Lockdown fatigue: The diminishing effects of quarantines on the spread of COVID-19

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Febrero de 2021

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Abstract

Non-Pharmaceutical Interventions (NPIs) have been for most countries the key policy instrument utilized to contain the impact of the COVID-19 pandemic. In this article, we conduct an empirical analysis of the impact of these policies on the virus' transmission and death toll, for a panel of 152 countries, from the start of the pandemic through December 31, 2020. We find that lockdowns tend to significantly reduce the spread of the virus and the number of related deaths. We also show that this benign impact declines over time: after four months of strict lockdown, NPIs have a significantly weaker contribution in terms of their effect in reducing COVID-19 related fatalities. Part of the fading effect of quarantines could be attributed to an increasing non-compliance with mobility restrictions, as reflected in our estimates of a declining effect of lockdowns on measures of actual mobility. However, we additionally find that a reduction in *de facto* mobility also exhibits a diminishing effect on health outcomes, which suggests that lockdown fatigues may have introduce broader hurdles to containment policies.

1. Introduction

Faced with the emergence and global spread of the COVID-19 virus pandemic, governments deployed restrictions on mobility and social life without precedents in peacetime. Lacking adequate vaccines or antiviral medications, non-pharmaceutical interventions (NPIs) to reduce SARS-CoV-2 transmission were implemented worldwide to constrain the spread of the virus. While these policies themselves (as well as voluntary reductions in social mobility) may have had a significantly detrimental effect on economic activity and individual livelihoods, there is a widespread belief that they were effective in containing the spread of the virus, avoiding congestion in the health system and ultimately reducing the toll of the pandemic. At the same time, there is an increasing sense that lockdown fatigue has placed limits on the efficacy of NPIs henceforth and on the ability to reintroduce them in the event of repeated peaks.

In this paper, we ask ourselves to what extent have NPIs and reductions in social mobility been effective in reducing the spread of COVID-19, and in improving the pandemic's epidemiological outcomes. We provide evidence that restrictions had a significant effect in the first weeks after their introduction. The effect of boosting NPIs on an estimate of the daily reproduction number R_t[1] peaks at about 10 days and disappears at about 20, consistent with a significant contribution to reducing the incidence of the pandemic. However, the initial effect cannot be replicated over time: after 120 (continuous or discontinuous) days or strict lockdown, the response flattens to a point that, even at its peak, it fails to reduce the spread significantly. A similar pattern is found when we measure impact in terms of cumulative or daily deaths per million. This suggests that restrictions applied for a long period or reintroduced late in the pandemic (for example, in the event of a resurgence of cases) would exert,

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[1] The reproduction number R_t is an estimate of the rate of spread of COVID-19 and can be defined as the average number of secondary infections that is generated by a primary infection.

at best, a weaker, attenuated effect on the evolution of cases and casualties. We find a similar pattern when we use mobility as the proxy for the mobility-related NPIs instead of an index of containment measures. Overall, we conclude that restrictions played a role early on the pandemic but had a transient effect that will be hard to replicate going forward.

The paper is organized as follows. The second section provides a literature review of the recent empirical literature providing estimates of the effect of containment measures on health outcomes associated with the COVID-19 pandemic. The third section describes the data and the econometric methodology. The fourth section presents our main results both on the effect of containment measures and on the non-linearity of their effectiveness over time. The last section discusses the implications of our findings in the face of the next outbreaks of COVID-19 and concludes.
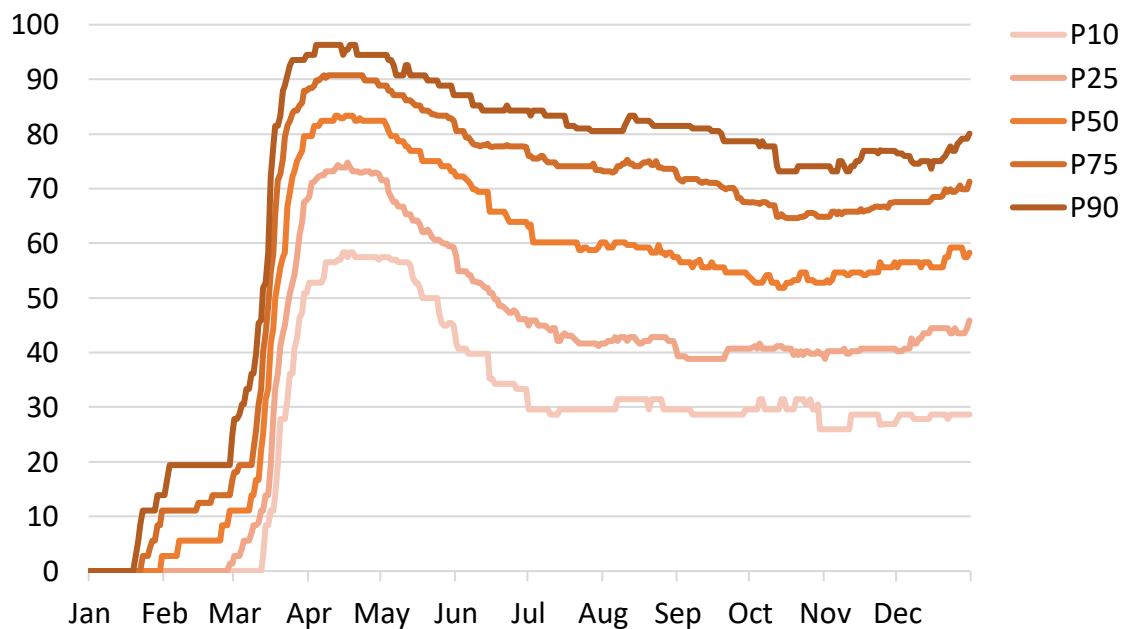
2. Literature Review

The start of the pandemic and the sudden advent of a global health, economic and social crisis has motivated the emergence of an increasingly sizeable and varied COVID-19 literature. Specifically, a strain of empirical studies has sought to improve our changing understanding of the causal impact of unprecedented non-pharmaceutical interventions on health outcomes, by providing statistical estimates of NPIs in key epidemiological variables. The majority of these studies have focused their analysis on the initial months of the pandemic and have for the most part documented significant effects of NPIs in reducing the spread of the virus. However, given their different time frames and econometric methods used, these studies have not arrived at uniform conclusions.

