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Pandemic: COVID-19 Mortality in Spain**

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ABSTRACT

Timing is Everything when Fighting a Pandemic: COVID-19 Mortality in Spain

In an effort to contain the spread of the COVID-19 pandemic, many countries around the globe adopted social distancing measures. Previous studies have relied on the geographical and temporal variation in the adoption of non-pharmaceutical interventions (NPIs) to show that early adoption of NPIs is correlated to lower infection and mortality rates. However, due to the non-random adoption of NPIs, the findings may not be interpreted as causal. We address this limitation using a different source of identification –namely, the regional variation in the placement on the pandemic curve at the time of a nationwide lockdown. Our results reveal how, relative to regions for which the lockdown arrived 10+ days after the pandemic's outbreak, regions where the outbreak had just started were able to lower their daily fatality rate by 2.5 deaths per 100,000 inhabitants. We also provide suggestive evidence of contagion deceleration as the main mechanism behind the effectiveness of the early adoption of NPIs in lowering the death rate, rather than increased healthcare capacity.

JEL Classification: J10, I12, I18

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1. Introduction

In December 2019, the first case of COVID-19 was detected in the province of Wuhan (China). Given its easy and fast transmission, the virus quickly reached other countries, generating a serious health problem worldwide. At the end of January, in response to the first cases of confirmed infections outside China, the WHO decided to declare a “Public Health Emergency of International Importance (ESPII)”. Along with Italy, Spain became one of the epicentres of the outbreak in Europe, with 216,582 confirmed cases and 25,100 deaths as of May 2, 2020 (Ministry of Health). These figures represented approximately 15% of all confirmed cases and 18% of deaths in Europe, as well as 7% of confirmed cases and just over 10% of deaths worldwide.

The rapid growth in the number of confirmed cases, together with the severity of the disease, shocked governments around the globe. In a desperate attempt to control the spread of the virus, countries adopted a variety of non-pharmaceutical interventions (NPIs) ranging from immediate, strict, and either regional or nationwide lockdowns (as in Italy or Spain), to more gradual step-by-step social distancing (as in the U.K. and the U.S.) (Ferguson *et al.*, 2020). In the absence of an effective vaccine, the hope was that NPIs would “flatten the curve” of the pandemic before healthcare systems become overwhelmed. Yet, due to the economic costs associated with the adoption of social distancing measures, the implementation of NPIs is sometimes dangerously delayed. As the COVID-19 virus quickly spreads throughout the developed and developing world, it is urgent to gain a better understanding of the consequences associated to the timing of public health responses.

The epidemiological and economic literatures agree that social distancing is very effective in flattening the pandemic curve by reducing the viral transmission and avoiding the overwhelming of the healthcare system (Adda, 2016; Ferguson *et al.*, 2006; Pichler *et al.*, 2017; Tian *et al.*, 2020). At the present time, the evidence on the effectiveness of early adoption of NPIs in the case of the COVID-19 pandemic originates from mathematical models (Atkeson, 2020), or from studies that exploit the temporal and geographic variation in the adoption of NPIs by counties, states or regions (Dave *et al.*, 2020). A caveat

with the last approach is the non-random adoption of NPIs, which might be logically correlated to incidence and awareness of the disease. In this regard, historical evidence from the 1918 flu pandemic suggests that cities struck by the pandemic at a later time responded more quickly to the spread of the virus because they were made aware of the severity of the pandemic several weeks in advance (Hatchett *et al.*, 2007). As such, the estimated effectiveness of early adoptions of NPIs in containing deaths could be biased upwards. In addition, the more recent COVID-19-related research suggests that U.S. Shelter-in-Place-Orders (SIPOs) have been introduced more diligently in democratic-controlled states (Gupta *et al.*, 2020). If this is the case, the estimated effectiveness of early adoptions of NPIs could also be biased upwards due to increased social distancing on the part of more complying residents from democratic-controlled states (Painter and Qiu, 2020).

In this paper, we address the aforementioned limitation using the regional variation that stems from the random placement of regions on the pandemic curve at the time of a nationwide NPI. We focus on the Spanish case, which is of interest for various reasons. Spain has been one of the most hard hit countries by the COVID-19 pandemic. It became one of Europe's epicenters after Italy, ranked second (after Belgium) in the number of deaths per 100,000 (45.5 as of April 21st), and third in total deaths after the U.S. and Italy (21,282 as of April 21st) (Johns Hopkins University, 2020). The Spanish government declared the state of emergency on March 14th, 2020, imposing a strict and nationwide lockdown. The lockdown involved school closures, the closure of non-essential businesses, and a stringent shelter in place order. A key aspect in our identification strategy is the fact that, while the lockdown was uniformly applied to the entire country, there was a great degree of regional variation with regards to where each region stood on the pandemic curve at the time of the lockdown. Regions such as La Rioja and Madrid already had between 50 and 100 confirmed COVID-19 cases per 100,000; in contrast, regions like Baleares, Murcia, or the Canary Islands had fewer than 5 confirmed cases per 100,000. As has been shown to be the case in other pandemics (Correia *et al.*, 2020), this regional variation is likely to be orthogonal to pre-COVID mortality rates, as suggested by the arbitrary rollout of the pandemic from main ports of entry (*e.g.* Madrid, Barcelona, and

more touristic regions, like the Canary and Balearic Islands, where the first cases were confirmed) to the rest of the country.

