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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 (Rf) 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.dime
nsions.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 Rf) of COVID-19 in 79 territories worldwide. They observe that no single NPI can decrease Rf 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 death 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 was 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 groups.

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 Petzer 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), postulates 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 than 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.
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 in 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-effects models. The results are presented in Table 2.
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  |
| NDM         | $R_t$       | NDM         | $R_t$       |
| COVID-19 GRT|             | $R^2$       |             |
| 0.24172***  | -0.00188    | 0.03627***  | -0.01832*** |
| (0.04413)   | (0.00368)   | (0.00820)   | (0.00124)   |
| Obs. 2520   | 2488        | 2495        | 2482        |

| Panel B: FE |
|-------------|
| Full sample | First wave | Second Wave |
| Variability | Strictness | Variability | Strictness |
| NDM         | $R_t$       | NDM         | $R_t$       |
| COVID-19 GRT|             | $R^2$       |             |
| 0.24145***  | -0.00241    | 0.03625***  | -0.01844*** |
| (0.05732)   | (0.00461)   | (0.01049)   | (0.00154)   |
| Obs. 2520   | 2488        | 2495        | 2482        |

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: with 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.

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  |
| NDM         | $R_t$       | NDM         | $R_t$       |
| COVID-19 GRT|             | $R^2$       |             |
| 0.03498     | 0.00823*    | 0.02279**   | -0.01175*** |
| (0.04501)   | (0.00384)   | (0.00735)   | (0.00179)   |
| Obs. 6660   | 6598        | 6591        | 6547        |

| Panel B: FE |
|-------------|
| Full sample | First wave | Second Wave |
| Variability | Strictness | Variability | Strictness |
| NDM         | $R_t$       | NDM         | $R_t$       |
| COVID-19 GRT|             | $R^2$       |             |
| 0.03503     | 0.00838*    | 0.02276**   | -0.01183*** |
| (0.04524)   | (0.00373)   | (0.00718)   | (0.00190)   |
| Obs. 6660   | 6598        | 6591        | 6547        |

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: with 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.
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 |
| $NDM$ | $R_t$ | $NDM$ | $R_t$ | $NDM$ | $R_t$ | $NDM$ | $R_t$ | $NDM$ | $R_t$ |
| COVID-19 GRT | 0.05809 | -0.00710*** | 0.02234* | -0.00499*** | 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 |
| $NDM$ | $R_t$ | $NDM$ | $R_t$ | $NDM$ | $R_t$ | $NDM$ | $R_t$ |
| 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 |
| $NDM$ | $R_t$ | $NDM$ | $R_t$ | $NDM$ | $R_t$ | $NDM$ | $R_t$ |
| 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 | 0.08551 | 0.11790 | 0.09861 | 0.11192 | 0.09796 | 0.12603 | 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 |
| $NDM$ | $R_t$ | $NDM$ | $R_t$ | $NDM$ | $R_t$ | $NDM$ | $R_t$ |
| 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) | (0.00347) | (0.00833) | (0.00218) | (0.01517) | (0.00351) | (0.00773) | (0.00295) | (0.03108) | (0.00332) | (0.02589) | (0.00204) |
| $R^2$ | 0.00977 | 0.00604 | 0.00232 | 0.04564 | 0.11902 | 0.09796 | 0.12603 | 0.01621 | 0.15064 | 0.19312 | 0.13151 | 0.15897 |
| Obs. | 4884 | 4542 | 4765 | 4481 | 2274 | 1972 | 2103 | 1700 | 2436 | 2422 | 2436 | 2422 |

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

| Panel A: BE | | Panel B: FE | |
|------------|------------|------------|------------|
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control the transmission of the virus, but not its mortality. First, our generally significant. Thus, government response to COVID-19 could strictness and variability did not succeed in limiting deaths. The effects estimate is not significant. Furthermore, the variability leads to an in increase in the number of deaths from COVID-19 in both the first and lower mortality rate only in the first wave. However, the coefficient effects 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. 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 Lopez Obrador set his Government’s policy priorities to combat the adverse economic effects provoked by the spread of the pandemic. Furthermore, research advocates early implementation of NPIs, but strongly advises against early termination of NPIs (Nonghala 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 (ActuNa-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 strictness 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 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,

