveness of government interventions in the first and the second contagion wave.

Our fifth contribution is that the effectiveness of government policies in our work is assessed by focusing on reductions in the number of deaths. Therefore, as opposed to existing studies, which center on the rate of reproduction, we do not interpret government response effectiveness only as reproduction rate cuts. Our choice is motivated by the fact that governments around the world face unprecedented challenges detecting infected individuals and trace their prior contacts and this in providing robust and realistic R_t estimates. An unsuccessful contact tracing has been mainly driven by the fact that around 80% of infections have been shown to be induced by asymptomatic individuals. It is thus clear that in the absence of an efficient contact tracing, R_t-based estimates can be biased. To preserve the comparability across studies, we also scrutinize the response of the reproduction rate in our empirical analyses. Moreover, the ultimate objective of an accountable and responsible government is to save lives, which justifies the use of the number of deaths, an easier to quantify and more intuitive measure of the effectiveness of government interventions.

Our main results are as follows. First, in line with existing studies, we find that the implementations of NPIs helped to mitigate the contagion risk by reducing R_t. However, in terms of reduction in the number of deaths government interventions have proved to be less effective. In fact, higher overall strictness of NPIs is associated with more of deaths of COVID-19. This effect appears to be stronger in the second wave (i.e., 01 September 2020–21 February 2021). These results reconcile with Rafkin et al. (2021) who argue that confusing and inconsistent communication about COVID-19 deteriorates government's credibility and thus reduce the effectiveness of NPIs. Similarly, the variability in NPIs is associated with a higher mortality rate. On the one hand, in countries were COVID-19 health policies are less decisive, transparent, trustworthy, and where they place a more significant psychological burden on individuals. On the other hand, simultaneous ending of NPIs ignores the importance of differential impacts of the virus on various population group.

All in all, our research findings show that the inadequacy, inappropriateness and leniency of existing NPIs in many countries has called for more stringent containment measures and thus forced governments to devise alternative policies. Importantly, this came at a cost of higher uncertainty in government response to the COVID-19 pandemic. Such uncertainty has been found to increase both mortality and contagion risk. Importantly, our research shows that 'one-size-fits-it-all' approach is not necessarily an optimal solution to a public health emergency of international concern.

Our paper is structured as follows. In Section 2, we set out the theoretical views that guide our research. In Section 3, we describe the data and outline the methodology. In Section 4, we present and analyze our research findings. Finally, Section 5 concludes.

2. Theoretical framework

In this section, we discuss why government policy responses to COVID-19 had unintended consequences. We organize them into four groups, the public transparency view, the public health trust view, the decisive leadership view, and the behavioral public response view. We now turn to discuss each of the views in turn.

Public health transparency view. First and foremost, it is imperative that the society is provided with accurate and timely information about the pandemic risk and public policies undertaken. Misrepresenting such information can have adverse effects on public health, particularly on the most vulnerable members of the society. For instance, Hansson et al. (2021) assert that fallacious, false or untruthful information contents can render the society more vulnerable to the COVID-19 pandemic in at least six ways: a) discouragement of appropriate protective actions against contracting the virus, b) promotion of the use of false remedies against the virus, c) misrepresentation of the transmission mechanisms of COVID-19, d) downplaying the risks related to the pandemic, e) tricking people into buying fake protection against COVID-19, and f) harassing the alleged spreaders of the virus. Therefore, if public policy changes are not followed by transparent risk communication, they can translate into greater uncertainty as to whether such policy changes can achieve the intended health outcomes, and ultimately can exacerbate public health emergency. This is referred to as the public transparency view.

Public health trust view. Second, the implementation effectiveness of policy responses to COVID-19 depends on public trust in the health models, and it is mediated by a range of uncontrolled and unobserved factors. For instance, Adam (2020) argues that the effectiveness of government policies depends on the models used by health scientists to inform such government policies. The health models seek to understand how people move among three states, and how quickly. In particular, individuals are either susceptible to COVID-19 (S) or become infected (I). If they become infected, then they either recover (R) or die (Adam, 2020). The uncertainty as to whether these categories are fairly represented in the health models can have profound implications on the health outcomes. It is persuasively argued that also the effectiveness of policies depends the degree of public trust (Balog-Way and McComas, 2020). One of the key goals of government response to the COVID-19 is to reduce social interaction by way of limiting human mobility. In this regard, Bargain and Aminjonov (2020) find that, following the introduction of containment policies, non-essential mobility diminishes more in European regions with relatively higher public trust in policy makers before the pandemic. Moreover, the health models predict a larger COVID-19 death rate unless decisive and stable policy actions are undertaken earlier and maintained, a view supported by the results of a survey conducted by Fetzer et al. (2020). Failure to do so can erode public trust, which is conducive to the worsening of public health. The Cummings scandal, extensively reported in several British newspapers, engendered public distrust in the British government (Fancourt et al., 2020), which undermined the effectiveness of containment policies (O'Donnell and Begg, 2020). For instance, the position taken by the UK government regarding COVID-19 is centered on the "holding back the tide" viewpoint. This viewpoint advocates short-term, albeit not long-term defences against a rising tide (Chater, 2020), which are not sustainable and can trigger an increase in the risk and uncertainty of public policy responses to COVID-19. In this regard, recent anecdotal evidence shows that in countries governed by indecisive governments, new infections and deaths are likely to spiral out of control. In the UK, at the end of January 2021, the official COVID-19 death count exceeded 100,000 (see, e.g., https://coronavirus.data.gov.uk/details/deaths).

Decisive leadership view. Third, even if the degree of public trust in the health models is high, the effectiveness of government response to the pandemic depends on whether the political leaders are capable of making decisive decisions. In this regard, a theory of decisive leadership, developed by Bernheim and Bodoh-Creed (2020), posits that agency problems between voters and politicians can translate into changes in preferences among voters for leaders who perceive high costs of delay and have little uncertainty about the decision problem. Guided by such preferences, voters will choose leaders who make decisions more expeditiously then typical voters, despite possessing no special skill at collecting and processing relevant information. In the context of a public health emergency, the theory of political economy of Bernheim and Bodoh-Creed (2020) predicts that voters will abide by decisive and swift pandemic responses undertaken by political leaders. On the contrary, this theory implies that voters are less likely to follow relatively more hesitant, sloppy and indecisive health policies, which translated into a higher variability in the stringency index.

Behavioral public response view. Fourth, even if the degree of public trust is high, and the incumbent political party is decisive, the pandemic places significant psychological burdens on individuals, which requires large effort to align human behavior with the recommendations of public health experts (Van Bavel et al., 2020), and might not lead to the intended health outcomes, particularly if public policies feature heightened volatility. In this regard, the ineffectiveness of the British government's initial laissez-faire policy choice, which was founded on behavioral insights and herd immunity, was met with skepticism (Sibony, 2020), and was soon abandoned to more stringent containment policies.

3. Data and methodology

Data All data have been retrieved from Roser et al. (2020) and span the period 01 January 2020–21 February 2021. Strictness in government response against COVID-19 transmission is captured by the Oxford COVID-19 Government Response Tracker (i.e., `COVID-19 GRT`). As described by Hale et al. (2020a), `COVID-19 GRT` represents a composite measure based on nine response indicators (i.e., school and workplace closures, public event cancellations, public transport closures, public-gathering restrictions, international movement restrictions, stay-at-home measures, international travel controls) on a scale 0–100 where 100 denotes the maximum level of strictness.[1] Since our analysis is aimed at examining the effectiveness of both variability and strictness of governments' NPIs, an indicator capturing variations in countries' `COVID-19 GRT` is built. The latter is simply captured by the standard deviation of `COVID-19 GRT` estimated using a rolling window of 20 days (running from day -40 to day -20). On the one hand, this novel indicator measures the volatility of `COVID-19 GRT`. Said differently, uncertainty in NPIs. On the other hand, the increasing frequency in the implementation of new NPIs can be interpreted as governments'

[1] Note that the `COVID-19 GRT` is meant to record only the number and strictness of government policies and does not provide any insights on the appropriateness or effectiveness of each governments' response.

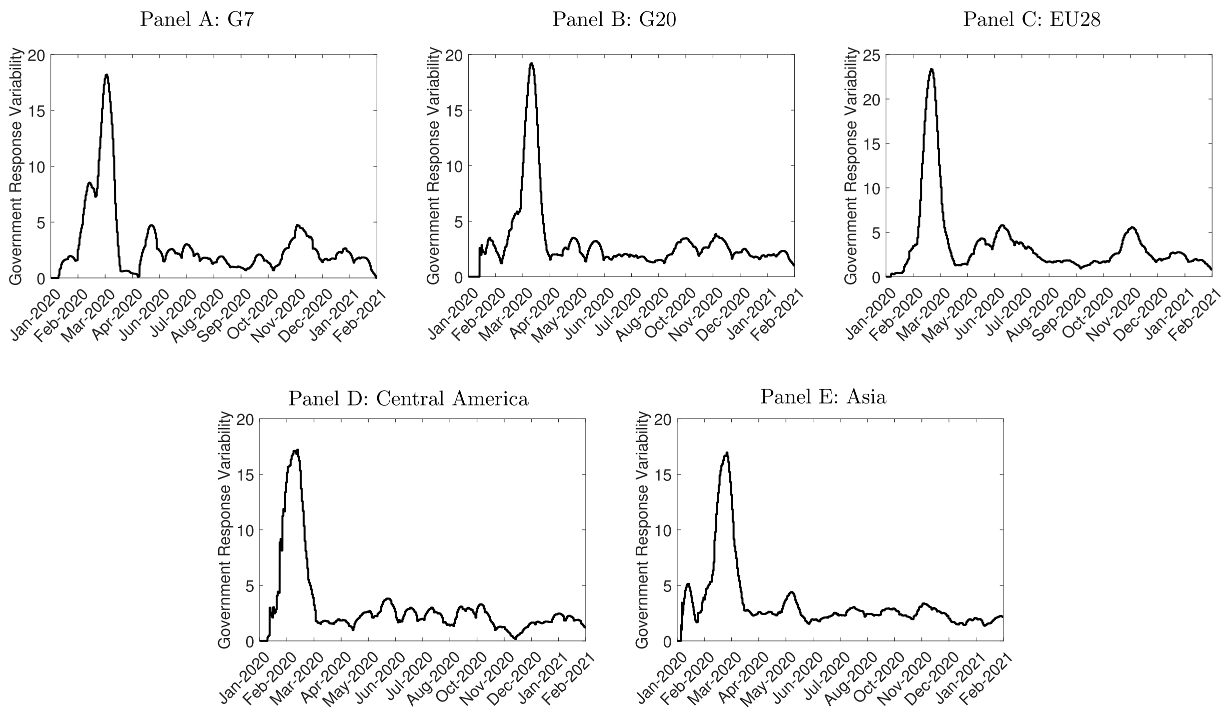

Fig. 1. Government Response Variability. *Notes:* This figure shows average variability of government response, proxied by the the average standard deviation of `COVID-19 GRT` computed using a rolling window from $t-40$ to $t-20$ in the G7 (Panel A), G20 (Panel B), EU28 (Panel C), Central America (Panel D) and Asia (Panel E). Sample: 01 Jannuary 2020–21 February 2021.