The analyses have benefitted from the publication of high-frequency cross-country metrics on *de jure* restrictions to social interactions and *de facto* compliance to these. The Oxford COVID-19 Government Response Tracker's (OxCGRT) "Stringency Index" has been amongst these the most

widely used (Hale et al. 2020). OxCGRT collects at a regular basis nineteen indicators of government responses to the virus (eight indicators on "containment and closure", four on economic policies and seven on health system policies). The "Stringency Index" is a composite indicator which combines information on the legal intensity of eight "containment and closure" policies: (i) school closures, (ii) workplace closures, (iii) public event bans, (iv) restrictions on private gatherings, (v) public transportation closures, (vi) "stay-at-home" requirements; (vii) restrictions on internal movement; and (viii) international travel controls. Analysis of the impact of *de jure* NPIs take advantage of the cross-country and time variation of the index and its components, as illustrated by *Figure 1*, which displays variations in the Stringency index for 160 countries up to January 15, 2021.
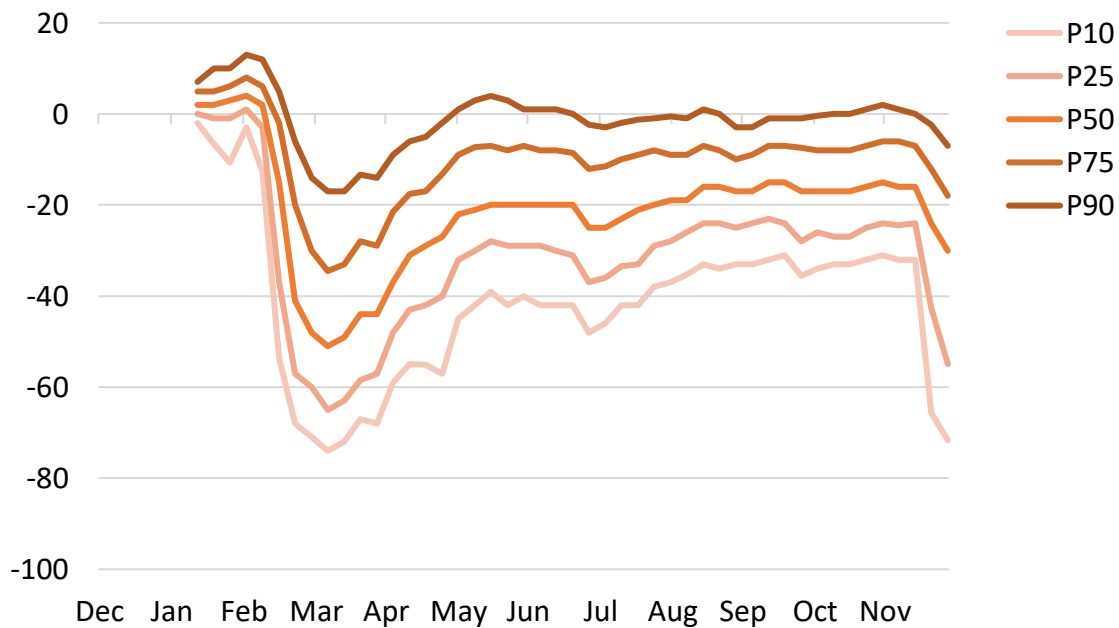
Figure 1. OxCGRT Stringency Index

Source: Oxford's COVID-19 Government Response Tracker (OxCGRT)

Beyond policies implemented to contain social interactions, other studies have relied on measures of social mobility itself, as captured by anonymized location history data from Google Maps (or Apple Maps) users. Google Mobility Reports provide daily changes in mobility with respect to a January-

February 2020 median baseline for each corresponding day of the week. The reports record changes in mobility for six different location categories: (i) workplaces, (ii) residential, (iii) transit stations, (iv) parks, (v) groceries and pharmacies, (vi) centers of retail and recreation. *Figure 2* illustrates the evolution of workplaces mobility for 120 countries up to January 15, 2021. The figure – and our corresponding analysis in the next section – averages out daily variations in the index though the week to reduce its strong seasonality.

Figure 2. Google Workplaces Mobility Index

Leveraging within and between country variation in OxCGRT and Google mobility data, Askitas et al. (2020) presented in May a model to study the effects of NPIs both on epidemiological outcomes of COVID-19 and mobility. A multiple events model is developed by the authors in an effort to disentangle the distinct effect of concurrent interventions, using a panel data set of 135 countries. The authors conclude that the cancelation of public events and restrictions on private gatherings have the largest effects both on mobility and COVID-19 cases, followed by school and workplace closures. In

a similar fashion, Wong et al. (2020) analyzed the concurrent impact of NPIs as recorded by OxCGRT for 131 countries for the period between April 15 to April 30, including country-specific controls, and found more stringent containment associated with a better control of the pandemic.

In Deb et al. (2020), the dynamic cumulative effect of both NPIs and reduction in mobility is estimated for a panel of 129 countries until June 15 by adopting the methodology developed by Jordà (2005) to estimate impulse responses without specifications through local projections. In a second econometric specification, the authors allow for the effect of containment measures to vary according to country characteristics. A variety of controls such as temperature and humidity, testing and contact tracing policies are included, as well as country specific time trends and lags of the changes in the number of infected cases (this serving as a control for the reverse causality of infections on governments' response to the pandemic). The authors document a high effectiveness of measures implemented to containing the spread the pandemic, with high heterogeneity across countries depending on factors such as average daily temperature, countries' population density, the quality of their health system and their age structure. Authors also find that easing the stringency of NPIs has resulted in an increase in the number of cases and deaths lower than the reduction associated with tightening measures. Finally, Li et al. (2020) evaluates the effect of NPIs for 131 countries up to July 20 by observing their effect on an estimated country-specific and time-varying reproduction number. The authors find that the introduction of measures such as school closures, workplace closures, bans on public events, requirements to stay at home, and internal movement limits are associated with a decreasing trend over time in the reproduction number, although this association is only significant for the public events ban. The relaxation of these measures is conversely associated with an increase in the reproduction number, although only significant for the case of school reopening.

The nascent COVID-19 literature has for the most part agreed on the significance NPIs have had in reducing the spread and consequences of the pandemic, despite differences in both methodologies and econometric estimates (in particular, regarding the effect of specific NPIs). However, there are reasons to believe additional research is needed to characterize the pandemic's evolving impact. Published studies focused on the impact during the pandemic's "first wave", with data limited to the first semester of 2020, and as a result tested only partially for the presence of lockdown fatigue or, more generally, non-linear effects due to the cumulative economic and psycho-sociological burden of the restrictions and the diminishing degree of compliance.[2] Moreover, even when enforcement is high, improvements in protocols for economic, academic, and recreational activities, expansion of tracking and isolation capacities, and better treatments could render containment relatively less influential in improving epidemiological outcomes in the presence of new peaks.
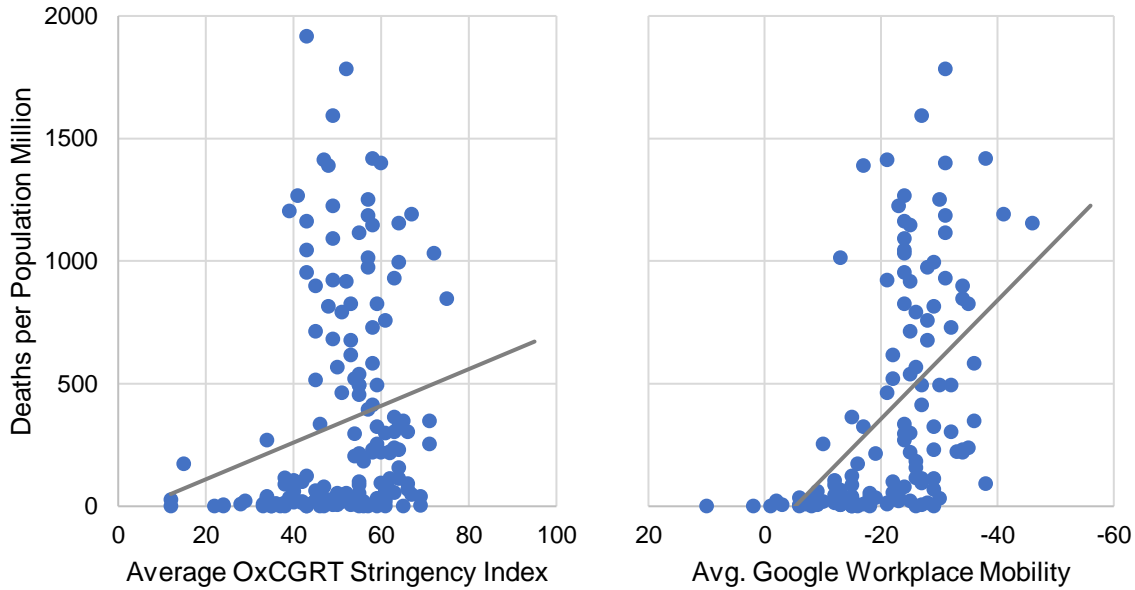
3. Methodology and Data