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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 assess 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.
### 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 | Malaysia               | 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).

|            | Variability | Stringency | Variability | Stringency | Variability | Stringency |
|------------|-------------|------------|-------------|------------|-------------|------------|
|            | NDM         | $R_t$      | NDM         | $R_t$      | NDM         | $R_t$      |
| COVID-19 GRT | -0.00734    | 0.00172    | 0.00699*    | -0.00513***| 0.02153     | 0.00088    |
|            | (0.01204)   | (0.00139)  | (0.00324)   | (0.00064)  | (0.01280)   | (0.00138)  |
|            | 0.03800     | 0.01037    | 0.03677     | 0.03451    | 0.09766***  | -0.00213   |
|            | (0.02707)   | (0.00206)  | (0.00227)   | (0.00070)  | (0.02707)   | (0.00089)  |
|            | 0.15143     | 0.05837    | 0.17175     | 0.00542    | 0.15143     | 0.05837    |
|            | (0.00988)   | (0.00089)  | (0.00865)   | (0.00083)  | (0.00988)   | (0.00089)  |
| Obs.       | 45,862      | 45,815     | 45,036      | 45,209     | 21,469      | 21,076     |
|            | 45,815      | 21,076     | 20,648      | 20,475     | 21,469      | 21,076     |
|            | 45,209      | 20,648     | 20,475      | 20,475     | 21,469      | 21,076     |
|            | 24,393      | 24,739     | 24,393      | 24,739     | 24,393      | 24,739     |
|            | 24,739      | 24,393     | 24,393      | 24,739     | 24,393      | 24,739     |

Panel B: FE

|            | Variability | Stringency | Variability | Stringency | Variability | Stringency |
|------------|-------------|------------|-------------|------------|-------------|------------|
|            | NDM         | $R_t$      | NDM         | $R_t$      | NDM         | $R_t$      |
| COVID-19 GRT | 0.00118    | 0.00178    | 0.00437    | -0.00461***| 0.02823*    | 0.00132    |
|            | (0.01216)   | (0.00118)  | (0.00317)   | (0.00060)  | (0.01279)   | (0.00130)  |
|            | 0.00442     | 0.00065    | 0.00001    | 0.18171    | 0.08695***  | -0.00166   |
|            | (0.02416)   | (0.00193)  | (0.00069)   | (0.00033)  | (0.02416)   | (0.00193)  |
|            | 0.00452     | 0.00055    | 0.01466    | 0.05884    | 0.00452     | 0.00055    |
| Obs.       | 52,937      | 52,672     | 51,031      | 51,996     | 24,542      | 23,910     |
|            | 52,672      | 23,910     | 23,601      | 23,240     | 24,542      | 23,910     |
|            | 51,031      | 23,601     | 23,240      | 23,240     | 24,542      | 23,910     |
|            | 28,395      | 28,762     | 28,395      | 28,762     | 28,395      | 28,762     |
|            | 28,762      | 28,395     | 28,395      | 28,762     | 28,395      | 28,762     |

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.
**Table B2**

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

|                  | Full sample | Stringency | First wave | Stringency | Second Wave | Stringency |
|------------------|-------------|------------|------------|------------|-------------|------------|
|                  | Variability | Stringency | Variability | Stringency | Variability | Stringency |
|                  | ΔNDM        | ΔNDM       | ΔNDM       | ΔNDM       | ΔNDM        | 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)  |
| R²               | 0.00011     | 0.00150    | 0.00052    | 0.00059    | 0.00003     | 0.00060    |
| Obs.             | 2513        | 2491       | 1295       | 1273       | 1218        | 1218       |