We use daily COVID-19 mortality and infection rates across Spanish regions over the March 4, 2020 through April 17, 2020 period, along with a difference-in-differences approach, to estimate the mortality impact of acting earlier. We account for time-varying regional factors, such as the average daily local temperature and sun exposure, as well as for other regional traits, including population composition and healthcare provision differences that could have influenced mortality. Likewise, we control for time invariant regional idiosyncrasies through regional fixed-effects, as well as for temporal trends to captured changes in testing availability and therapeutic improvements, which could also affect differential changes in mortality. We find that introducing the lockdown one day earlier could have reduced daily COVID-19 mortality rates by 0.19 deaths per 100,000 inhabitants. Simulation exercises show that locking down regions with higher infection rates on March 14th, *e.g.* locking down Madrid 6 days earlier, could have avoided about 77 daily deaths at the peak of the pandemic between March 30th and April 17th, 2020.

The last part of the paper provides suggestive evidence of how containment of the pandemic spread was the main mechanism responsible for the lockdown's efficacy in curtailing mortality. We show that infection rates after the lockdown dropped by a similar magnitude to mortality rates –despite the increased availability of testing. We also consider other channels, such as the possibility that the earlier adoption of a NPI prevented the health care system from reaching full capacity. After all, there were signals of the Spanish healthcare system being severely affected by the pandemic. For instance, on April 21st, more than 20 percent of confirmed cases were doctors and nurses (Equipo Covid-19, 2020); this, as well as the shortage of masks, gloves and other essential gear, was expected to have seriously hampered the healthcare system's ability to fight the pandemic. However, once we exclude the regions where the healthcare system became clearly overwhelmed, as evidenced by the setup of mobile hospitals, we continue to find similar results. Finally, we also show that non-COVID deaths did not change with the timing of the lockdown. Jointly, the two last results suggest that the main channel for the reduction of COVID-related deaths that

trailed the nationwide lockdown was the decrease in infection rates, rather than the avoidance of a congested healthcare system.

The analysis herein makes a couple of important contributions to the scientific literature. First, it contributes to a broad literature investigating the causal impact of school closures, sick leave schemes or even being in close contact with others at work, on the rate of transmission of contagious diseases (Adda 2016, Pichler and Ziebert 2017, Markovitz *et al.* 2019), as well as the association between social distancing measures and the flattening of pandemic curves for diseases other than COVID-19 (Ferguson *et al.*, 2006; Hatchett *et al.*, 2007) Ferguson *et al.*, 2006, Markel *et al.*, 2006). A second contribution refers to a similar, more recent literature focused on gauging the impact of NPI measures during the present COVID-19 pandemic (Dave *et al.*, 2020; Friedson *et al.*, 2020; Qiu *et al.*, 2020). Instead of relying on the staggered, yet non-random adoption of policies influenced by the locality's awareness of the pandemic, exposure to the pandemic, or even its political partisan ideology (Dave *et al.*, 2020; Gupta *et al.*, 2020), we rely on the more exogenous regional variation stemming from the location on the pandemic curve at the time of the nationwide lockdown.

The paper is organized as follows. Section 2 details the adoption of the nationwide lockdown in Spain. Section 3 describes the data sets used in the analysis, and Section 4 outlines the empirical strategy. Section 5 presents the main findings, Section 6 discusses the mechanisms at play, and Section 7 concludes the study.

2. Institutional Setting

With the aim of fighting the spread of COVID-19 and avoid overwhelming the public healthcare system, the Spanish Government declared a state of emergency on March 14th, 2020. Along with the declaration, an immediate nationwide lockdown was mandated, resulting in school and non-essential business closures, along with the requirement that all residents remained indoors other than for essential

activities limited to buying food or medicine, working in essential businesses, caring for relatives, or pet walking. Working from home was encouraged, and religious gathering discouraged, including funerals.

The measure was abruptly adopted and unanticipated. It was approved in an extraordinary session of the Council of Ministers and announced in a broadcasted interview the previous evening. In addition, the lockdown was strictly enforced. No outings for exercise were allowed and essential shopping or dog walking had to be performed alone. Curfew violators were subject to fines equivalent to half a month's salary for most Spaniards –fines ranging between €600 and €3,000, and even imprisonment if refusing to obey.

The Spanish lockdown was a nationwide measure and presented the same characteristics across all Spanish regions, regardless of where each region was on the pandemic curve. As such, its implementation was not guided by regional variations in the spread of the virus, awareness about the pandemic or prevalence of a particular political party, as it appears to have been the case for the adoption of NPIs across the United States during the 1918 influenza (Markel *et al.*, 2007) and the current COVID-19 pandemic (Gupta *et al.*, 2020). Finally, the lockdown was similarly observed across all Spanish regions, as can be seen in the Google Mobility measures depicted in Figures A.1 through A.6 in the Appendix (Google LLC, 2020).

3. Data and Descriptive Evidence

3.1. Mortality and Infection Data

To assess how the lockdown affected COVID-19 mortality, we use official data on daily COVID-19 fatalities and on newly confirmed cases published by the Spanish Ministry of Health.¹ The Spanish Ministry of Health keeps a daily record of all new COVID-19 cases and fatalities reported by the regional epidemiological surveillance services to the National Center for Coordination of Alerts and Emergencies of the Ministry of Health. The dataset contains information on total confirmed cases, hospitalized cases,

¹ Our analysis relies on COVID-19 deaths. However, when examining the mechanisms through which social distancing measure might be impacting COVID-19 mortality, we also make use of daily counts of newly COVID-19 confirmed cases.

ICU admissions, as well as on deceased and recovered individuals. It allows us to compute the accumulated number of COVID-19 cases by region and date, together with daily regional COVID-19 deaths. Using population figures from the Spanish Statistical Institute, we next compute COVID-related mortality rates.