The key obstacles to isolate the effect of NPIs on the main epidemiological outcomes associated with COVID-19 are its time-varying nature and the associated non-linearity of the effect. As *Figure 3* shows, a simple comparison of the average intensity of *de jure* and *de facto* reductions in social mobility (from March through December 2020) with COVID 19-related deaths does not reveal a consistent and meaningful link. The presence of reverse causality (a higher death toll should elicit to more stringent containment measures) and country-specific factors (demographics, health system strength, urban density) that shape both the lethality of the virus and the willingness and ability to enforce NPIs make a basic two-way correlation uninformative. More to the focus of this paper, to the extent that the effectiveness of NPIs varies over time, an average over long periods is a poor proxy of

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[2] As Levy Yeyati and Sartorio (2020) show for a broad set of developed, emerging and developing countries, the distance between the *de jure* severity of a lockdown and the *de facto* impact on mobility tends to grow steadily over time, the more so the lower the country´s per capita income and the degree of labor formality.

actual intensity, as the effectiveness of short periods of high intensity and long periods of moderate intensity may differ.

Figure 3. OxCGRT Stringency Index, Google Workplace Mobility and COVID-19 Deaths

Sources: Oxford's COVID-19 Government Response Tracker (OxCGRT), Google Mobility Reports

To estimate the effect of NPIs over time, we followed Deb et al. (2020) in their use of the local projections methodology first introduced in Jordà (2005). By estimating one-step-ahead ordinary regressions for each time period –instead of approximating the data globally through, for example, a vector autoregression– local projections provide impulse-response functions that are not only more suitable for non-linear and flexible relations but also less susceptible to misspecification and simpler for statistical inference.

To conduct our analysis, we use data on COVID-19 deaths provided by University of Oxford's Our World in Data COVID-19 tracker, and estimates of the effective reproduction number (R_t) from the Metrics COVID-19 Analysis website, published by epidemiologists from Harvard´s T.H. Chan School of Public Health (Adam 2020). These R_t estimates, based on the EpiEstim methodology, are calculated

using the number of reported daily new cases. These could be lower than actual cases given under-reporting or insufficient testing capabilities, which could bias the estimates. In both cases, we have conducted our analysis with seven day averages of the COVID-19 outcome variables, to smooth out high frequency variations and short-lived reporting lags in the data. For robustness, we also estimated our main specifications using R_t estimates from Arroyo-Marioli et al. (2021), as well as data on COVID-19 cases. For the policy intervention variable, we use the OxCGRT Stringency Index (alternatively, we the workplace mobility estimate from Google Mobility Reports, re-indexed to account for seasonality). The panel dataset includes 152 countries with data from the onset of the pandemic until December 31, 2020. Only 146 countries have R_t estimates, and only 114 of these countries have Google mobility data.

We estimate the following two base specifications for both COVID-19 deaths and the disease's reproduction number R_t:

$$d_{i,t+z} - d_{i,t} = D_i + B_{i,t}X_{i,t} + \beta_h S_{i,t} + \phi_{i,t}(d_{i,t} - d_{i,t-7}) + \gamma_t H_t + \varepsilon_{i,t+z} \tag{1}$$

$$d_{i,t+z} - d_{i,t+z-7} = D_i + +B_{i,t}X_{i,t} + \beta_h S_{i,t} + \phi_{i,t}(d_{i,t} - d_{i,t-7}) + \gamma_t H_t + \varepsilon_{i,t+z} \tag{2}$$

where $d_{i,t+z} - d_{i,t}$ is the difference in logarithms of the variable of interest for country i between times t and $t + z$, and $d_{i,t+z} - d_{i,t+z-7}$ is the difference in logarithm at time $t + z$ and one week before that. The first regression measures the cumulative change in the dependent variable since the start of the intervention, while the second regression measures the intervention's impact in the weekly evolution of the variable. D_i are country fixed-effects and $S_{i,t}$ is our tested intervention (measures of intensity of *de jure* and *de facto* reduction in social interactions). We include as controls $X_{i,t}$ temperature and humidity, using daily data of the largest city of each country from the Air Quality Open Data Platform. We also estimate the effect of testing and contract tracing policies (using data from OxCGRT) as a

robustness check. Following Deb et al. (2020), we include a lag of the dependent variable as a control for the endogenous adoption of NPIs (as a response to an increase in the number of COVID-related deaths or in the reproduction number). Finally, when the dependent variable is based on COVID-19 deaths, we include the sample median of deaths per population at each point in time, as a proxy for the global evolution of the pandemic.

To account for the lockdown´s diminishing marginal effect, our second set of specifications includes a variable $T_{i,t}$ that estimates the cumulative past "intensity" of NPI measures as the number of days in the past for which the Stringency Index was at least 70, and an interaction between this variable and the intervention variable of interest:

$$d_{i,t+z} - d_{i,t} = D_i + B_{i,t}X_{i,t} + \beta_h S_{i,t} + \delta_h T_{i,t} + \gamma_{i,t}(S_{i,t} \times T_{i,t}) \tag{3}$$