Panel B: FE

|                  | Full sample | Stringency | First wave | Stringency | Second Wave | Stringency |
|------------------|-------------|------------|------------|------------|-------------|------------|
|                  | Variability | Stringency | Variability | Stringency | Variability | Stringency |
|                  | ΔNDM        | ΔNDM       | ΔNDM       | ΔNDM       | ΔNDM        | 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)  |
| R²               | 0.00010     | 0.00154    | 0.00052    | 0.00077    | 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).

|                  | Full sample | Stringency | First wave | Stringency | Second Wave | Stringency |
|------------------|-------------|------------|------------|------------|-------------|------------|
|                  | Variability | Stringency | Variability | Stringency | Variability | Stringency |
|                  | ΔNDM        | ΔNDM       | ΔNDM       | ΔNDM       | ΔNDM        | 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)  |
| R²               | 0.00001     | 0.00028    | 0.00017    | 0.00164    | 0.00001     | 0.00010    |
| Obs.             | 6645        | 6580       | 3339       | 3274       | 3306        | 3306       |

Panel B: FE

|                  | Full sample | Stringency | First wave | Stringency | Second Wave | Stringency |
|------------------|-------------|------------|------------|------------|-------------|------------|
|                  | Variability | Stringency | Variability | Stringency | Variability | Stringency |
|                  | ΔNDM        | ΔNDM       | ΔNDM       | ΔNDM       | ΔNDM        | 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)  |
| R²               | 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 | Stringency | Variability | Stringency | Variability | Stringency |
| \( \Delta \text{NDM} \) | \( \Delta \text{NDM} \) | \( \Delta \text{NDM} \) | \( \Delta \text{NDM} \) | \( \Delta \text{NDM} \) |
| 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 | Stringency | Variability | Stringency | Variability | Stringency |
| \( \Delta \text{NDM} \) | \( \Delta \text{NDM} \) | \( \Delta \text{NDM} \) | \( \Delta \text{NDM} \) |
| 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 | 0.0049 | 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 (\( \Delta \text{NDM} \)) 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. 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 | Stringency | Variability | Stringency |
| \( \Delta \text{NDM} \) | \( \Delta \text{NDM} \) | \( \Delta \text{NDM} \) |
| 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 |
|------------|-------------|------------|-------------|
| Variability | Stringency | Variability | Stringency | \( \Delta \text{NDM} \) | \( \Delta \text{NDM} \) |
| 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 (\( \Delta \text{NDM} \)) 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. 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**

| Variability | Stringency | Variability | Stringency | Variability | Stringency |
|-------------|------------|-------------|------------|-------------|------------|
| $$\Delta \text{NDM}$$ | $$\Delta \text{NDM}$$ | $$\Delta \text{NDM}$$ | $$\Delta \text{NDM}$$ | $$\Delta \text{NDM}$$ | $$\Delta \text{NDM}$$ |
| COVID-19 GRT | 0.00002 | -0.00005 | -0.00003 | 0.00007 | -0.00004 |
| ($0.00018$) | ($0.00008$) | ($0.00006$) | ($0.00006$) | ($0.00008$) | ($0.00020$) |
| $$R^2$$ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| Obs. | 11,959 | 11,778 | 5599 | 5418 | 6360 |

**Panel B: FE**

| Variability | Stringency | Variability | Stringency | Variability | Stringency |
|-------------|------------|-------------|------------|-------------|------------|
| $$\Delta \text{NDM}$$ | $$\Delta \text{NDM}$$ | $$\Delta \text{NDM}$$ | $$\Delta \text{NDM}$$ | $$\Delta \text{NDM}$$ | $$\Delta \text{NDM}$$ |
| COVID-19 GRT | 0.00013 | -0.00009 | -0.00005 | 0.00003 | 0.00078 |
| ($0.00023$) | ($0.00009$) | ($0.00009$) | ($0.00006$) | ($0.00112$) | ($0.00047$) |
| $$R^2$$ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00005 |
| Obs. | 12,975 | 12,101 | 6093 | 5895 | 6882 |