We also make use of an alternative mortality dataset –the Spanish Daily Mortality Monitoring System (MoMo) in our robustness checks, as well as when assessing the main determinants of the effectiveness of the nationwide lockdown in curtailing COVID-19 deaths. MoMo is a surveillance system shared by European countries aimed at detecting *excess* deaths related to seasonal influenza, pandemics and other public health threats. In Spain, the information is obtained from the computerized entries in the Civil Registers and Notaries of the Ministry of Justice. The entries account for approximately for 92% of deaths nationwide, although that percentage ranges from 100% to 54% depending on the region. We use data on COVID-19 deaths from this alternative dataset as a robustness check. Additionally, we use the information on daily *total* and *COVID-19* mortality figures at the regional level to compute daily *non-COVID* deaths at the regional level, which we use to identify some of the mechanisms responsible for the estimated impact of the lockdown on COVID-19 deaths.

Our dataset spans from March 4, 2020 through April 17, 2020. March 4, 2020, is the date of the first COVID-19 death in Spain, whereas April 17, 2020 represents a break in the series. After that date, the Spanish Ministry of Health changed the definition of COVID-19 confirmed cases. Only those diagnosed through polymerized chain reaction (PCR) and antibody testing were included. See descriptive statistics in Table A.1 in the Appendix.

While the lockdown was implemented uniformly nationwide, we are able to construct a measure how early or late the measure was adopted in each region based on its placement on the pandemic curve at that point in time. Following Correia *et al.*, (2020), we define the speed of the lockdown response as the number of days elapsed between the outbreak of the pandemic (defined as the day when 3/100,000 COVID-19 cases were confirmed in the region) and the national lockdown (that is, March 14, 2020). We use the cutoff of 3 cases per 100,000 inhabitants as the outbreak benchmark because that was the lowest COVID-

19 infection rate at the time of the lockdown (in the region of Balears).² We experiment with alternative outbreak definitions –such as having 2, as well as 4, confirmed cases per 100,000 inhabitants, in Section 5.2. As we shall discuss therein, our results prove robust to the use of those alternative definitions.

3.2. Additional Data Sources

We also make use of two additional data sources. One includes data on the average daily temperature and sun exposure, which can affect the transmission of viruses affecting the respiratory system (Adda, 2016; Qiu *et al.*, 2020). The data, which is gathered from the Spanish Meteorological Agency, captures the average daily temperature (in °C) and sun exposure (in hours) 15 days before the death is registered, allowing us to address weather conditions around the time of contagion.

In addition, in our robustness checks, we make use of daily mobility data for each region obtained from Google (Google LLC, 2020). Google Community Mobility Reports measure changes in mobility related to visits to six different destination categories: grocery stores and pharmacies, parks, transit stations, restaurants and other recreation centres, workplaces, and places of residence. The baseline is the median value for the corresponding day of the week, during the 5-week period spanning from January 3 through February 6, 2020. The sample is composed of Google users who have opted-in to location history for their accounts.

3.3. Some Descriptive Evidence

Figure 1 displays the daily number of COVID-19 deaths per 100,000 in two sets of regions –regions for which the relative adoption speed of the national lockdown was higher than the median (*early-on-the-curve*) vs. regions where it was lower than the median (*late-on-the-curve*). In *early-on-the-curve* regions, the lockdown occurred 2 days or less after the pandemic outbreak [*i.e.* Andalucía (1), Balears (0), Canarias (2), Cantabria (2), C. Valenciana (0), Extremadura (2), Castilla-León (2), Galicia (2) and Murcia (2)]. In

² Previous epidemiology literature has used the first death in the locality as the outbreak threshold (Market *et al.*, 2007). We cannot use that same cut-off because some regions only experienced a COVID-related death after the lockdown.

contrast, in *late-on-the-curve* regions, the lockdown took place 3+ days after the outbreak [*i.e.* Aragón (4), Asturias (4), Madrid (6), País Vasco (7), Castilla La Mancha (4), Cataluña (3), Navarra (4) and La Rioja (10)].

The contrast in mortality rates between the two sets of regions in Figure 1 is striking. At the top of the pandemic curve (between April 1 and April 5, 2020), the daily mortality rate in *late-on-the-curve* regions averaged 2.72 per 100,000 inhabitants –almost four fold the mortality rate in the remaining *early-on-the-curve* regions (0.82 per 100,000 inhabitants) (difference=1.90, $t=25.05$). Even as recently as April 17, 2020 –towards the end of the analyzed period, the COVID-19 fatality rate in the *late-on-the-curve* regions more than doubled the rate in *early-on-the-curve* regions.

4. Empirical Specification

We rely on the natural experiment created by the COVID-19 pandemic, along with the unexpected and nationwide implementation of a stringent lockdown in Spain, to gauge the effectiveness of social distancing measures in containing pandemic deaths using the following differences-in-differences (DD) model specification:

$$Y_{jt} = \alpha + \beta Post_t * S_j + X_{jt}\gamma + \eta_j + \mu_t + \varepsilon_j \quad (1)$$

where Y_{jt} represents COVID-19 deaths in region j and date t . Our key regressor is an interaction term of two variables: (1) the relative speed of adoption of the nationwide lockdown based on where each region j was at the time of its implementation, S_j ; and (2) a dummy variable indicative of the post-lockdown period, $Post_t$. The relative speed (S_j) is measured by the number of days elapsed between the regional outbreak, defined as having 3 confirmed cases per 100,000, and the nationwide lockdown. This figure is then multiplied by minus one so that higher values denote a faster response, as in prior studies (Correia *et al.*, 2020). The post-lockdown period dummy ($Post_t$) includes a 15-days delay to account for the average number of days between infection and potential death (Lauer *et al.*, 2020); hence, it takes the value of 1

from March 29, 2020 onwards.³ If the lockdown was effective at containing pandemic's deaths, we should expect β to take negative values, signaling that, the faster the response, the lower the mortality rate associated to the pandemic.