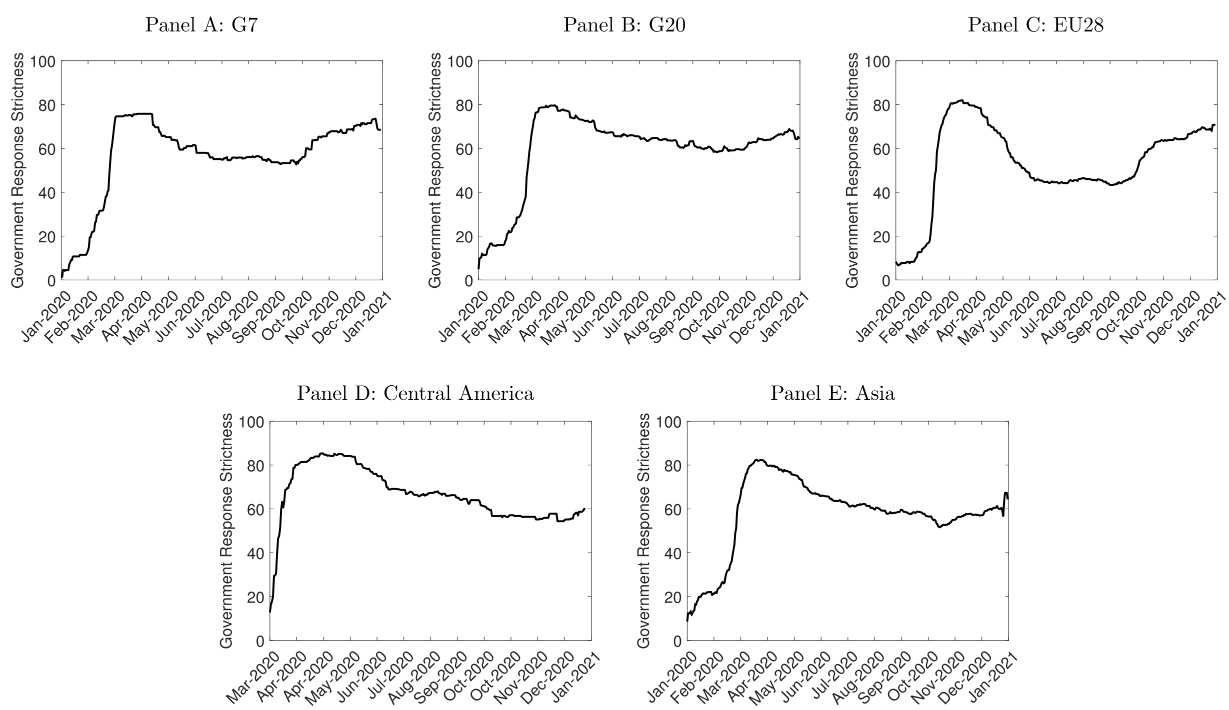

Fig. 2. Government Response Strictness. *Notes:* This figure shows average strictness of government response, proxied by the `COVID-19 GRT` in the G7 (Panel A), G20 (Panel B), EU28 (Panel C), Central America (Panel D) and Asia (Panel E). Sample: 01 Jannuary 2020–21 February 2021.

aggressiveness in fighting the COVID-19 transmission. The average level of government response variability and strictness in the five world regions (i.e., G7, G20, EU28, Asia, and Central America) are depicted in Figs. 1 and 2, respectively.

Let us stress that Roser et al. (2020) provide data for 180 countries. In order to create a more homogeneous dataset and to minimize the number of missing observation in our analysis, we have decided to restrict our analysis to the richest countries in terms of COVID-related data leading to a sample of 103 countries. Countries included is each macro-region are listed in Table A.1

Model description The effects of strictness and variability of government responses are estimated by means of random-effects and fixed-

Table 1

Variability and strictness of Government Response vs. COVID-19 New Deaths and R_t (**G7**).

Panel A: RE	Full sample				First wave				Second Wave			
	Variability		Strictness		Variability		Strictness		Variability		Strictness	
	NDM	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t
COVID-19 GRT	0.24172***	-0.00188	0.03627***	-0.01832***	0.28110***	-0.00436	0.00590	-0.01949***	0.51145***	-0.01904*	0.16648***	-0.01183***
	(0.04413)	(0.00368)	(0.00820)	(0.00124)	(0.04840)	(0.00303)	(0.00808)	(0.00125)	(0.13299)	(0.00935)	(0.03310)	(0.00252)
R^2	0.20973	0.00258	0.15520	0.57422	0.37701	0.00865	0.11311	0.62440	0.23960	0.04732	0.29049	0.27505
Obs.	2520	2488	2495	2482	1302	1277	1277	1271	1218	1211	1218	1211

Panel B: FE	Full sample				First wave				Second Wave			
	Variability		Strictness		Variability		Strictness		Variability		Strictness	
	NDM	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t
COVID-19 GRT	0.24145***	-0.00241	0.03625***	-0.01844***	0.28110***	-0.00449	0.00590	-0.01954***	0.50403**	-0.01923	0.16650***	-0.01268***
	(0.05732)	(0.00461)	(0.01049)	(0.00154)	(0.05947)	(0.00402)	(0.00995)	(0.00151)	(0.16725)	(0.01305)	(0.04374)	(0.00318)
R^2	0.09257	0.00061	0.03392	0.60107	0.30781	0.00208	0.00216	0.65022	0.07509	0.03953	0.15698	0.32801
Obs	2520	2488	2495	2482	1302	1277	1277	1271	1218	1211	1218	1211

Notes: This table reports the results for panel regressions of new deaths per million (*NDM*) and reproduction rate (R_t) on the variability and strictness of NPIs in the **G7**. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20) Strictness:= 30 days lagged COVID-19 GRT. Panel A: within and across country analysis (i.e., random effects). Panel B: cross-country analysis (i.e., fixed effects). Controls: aged 65 and older (% of population), population density, log GDP per capita, hospital beds per thousand (5 days lagged). Data are winsorized, i.e. negative NDM values are replaced with zero. Bootstrapped standard errors (1000 reps) are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Table 2

Variability and strictness of Government Response vs. COVID-19 New Deaths and R_t (**G20**).

Panel A: RE	Full sample				First wave				Second Wave			
	Variability		Strictness		Variability		Strictness		Variability		Strictness	
	NDM	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t
COVID-19 GRT	0.03498	0.00823*	0.02279**	-0.01175***	0.06682	0.00452	0.01280*	-0.01319***	0.10357	0.00096	0.06863*	-0.00804***
	(0.04501)	(0.00384)	(0.00735)	(0.00179)	(0.04618)	(0.00410)	(0.00576)	(0.00191)	(0.07467)	(0.00686)	(0.02848)	(0.00211)
R^2	0.10118	0.01114	0.12427	0.25933	0.13936	0.00509	0.12481	0.34017	0.11163	0.01997	0.16960	0.08892
Obs.	6660	6598	6591	6547	3354	3311	3285	3260	3306	3287	3306	3287

Panel B: FE	Full sample				First wave				Second Wave			
	Variability		Strictness		Variability		Strictness		Variability		Strictness	
	NDM	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t
COVID-19 GRT	0.03503	0.00838*	0.02276**	-0.01183***	0.06680	0.00453	0.01280*	-0.01323***	0.10493	0.00100	0.06851*	-0.00841***
	(0.04524)	(0.00373)	(0.00718)	(0.00190)	(0.04785)	(0.00400)	(0.00587)	(0.00189)	(0.07216)	(0.00694)	(0.02952)	(0.00198)
R^2	0.00405	0.01099	0.02250	0.29003	0.04175	0.00329	0.02031	0.37549	0.00799	0.00014	0.03979	0.11873
Obs	6660	6598	6591	6547	3354	3311	3285	3260	3306	3287	3306	3287

Notes: This table reports the results for panel regressions of new deaths per million (*NDM*) and reproduction rate (R_t) on the variability and strictness of NPIs in the **G20**. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20) Strictness:= 30 days lagged COVID-19 GRT. Panel A: within and across country analysis (i.e., random effects). Panel B: cross-country analysis (i.e., fixed effects). Controls: aged 65 and older (% of population), population density, log GDP per capita, hospital beds per thousand (5 days lagged). Data are winsorized, i.e. negative NDM values are replaced with zero. Bootstrapped standard errors (1000 reps) are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Table 3
Variability and strictness of Government Response vs. COVID-19 New Deaths and R_t (**EU28**).