**Notes:** This table reports the results for panel regressions of new deaths per million ($\Delta \text{NDM}$) 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. COVID-19 New Deaths and $R_t$ (G7).

| Variability | Stringency | $R_t$ | Variability | Stringency | $R_t$ | Variability | Stringency | $R_t$ |
|-------------|------------|------|-------------|------------|------|-------------|------------|------|
| 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 |
| ($0.03906$) | ($0.00339$) | ($0.00743$) | ($0.00189$) | ($0.03780$) | ($0.00552$) | ($0.00567$) | ($0.00192$) | ($0.06832$) | ($0.00619$) |
| $$R^2$$ | 0.23640 | 0.00306 | 0.25012 | 0.27203 | 0.23201 | 0.04883 | 0.23820 | 0.37313 | 0.30388 | 0.03091 |
| Obs. | 5231 | 5189 | 5186 | 5147 | 2621 | 2594 | 2576 | 2552 | 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 smokers, male smoker, 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 | Stringency | First wave | Stringency | Second Wave | Stringency |
| NDM  | Variability | $R_t$      | Variability | $R_t$      | Variability | $R_t$      |
|      | CDI-19 GRT  | ($\sigma$) | CDI-19 GRT  | ($\sigma$) | CDI-19 GRT  | ($\sigma$) |
|      | 0.01085     | 0.00806*  | 0.02105**  | -0.01127*** | 0.04550     | 0.00389    | 0.01473*   | -0.01238*** | 0.06076     | 0.00475    | 0.04941     | -0.00778*** |
|      | (0.03987)   | (0.00340) | (0.00738)  | (0.00189)   | (0.03927)   | (0.00373)  | (0.00593)  | (0.00181)   | (0.07137)   | (0.00643)  | (0.02762)   | (0.00204)   |
|      | 0.23640     | 0.03006   | 0.25012    | 0.27203     | 0.23201     | 0.04883    | 0.23820    | 0.37313     | 0.30388     | 0.03091    | 0.31515     | 0.10643     |
|      | 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 smokers, male smoker, extreme poverty, population, hospital beds per thousand (5 days lagged). Data are winorized, 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. COVID-19 New Deaths and $R_t$ (Central America).

|                | Full sample |            |            | First wave |            |            | Second Wave |            |            |
|----------------|-------------|------------|------------|------------|------------|------------|-------------|------------|------------|
|                | Variability | Stringency | Variability | Stringency | Variability | Stringency | Variability | Stringency | Variability |
| $R_t$          | NDM         |            | $R_t$      |            | $R_t$      |            | $R_t$       |            | $R_t$       |
| COVID-19 GRT   | -0.06226    | 0.00640    | 0.05336    | -0.0225    | -0.05347   | 0.00407    | 0.02191     | -0.00407   | -0.0045    |
|               | (0.00000)   | (0.00000)  | (0.00000)  | (0.00000)  | (0.00000)  | (0.00000)  | (0.00000)   | (0.00000)  | (0.00000)  |
| $R_t^2$        | 0.04007     | 0.07085    | 0.39278    | 0.12909    | 0.45832    | 0.09582    | 0.47420     | 0.34156    | 0.46661    |
| Obs.           | 1969        | 1935       | 1924       | 1900       | 925        | 897        | 880         | 862        | 1044       |

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 smokcers, male smoker, 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. COVID-19 New Deaths and $R_t$ (Asia).