The model also accounts for other regional time-varying factors potentially affecting COVID-19 deaths (X_{jt}), such as the average temperature and sun exposure 15 days prior to the recorded deaths –that is, close to infection time, to better account for atmospheric factors potentially affecting the spread of the virus and contagion. It also includes region fixed effects (η_j) to account for time-invariant differences across regions, such as regional differences in mortality rates or other traits potentially related to COVID-19 deaths through contagion, such as population density or openness to tourism. In addition, date fixed effects (μ_t) help us address over time variation affecting fatality rates across regions due, for example, to changes in testing capabilities or treatment improvements.⁴ Equation (1) is estimated by ordinary least squares, and robust standard errors are clustered at the region level.

Our identifying assumption is that the relative speed of adoption of the lockdown for any given region is exogenous to the region's COVID-19 mortality rate. This identification strategy relies on the arbitrary regional variation in the spread of the virus when the lockdown was mandated. The rollout of the pandemic occurred from main ports of entry (*e.g.* Madrid, Barcelona, and more touristic regions, like the Canary Islands, where the first cases were confirmed), which spread to the rest of the country in a way that was likely orthogonal to the *ex-ante* mortality rates. In a similar vein to what has been found for other respiratory pandemics (*e.g.* Brainerd and Siegler, 2004), the spread of the virus in Spain has been mainly influenced by what it is referred to as “international connectivity” (Orea and Alvarez, 2020). This is a feature likely correlated to the population of the region, its touristic appeal, and the number of overseas students, but not necessarily to the region's pre-COVID mortality rate. Figure A.7 in the Appendix provides

³ In robustness checks, we experiment with using different delays. Results prove to be consistent.

⁴ Note that both S_j and $Post_t$ drop with the inclusion of region and date fixed-effects.

some evidence of the arbitrary spread of the disease across regions, with *early-in-the-curve* and *late-in-the-curve* displaying very similar mortality rates from March 4 through April 17, 2019 –that is, during the same dates when the virus was spreading this year, but one year earlier.

5. Quantifying the Importance of Early Intervention when Responding to a Pandemic

5.1. Main Findings

Table 1 shows the results from estimating equation (1) using a sample of daily COVID-19 mortality rates by region. Column (1) shows our estimates without any controls, other than date and region fixed effects. Column (2) further includes the daily average temperature and sun exposure in the region to address for changing weather conditions. According to the estimates in this second specification, imposing the nationwide lockdown one day earlier would have lowered COVID-19 deaths by 0.162 per 100,000 residents or 11%.

Figure 2 shows average regional COVID-19 mortality rates (in black), together with the results of performing a simulation exercise using the estimated coefficients from the differences-in-differences regression in column (2) of Table 1 (blue line). Adopting a nationwide lockdown immediately after the outbreak (maximum speed), would have lowered the daily fatality rate by 0.65 per 100,000 inhabitants each day from March 29th onwards (that is, 15 days after the lockdown). Our model also implies that, if Madrid (speed=-6) had had the lockdown in place immediately after the outbreak –as Balears (speed=0), 1.16 daily deaths per 100,000 inhabitants could have been avoided. Given Madrid’s population of 6.64 million, this implies 77 fewer daily deaths had the lockdown been implemented earlier.

5.2. Robustness Checks

We conduct several robustness checks to assess the sensitivity of our findings to: (1) alternative definitions of what is considered an outbreak (using 2 and 4 cases per 100,000 inhabitants, as opposed to 3); (2) assuming different time spans from infection to death (14 and 16 days vs. 15); (3) controlling for any mobility using Google Mobility data to better account for compliance with the mandated lockdown;

(4) performing the analysis at the province vs. regional level; and (5) using an alternative database to calculate mortality rates (*i.e.* MoMo data).⁵ In what follows, we briefly refer to each one.

5.2.1. Sensitivity to Alternative Definitions of an Outbreak

The main analysis considered the outbreak of the pandemic to occur when there were, at least, 3 confirmed COVID-19 cases per 100,000 inhabitants in the region, as that was the lowest COVID-19 infection rate at the time of the lockdown (in the region of Balears). In columns (1) and (2) of Table 2, we experiment with alternative definitions of an outbreak –namely, having 2 and, later on, 4 confirmed cases per 100,000 inhabitants.⁶ Our results prove robust to the use of these alternative outbreak thresholds. Accelerating the adoption of the nationwide lockdown by one day lowers the COVID-19 fatality rate by 8.5% when a lower threshold is used as the outbreak, and by 10% when the threshold is slightly higher.

5.2.2. Sensitivity to Alternative Infection-to-Death Time Spans

Using information from official COVID-19 reports, together with research from China, we estimated the time span from infection to death to average 15 days. This implies 5 days for incubation and 10 days from the onset of symptoms to death (Equipo Covid-19, 2020; Lauer *et al.*, 2020). In columns (3) and (4), we experiment with using alternative infection-to-death times spans of one-day shorter and one-day longer. As a result, the post-lockdown period dummy ($Post_t$) now takes the value of 1 from March 28, 2020 onward when the time span is shortened by one day, and from March 30, 2020 onward when it is lengthened by one more day. As can be seen in Table 2, the estimates in columns (3) and (4) continue to support our prior findings, as speeding up the adoption of the nationwide lockdown would have lowered mortality from COVID-19 by 11% and 10%, respectively.

⁵ We also assess the sensitivity of our findings to excluding any one region from the analysis by removing one region at a time. Figure A.8 in the Appendix shows that no single region appears to be driving our key findings.