Panel A: RE	Full sample				First wave				Second Wave			
	Variability		Stringency		Variability		Stringency		Variability		Stringency	
	NDM	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t
COVID-19 GRT	0.05809	-0.00710***	0.02234*	-0.00949***	0.15144***	-0.00574***	-0.00941	-0.00992***	0.43052***	-0.01974***	0.14643***	-0.00958***
	(0.04670)	(0.00164)	(0.01055)	(0.00091)	(0.04463)	(0.00166)	(0.00530)	(0.00121)	(0.08686)	(0.00413)	(0.02001)	(0.00092)
R^2	0.01091	0.02038	0.01831	0.30709	0.14927	0.02024	0.04841	0.35318	0.08292	0.06371	0.15032	0.22492
Obs.	9191	9223	9038	9059	4493	4552	4340	4388	4698	4671	4698	4671

Panel B: FE	Full sample				First wave				Second Wave			
	Variability		Stringency		Variability		Stringency		Variability		Stringency	
	NDM	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t
COVID-19 GRT	0.05808	-0.00708***	0.02214*	-0.00961***	0.15156***	-0.00574***	-0.00952	-0.00997***	0.43158***	-0.01974***	0.14757***	-0.00993***
	(0.04472)	(0.00167)	(0.01056)	(0.00093)	(0.04188)	(0.00172)	(0.00501)	(0.00124)	(0.09078)	(0.00397)	(0.01983)	(0.00091)
R^2	0.00388	0.01306	0.00693	0.35731	0.13319	0.00904	0.00588	0.40101	0.04495	0.05537	0.12041	0.31982
Obs	9191	9223	9038	9059	4493	4552	4340	4388	4698	4671	4698	4671

Notes: This table reports the results for panel regressions of new deaths per million (*NDM*) and reproduction rate (R_t) on the variability and strictness of NPIs in the **EU28**. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20) Strictness:= 30 days lagged COVID-19 GRT. Panel A: within and across country analysis (i.e., random effects). Panel B: cross-country analysis (i.e., fixed effects). Controls: aged 65 and older (% of population), population density, log GDP per capita, hospital beds per thousand (5 days lagged). Data are winsorized, i.e. negative NDM values are replaced with zero. Bootstrapped standard errors (1000 reps) are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Table 4
Variability and strictness of Government Response vs. COVID-19 New Deaths and R_t (**Central America**).

Panel A: RE	Full sample				First wave				Second Wave			
	Variability		Stringency		Variability		Stringency		Variability		Stringency	
	NDM	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t
COVID-19 GRT	-0.04292*	0.00408	0.00291	-0.00301	-0.03321*	0.00254	0.01466	-0.00684*	0.05155	0.00548	-0.01115	-0.00027
	(0.01781)	(0.00343)	(0.00833)	(0.00218)	(0.01599)	(0.00376)	(0.00773)	(0.00295)	(0.04188)	(0.00378)	(0.02589)	(0.00204)
R^2	0.11827	0.08591	0.11790	0.00861	0.11192	0.09706	0.12620	0.01621	0.15064	0.19312	0.13151	0.15897
Obs.	4559	4174	4449	4122	2123	1752	2013	1700	2436	2422	2436	2422

Panel B: FE	Full sample				First wave				Second Wave			
	Variability		Stringency		Variability		Stringency		Variability		Stringency	
	NDM	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t
COVID-19 GRT	-0.03981*	0.00385	0.00243	-0.00331	-0.03084*	0.00285	0.01311	-0.00669**	0.04750	0.00347	-0.01130	-0.00144
	(0.01651)	(0.00317)	(0.00797)	(0.00177)	(0.01517)	(0.00351)	(0.00796)	(0.00252)	(0.03108)	(0.00332)	(0.02445)	(0.00193)
R^2	0.00977	0.00604	0.00036	0.04583	0.02416	0.00340	0.02973	0.11855	0.00224	0.00597	0.00172	0.01311
Obs	4884	4542	4765	4481	2274	1903	2155	1842	2610	2639	2610	2639

Notes: This table reports the results for panel regressions of new deaths per million (*NDM*) and reproduction rate (R_t) on the variability and strictness of NPIs in the **Central America**. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20) Strictness:= 30 days lagged COVID-19 GRT. Panel A: within and across country analysis (i.e., random effects). Panel B: cross-country analysis (i.e., fixed effects). Controls: aged 65 and older (% of population), population density, log GDP per capita, hospital beds per thousand (5 days lagged). Data are winsorized, i.e. negative NDM values are replaced with zero. Bootstrapped standard errors (1000 reps) are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Table 5
Variability and strictness of Government Response vs. COVID-19 New Deaths and R_t **(Asia)**.

	Full sample				First wave				Second Wave			
	Variability		Stringency		Variability		Stringency		Variability		Stringency	
	NDM	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t
Panel A: RE												
COVID−19 GRT	-0.02000***	0.00692*	0.00528*	-0.00333**	-0.01094*	0.00531	0.00180	-0.00670***	-0.01327	0.00518	0.01766	-0.00242
	(0.00607)	(0.00341)	(0.00265)	(0.00109)	(0.00471)	(0.00375)	(0.00119)	(0.00111)	(0.02501)	(0.00334)	(0.01338)	(0.00137)
R^2	0.02072	0.02735	0.02946	0.00266	0.01241	0.01560	0.01165	0.01134	0.08457	0.04341	0.13006	0.00425
Obs.	11,981	12,771	11,792	12,604	5619	6024	5430	5857	6362	6747	6362	6747
Panel B: FE												
COVID−19 GRT	-0.01791**	0.00717*	0.00361	-0.00323**	-0.01086*	0.00547	0.00145	-0.00673***	-0.00640	0.00669	0.01328	-0.00240
	(0.00601)	(0.00330)	(0.00302)	(0.00102)	(0.00455)	(0.00357)	(0.00115)	(0.00116)	(0.02572)	(0.00351)	(0.01389)	(0.00135)
R^2	0.00308	0.01222	0.00145	0.02928	0.00164	0.00825	0.00027	0.11982	0.00024	0.00907	0.01198	0.01294
Obs	12,999	13,706	12,115	13,534	6115	6440	5908	6268	6884	7266	6884	7266

Notes: This table reports the results for panel regressions of new deaths per million (*NDM*) and reproduction rate (R_t) on the variability and strictness of NPIs in the **Asia**. Variability:= dynamic standard deviation of COVID−19 GRT (computed using a rolling window from t-40 to t-20) Strictness:= 30 days lagged COVID−19 GRT. Panel A: within and across country analysis (i.e., random effects). Panel B: cross-country analysis (i.e., fixed effects). Controls: aged 65 and older (% of population), population density, log GDP per capita, hospital beds per thousand (5 days lagged). Data are winsorized, i.e. negative NDM values are replaced with zero. Bootstrapped standard errors (1000 reps) are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

effects panel-regression models. Our panel data regression model is outlined in Eq. (1) below:

$$Y_{i,t} = \gamma_0 + \gamma_1 \times NPI_{i,t} + \Gamma'_{-1} \times \mathbf{X_{1,i,t}} + u_{i,t} \quad (1)$$

In Eq. (1), $Y_{i,t}$ is the COVID-19-related death rate or reproduction rate in country i at time t, $NPI_{i,t}$ is either the variability or strictness of non-pharmaceutical interventions, $\mathbf{X_{1,i,t}}$ is a vector of control variables. The random disturbance term can be decomposed into two components, $u_{i,t} = \nu_i + \varepsilon_{i,t}$, where ν_i captures unobservable country-specific heterogeneity in the number of death or reproduction rate, and $\varepsilon_{i,t}$ captures the idiosyncratic error, which varies both across countries and over time.

An advantage of the fixed-effects model is that it conveniently allows us to evaluate the effects of explanatory variables that vary over time. This model builds on the assumption that each county features its own unique but unobservable characteristics, whose information contents may or may not overlap with the time-varying determinants of $Y_{i,t}$. Thus, this model allows us capture arbitrary correlation among unobserved country-specific fixed effect ν_i and the time-varying determinants of $Y_{i,t}$. However, the random-effects model may be preferred under certain scenarios. First, when the sample is relatively small relative to the entire population (Gelman et al., 2005; Green and Tukey, 1960). Second, if the goal of an empirical study is to carry inference on the entire population, from which the sample is drawn, rather than in unobserved country specific characteristics *per se* (Gelman et al., 2005; Searle et al., 2009, p. 15-16). Third, the fixed effects estimation method requires estimating country-specific intercepts, which can come at the cost of a significant reduction in the number of degrees of freedom (Zaremba et al., 2021) if the cross-sectional dimension is large. Fifth, the random-effect model allows to control for time-invariant predictors of of $Y_{i,t}$. In line with other studies Hale et al. (2020b), we control for country-specific factors such as population density, percentage of population aged 65 or older, log of GDP per capita and hospital beds per thousand (lagged by five days). Population density and hospital beds per thousand were used by Zaremba et al. (2021). The percentage of population over 65 (log of GDP per capita) is conceptually similar to the age bracket of patient (the index of deprivation) used in Williamson et al. (2020).

The model is estimated separately for each macro region. Furthermore, to highlight the differences in the government response during the first and second wave, in which they should have been more prepared, we estimated the model on full sample, I wave (01 January 2020–31 August 2020) and II wave (01 September 2021–21 February 2021). Standard errors are robust to 1000 bootstrap replications.

4. Results

Main findings Estimates on the effectiveness of NPIs and their variability on deaths and transmission for the five different world regions are reported in Tables 1–5.

Table 1 reports the estimated coefficients for variability and strictness of government response for G7 countries. Results in Panel A show a positive and significant impact of NPIs on NDM, and a negative and significant impact on the reproduction rate. The strengthening in NPIs is positively related to an increase in deaths, whereas the strictness of government response helps to reduce the reproduction rate. However, the uncertainty generated by government response has a positive effect on the mortality rate from the COVID-19 pandemic, represented by NDM. It is worth noting that an increase in the strictness and/or variability of NPIs has a relatively stronger (weaker) effect on NDM (transmission) during the second wave. Results obtained with the fixed-effects estimator are virtually indistinguishable. Overall, these results highlight the complexity of the public response to government health policies. Thus, the presence of ambiguous communication of government health policies, the lack of trust in such health policies, the lack of decisive decision making at the government's upper echelon, as well as behavioral public response, or a combination of two or more aforementioned channels can drive the documented positive effect of NPIs on NDM. For instance, when the virus was detected in Asia and Europe, answers of US policy makers and health authorities to rapidly emerged questions: how fatal the virus is, how it transmits, how it can be contained, etc. were still unclear (Perra, 2021). In the G7 countries, in a relatively larger population of forward-looking, non-cooperative, self-interested individuals NPIs can trigger disinhibition, according to which a decline in the infection risks increases disease prevalence (Toxvaerd, 2019). The positive variability effect on NDM shows that a simultaneous ending of NPIs and release of COVID-19 restrictions could have ignored the importance of differential impacts of disease on various population groups (Zhao and Feng, 2020). Arguably, a release of NPIs can increase the overall variability in NPIs and can pose significant health risk to more vulnerable population groups. The variability would be lower if staggered-release policies are instead rolled out (Zhao and Feng, 2020).