$$+ \phi_{i,t}(d_{i,t} - d_{i,t-7}) + \gamma_t H_t + \varepsilon_{i,t+z}$$

$$d_{i,t+z} - d_{i,t+z-7} \tag{4}$$

$$= D_i + B_{i,t}X_{i,t} + \beta_h S_{i,t} + \delta_h T_{i,t} + \gamma_{i,t}(S_{i,t} \times T_{i,t})$$
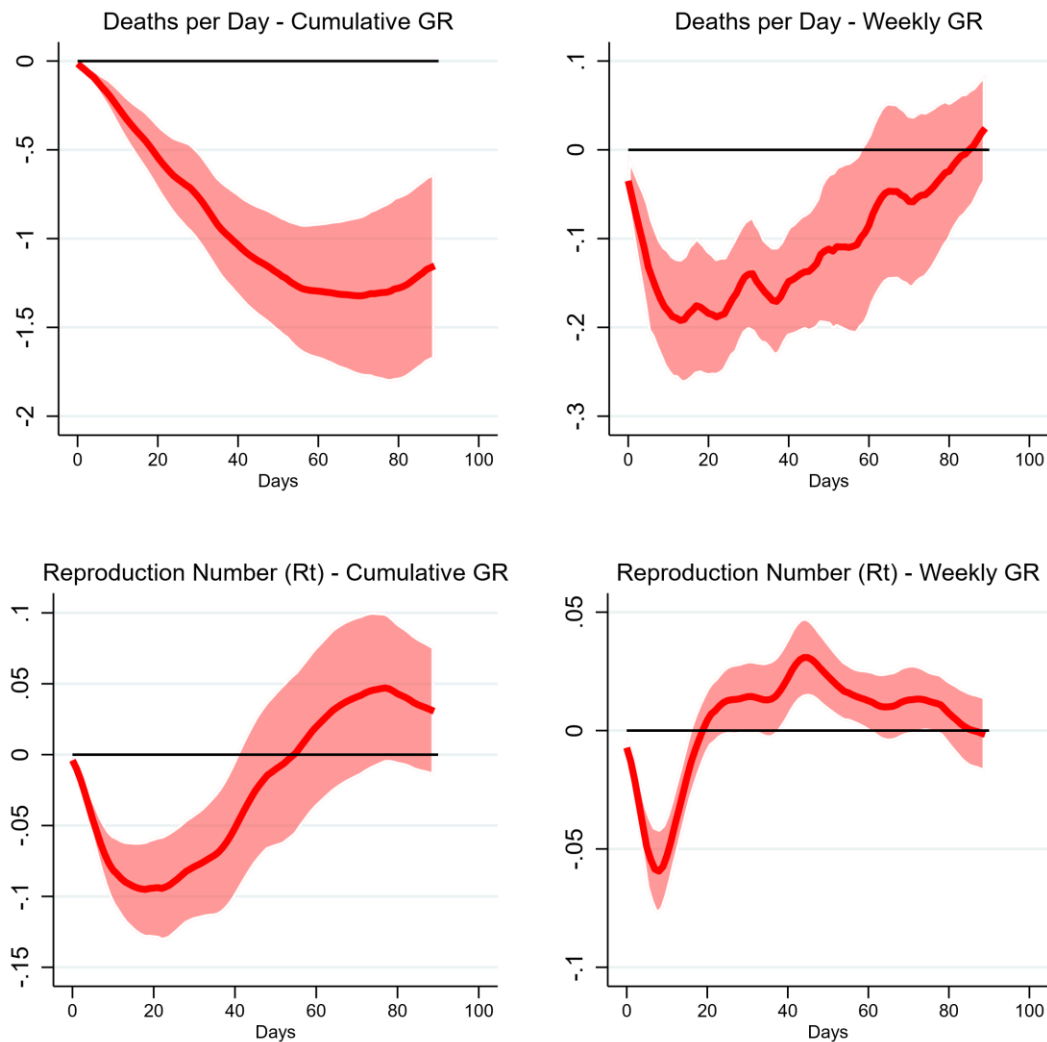
$$+ \phi_{i,t}(d_{i,t} - d_{i,t-7}) + \gamma_t H_t + \varepsilon_{i,t+z}$$

4. Results

Figure 4 shows the estimated dynamic cumulative response and corresponding daily growth rate of the two impact metrics – the reproduction number and the number of daily deaths – to a standard deviation change in the Stringency index over the 90-day period following the intensification of containment measures. The *de jure* rigidity of NPIs is associated with a gradual, significant and negative reduction of the spread of the virus and of COVID-related deaths. The effect in the evaluated time period is fairly persistent, as its cumulative effect on deaths peaks at about 60 days after the

increase in NPI intensity; the effect on the reproduction rate peaks at 20 days. Specifically, a one standard deviation in the Stringency index yields a maximum cumulative 75% decline in deaths per million with respect to the 60-day evolution projected without intervention, and a maximum 10% decline in the reproduction number.[3]

Figure 4. Impact of OxCGRT Stringency Index on Effective Reproduction Rate and COVID-19 Related Deaths
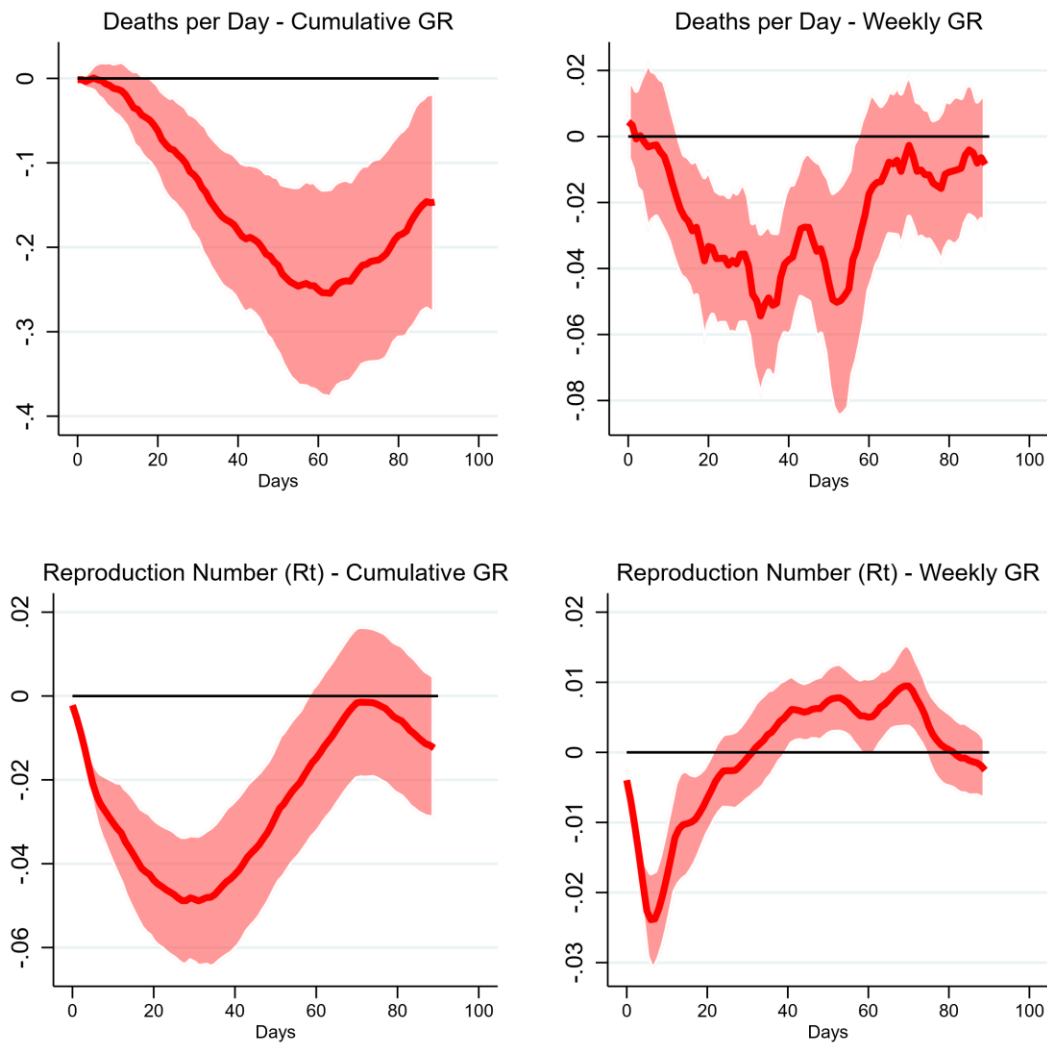

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[3] Since the results are presented in log differences, a one standard deviation increase in the index which yields a 1.37 log difference of the dependent variable is equivalent to a $e^{-1.37} - 1 = -0.75$ decline in weekly deaths per million.