|                | Full sample |            |            | First wave |            |            | Second Wave |            |            |
|----------------|-------------|------------|------------|------------|------------|------------|-------------|------------|------------|
|                | Variability | Stringency | Variability | Stringency | Variability | Stringency | Variability | Stringency | Variability |
| $R_t$          | NDM         |            | $R_t$      |            | $R_t$      |            | $R_t$       |            | $R_t$       |
| COVID-19 GRT   | -0.00861    | 0.00573    | -0.00350   | -0.00464** | -0.00444   | 0.00400    | -0.00163    | -0.00740** | 0.01544    |
|               | (0.00558)   | (0.00483)  | (0.00236)  | (0.00176)  | (0.00631)  | (0.00469)  | (0.00203)   | (0.00194)  | (0.03278)  |
| $R_t^2$        | 0.08295     | 0.04972    | 0.08289    | 0.06501    | 0.01026    | 0.10345    | 0.00991     | 0.16402    | 0.33146    |
| Obs.           | 6249        | 6562       | 6159       | 6486       | 2899       | 3102       | 2799        | 3026       | 3360       |

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 smokcers, male smoker, 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 B12

Variability and strictness of Government Response vs. COVID-19 News deaths and $R_t$ (G7).

|          | G7 | Variability | NDM | 20th | 0.17550*** (0.02050) | 2520 |
|----------|----|-------------|-----|------|----------------------|------|
|          |    |             | NDM | 80th | 0.31457*** (0.04217) | 2520 |
|          |    |             | $R_t$ | 20th | 0.03034*** (0.00425) | 2495 |
|          |    |             | $R_t$ | 80th | 0.04181*** (0.01441) | 2495 |
|          |    | Strictness  | NDM | 20th | 0.00016 (0.00148) | 2488 |
|          |    |             | NDM | 80th | -0.00374 (0.00256) | 2488 |
|          |    |             | $R_t$ | 20th | -0.01277*** (0.00068) | 2482 |
|          |    |             | $R_t$ | 80th | -0.02565* (0.01203) | 2482 |

#### I wave

|          | G7 | Variability | NDM | 20th | 0.19292*** (0.01816) | 1302 |
|----------|----|-------------|-----|------|----------------------|------|
|          |    |             | NDM | 80th | 0.40200*** (0.05168) | 1302 |
|          |    |             | $R_t$ | 20th | 0.01446*** (0.00406) | 1277 |
|          |    |             | $R_t$ | 80th | -0.00369 (0.00818) | 1277 |
|          |    | Strictness  | NDM | 20th | 0.00657*** (0.00156) | 1277 |
|          |    |             | NDM | 80th | -0.01384*** (0.00379) | 1277 |
|          |    |             | $R_t$ | 20th | -0.01357*** (0.00126) | 1271 |
|          |    |             | $R_t$ | 80th | -0.02659*** (0.00522) | 1271 |