Results for the G20 countries are reported in Panels A and B of Table 2. The random effects estimates show that the strengthening of NPIs helps to reduce the transmission rate (R_t). However, stricter NPIs have a positive and marginally significant effect (at 10%) on COVID-19 deaths. We also find that the variability in NPIs has a positive and marginally significant effect on the virus reproduction rate in the full sample, and a positive, albeit insignificant effect on deaths. As in the G7 countries, the effect of stricter NPIs on the reproduction rate is weaker during the second wave. The fixed effects estimates are very similar. Overall, while stricter NPIs lead to a decline in the reproduction rate, frequent policy changes are associated with positive changes in the reproduction rate, which partially offset the accrued health benefits. Furthermore, Table 2 does not lend support to the notion that stricter NPIs lead to a lower death rate from COVID-19. The latter finding is not unexpected, since NPIs do not target the mortality rate, but rather seek to prevent the virus from spreading within the society. It should be noted that the G20 group is composed of aging societies. For instance, in 2019, in the high-income countries 18% of the population was aged 65 and above.[2] In this country group, there is a larger share of the population at high risk, but that share is less intensely connected with younger individuals, who are more likely to be exposed to COVID-19 (Perra, 2021). However, there is no evidence if the inter-generational mixing remains stable in periods of pandemic crises due to other factors, such as behavioral markers. In this regard, Chen et al. (2013) demonstrate that an individual's self-protective behavior is driven by the cost of self-protection, the reported prevalence of disease, and their experiences earlier in the epidemic. For instance, if the opportunity cost of self-protection is high due to e.g. income foregone, then an individual is less likely to self-protect.

Similarly, the results for EU28 countries suggest that variability and strictness of government response is more effective in reducing the R_t than in controlling the mortality of COVID-19 (Table 3). We find that both the strictness and variability in NPIs exert a positive effect on the reproduction rate. Moreover, the strictness of NPIs is associated with a lower mortality rate only in the first wave. However, the coefficient estimate is not significant. Furthermore, the variability leads to an increase in the number of deaths from COVID-19 in both the first and second waves. Taken together, government response both in terms of strictness and variability did not succeed in limiting deaths. The effects of both the variability and strictness on new deaths is positive and generally significant. Thus, government response to COVID-19 could control the transmission of the virus, but not its mortality. First, our results are indicative that the variability in NPIs can be regarded as a significant risk factor. Second, consistently negative death effects might take more time to materialize. Third, effects of NPIs could be different on the overall mortality rate than on the reproduction rate. For instance, NPIs might have important transmission-reducing effects mostly among low-risk population groups. However, the differential response of COVID-19 mortality and transmission to NPIs possibly indicates that the virus was spreading among high-risk population groups (e.g., inhabitants of nursing homes) (Dave et al., 2021).

Panel A of Table 4 shows the estimated coefficients for Central America. Differently than from the previous country groups, the response of governments has limited effects on the transmission of COVID-19. Frequent changes in NPIs, i.e. variability, is associated with a reduction in NDM in the full sample estimates and particularly during the first wave (at 10%). Also, more stringent government response significantly reduced the reproduction rate R_t in the period from 01 January 2020 to 31 August 2020 (at 10%). The fixed effect estimates, reported in Panel B, are almost indistinguishable. The results indicate that governments' responses appear to be less effective in controlling the COVID-19 spread compared to developed countries. In Central America, a relatively larger share of informal economy, lack of social protection, as well as weak health infrastructure eroded the effectiveness of NPIs (OECD, 2020). Moreover, higher and increasing poverty rates determined a different set of priorities for policy makers compared to developed countries. For instance, in Mexico, the largest country of Central America, President López Obrador set his Government's policy priorities to combat the adverse economic effects provoked by the spread of the pandemic.[3] Furthermore, research advocates early implementation of NPIs, but strongly advises against early termination of NPIs (Ngonghala et al., 2020). This is indicative of the lack of effectiveness in the timing and strictness of NPIs, and potentially a low adherence level of social-distancing protocols in Central America. The adherence level is driven on the population's behavioral response, which is regarded one of the key public health control mechanisms for enhancing social distancing measures (AcuÑa-Zegarra et al., 2020).

Results for Asia countries are reported in Table 5. The stringency of government response helps reducing the spread of the virus, especially if the full sample and the first wave are considered. The variability in NPIs instead effectively diminishes NDM, but differently than in the other country groups it is associated with an increase in the reproduction rate R_t. We also find that the strengthening of NPIs has no significant effects during the second wave. Thus, whilst China was a showcase of the effectiveness of government response to COVID-19, where the early implementation of NPIs could have contained a a rapid spread of the COVID-19 pandemic (Lai et al., 2020), other Asian countries took different directions.

To sum up, G7, G20, and EU28 countries are found to be able to contain the transmission of COVID-19, but delays, inadequacy and ineffective communication of NPIs, as well as inefficiencies in the health care system actually increased the number of deaths in these country groups. Importantly, in these country groups the control of the mortality is weaker during the second wave. Both variability and stringency of government response is positively associated with new deaths and the effect is larger in the period 01 September 2020 – 21 February 2021. The latter is in line with Rafkin et al. (2021) findings, which show how inconsistent government communication weakens the effectiveness of NPIs. More generally, these results can be potentially explained by the risk and uncertainty surrounding the communication, implementation,

[2] https://data.worldbank.org/indicator/SP.POP.65UP.TO.ZS?most_recent_value_desc=false

[3] See https://www.imf.org/en/Topics/imf-and-covid19/Policy-Responses-to-COVID-19

trust and behavioral response to public policies. Differently, there is little reduction in NDM associated with variability and strictness of government response in Central America and Asia countries, although less effective during the second wave.

Additional results Our main results are supported by an array of robustness checks. Table B.1 summarizes the coefficient estimates when all of the 213 countries from Roser et al. (2020) are considered. Similarly to the results obtained for the G7, G20 and EU28 country groups, the strictness of government response is negatively associated to the reproduction rate R_t. However, both variability and strictness increased the number of deaths during the second wave, whereas in the full sample there is little or no effect.

In addition, we follow Hale et al. (2020b) and examine whether results are robust to a different measures of the dependent variable, calculated as the first difference of (daily) new deaths per million of inhabitants. Estimates reported in Tables B.2–B.6, provide the following insights. First, an increase in the strictness of government response induces a significantly lower number of new deaths (except for Asia and Central America). Second, the variability in government response has now influence on the change in the number of new deaths.

Moreover, our results are robust when controlling for life expectancy, human development index, male and female smokers (% of population), percentage of population in extreme poverty, log of population, as well as five days lagged hospital beds per thousand (Tables B.7–B.11).

Furthermore, to account for the different effects of strictness and variability of government response when new deaths per million are low or high, we run a quantile regression for the 20th and 80th percentiles. Results in Tables B.12–B.16 still indicates that strictness instigates a larger number of new deaths. Nevertheless, we also find that strictness significantly reduces R_t. By contrast, variability is positively associated with NDM and R_t, particularly for G7 and EU28 countries. Also, we observe negligible differences between estimates from the 20th and 80th percentiles.

Also, we check the robustness of our results by undertaking a fractional regression model of new deaths per million on variability and strictness of government response. The motivation behind the fractional regression approach is two-fold. First, unlike in a linear model, the number of new deaths cannot exceed the population. Second, this approach is more adequate if the underlying relation between the number of new deaths and the explanatory variables is non-linear. Results in Tables B17–B21 show that variability increases new deaths in G20 and EU28 countries, but not in Central America and Asia, except when only the second wave is considered. Stringency instead is positively associated to more deaths by COVID-19 in all country groups with few exceptions.

Finally, we ask if the effects of variability and stringency are driven by average income per capita. To this end, we split our sample into three subsamples according to GDP per capita, low-income (first third), middle-income (second third), and high-income countries (last third). Results are reported in Table B.22. They provide evidence of heterogeneous responses of NDM and R_t to variability and strictness. In low- and middle-income countries, higher variability influences negatively new deaths. Also, in middle-income countries, higher stringency is conducive to a lower reproduction rate. By contrast, in high-income countries, both variability and stringency positively influence new deaths, but higher stringency can lead to a lower reproduction rate. We also find some variation between the first and second waves. For instance, in the second wave, the negative effects of variability on NDM in low- and middle-income countries cease to be significant. Therefore, frequent policy changes can significantly diminish the effectiveness of government response in high-income countries.

5. Concluding remarks

In this paper we use daily data spanning the period 01 January 2020–21 February 2021 retrieved from Roser et al. (2020) to asses the effectiveness of government NPIs on COVID-19 in reducing contagion and mortality risk. Our analysis relies on 103 countries classified in five macro-regions, i.e. (*i*) G7, (*ii*) G20, (*iii*) EU28, (*iv*) Central America and (*v*) Asia. The effectiveness of government interventions is evaluated by focusing on both the strictness and the variability of NPIs.