These results are robust to a number of checks to the main econometric specification, which include: i) eliminating the climate control variables: temperature and humidity (*Figure A1*), ii) eliminating the time trend of the pandemic and the dependent variable lag (*Figure A2*) and iii) adding additional controls variables to identify the intensity of other relevant NPIs such as testing policies, contact tracing and public information campaigns (*Figure A3*). None of these changes to the baseline specification substantially altered the size of the impact, its statistical significance, and its fading time pattern.

As noted above, we replicate the previous estimations using Google Workplace Mobility index instead of the Stringency Index. This robustness check is of particular interest not only because mobility is not a policy variable but an outcome – and, as such, could be *a priori* less endogenous to COVID-related variables (although voluntary reductions in social mobility could also respond to the evolution of the pandemic)– but also because, as has been shown in the literature, lockdowns face diverse degrees of compliance, of which the evolution of the concomitant changes in workplace mobility are a good illustration. As can be seen in *Figure 5*, this proxy of the *de facto* consequences of a quarantine shows a similar to –albeit more muted pattern than–the Stringency Index: a one standard deviation reduction in mobility yields a maximum cumulative decline of near 22 pp in weekly deaths per million (with respect to baseline change expected in a 60-day period), and a nearly 5 pp cut in the reproduction coefficient (with respect to baseline change expected in a 30-day period). The more attenuated impact seems realistic: we conjecture that it possibly reflects a smoother variation of the intervention variable as well as the presence of channels other than mobility through which the lockdown influence health outcomes.

Figure 5. Impact of Google Workplace Mobility on Effective Reproduction Rate and COVID-19 Related Deaths

Note. The graph represents the estimated impulse response function for a one standard deviation change in the Google Workplace Mobility index. The shaded area represents the 90% confidence interval for the coefficient.
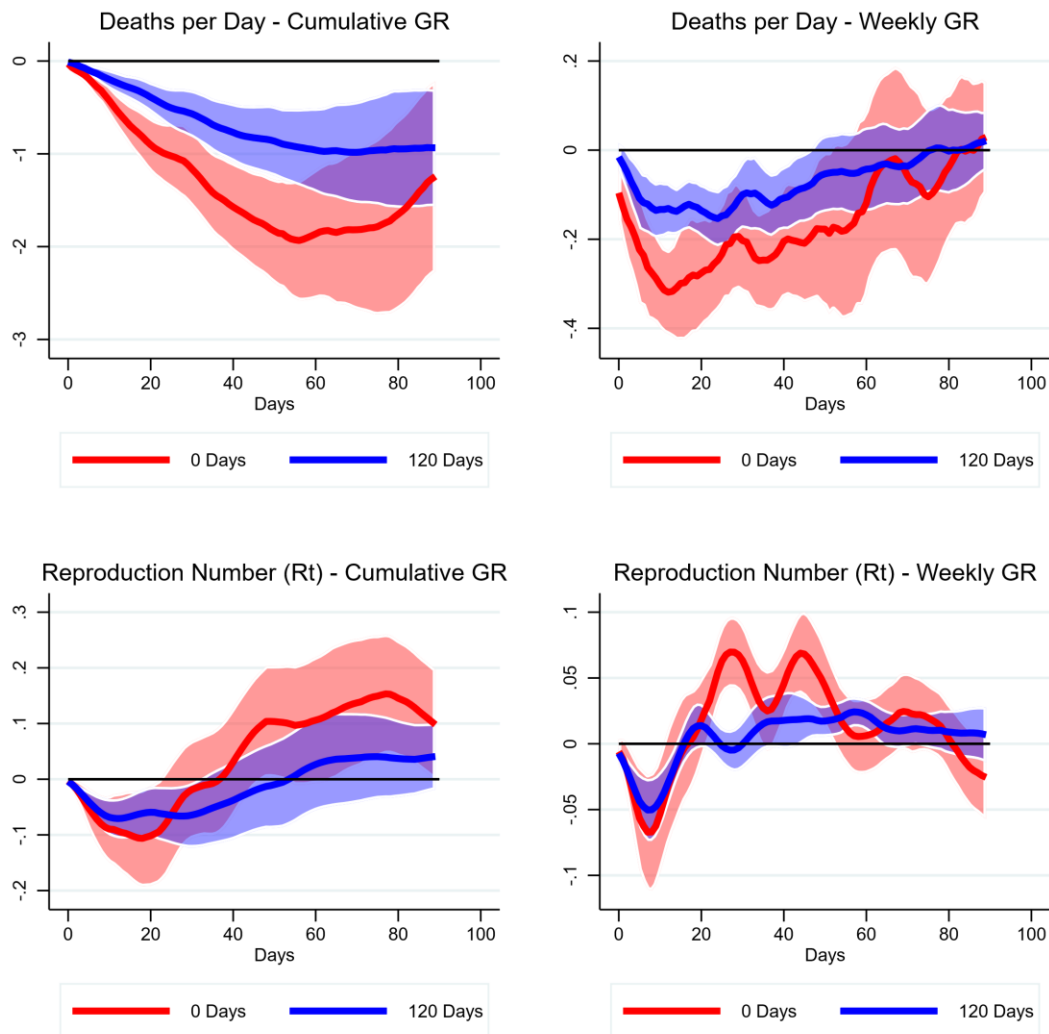
Having shown that, in general, NPIs do have a significant benign and persistent effect on the spread of the virus and its death toll, the natural follow-up question is: *for how long?* More precisely, how much is lost if we go from one-week to four-month lockdowns? The question is particularly relevant

at a time when many countries facing a surprisingly strong second wave of infections are already re-imposing restrictions.

Taking advantage of an expanded year of COVID-19 data, we estimate a quantitative answer to this question by interacting restrictions with a proxy for "lockdown fatigue": the number of days (since the beginning of the pandemic) that the country had a strict lockdown (where a strict lockdown is defined as one with a Stringency Index at 70 or above) as in models (3) and (4) above.