⁶ When the outbreak is defined as reaching 4 in 100,000 confirmed cases, the one region -Balears- with a prevalence lower than 4 in 100,000 at the time of the lockdown (March 14th) is set to have a relative speed of zero, together with Andalusia, the Community of Valencia, and Murcia Region that reached the 4 in 100,000 infection rate precisely on March 14th.

5.2.3. Sensitivity to Controlling for Mobility Patterns

Our identification strategy is grounded on the random placement of regions on the pandemic curve at the time of a nationwide lockdown. As noted earlier, the lockdown was strictly observed throughout Spain. However, if compliance with the mandated lockdown differed across regions, our results could be reflecting the distinct rigor with which the lockdown was being observed. To address this concern, in Column (5) of Table 2, we display the estimates when we further account for regional daily mobility patterns obtained from Google (Google LLC, 2020). As can be seen therein, our findings also prove robust to accounting for mobility patterns, which is not surprising since these did not differ much across regions. Specifically, accelerating the implementation of the lockdown by one day would have reduced COVID-19 mortality by 9.5%.

5.2.4. Sensitivity to Using Data Disaggregated by Province

We also collect data from the regional Ministries of Health to perform the analysis at a higher level of disaggregation, *i.e.* province vs. region.⁷ The data, which are compiled through data scraping techniques from different data sources –mainly regional press releases, are subject to variations in the recording of confirmed COVID-19 cases. Therefore, we ought to be more cautious when using it. Notwithstanding this caveat, the estimate in column (6) of Table 2 confirms our prior findings. Speeding up the implementation of the nationwide lockdown by one day would have lowered COVID-19 deaths by 6%. This estimate results from using 2 deaths per 100,000 inhabitants as the outbreak definition, since many provinces had not yet reached the 3 in 100,000 threshold used in the main analysis. Overall, the impact is not significantly different from the 8.5% impact reported in Column (1) of Table 2, when using the same fatality threshold.

5.2.5. Sensitivity to Using an Alternative Dataset to Calculate Mortality Rates

We also experiment with using total daily mortality rates by region computed using data from the Spanish Daily Mortality Monitoring System (MoMo). As noted earlier, the information contained in this

⁷ There are 52 provinces and 17 regions in Spain.

alternative dataset is gathered from the General Registry of Civil Registers and Notaries of the Ministry of Justice. Column (7) in Table 2 shows that our results are robust to using mortality rates computed using the MoMo data. Declaring the lockdown one day earlier would have reduced total deaths by 3%. Because COVID-19 deaths account for approximately 34% of the Momo deaths, this estimate implies a 9% reduction in COVID-19 deaths had the lockdown started one day earlier –an impact similar to the one documented in Table 1.

6. Preventing Contagion as the Main Mechanism behind the Lockdown’s Effectiveness

According to the World Health Organization (2020), the COVID-19 virus is primarily transmitted between people through respiratory droplets emitted during coughing or sneezing and through fomites in the close environment around the infected person (*e.g.*, stethoscope or thermometer). By reducing close contact between individuals, lockdowns may slow down the COVID-19 virus transmission and, therefore, deaths. In the absence of vaccines and reliable tracking systems, NPIs have also been invoked to flatten the pandemic curve by lowering the demands on public healthcare services, allowing for COVID-19 patients to be properly treated (Ferguson *et al.*, 2020). As such, the lockdown could help lower COVID-19 mortality through both –a direct channel consisting in reducing contagion, as well as an indirect channel that prevents the congestion of the healthcare system.

In what follows, we attempt to sort out these two channels. To that end, we first examine infection rates –known to provide a lower bound of the spread of the disease. If the effectiveness of the lockdown did not primarily stem from reducing contagion but, rather, avoiding an overwhelmed healthcare system, we should not necessarily observe a reduction in the infection rate. Yet, as displayed in column (1) of Table 3, adopting the nationwide lockdown one day earlier would have curtailed infections by 13.5%.

Next, we experiment with excluding from the analysis two regions where the healthcare system became clearly overwhelmed, as captured by the establishment of mobile hospitals to be able to attend the growing number of hospitalizations, *e.g.* Madrid and Catalonia. If the effectiveness of the nationwide

lockdown in curtailing COVID-19 deaths primarily stemmed from avoiding an overwhelmed healthcare system, we should not continue to find a significant impact in reducing mortality after removing those two regions. However, as can be seen in column (2) of Table 3, we continue to find evidence of how adopting the lockdown one day earlier would have helped lower the mortality rate by approximately 16%.

Finally, we look at how the earlier vs. later adoption of the lockdown for any given region –based on its placement on the pandemic curve, might have affected non-COVID mortality. If the lockdown primarily helped curtail pandemic deaths by preventing the healthcare system from becoming overwhelmed, non-COVID mortality rates should also be lower in those regions where the lockdown took place earlier in the pandemic curve, as non-COVID patients could still be treated. Based on the results in column (3) of Table 3, which estimates equation (1) for non-COVID death rates, we observe no significant relationship between the speed of response to the pandemic –as captured by the number of days after the first region’s outbreak and the nationwide lockdown, and non-COVID deaths. In other words, the response speed does not significantly alter non-COVID deaths, as one would expect if the overwhelming of the healthcare system was a primary channel for the reduction in COVID-19 mortality following the nationwide lockdown.

In sum, the estimates in Table 3 overall point to preventing contagion as the main mechanism through which the nationwide lockdown might have effectively helped contain pandemic deaths in Spain.

7. Summary and Conclusions

The COVID-19 pandemic will only be over once a vaccine or effective therapeutic drugs are developed, and there is a lot of uncertainty as to when either one will be delivered (Ferretti *et al.*, 2020). As the pandemic slows in developed nations, it accelerates in developing countries. As NPIs measures are relaxed in developed nations, infection rates will likely pick up in response (Prem *et al.*, 2020). In the absence of testing and tracking systems, social distancing measures remain the only proven tools to curtail pandemic deaths.