Regression results show that strictness is actually positively related to new deaths. Because the incubation period of COVID-19 is about 10 days, the effects of NPIs are delayed with respect to the implementation date. The positive coefficient estimate associated to strictness on NDM can be interpreted as a systematic delay in the implementation of policies aimed to control the spread of COVID-19. Moreover, we show the frequently changes in the policies and rules, as proxied by the variability of government response, increases the number of new deaths. This result holds particularly in G7, G20, and EU28 countries and during the II wave (01 September–21 February). However, we document evidence that more stringent NPIs reduce the transmission of the virus, but the effect is partially offset by the increase in R_t generated by government response variability-related uncertainty. Even thought this detrimental effects are less pronounced in the II wave, still the delayed implementation of containment measures actually worsened the healthcare situation in the analyzed countries. To this end, a punctual government response and consistent communication are of first order importance to control the spread of the virus and limit mortality. Most importantly, one cannot neglect the adverse effects from the government response variability-related uncertainty that ultimately weaken the effectiveness of NPIs. It should be noted that our study has several shortcomings. First, our sample period is limited by the data availability on the COVID-19 reproduction rate, mortality rate, as well as the stringency index of government responses to the COVID-19 pandemic. At the time of writing of this article, the COVID-19 pandemic was still spreading, albeit to a varying degree across countries. Therefore, we are able to draw preliminary rather than definitive conclusions on the effectiveness of NPIs. Second, we examine the likelihood of COVID-19 transmission and mortality for an average citizen in each country. However, evidence shows that older adults are more vulnerable to COVID-19 than younger adults and children. Therefore, future research should center on the response of the reproduction and mortality rates of individuals of the same age group across countries. In fact, our cross section of countries is heterogeneous in terms of the average population age. Third, it should be noted that our research is agnostic, empirical and exploratory. Our study sheds light on different views as to why NPIs implemented across countries had limited effectiveness. In this regard, future research could compile evidence that confirms or rebuffs the aforementioned views. Fourth, aging societies are likely to suffer from parallel diseases, which can restrain the effectiveness of NPIs.

Appendix A. Countries

Table A1
Countries.

G7	G20	EU28	Central America	Asia
Canada	Argentina	Austria	Antigua and Barbuda	Afghanistan
France	Australia	Belgium	Bahamas	Armenia
Germany	Brazil	Bulgaria	Barbados	Azerbaijan
Italy	Canada	Croatia	Belize	Bahrain
Japan	China	Cyprus	Costa Rica	Bangladesh
United Kingdom	France	Czech Rep	Cuba	Bhutan
United States	Germany	Denmark	Dominica	Brunei
	India	Estonia	Dominican Republic	Cambodia
	Indonesia	Finland	El Salvador	China
	Italy	France	Grenada	Georgia
	Japan	Germany	Guatemala	Hong Kong
	Mexico	Greece	Haiti	India
	Russia	Hungary	Honduras	Indonesia
	Saudi Arabia	Ireland	Jamaica	Iran
	South Africa	Italy	Mexico	Iraq
	South Korea	Latvia	Nicaragua	Israel
	Turkey	Lithuania	Panama	Japan
	United Kingdom	Luxembourg	Saint Kitts and Nevis	Jordan
	United States	Malta	Saint Lucia	Kazakhstan
		Netherlands	Saint Vincent and the Grenadines	Kuwait
		Poland	Trinidad and Tobago	Kyrgyzstan
		Portugal		Laos
		Romania		Lebanon
		Slovakia		Malaysia
		Slovenia		Maldives
		Spain		Mongolia
		Sweden		Myanmar
				Nepal
				Oman
				Pakistan
				Palestine
				Philippines
				Qatar
				Saudi Arabia
				Singapore
				South Korea
				Sri Lanka
				Syria
				Taiwan
				Tajikistan
				Thailand
				Timor
				Turkey
				United Arab Emirates
				Uzbekistan
				Vietnam
				Yemen

Appendix B. Additional empirical tests

All countries Table B.1

Table B1
Variability and strictness of Government Response vs. COVID-19 New Deaths and R_t (**World**).

Panel A: RE

	Full sample				First wave				Second Wave			
	Variability		Stringency		Variability		Stringency		Variability		Stringency	
	NDM	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t
COVID-19 GRT	-0.00734	0.00172	0.00699*	-0.00513***	0.02153	0.00088	0.00156	-0.00771***	0.09766***	-0.00213	0.04769***	-0.00461***
	(0.01204)	(0.00139)	(0.00324)	(0.00064)	(0.01280)	(0.00138)	(0.00227)	(0.00070)	(0.02707)	(0.00206)	(0.00988)	(0.00089)
R^2	0.07878	0.02806	0.08522	0.01159	0.03800	0.01037	0.03677	0.03451	0.15143	0.05837	0.17175	0.00542
Obs.	45,862	45,815	45,036	45,209	21,469	21,076	20,648	20,475	24,393	24,739	24,388	24,734

Panel B: FE

	Full sample				First wave				Second Wave			
	Variability		Stringency		Variability		Stringency		Variability		Stringency	
	NDM	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t
COVID-19 GRT	0.00118	0.00178	0.00437	-0.00461***	0.02823*	0.00132	-0.00049	-0.00710***	0.08695***	-0.00166	0.04167***	-0.00462***
	(0.01216)	(0.00118)	(0.00317)	(0.00060)	(0.01279)	(0.00130)	(0.00228)	(0.00069)	(0.02416)	(0.00193)	(0.00865)	(0.00083)
R^2	0.00000	0.00098	0.00050	0.07916	0.00442	0.00065	0.00001	0.18171	0.00452	0.00055	0.01466	0.05884
Obs	52,937	52,672	51,031	51,996	24,542	23,910	23,601	23,240	28,395	28,762	28,389	28,756

Notes: This table reports the results for panel regressions of new deaths per million (*NDM*) and reproduction rate (R_t) on the variability and strictness of NPIs in the **World** (213 countries). Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20) Strictness:= 30 days lagged COVID-19 GRT. Panel A: within and across country analysis (i.e., random effects). Panel B: cross-country analysis (i.e., fixed effects). Controls: aged 65 and older (% of population), population density, log GDP per capita, hospital beds per thousand (5 days lagged). Data are winsorized, i.e. negative NDM values are replaced with zero. Bootstrapped standard errors (1000 reps) are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

First difference (ΔNDM) Tables B.2–B.6

Table B2
Variability and strictness of Government Response vs. COVID-19 New Deaths **(G7)**.

Panel A: RE	Full sample		First wave		Second Wave	
	Variability *ΔNDM*	Stringency *ΔNDM*	Variability *ΔNDM*	Stringency *ΔNDM*	Variability *ΔNDM*	Stringency *ΔNDM*
COVID-19 GRT	0.00475	-0.00452***	0.00546	-0.00449***	0.00432	-0.00686**
	(0.00274)	(0.00069)	(0.00293)	(0.00081)	(0.00544)	(0.00233)
R^2	0.00011	0.00150	0.00052	0.00559	0.00003	0.00060
Obs.	2513	2491	1295	1273	1218	1218
Panel B: FE	Full sample		First wave		Second Wave	
	Variability *ΔNDM*	Stringency *ΔNDM*	Variability *ΔNDM*	Stringency *ΔNDM*	Variability *ΔNDM*	Stringency *ΔNDM*
COVID-19 GRT	0.00483	-0.00469***	0.00551	-0.00465***	0.00465	-0.00756**
	(0.00338)	(0.00087)	(0.00372)	(0.00096)	(0.00706)	(0.00284)
R^2	0.00010	0.00154	0.00052	0.00577	0.00001	0.00063
Obs	2513	2491	1295	1273	1218	1218

Notes: This table reports the results for panel regressions of new deaths per million (*ΔNDM*) on the variability and strictness of NPIs in the **G7**. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20) Strictness:= 30 days lagged COVID-19 GRT. Panel A: within and across country analysis (i.e., random effects). Panel B: cross-country analysis (i.e., fixed effects). Controls: aged 65 and older (% of population), population density, log GDP per capita, hospital beds per thousand (5 days lagged). Data are winsorized, i.e. negative NDM values are replaced with zero. Bootstrapped standard errors (1000 reps) are reported in parenthesis). Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Table B3
Variability and strictness of Government Response vs. COVID-19 New Deaths **(G20)**.

Panel A: RE	Full sample		First wave		Second Wave	
	Variability *ΔNDM*	Stringency *ΔNDM*	Variability *ΔNDM*	Stringency *ΔNDM*	Variability *ΔNDM*	Stringency *ΔNDM*
COVID-19 GRT	0.00133	-0.00179**	0.00209	-0.00179*	-0.00174	-0.00226
	(0.00126)	(0.00067)	(0.00140)	(0.00073)	(0.00271)	(0.00121)
R^2	0.00001	0.00028	0.00017	0.00164	0.00001	0.00010
Obs.	6645	6580	3339	3274	3306	3306
Panel B: FE	Full sample		First wave		Second Wave	
	Variability *ΔNDM*	Stringency *ΔNDM*	Variability *ΔNDM*	Stringency *ΔNDM*	Variability *ΔNDM*	Stringency *ΔNDM*
COVID-19 GRT	0.00142	-0.00198**	0.00212	-0.00191**	-0.00179	-0.00398*
	(0.00129)	(0.00068)	(0.00140)	(0.00073)	(0.00290)	(0.00172)
R^2	0.00001	0.00031	0.00017	0.00172	0.00000	0.00017
Obs.	6645	6580	3339	3274	3306	3306

Notes: This table reports the results for panel regressions of new deaths per million (*ΔNDM*) on the variability and strictness of NPIs in the **G20**. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20) Strictness:= 30 days lagged COVID-19 GRT. Panel A: within and across country analysis (i.e., random effects). Panel B: cross-country analysis (i.e., fixed effects). Controls: aged 65 and older (% of population), population density, log GDP per capita, hospital beds per thousand (5 days lagged). Data are winsorized, i.e. negative NDM values are replaced with zero. Bootstrapped standard errors (1000 reps) are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Table B4
Variability and strictness of Government Response vs. COVID-19 New Deaths **(EU28)**.