Figure 6 shows the results of this exercise. As can be seen, there are significant differences in the effect of distancing measures in reducing deaths from COVID-19 when comparing the onset of the pandemic with the re-imposition after 120 days of strict (and possibly intermittent) lockdown, a scenario more similar to that faced by countries at the beginning of the second wave of contagions. Containment policies generate lower reductions in deaths from COVID-19 than in the first stage of the epidemic and the effect tends to lose its statistical significance faster. By contrast, no significant differences are observed between the two phases of the pandemic for impact on the reproduction rate.

Figure 6. Impact of OxCGRT Stringency Index on Effective Reproduction Rate and COVID-19 Related Deaths (coefficient and interaction term at 120 days)
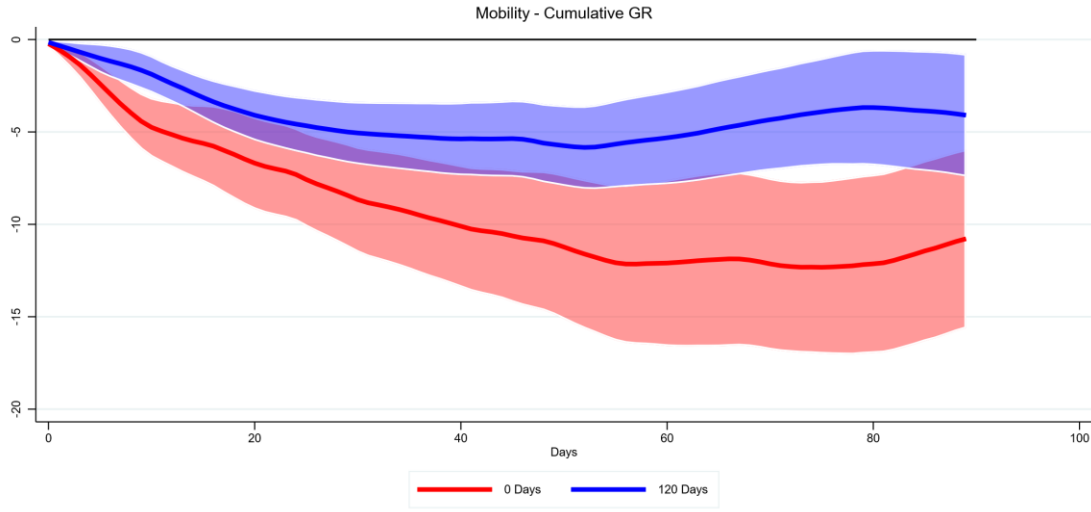

Note. The graph represents the estimated impulse response function for a one standard deviation change in the OxCGRT Stringency Index, including the effect of the duration-Stringency interaction valued at the specified period. The shaded area represents the 90% confidence interval for the linear combination.

A priori, it could be assumed that the fading impact of the lockdown may owe in part to the fact that compliance with mobility restrictions is hard to sustain economically and socially for long periods of time, as was highlighted by Levy Yeyati and Sartorio (2020). If that were the case, one would expect that the estimated effect of the *de jure* lockdown on COVID-related outcomes should decline by more

than the effect the *de facto* mobility reductions, simply because de jure restrictions are increasingly ignored. Indeed, substituting workplace mobility for death per million in model (3) above, we can see both that a higher stringency index tends to generate a significant reduction in mobility, and that the impact looks more attenuated –albeit not significantly different– after 120 days of strict lockdown.
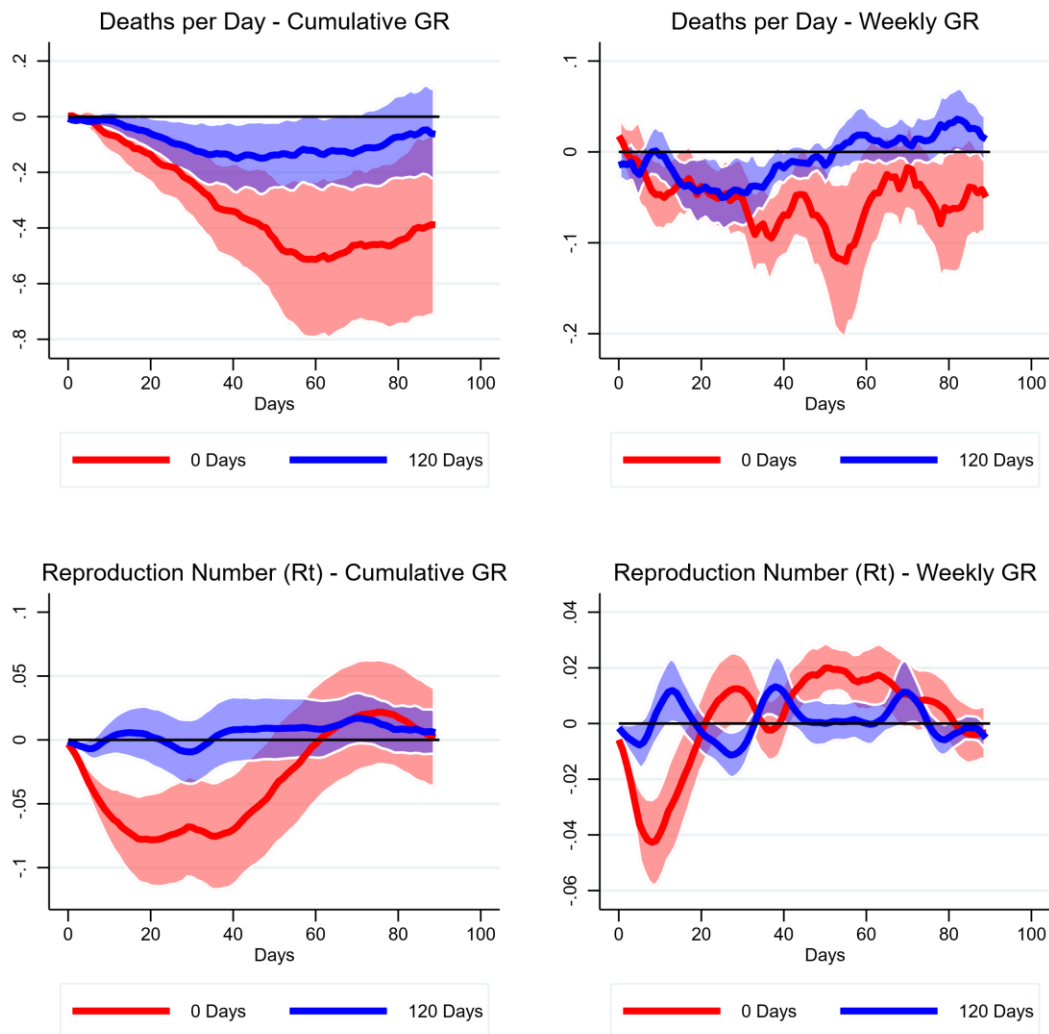
Figure 7. Impact of OxCGRT Stringency Index on Google Workplace Mobility (coefficient and interaction term at 120 days)

Mobility - Cumulative GR

Note. The graph represents the estimated impulse response function for a one standard deviation change in the O xCGRT Stringency Index, including the effect of the duration-Stringency interaction valued at the specified period. The shaded area represents the 90% confidence interval for the linear combination.