Our findings reveal the importance of implementing social-distancing measures early on. The adoption of a nationwide lockdown proved more effective in curtailing COVID-19 deaths in regions that were at an earlier stage of the pandemic spread at the time of the lockdown, than in regions that were at a more advanced stage, even during this short period. Additional evidence suggests that the reduction in fatalities caused by the early implementation of NPIs is mainly due to the deceleration of the contagion rate, rather than to the indirect benefit of freeing up health resources to better attend patients.

Overall, our findings underscore the important benefits of responding early to the pandemic –a benefit policy-makers will have to balance against any potential socio-economic costs associated to the adoption of social distancing measures.

References

- Adda, J., 2016. Economic Activity and the Spread of Viral Diseases: Evidence from High Frequency Data. *Q. J. Econ.* 131, 891–941. <https://doi.org/10.1093/qje/qjw005>
- Atkeson, A., 2020. What Will Be the Economic Impact of COVID-19 in the US? Rough Estimates of Disease Scenarios. Cambridge, MA. <https://doi.org/10.3386/w26867>
- Correia, S., Luck, S., Verner, E., 2020. Pandemics Depress the Economy , Public Health Interventions Do Not : Evidence from the 1918 Flu.
- Dave, D., Friedson, A., Matsuzawa, K., Sabia, J., 2020. When Do Shelter-in-Place Orders Fight COVID-19 Best? Policy Heterogeneity Across States and Adoption Time. Cambridge, MA. <https://doi.org/10.3386/w27091>
- Equipo Covid-19, 2020. Informe sobre la situación de COVID-19 en España. Red Nac. Vigil. Epidemiológica. Inst. Salud Carlos III 1–14.
- Ferguson, N., Laydon, D., Nedjati-Gilani, G., Imai, N., Ainslie, K., Baguelin, M., Bhatia, S., Boonyasiri, A., Cucunubá, Z., Cuomo-Dannenburg, G., Dighe, A., 2020. Report 9 - Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand | Faculty of Medicine | Imperial College London [WWW Document]. Imp. Coll. COVID Response Team. URL <https://www.imperial.ac.uk/mrc-global-infectious-disease-analysis/covid-19/report-9-impact-of-npis-on-covid-19/> (accessed 5.10.20).
- Ferguson, N.M., Cummings, D.A.T., Fraser, C., Cajka, J.C., Cooley, P.C., Burke, D.S., 2006. Strategies for mitigating an influenza pandemic 442. <https://doi.org/10.1038/nature04795>
- Ferretti, L., Wymant, C., Kendall, M., Zhao, L., Nurtay, A., Abeler-Dörner, L., Parker, M., Bonsall, D., Fraser, C., 2020. Quantifying SARS-CoV-2 transmission suggests epidemic control with digital contact tracing. *Science* (80-.). 6936, eabb6936. <https://doi.org/10.1126/science.abb6936>
- Friedson, A., McNichols, D., Sabia, J., Dave, D., 2020. Did California’s Shelter-in-Place Order Work? Early Coronavirus-Related Public Health Effects. Cambridge, MA. <https://doi.org/10.3386/w26992>
- Google LLC, 2020. COVID-19 Community Mobility Reports [WWW Document]. URL <https://www.google.com/covid19/mobility/> (accessed 4.28.20).
- Gupta, S., Nguyen, T., Rojas, F.L., Raman, S., Lee, B., Bento, A., Simon, K., Wing, C., 2020. Tracking Public and Private Responses to the COVID-19 Epidemic: Evidence from State and Local Government Actions. Cambridge, MA. <https://doi.org/10.3386/w27027>
- Hatchett, R.J., Mecher, C.E., Lipsitch, M., 2007. Public health interventions and epidemic intensity during the 1918 influenza pandemic. *Proc. Natl. Acad. Sci.* 104, 7582–7587. <https://doi.org/10.1073/PNAS.0610941104>
- Johns Hopkins University, 2020. Mortality Analyses - Johns Hopkins Coronavirus Resource Center [WWW Document]. Johns Hopkins Coronavirus Resour. Cent. URL <https://coronavirus.jhu.edu/data/mortality> (accessed 5.10.20).