Panel A: RE

	Full sample		First wave		Second Wave	
	Variability ΔNDM	Stringency ΔNDM	Variability ΔNDM	Stringency ΔNDM	Variability ΔNDM	Stringency ΔNDM
COVID-19 GRT	-0.00062	-0.00351***	-0.00065	-0.00338***	0.00348	-0.00392***
	(0.00137)	(0.00065)	(0.00150)	(0.00089)	(0.00500)	(0.00103)
R^2	0.00000	0.00044	0.00001	0.00177	0.00001	0.00021
Obs.	9172	9026	4474	4328	4698	4698

Panel B: FE

	Full sample		First wave		Second Wave	
	Variability ΔNDM	Stringency ΔNDM	Variability ΔNDM	Stringency ΔNDM	Variability ΔNDM	Stringency ΔNDM
COVID-19 GRT	-0.00067	-0.00398***	-0.00065	-0.00357***	0.00292	-0.00604***
	(0.00138)	(0.00068)	(0.00154)	(0.00090)	(0.00478)	(0.00131)
R^2	0.00000	0.00049	0.00001	0.00186	0.00000	0.00032
Obs.	9172	9026	4474	4328	4698	4698

Notes: This table reports the results for panel regressions of new deaths per million (ΔNDM) on the variability and strictness of NPIs in the **EU28**. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20) Strictness:= 30 days lagged COVID-19 GRT. Panel A: within and across country analysis (i.e., random effects). Panel B: cross-country analysis (i.e., fixed effects). Controls: aged 65 and older (% of population), population density, log GDP per capita, hospital beds per thousand (5 days lagged). Data are winsorized, i.e. negative NDM values are replaced with zero. Bootstrapped standard errors (1000 reps) are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Table B5
Variability and strictness of Government Response vs. COVID-19 New Deaths **(Central America)**.

Panel A: RE

	Full sample		First wave		Second Wave	
	Variability ΔNDM	Stringency ΔNDM	Variability ΔNDM	Stringency ΔNDM	Variability ΔNDM	Stringency ΔNDM
COVID-19 GRT	-0.00029	0.00000	-0.00068	0.00013	0.00244	-0.00010
	(0.00033)	(0.00016)	(0.00042)	(0.00021)	(0.00341)	(0.00080)
R^2	0.00000	0.00000	0.00004	0.00003	0.00001	0.00000
Obs.	4557	4448	2121	2012	2436	2436

Panel B: FE

	Full sample		First wave		Second Wave	
	Full sample		First wave		Second Wave	
	ΔNDM	ΔNDM	ΔNDM	ΔNDM	ΔNDM	ΔNDM
COVID-19 GRT	-0.00029	-0.00002	-0.00068	0.00014	0.00235	-0.00028
	(0.00031)	(0.00021)	(0.00040)	(0.00025)	(0.00325)	(0.00115)
R^2	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000
Obs.	4882	4764	2272	2154	2610	2610

Notes: This table reports the results for panel regressions of new deaths per million (ΔNDM) on the variability and strictness of NPIs in the **Central America**. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20) Strictness:= 30 days lagged COVID-19 GRT. Panel A: within and across country analysis (i.e., random effects). Panel B: cross-country analysis (i.e., fixed effects). Controls: aged 65 and older (% of population), population density, log GDP per capita, hospital beds per thousand (5 days lagged). Data are winsorized, i.e. negative NDM values are replaced with zero. Bootstrapped standard errors (1000 reps) are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Table B6
Variability and strictness of Government Response vs. COVID-19 New Deaths **(Asia)**.

Panel A: RE	Full sample		First wave		Second Wave	
	Variability ΔNDM	Stringency ΔNDM	Variability ΔNDM	Stringency ΔNDM	Variability ΔNDM	Stringency ΔNDM
COVID-19 GRT	0.00002	-0.00005	-0.00003	0.00007	-0.00004	-0.00027
	(0.00018)	(0.00008)	(0.00008)	(0.00006)	(0.00086)	(0.00020)
R^2	0.00000	0.00000	0.00000	0.00000	0.00001	0.00003
Obs.	11,959	11,778	5599	5418	6360	6360

Panel B: FE	Full sample		First wave		Second Wave	
	Variability ΔNDM	Stringency ΔNDM	Variability ΔNDM	Stringency ΔNDM	Variability ΔNDM	Stringency ΔNDM
COVID-19 GRT	0.00013	-0.00009	-0.00005	0.00003	0.00078	-0.00071
	(0.00023)	(0.00010)	(0.00009)	(0.00006)	(0.00112)	(0.00047)
R^2	0.00000	0.00000	0.00000	0.00000	0.00001	0.00005
Obs.	12,975	12,101	6093	5895	6882	6882

Notes: This table reports the results for panel regressions of new deaths per million (ΔNDM) on the variability and strictness of NPIs in **Asia**. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20) Strictness:= 30 days lagged COVID-19 GRT. Panel A: within and across country analysis (i.e., random effects). Panel B: cross-country analysis (i.e., fixed effects). Controls: aged 65 and older (% of population), population density, log GDP per capita, hospital beds per thousand (5 days lagged). Data are winsorized, i.e. negative NDM values are replaced with zero. Bootstrapped standard errors (1000 reps) are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Additional controls Tables B.7–B.11

Table B7
Variability and strictness of Government Response vs. CODID-19 New Deaths and R_t (**G7**).

	Full sample				First wave				Second Wave			
	Variability		Stringency		Variability		Stringency		Variability		Stringency	
	NDM	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t
COVID-19 GRT	0.01085	0.00808*	0.02105**	-0.01127***	0.04350	0.00389	0.01473**	-0.01238***	0.06076	0.00475	0.04941	-0.00778***
	(0.03906)	(0.00339)	(0.00743)	(0.00189)	(0.03780)	(0.00352)	(0.00567)	(0.00192)	(0.06832)	(0.00619)	(0.02724)	(0.00202)
R^2	0.23640	0.03006	0.25012	0.27203	0.23201	0.04883	0.23820	0.37313	0.30388	0.03091	0.31515	0.10643
Obs.	5231	5189	5186	5147	2621	2594	2576	2552	2610	2595	2610	2595

Notes: This table reports the results for panel regressions of new deaths per million (*NDM*) and reproduction rate (R_t) on the variability and strictness of NPIs in the **G7**. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20) Strictness:= 30 days lagged COVID-19 GRT. Within and across country analysis (i.e., random effects). Controls: democracy index, life expectancy, human development index, female smockers, male smocker, extreme poverty, population, hospital beds per thousand (5 days lagged). Data are winsorized, i.e. negative NDM values are replaced with zero. Bootstrapped standard errors (1000 reps) are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Table B8
Variability and strictness of Government Response vs. CODID-19 New Deaths and R_t (**G20**).

	Full sample				First wave				Second Wave			
	Variability		Stringency		Variability		Stringency		Variability		Stringency	
	NDM	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t
COVID-19 GRT	0.01085	0.00808*	0.02105**	-0.01127***	0.04350	0.00389	0.01473*	-0.01238***	0.06076	0.00475	0.04941	-0.00778***
	(0.03867)	(0.00340)	(0.00738)	(0.00189)	(0.03927)	(0.00373)	(0.00593)	(0.00181)	(0.07137)	(0.00643)	(0.02762)	(0.00204)
R^2	0.23640	0.03006	0.25012	0.27203	0.23201	0.04883	0.23820	0.37313	0.30388	0.03091	0.31515	0.10643
Obs.	5231	5189	5186	5147	2621	2594	2576	2552	2610	2595	2610	2595

Notes: This table reports the results for panel regressions of new deaths per million (*NDM*) and reproduction rate (R_t) on the variability and strictness of NPIs in the **G20**. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20) Strictness:= 30 days lagged COVID-19 GRT. Within and across country analysis (i.e., random effects). Controls: democracy index, life expectancy, human development index, female smockers, male smocker, extreme poverty, population, hospital beds per thousand (5 days lagged) Data are winsorized, i.e. negative NDM values are replaced with zero.Bootstrapped standard errors (1000 reps) are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Table B9
Variability and strictness of Government Response vs. CODID-19 New Deaths and R_t (**G20**).

	Full sample				First wave				Second Wave			
	Variability		Stringency		Variability		Stringency		Variability		Stringency	
	NDM	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t
COVID-19 GRT	0.05409	-0.00615**	0.01203	-0.00873***	0.15456**	-0.00489*	-0.01201	-0.00901***	0.39923**	-0.02017***	0.14929***	-0.00923***
	(0.05777)	(0.00210)	(0.01287)	(0.00095)	(0.05441)	(0.00215)	(0.00666)	(0.00129)	(0.13376)	(0.00356)	(0.02608)	(0.00138)
R^2	0.03628	0.02867	0.03697	0.31563	0.21703	0.04730	0.12969	0.38351	0.11672	0.09006	0.18240	0.26138
Obs.	6441	6474	6340	6361	3135	3187	3034	3074	3306	3287	3306	3287

Notes: This table reports the results for panel regressions of new deaths per million (*NDM*) and reproduction rate (R_t) on the variability and strictness of NPIs in the **EU28**. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20) Strictness:= 30 days lagged COVID-19 GRT. Within and across country analysis (i.e., random effects). Controls: democracy index, life expectancy, human development index, female smockers, male smocker, extreme poverty, population, hospital beds per thousand (5 days lagged). Data are winsorized, i.e. negative NDM values are replaced with zero. Bootstrapped standard errors (1000 reps) are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Table B10
Variability and strictness of Government Response vs. CODID-19 New Deaths and R_t (**Central America**).

	Full sample				First wave				Second Wave			
	Variability		Stringency		Variability		Stringency		Variability		Stringency	
	NDM	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t
COVID-19 GRT	-0.06226	0.00640	0.00536	-0.00225	-0.05347	0.00407	0.02191	-0.00407	-0.00045	0.00127	-0.03575	-0.00120
	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)
R^2	0.40607	0.07085	0.39278	0.12909	0.45832	0.09582	0.47420	0.34156	0.46661	0.24466	0.47976	0.25868
Obs.	1969	1935	1924	1900	925	897	880	862	1044	1038	1044	1038

Notes: This table reports the results for panel regressions of new deaths per million (*NDM*) and reproduction rate (R_t) on the variability and strictness of NPIs in the **Central America**. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20) Strictness:= 30 days lagged COVID-19 GRT. Within and across country analysis (i.e., random effects). Controls: democracy index, life expectancy, human development index, female smockers, male smocker, extreme poverty, population, hospital beds per thousand (5 days lagged). Data are winsorized, i.e. negative NDM values are replaced with zero. Bootstrapped standard errors (1000 reps) are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Table B11
Variability and strictness of Government Response vs. CODID-19 New Deaths and R_t (**Asia**).