However, even if we take as given an increase in *de facto* non-compliance, the fading effect of restrictions in reducing the impact of the pandemic is again significant when we estimate the differential (early vs. late) impact over time of a reduction in *mobility*: after 120 days of strict lockdown, a decrease in workplace mobility has a significantly more attenuated effect on the reduction of COVID deaths and does not have a significant impact on R_t (*Figure 8*).

Figure 8. Impact of Google Workplace Mobility on Effective Reproduction Rate and COVID-19 Related Deaths (coefficient and interaction term at 120 days)

Note. The graph represents the estimated impulse response function for a one standard deviation change in the Google Workplace Mobility index, including the effect of the duration-Stringency interaction valued at the specified period. The shaded area represents the 90% confidence interval for the linear combination.

5. Final Remarks

Lockdowns, quarantines and curfews have been the most pivotal NPI used by governments worldwide in an effort to contain the spread of the COVID-19 pandemic. Their cost-effectiveness – balancing their ability to improve epidemiological outcomes and their social, economic and psychological costs – is still however at the center of an intense debate. In this paper, we contribute to this discussion by evaluating these interventions according to their ability to reduce the spread of the virus and its corresponding death toll, specifically addressing the question about whether and to what extent the development of lockdown fatigue in 2020 may have reduced their effectiveness as a resource to cope with new waves in 2021. In line with previous studies, we find that quarantines do have a significant and persistent effect on health outcomes. Additionally, we show that this effect weakens significantly after 120 days of strict lockdown.
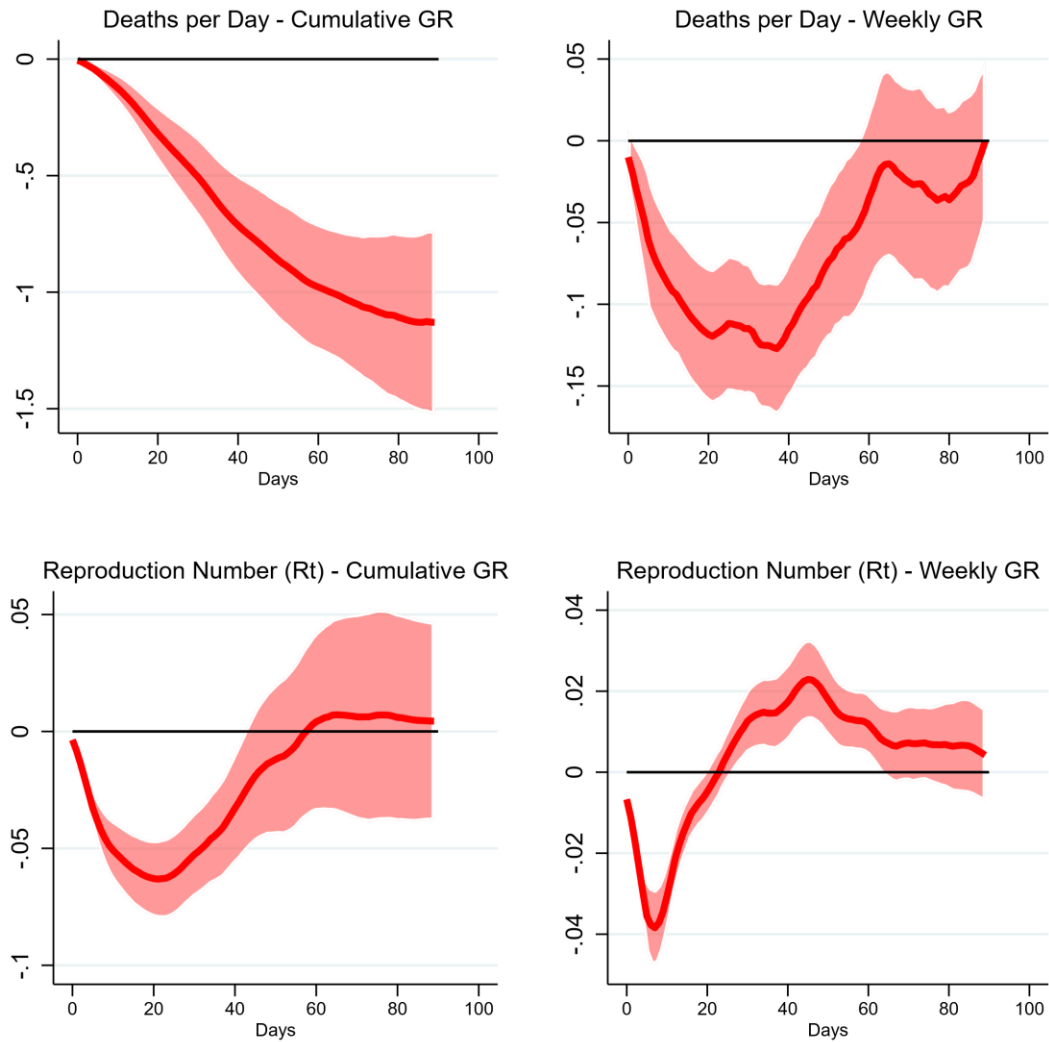
We interpret the fact that *de facto* reductions in mobility also display a diminishing effect on epidemiological outcomes as an indication that lockdowns work through other channels *in addition* to mobility restrictions – such as, for example, social distancing behavior or the use of face masks – and that all of these channels are negatively affected by lockdown fatigue. Alternatively, it could be argued that over time, the development of better testing, tracking and isolating capabilities, as well as better treatment of cases may reduce the sensitivity of health outcomes to lockdowns and reductions in mobility, in the presence of nonlinearities not captured by our model. In any case, our results suggest that the heavy reliance on lockdowns that characterized the early stages of the pandemic should be qualified moving forward.