- Lauer, S.A., Grantz, K.H., Bi, Q., Jones, F.K., Zheng, Q., Meredith, H.R., Azman, A.S., Reich, N.G., Lessler, J., 2020. The Incubation Period of Coronavirus Disease 2019 (COVID-19) From Publicly Reported Confirmed Cases: Estimation and Application. *Ann. Intern. Med.* 2019. <https://doi.org/10.7326/m20-0504>
- Markel, H., Lipman, H.B., Navarro, J.A., Sloan, A., Michalsen, J.R., Stern, A.M., Cetron, M.S., 2007. Nonpharmaceutical interventions implemented by US cities during the 1918-1919 influenza pandemic. *J. Am. Med. Assoc.* 298, 644–654. <https://doi.org/10.1001/jama.298.6.644>
- Painter, M., Qiu, T., 2020. Political Beliefs affect Compliance with COVID-19 Social Distancing Orders. *SSRN Electron. J.* <https://doi.org/10.2139/ssrn.3569098>
- Pichler, S., Ziebarth, N.R., Reilly, B.O., 2017. The pros and cons of sick pay schemes : Testing for contagious presenteeism and noncontagious absenteeism behavior & J. Public Econ. 156, 14–33. <https://doi.org/10.1016/j.jpubeco.2017.07.003>
- Prem, K., Liu, Y., Russell, T.W., Kucharski, A.J., Eggo, R.M., Davies, N., Flasche, S., Clifford, S., Pearson, C.A.B., Munday, J.D., Abbott, S., Gibbs, H., Rosello, A., Quilty, B.J., Jombart, T., Sun, F., Diamond, C., Gimma, A., van Zandvoort, K., Funk, S., Jarvis, C.I., Edmunds, W.J., Bosse, N.I., Hellewell, J., Jit, M., Klepac, P., 2020. The effect of control strategies to reduce social mixing on outcomes of the COVID-19 epidemic in Wuhan, China: a modelling study. *Lancet Public Heal.* 2667, 1–10. [https://doi.org/10.1016/S2468-2667\(20\)30073-6](https://doi.org/10.1016/S2468-2667(20)30073-6)
- Qiu, Y., Chen, X., Shi, W., 2020. Impacts of social and economic factors on the transmission of coronavirus disease 2019 (COVID-19) in China. *J. Popul. Econ.* 1–46. <https://doi.org/10.1007/s00148-020-00778-2>
- Tian, H., Liu, Y., Li, Y., Wu, C.-H., Chen, B., Kraemer, M.U.G., Li, B., Cai, J., Xu, B., Yang, Q., Wang, B., Yang, P., Cui, Y., Song, Y., Zheng, P., Wang, Q., Bjornstad, O.N., Yang, R., Grenfell, B.T., Pybus, O.G., Dye, C., 2020. An investigation of transmission control measures during the first 50 days of the COVID-19 epidemic in China. *Science (80-.).* eabb6105. <https://doi.org/10.1126/science.abb6105>

Table 1: The Impact of Accelerating the Implementation of the Lockdown on Daily COVID-19 Mortality

Model Specification	(1)	(2)
$Post_t * S_j$	-0.155*** (0.050)	-0.162*** (0.049)
Observations	782	782
R-squared	0.645	0.650
D. V. Mean in the Post Period	1.501	1.501
Date FE	Y	Y
Regional FE	Y	Y
Control for Daily Weather Conditions	N	Y

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Table 1 reports the results from estimating equation (1) on a sample of daily COVID-19 regional deaths spanning from March 4th through April 17, 2020. The specification in column (1) only includes date and regional fixed-effects. We then experiment with adding controls for average daily temperature and sun exposure 15 days before the death is registered in the model specification displayed in column (2). All regressions include a constant term, as well as controls for daily weather, which include average daily temperature and sun exposure. Robust standard errors are in parentheses and clustered at the regional level.

Table 2: The Impact of Accelerating the Implementation of the Lockdown on Daily COVID-19 Mortality – Robustness Checks

Model Specification:	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Alternative S_j		Alternative $Post_t$		Additional Controls	Alternative Samples	
	Cut-off 2/100,000	Cut-off 4/100,000	$Post_t = 1$ from March 28 th	$Post_t = 1$ from March 30 th	Accounting for Mobility	Province Level w/ Cut-off 2/100,000	Total Deaths (MoMo Data)
$Post_t * S_j$	-0.127*** (0.049)	-0.157*** (0.049)	-0.165*** (0.041)	-0.154*** (0.043)	-0.143*** (0.061)	-0.080*** (0.029)	-0.132** (0.049)
Observations	782	782	782	782	782	2,240	782
R-squared	0.641	0.651	0.652	0.647	0.660	0.530	0.697
D. V. Mean in the Post Period	1.501	1.501	1.501	1.501	1.501	1.467	4.414
Date FE	Y	Y	Y	Y	Y	Y	Y
Regional FE	Y	Y	Y	Y	Y	Y	Y
Control for Daily Weather Conditions	Y	Y	Y	Y	Y	Y	Y

Notes: *** p<0.01, ** p<0.05, * p<0.1. Table 2 reports the results from estimating equation (1) using a sample of daily COVID-19 deaths spanning from March 4th to April 17, 2020. In columns (1) and (2), we alter the definition of an outbreak (used to codify S_j) from 3 cases in 100,000 inhabitants, to 2 and 4 cases in 100,000 inhabitants, respectively. In columns (3) and (4), we modify the timespan of infection to death (used to codify the $Post_t$ period) from 15 days, to 14 days (March 28th) and 16 days (March 30th), respectively. In column (5), we experiment with adding a control for changes in mobility patterns across regions. Finally, in columns (6) and (7), we experiment with using alternative data samples. In column (6), we estimate equation (1) using province-level data, along with a cutoff of 2 cases per 100,000 inhabitants as the outbreak. In column (7), we estimate equation (1) using daily total regional deaths from MoMo. All regressions include a constant term, as well as controls for daily weather, which include average daily temperature and sun exposure. Robust standard errors are in parentheses and clustered at the regional level.