#### II wave

|          | G7 | Variability | NDM | 20th | 0.38838*** (0.07463) | 1218 |
|----------|----|-------------|-----|------|----------------------|------|
|          |    |             | NDM | 80th | 0.41453*** (0.10881) | 1218 |
|          |    |             | $R_t$ | 20th | 0.14700*** (0.01402) | 1218 |
|          |    |             | $R_t$ | 80th | 0.18439*** (0.01961) | 1218 |
|          |    | Strictness  | NDM | 20th | -0.01632*** (0.00341) | 1211 |
|          |    |             | NDM | 80th | -0.02196*** (0.00358) | 1211 |
|          |    |             | $R_t$ | 20th | -0.01117*** (0.00073) | 1211 |
|          |    |             | $R_t$ | 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.
| G20       | Variability | NDM  | 20th      | -0.0175   | (0.03736)  | 6660 |
|----------|-------------|------|-----------|-----------|------------|------|
|          |             | NDM  | 80th      | 0.06512   | (0.06686)  | 6660 |
|          |             | R   | 20th      | 0.02073***| (0.00210)  | 6591 |
|          |             | R   | 80th      | 0.02474***| (0.00390)  | 6591 |
| Strictness|             | NDM  | 20th      | 0.00485***| (0.00103)  | 6598 |
|          |             | NDM  | 80th      | 0.01066***| (0.00177)  | 6598 |
|          |             | R   | 20th      | -0.00789***| (0.0035)   | 6547 |
|          |             | R   | 80th      | -0.01510***| (0.00600)  | 6547 |
| I wave   | Variability | NDM  | 20th      | -0.00927  | (0.03806)  | 3354 |
|          |             | NDM  | 80th      | 0.15093***| (0.07417)  | 3354 |
|          |             | R   | 20th      | 0.01543***| (0.00238)  | 3285 |
|          |             | R   | 80th      | 0.01027***| (0.00292)  | 3285 |
|          | Strictness  | NDM  | 20th      | 0.00598***| (0.00114)  | 3311 |
|          |             | NDM  | 80th      | 0.00349   | (0.00195)  | 3311 |
|          |             | R   | 20th      | -0.00824***| (0.00653)  | 3260 |
|          |             | R   | 80th      | -0.01831***| (0.00996)  | 3260 |
| II wave  | Variability | NDM  | 20th      | 0.05306** | (0.01940)  | 3306 |
|          |             | NDM  | 80th      | 0.17121***| (0.0461)   | 3306 |
|          |             | R   | 20th      | 0.06260***| (0.00700)  | 3306 |
|          |             | R   | 80th      | 0.07517***| (0.01220)  | 3306 |
|          | Strictness  | NDM  | 20th      | 0.00430   | (0.00205)  | 3287 |
|          |             | NDM  | 80th      | -0.00196  | (0.00221)  | 3287 |
|          |             | R   | 20th      | -0.00828***| (0.00056)  | 3287 |
|          |             | R   | 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. |
|----------------|---------------------|-----------------------|------|
|                | NDM                 | 20th                  |      |
|                |                     | 80th                  |      |
| Variability    |                     | 20th                  |      |
| NDM            | 0.00183             | (0.00957)             |      |
|                 | 0.11948***          | (0.02505)             | 9191 |
| $R_t$          | 0.00864***          | (0.00222)             | 9038 |
| $R_t$          | 0.03621***          | (0.00835)             | 9038 |
| Strictness     |                     | 20th                  |      |
| NDM            | -0.00541***         | (0.00073)             | 9223 |
|                 | -0.00852***         | (0.00094)             | 9223 |
| $R_t$          | -0.00722***         | (0.00021)             | 9059 |
| $R_t$          | -0.01190***         | (0.00026)             | 9059 |
|                | I wave              |                       |      |
|                | NDM                 | 20th                  |      |
|                |                     | 80th                  |      |
| Variability    |                     | 20th                  |      |
| NDM            | 0.06132***          | (0.01783)             | 4493 |
|                 | 0.38299             | (0.43130)             | 4493 |
| $R_t$          | 0.00005             | (0.01478)             | 4340 |
| $R_t$          | -0.0261             | (0.13810)             | 4340 |
| Strictness     |                     | 20th                  |      |
| NDM            | 0.00108             | (0.00460)             | 4552 |
|                 | -0.01566***         | (0.00137)             | 4552 |
| $R_t$          | -0.00724***         | (0.00028)             | 4388 |
| $R_t$          | -0.01533***         | (0.00042)             | 4388 |
|                | II wave             |                       |      |
|                | NDM                 | 20th                  |      |
|                |                     | 80th                  |      |
| Variability    |                     | 20th                  |      |
| NDM            | 0.32492***          | (0.03578)             | 4698 |
|                 | 0.52793***          | (0.05552)             | 4698 |
| $R_t$          | 0.12373***          | (0.05577)             | 4698 |
| $R_t$          | 0.17063***          | (0.01000)             | 4698 |
| Strictness     |                     | 20th                  |      |
| NDM            | -0.03180***         | (0.00173)             | 4671 |
|                 | -0.02536***         | (0.00197)             | 4671 |
| $R_t$          | -0.00854***         | (0.00028)             | 4671 |
| $R_t$          | -0.01141***         | (0.00024)             | 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***  | 4884 |
|                     | (0.00444)       |              |      |
| NDM                 | 80th            | -0.04222***  | 4884 |
|                     | (0.00995)       |              |      |
| $R_t$               | 20th            | 0.000655     | 4765 |
|                     | (0.01627)       |              |      |
| $R_t$               | 80th            | -0.00129     | 4765 |
|                     | (0.01031)       |              |      |
| Strictness          |                 |              |      |
| NDM                 | 20th            | 0.00158      | 4542 |
|                     | (0.00091)       |              |      |
| NDM                 | 80th            | 0.00608***   | 4542 |
|                     | (0.00127)       |              |      |
| $R_t$               | 20th            | -0.00345***  | 4481 |
|                     | (0.00025)       |              |      |
| $R_t$               | 80th            | -0.00319***  | 4481 |
|                     | (0.00028)       |              |      |
| **I wave**          |                 |              |      |
| Variability         |                 |              |      |
| NDM                 | 20th            | -0.02312***  | 2274 |
|                     | (0.00335)       |              |      |
| NDM                 | 80th            | -0.03751*    | 2274 |
|                     | (0.01814)       |              |      |
| $R_t$               | 20th            | 0.01233***   | 2155 |
|                     | (0.00152)       |              |      |
| $R_t$               | 80th            | 0.01376***   | 2155 |
|                     | (0.00374)       |              |      |
| Strictness          |                 |              |      |
| NDM                 | 20th            | 0.00607      | 1903 |
|                     | (0.0470)        |              |      |
| NDM                 | 80th            | -0.0007      | 1903 |
|                     | (0.00169)       |              |      |
| $R_t$               | 20th            | -0.00508***  | 1842 |
|                     | (0.00065)       |              |      |
| $R_t$               | 80th            | -0.00848***  | 1842 |
|                     | (0.00080)       |              |      |
| **II wave**         |                 |              |      |
| Variability         |                 |              |      |
| NDM                 | 20th            | -0.00575     | 2610 |
|                     | (0.06743)       |              |      |
| NDM                 | 80th            | 0.09186      | 2610 |
|                     | (0.05254)       |              |      |
| $R_t$               | 20th            | -0.01108***  | 2610 |
|                     | (0.00308)       |              |      |
| $R_t$               | 80th            | -0.01154     | 2610 |
|                     | (0.00615)       |              |      |
| Strictness          |                 |              |      |
| NDM                 | 20th            | 0.00341*     | 2639 |
|                     | (0.01336)       |              |      |
| NDM                 | 80th            | 0.00353**    | 2639 |
|                     | (0.00121)       |              |      |
| $R_t$               | 20th            | -0.00128***  | 2639 |
|                     | (0.00034)       |              |      |
| $R_t$               | 80th            | -0.00161***  | 2639 |
|                     | (0.00034)       |              |      |