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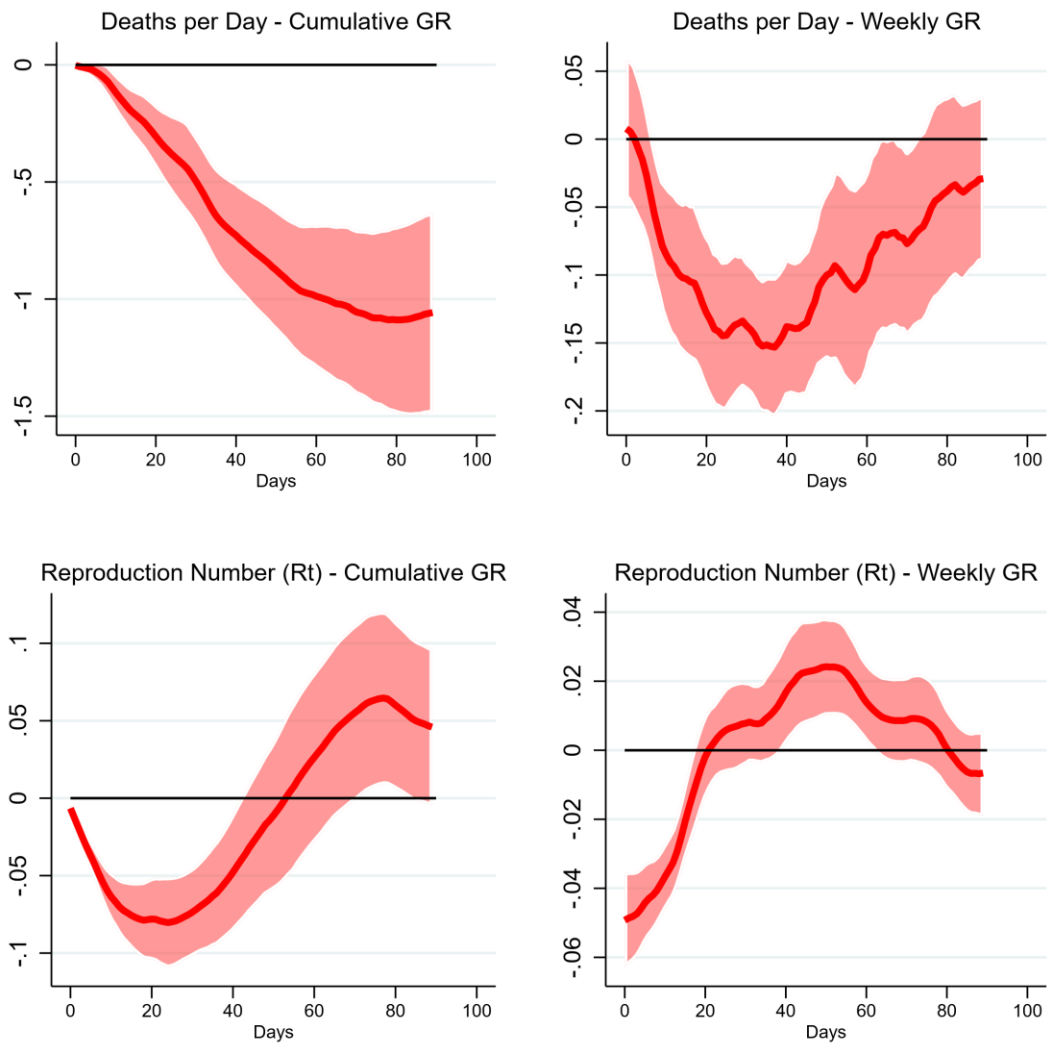
Appendix

Figure A1. Impact of OxCGRT Stringency Index on Effective Reproduction Rate and COVID-19 Related Deaths (No Temperature or Humidity covariates)
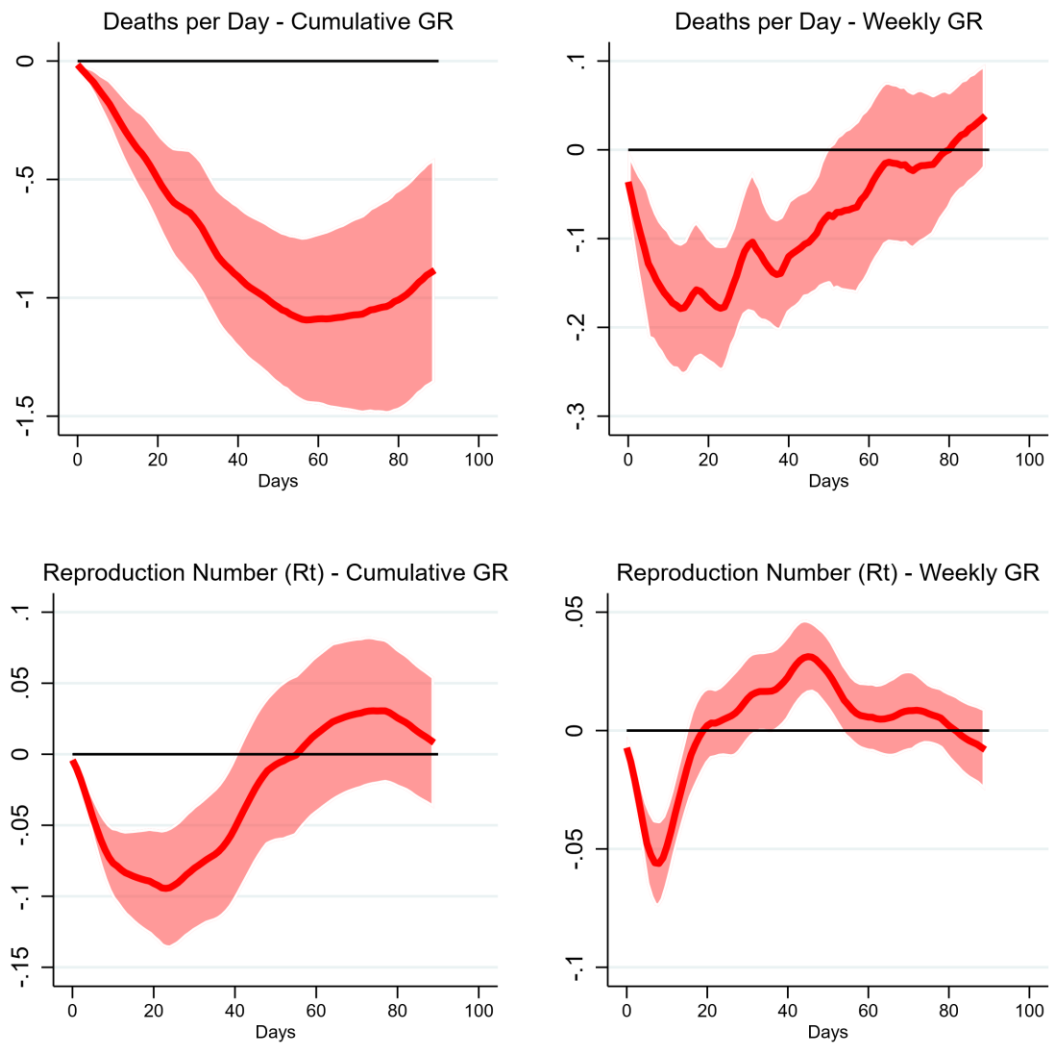

Note. The graph represents the estimated impulse response function for a one standard deviation change in the OxCGRT Stringency Index. The shaded area represents the 90% confidence interval for the coefficient.

Figure A2. Impact of OxCGRT Stringency Index on Effective Reproduction Rate and COVID-19 Related Deaths (No Trend or Lagged Dependent Variable)

Note. The graph represents the estimated impulse response function for a one standard deviation change in the OxCGRT Stringency Index. The shaded area represents the 90% confidence interval for the coefficient.

Figure A3. Impact of OxCGRT Stringency Index on Effective Reproduction Rate and COVID-19 Related Deaths (including Testing, Contract Tracing and Information Campaigns)

Note. The graph represents the estimated impulse response function for a one standard deviation change in the OxCGRT Stringency Index. The shaded area represents the 90% confidence interval for the coefficient.

Figure A4. Impact of OxCGRT Stringency Index on Effective Reproduction Rate (Arroyo-Mario et al. 2021) and COVID-19 Related Cases (coefficient and interaction term at 120 days)