	Full sample				First wave				Second Wave			
	Variability		Stringency		Variability		Stringency		Variability		Stringency	
	NDM	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t
COVID-19 GRT	-0.00801	0.00573	-0.00050	-0.00464**	-0.00444	0.00400	-0.00163	-0.00740***	0.01544	0.00430	0.00242	-0.00265
	(0.00558)	(0.00483)	(0.00216)	(0.00176)	(0.00631)	(0.00469)	(0.00203)	(0.00184)	(0.03278)	(0.00477)	(0.00844)	(0.00176)
R^2	0.08295	0.04972	0.08289	0.06501	0.01026	0.10345	0.00991	0.16402	0.33146	0.10878	0.32818	0.11003
Obs.	6249	6562	6159	6486	2889	3102	2799	3026	3360	3460	3360	3460

Notes: This table reports the results for panel regressions of new deaths per million (*NDM*) and reproduction rate (R_t) on the variability and strictness of NPIs in the **Asia**. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20) Strictness:= 30 days lagged COVID-19 GRT. Within and across country analysis (i.e., random effects). Controls: democracy index, life expectancy, human development index, female smockers, male smocker, extreme poverty, population, hospital beds per thousand (5 days lagged). Data are winsorized, i.e. negative NDM values are replaced with zero. Bootstrapped standard errors (1000 reps) are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Quantile regressions Tables B.12–B.16

Table B12
Variability and strictness of Government Reponse vs. COVID-19 News deaths and R_t (**G7**).

		G7		COVID-19 GRT	Obs.
Full sample	Variability	*NDM*	20th	0.17590*** (0.02050)	2520
		NDM	80th	0.31457*** (0.04217)	2520
		Rt	20th	0.03034*** (0.00425)	2495
		Rt	80th	0.04181** (0.01441)	2495
	Strictness	*NDM*	20th	0.00016 (0.00148)	2488
		NDM	80th	-0.00374 (0.00256)	2488
		Rt	20th	-0.01277*** (0.00068)	2482
		Rt	80th	-0.02565* (0.01203)	2482
I wave	Variability	*NDM*	20th	0.19292*** (0.01816)	1302
		NDM	80th	0.40200*** (0.05168)	1302
		Rt	20th	0.01446*** (0.00406)	1277
		Rt	80th	-0.00369 (0.00818)	1277
	Strictness	*NDM*	20th	0.00657*** (0.00156)	1277
		NDM	80th	-0.01384*** (0.00379)	1277
		Rt	20th	-0.01357*** (0.00126)	1271
		Rt	80th	-0.02659*** (0.00522)	1271
II wave	Variability	*NDM*	20th	0.38838*** (0.07463)	1218
		NDM	80th	0.61455*** (0.10881)	1218
		Rt	20th	0.14700*** (0.01402)	1218
		Rt	80th	0.18439*** (0.01961)	1218
	Strictness	*NDM*	20th	-0.01632*** (0.00341)	1211
		NDM	80th	-0.02196*** (0.00358)	1211
		Rt	20th	-0.01117*** (0.00073)	1211
		Rt	80th	-0.01417*** (0.00073)	1211

Notes: This table reports the results for panel quantile fixed effect regressions of new deaths per million (*NDM*) and reproduction rate (R_t) on the variability and strictness of NPIs in the **G7**. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20). Strictness:= 30 days lagged COVID-19 GRT in first difference. Data are winsorized, i.e. negative NDM values are replaced with zero. Standard errors are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Table B13
Variability and strictness of Government Reponse vs. COVID-19 News deaths and R_t (**G20**).

		G20		COVID-19 GRT	Obs.
Full sample	Variability	*NDM*	20th	-0.0175 (0.03736)	6660
		NDM	80th	0.08612 (0.06686)	6660
		Rt	20th	0.02073*** (0.00210)	6591
		Rt	80th	0.02474*** (0.00390)	6591
	Strictness	*NDM*	20th	0.00485*** (0.00103)	6598
		NDM	80th	0.01066*** (0.00177)	6598
		Rt	20th	-0.00789*** (0.00035)	6547
		Rt	80th	-0.01510*** (0.00060)	6547
I wave	Variability	*NDM*	20th	-0.00927 (0.03806)	3354
		NDM	80th	0.16504* (0.07417)	3354
		Rt	20th	0.01543*** (0.00238)	3285
		Rt	80th	0.01027*** (0.00292)	3285
	Strictness	*NDM*	20th	0.00598*** (0.00114)	3311
		NDM	80th	0.00349 (0.00195)	3311
		Rt	20th	-0.00824*** (0.00053)	3260
		Rt	80th	-0.01831*** (0.00096)	3260
II wave	Variability	*NDM*	20th	0.05306** (0.01940)	3306
		NDM	80th	0.17121*** (0.04661)	3306
		Rt	20th	0.06260*** (0.00700)	3306
		Rt	80th	0.07517*** (0.01220)	3306
	Strictness	*NDM*	20th	0.00430* (0.00205)	3287
		NDM	80th	-0.00196 (0.00221)	3287
		Rt	20th	-0.00828*** (0.00056)	3287
		Rt	80th	-0.00853*** (0.00062)	3287

Notes: This table reports the results for panel quantile fixed effect regressions of new deaths per million (*NDM*) and reproduction rate (R_t) on the variability and strictness of NPIs in the **G20**. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20). Strictness:= 30 days lagged COVID-19 GRT in first difference. Data are winsorized, i.e. negative NDM values are replaced with zero. Standard errors are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Table B14
Variability and strictness of Government Response vs. COVID-19 News deaths and R_t (**EU28**).

		EU28		COVID-19 GRT	Obs.
Full sample	Variability	*NDM*	20th	0.00183 (0.00957)	9191
		NDM	80th	0.11948*** (0.02505)	9191
		Rt	20th	0.00864*** (0.00222)	9038
		Rt	80th	0.03621*** (0.00835)	9038
	Strictness	*NDM*	20th	-0.00541*** (0.00073)	9223
		NDM	80th	-0.00852*** (0.00094)	9223
		Rt	20th	-0.00722*** (0.00021)	9059
		Rt	80th	-0.01190*** (0.00026)	9059
I wave	Variability	*NDM*	20th	0.06132*** (0.01783)	4493
		NDM	80th	0.38299 (0.43138)	4493
		Rt	20th	0.00005 (0.01478)	4340
		Rt	80th	-0.0201 (0.13810)	4340
	Strictness	*NDM*	20th	0.00108 (0.00460)	4552
		NDM	80th	-0.01156*** (0.00137)	4552
		Rt	20th	-0.00724*** (0.00028)	4388
		Rt	80th	-0.01253*** (0.00042)	4388
II wave	Variability	*NDM*	20th	0.32492*** (0.03578)	4698
		NDM	80th	0.52783*** (0.05552)	4698
		Rt	20th	0.12373*** (0.00577)	4698
		Rt	80th	0.17083*** (0.01000)	4698
	Strictness	*NDM*	20th	-0.01380*** (0.00173)	4671
		NDM	80th	-0.02536*** (0.00187)	4671
		Rt	20th	-0.00854*** (0.00028)	4671
		Rt	80th	-0.01144*** (0.00034)	4671

Notes: This table reports the results for panel quantile fixed effect regressions of new deaths per million (*NDM*) and reproduction rate (R_t) on the variability and strictness of NPIs in the **EU28**. Variability:= dynamic standard deviation of `COVID-19 GRT` (computed using a rolling window from t-40 to t-20). Strictness:= 30 days lagged `COVID-19 GRT` in first difference. Data are winsorized, i.e. negative NDM values are replaced with zero. Standard errors are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Table B15
Variability and strictness of Government Response vs. COVID-19 News deaths and R_t (**Central America**).

		Central America		COVID-19 GRT	Obs.
Full sample	Variability	*NDM*	20th	-0.03653*** (0.00444)	4884
		NDM	80th	-0.04222*** (0.00995)	4884
		Rt	20th	0.00655 (0.01627)	4765
		Rt	80th	-0.00129 (0.01031)	4765
	Strictness	*NDM*	20th	0.00158 (0.00091)	4542
		NDM	80th	0.00608*** (0.00127)	4542
		Rt	20th	-0.00345*** (0.00025)	4481
		Rt	80th	-0.00319*** (0.00028)	4481
I wave	Variability	*NDM*	20th	-0.02312*** (0.00335)	2274
		NDM	80th	-0.03751* (0.01814)	2274
		Rt	20th	0.01233*** (0.00152)	2155
		Rt	80th	0.01376*** (0.00374)	2155
	Strictness	*NDM*	20th	0.00607 (0.00470)	1903
		NDM	80th	-0.0007 (0.00169)	1903
		Rt	20th	-0.00508*** (0.00065)	1842
		Rt	80th	-0.00848*** (0.00080)	1842
II wave	Variability	*NDM*	20th	-0.00575 (0.06743)	2610
		NDM	80th	0.09186 (0.05254)	2610
		Rt	20th	-0.01108*** (0.00308)	2610
		Rt	80th	-0.01154 (0.00615)	2610
	Strictness	*NDM*	20th	0.00341* (0.00136)	2639
		NDM	80th	0.00353** (0.00121)	2639
		Rt	20th	-0.00126*** (0.00034)	2639
		Rt	80th	-0.00161*** (0.00034)	2639

Notes: This table reports the results for panel quantile fixed effect regressions of new deaths per million (*NDM*) and reproduction rate (R_t) on the variability and strictness of NPIs in the **Central America**. Variability:= dynamic standard deviation of `COVID-19 GRT` (computed using a rolling window from t-40 to t-20). Strictness:= 30 days lagged `COVID-19 GRT` in first difference. Data are winsorized, i.e. negative NDM values are replaced with zero. Standard errors are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Table B16
Variability and strictness of Government Response vs. COVID-19 News deaths and R_t (**Asia**).