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.
| 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 | -0.0263 (0.03046) | 12999 |
| $R_t$ | 20th | 0.00602 (0.00513) | 12792 |
| $R_t$ | 80th | 0.00661 (0.00234) | 12792 |
| Strictness | | |
| NDM | 20th | 0.00066 (0.00085) | 13706 |
| NDM | 80th | 0.01317 (0.00133) | 13706 |
| $R_t$ | 20th | -0.00164 (0.0012) | 13534 |
| $R_t$ | 80th | -0.00436 (0.00046) | 13534 |
| **I wave** | | |
| Variability | | |
| NDM | 20th | -0.00947 (0.00107) | 6115 |
| NDM | 80th | -0.01219 (0.00319) | 6115 |
| $R_t$ | 20th | 0.00145 (0.00031) | 5908 |
| $R_t$ | 80th | 0.00146 (0.00079) | 5908 |
| Strictness | | |
| NDM | 20th | -0.00032 (0.00111) | 6440 |
| NDM | 80th | 0.01057 (0.00176) | 6440 |
| $R_t$ | 20th | -0.00385 (0.00034) | 6268 |
| $R_t$ | 80th | -0.00967 (0.00051) | 6268 |
| **II wave** | | |
| Variability | | |
| NDM | 20th | -0.0103 (0.0097) | 6884 |
| NDM | 80th | -0.00325 (0.01464) | 6884 |
| $R_t$ | 20th | 0.00776 (0.00338) | 6884 |
| $R_t$ | 80th | 0.02994 (0.00411) | 6884 |
| Strictness | | |
| NDM | 20th | 0.01791 (0.00213) | 7266 |
| NDM | 80th | 0.00549 (0.00127) | 7266 |
| $R_t$ | 20th | -0.00285 (0.00034) | 7266 |
| $R_t$ | 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 | 1302 | 1218 | 1218 | 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 | 1302 | 1218 | 1218 | 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 | 4493 | 4493 | 4698 | 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