		Asia		COVID-19 GRT	Obs.
Full sample	Variability	*NDM*	20th	-0.01134 (0.02759)	12999
		NDM	80th	-0.02363 (0.03046)	12999
		Rt	20th	0.00002 (0.00513)	12792
		Rt	80th	0.00618** (0.00234)	12792
	Strictness	*NDM*	20th	0.00066 (0.00085)	13706
		NDM	80th	0.01317*** (0.00133)	13706
		Rt	20th	-0.00164 (0.0012)	13534
		Rt	80th	-0.00486*** (0.00046)	13534
I wave	Variability	*NDM*	20th	-0.00947*** (0.00107)	6115
		NDM	80th	-0.01219*** (0.00319)	6115
		Rt	20th	0.00145*** (0.00031)	5908
		Rt	80th	0.00146 (0.00079)	5908
	Strictness	*NDM*	20th	-0.00032 (0.00111)	6440
		NDM	80th	0.01055*** (0.00176)	6440
		Rt	20th	-0.00385*** (0.00034)	6268
		Rt	80th	-0.00987*** (0.00051)	6268
II wave	Variability	*NDM*	20th	-0.0103 (0.0097)	6884
		NDM	80th	-0.00325 (0.01484)	6884
		Rt	20th	0.00776* (0.00338)	6884
		Rt	80th	0.02094*** (0.00541)	6884
	Strictness	*NDM*	20th	0.00791*** (0.00123)	7266
		NDM	80th	0.00549*** (0.00127)	7266
		Rt	20th	-0.00285*** (0.00034)	7266
		Rt	80th	-0.00196*** (0.00039)	7266

Notes: This table reports the results for panel quantile fixed effect regressions of new deaths per million (*NDM*) and reproduction rate (R_t) on the variability and strictness of NPIs in the **Asia**. Variability:= dynamic standard deviation of `COVID-19 GRT` (computed using a rolling window from t-40 to t-20). Strictness:= 30 days lagged `COVID-19 GRT` in first difference. Data are winsorized, i.e. negative NDM values are replaced with zero. Standard errors are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Fractional regression Tables B17–B21

Table B17
Variability and strictness of Government Response vs. COVID-19 New Deaths (**G7**).

	Full sample		First wave		Second Wave	
	Variability	Stringency	Variability	Stringency	Variability	Stringency
COVID-19 GRT	0.05082***	0.01554***	0.07198***	0.00379*	0.12026***	0.04306***
	(0.00293)	(0.00191)	(0.00373)	(0.00185)	(0.00936)	(0.00273)
Obs.	2520	2495	1302	1277	1218	1218

Notes: This table reports the results for fractional GLM regressions of new deaths per billion (*NDM*) on the variability and strictness of NPIs in the **G7**. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20). Strictness:= 30 days lagged COVID-19 GRT. Controls: aged 65 and older (% of population), population density, log GDP per capita, hospital beds per thousand (5 days lagged). Data are winsorized, i.e. negative NDM values are replaced with zero. Bootstrapped standard errors (1000 reps) are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Table B18
Variability and strictness of Government Response vs. COVID-19 New Deaths (**G20**).

	Full sample		First wave		Second Wave	
	Variability	Stringency	Variability	Stringency	Variability	Stringency
COVID-19 GRT	0.05082***	0.01554***	0.07198***	0.00379*	0.12026***	0.04306***
	(0.00293)	(0.00191)	(0.00373)	(0.00185)	(0.00936)	(0.00273)
Obs.	2520	2495	1302	1277	1218	1218

Notes: This table reports the results for fractional GLM regressions of new deaths per billion (*NDM*) on the variability and strictness of NPIs in the **G20**. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20). Strictness:= 30 days lagged COVID-19 GRT. Controls: aged 65 and older (% of population), population density, log GDP per capita, hospital beds per thousand (5 days lagged). Data are winsorized, i.e. negative NDM values are replaced with zero. Bootstrapped standard errors (1000 reps) are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Table B19
Variability and strictness of Government Response vs. COVID-19 New Deaths (**EU28**).

	Full sample		First wave		Second Wave	
	Variability	Stringency	Variability	Stringency	Variability	Stringency
COVID-19 GRT	0.01655***	0.00878***	0.08077***	-0.00452**	0.06592***	0.02412***
	(0.00309)	(0.00084)	(0.00379)	(0.00174)	(0.00446)	(0.00100)
Obs.	9191	9038	4493	4340	4698	4698

Notes: This table reports the results for fractional GLM regressions of new deaths per billion (*NDM*) on the variability and strictness of NPIs in the **EU28**. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20). Strictness:= 30 days lagged COVID-19 GRT. Controls: aged 65 and older (% of population), population density, log GDP per capita, hospital beds per thousand (5 days lagged). Data are winsorized, i.e. negative NDM values are replaced with zero. Bootstrapped standard errors (1000 reps) are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Table B20
Variability and strictness of Government Response vs. COVID-19 New Deaths (**Central America**).

	Full sample		First wave		Second Wave	
	Variability	Stringency	Variability	Stringency	Variability	Stringency
COVID-19 GRT	-0.03518***	0.00844***	-0.04206***	0.02008***	0.04348***	0.01204***
	(0.00487)	(0.00089)	(0.00796)	(0.00173)	(0.00932)	(0.00125)
Obs.	4559	4449	2123	2013	2436	2436

Notes: This table reports the results for fractional GLM regressions of new deaths per billion (*NDM*) on the variability and strictness of NPIs in the **Central America**. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20). Strictness:= 30 days lagged COVID-19 GRT. Controls: aged 65 and older (% of population), population density, log GDP per capita, hospital beds per thousand (5 days lagged). Data are winsorized, i.e. negative NDM values are replaced with zero. Bootstrapped standard errors (1000 reps) are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Table B21
Variability and strictness of Government Response vs. COVID-19 New Deaths (**Asia**).

	Full sample		First wave		Second Wave	
	Variability	Stringency	Variability	Stringency	Variability	Stringency
COVID-19 GRT	-0.02105***	0.01838***	-0.04900***	0.00935***	0.02516***	0.03543***
	(0.00365)	(0.00103)	(0.00722)	(0.00128)	(0.00415)	(0.00188)
Obs.	11,981	11,792	5619	5430	6362	6362

Notes: This table reports the results for fractional GLM regressions of new deaths per billion (*NDM*) on the variability and strictness of NPIs in the **Asia**. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20). Strictness:= 30 days lagged COVID-19 GRT. Controls: aged 65 and older (% of population), population density, log GDP per capita, hospital beds per thousand (5 days lagged). Data are winsorized, i.e. negative NDM values are replaced with zero. Bootstrapped standard errors (1000 reps) are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

Regression by different income levels Table B.22

Table B22
Variability and strictness of Government Response vs. COVID-19 New Deaths and R_t.

	Full Sample				First Wave				Second Wave			
	Variability		Stringency		Variability		Stringency		Variability		Stringency	
	NDM	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t
Panel A: Low GDP												
COVID-19 GRT	-0.02580***	0.00552	-0.00273	-0.00081	-0.01912**	0.00281	0.00366	-0.00388***	0.02506	0.00766*	-0.00807	-0.00159
	(0.00782)	(0.00376)	(0.00313)	(0.00099)	(0.00694)	(0.00415)	(0.00211)	(0.00116)	(0.01659)	(0.00366)	(0.00879)	(0.00165)
R^2	0.00361	0.01028	0.00052	0.00275	0.00285	0.00376	0.00086	0.05521	0.00171	0.01430	0.00254	0.00758
Obs.	8074	8665	7920	8583	3626	3777	3472	3695	4448	4888	4448	4888
Panel B: Mid GDP												
	Full Sample				First Wave				Second Wave			
	Variability		Stringency		Variability		Stringency		Variability		Stringency	
	NDM	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t
COVID-19 GRT	-0.06411***	0.00292	0.01477	-0.00656***	-0.01264	0.00193	0.00681	-0.00753***	0.12735	0.00196	0.10174***	-0.00729***
	(0.01410)	(0.00250)	(0.00887)	(0.00082)	(0.01083)	(0.00269)	(0.00424)	(0.00111)	(0.07667)	(0.00373)	(0.02488)	(0.00127)
R^2	0.00945	0.00251	0.00522	0.14711	0.00537	0.00126	0.01475	0.20861	0.00855	0.00070	0.07992	0.14130
Obs.	10,095	9924	9895	9734	4875	4734	4675	4544	5220	5190	5220	5190
Panel C: High GDP												
	Full Sample				First Wave				Second Wave			
	Variability		Stringency		Variability		Stringency		Variability		Stringency	
	NDM	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t	*NDM*	R_t
COVID-19 GRT	0.10268**	-0.00217	0.01880*	-0.01063***	0.15532***	-0.00145	-0.00615	-0.01226***	0.22833*	-0.01572***	0.09463***	-0.00795***
	(0.03908)	(0.00307)	(0.00748)	(0.00124)	(0.04151)	(0.00318)	(0.00544)	(0.00126)	(0.09914)	(0.00381)	(0.01755)	(0.00173)
R^2	0.01938	0.00087	0.00823	0.29669	0.12267	0.00038	0.00232	0.38170	0.02341	0.03938	0.06762	0.16859
Obs.	11,681	11,631	10,870	11,497	5765	5749	5631	5615	5916	5882	5916	5882

Notes: This table reports the results for fixed effect panel regressions of new deaths per million (*NDM*) and reproduction rate (R_t) on the variability and strictness of NPIs in the low GDP per capita (Panel A), intermediate GDP capita (Panel B) and high GDP (Panel C) subsamples. In low, middle and high income countries, GDP per capita is (*i*) below the 33th percentile, (*ii*) above the 33th and below the 67th percentile, and (*iii*) above the 67th percentile, respectively. Variability:= dynamic standard deviation of COVID-19 GRT (computed using a rolling window from t-40 to t-20) Strictness:= 30 days lagged COVID-19 GRT. Controls: aged 65 and older (% of population), population density, log GDP per capita, hospital beds per thousand (5 days lagged). Data are winsorized, i.e. negative NDM values are replaced with zero. Bootstrapped standard errors (1000 reps) are reported in parenthesis. Sample: 01 January 2020–21 February 2021. I wave: 01 January 2020–31 August 2020. II wave: 01 September 2020–21 February 2021.

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