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

Panel A: Low GDP

| Variability | Stringency | Variability | Stringency | Variability | Stringency | Variability | Stringency |
|-------------|------------|-------------|------------|-------------|------------|-------------|------------|
| NDM $R_t$   | $R_t$      | NDM $R_t$   | $R_t$      | NDM $R_t$   | $R_t$      | NDM $R_t$   | $R_t$      |
| COVID-19 GRT| -0.02580***| 0.00552     | -0.00273   | -0.00081    | -0.01912** | 0.00281     | 0.00366    | -0.00388***|
|             | (0.00782)   | (0.00376)   | (0.00313)  | (0.00099)   | (0.00604)  | (0.00415)   | (0.00211)  | (0.00116)  |
| $R^2$       | 0.00361     | 0.01028     | 0.00052    | 0.00275     | 0.00285    | 0.00376     | 0.00086    | 0.05521    |
| Obs.        | 8074       | 8665        | 7920       | 8583        | 3626       | 3777        | 3472       | 3695        |

Panel B: Mid GDP

| Variability | Stringency | Variability | Stringency | Variability | Stringency | Variability | Stringency |
|-------------|------------|-------------|------------|-------------|------------|-------------|------------|
| NDM $R_t$   | $R_t$      | NDM $R_t$   | $R_t$      | NDM $R_t$   | $R_t$      | NDM $R_t$   | $R_t$      |
| COVID-19 GRT| -0.06411***| 0.00292     | 0.01477    | -0.00656*** | -0.01264   | 0.00193     | 0.00681    | -0.00753***|
|             | (0.01410)   | (0.00250)   | (0.00887)  | (0.00082)   | (0.01083)  | (0.00269)   | (0.00424)  | (0.00111)  |
| $R^2$       | 0.00945     | 0.00251     | 0.00522    | 0.14711     | 0.00537    | 0.00126     | 0.01475    | 0.20861    |
| Obs.        | 10,095     | 9924        | 9895       | 9734        | 4875       | 4734        | 4675       | 4544        |

Panel C: High GDP

| Variability | Stringency | Variability | Stringency | Variability | Stringency | Variability | Stringency |
|-------------|------------|-------------|------------|-------------|------------|-------------|------------|
| NDM $R_t$   | $R_t$      | NDM $R_t$   | $R_t$      | NDM $R_t$   | $R_t$      | NDM $R_t$   | $R_t$      |
| COVID-19 GRT| 0.10268**  | -0.00217    | 0.01880*   | -0.01063*** | 0.15532*** | -0.00145    | -0.00615   | -0.01226***|
|             | (0.03908)   | (0.00307)   | (0.00748)  | (0.00124)   | (0.04151)  | (0.00318)   | (0.00544)  | (0.00126)  |
| $R^2$       | 0.01938     | 0.00087     | 0.00823    | 0.29669     | 0.12267    | 0.00038     | 0.00232    | 0.38170    |
| Obs.        | 11,681     | 11,631      | 10,870     | 11,497      | 5765       | 5749        | 5631       | 5615        |

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.