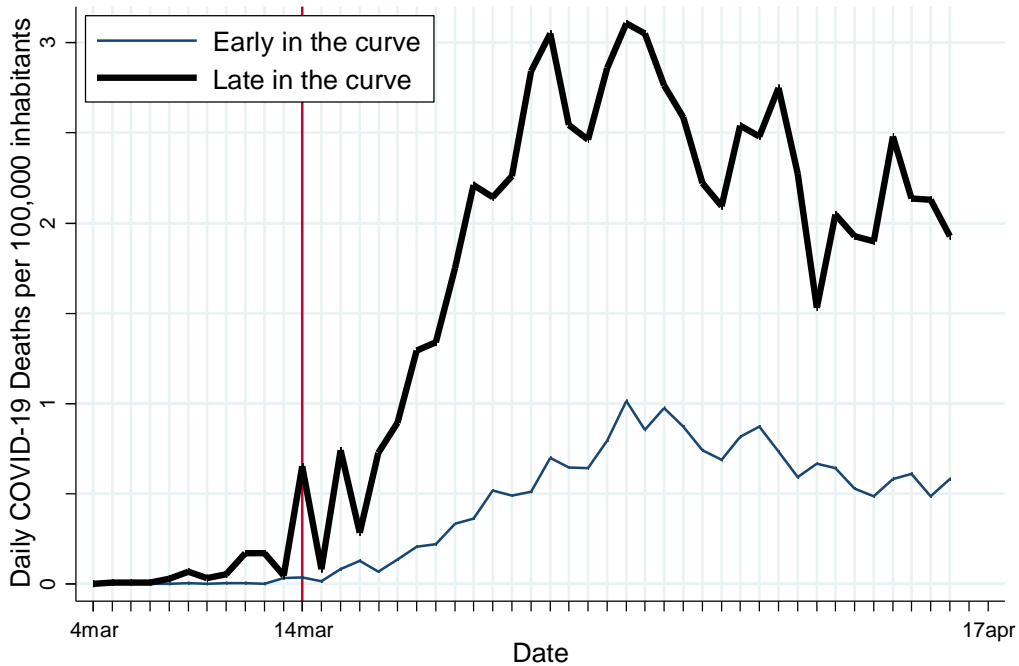
Table 3: Mechanism behind the Lockdown’s Effectiveness – Preventing Contagion vs. an Overwhelmed Healthcare System

Model Specification:	(1)	(2)	(3)
	Using COVID-19 Cases	Excluding Catalonia and Madrid	Using Non-COVID Deaths
$Post_t * S_j$	-1.864** (0.681)	-0.218*** (0.034)	0.011 (0.061)
Observations	782	690	782
R-squared	0.703	0.642	0.539
D. V. Mean in the Post Period	13.781	1.369	2.958
Date FE	Y	Y	Y
Regional FE	Y	Y	Y
Control for Daily Weather Conditions	Y	Y	Y

Notes: *** p<0.01, ** p<0.05, * p<0.1. Table 3 reports the results from estimating equation (1) using different outcomes and samples. In column (1), we use the daily number of confirmed COVID-19 cases per 100,000 inhabitants in the region as the dependent variable. In column (2), we continue to look at COVID-19 deaths, but exclude the two worst affected regions, *i.e.* Catalonia and Madrid. Finally, in column (3), we use daily non-COVID regional deaths per 100,000 inhabitants as the dependent variable. All regressions include a constant term, as well as controls for daily weather, which include average daily temperature and sun exposure. Robust standard errors are in parentheses and clustered at the regional level.

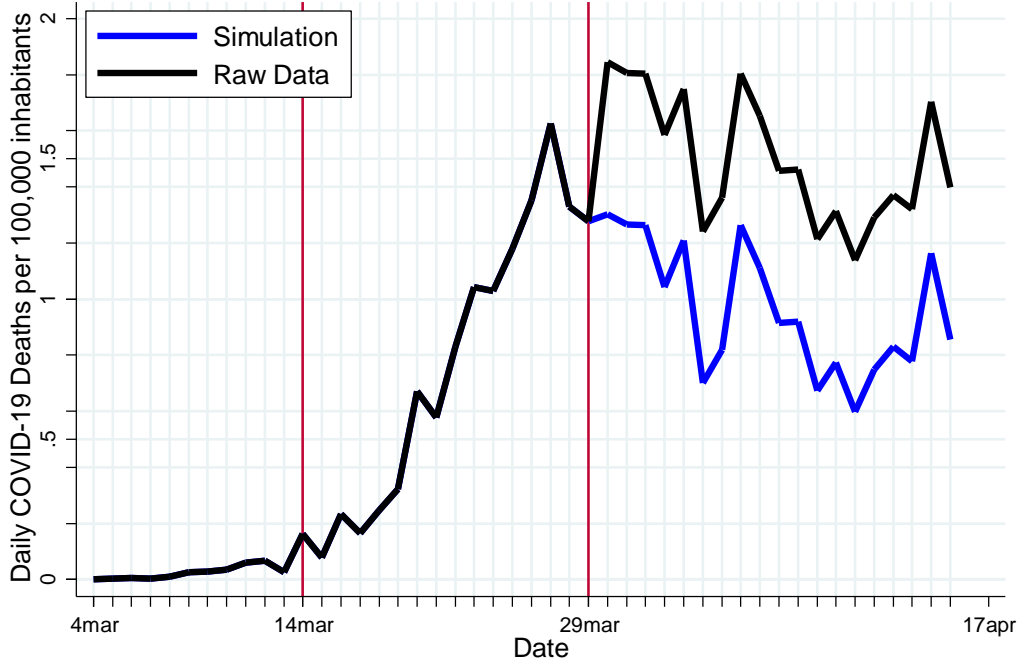
FIGURES

Figure 1
Daily COVID-19 Deaths per 100,000 Inhabitants



Notes: *Early-on-the-curve* refers to regions for which the lockdown occurred 2 days or less after the pandemic outbreak [*i.e.* Andalucía (1), Baleares (0), Canarias (2), Cantabria (2), C. Valenciana (0), Extremadura (2), Castilla-León (2), Galicia (2) and Murcia (2)]. *Late-on-the-curve* refers to regions for which the lockdown took place 3+ days after the outbreak [*i.e.* Aragón (4), Asturias (4), Madrid (6), País Vasco (7), Castilla La Mancha (4), Cataluña (3), Navarra (4) and La Rioja (10)].

Figure 2
Predicted Daily COVID-19 Deaths per 100,000 Inhabitants
by Days Elapsed from Outbreak to Lockdown



Notes: Raw data are average regional daily death rates. Simulation shows predictions from the model in equation (1) when the variable S_j is set equal to 0.

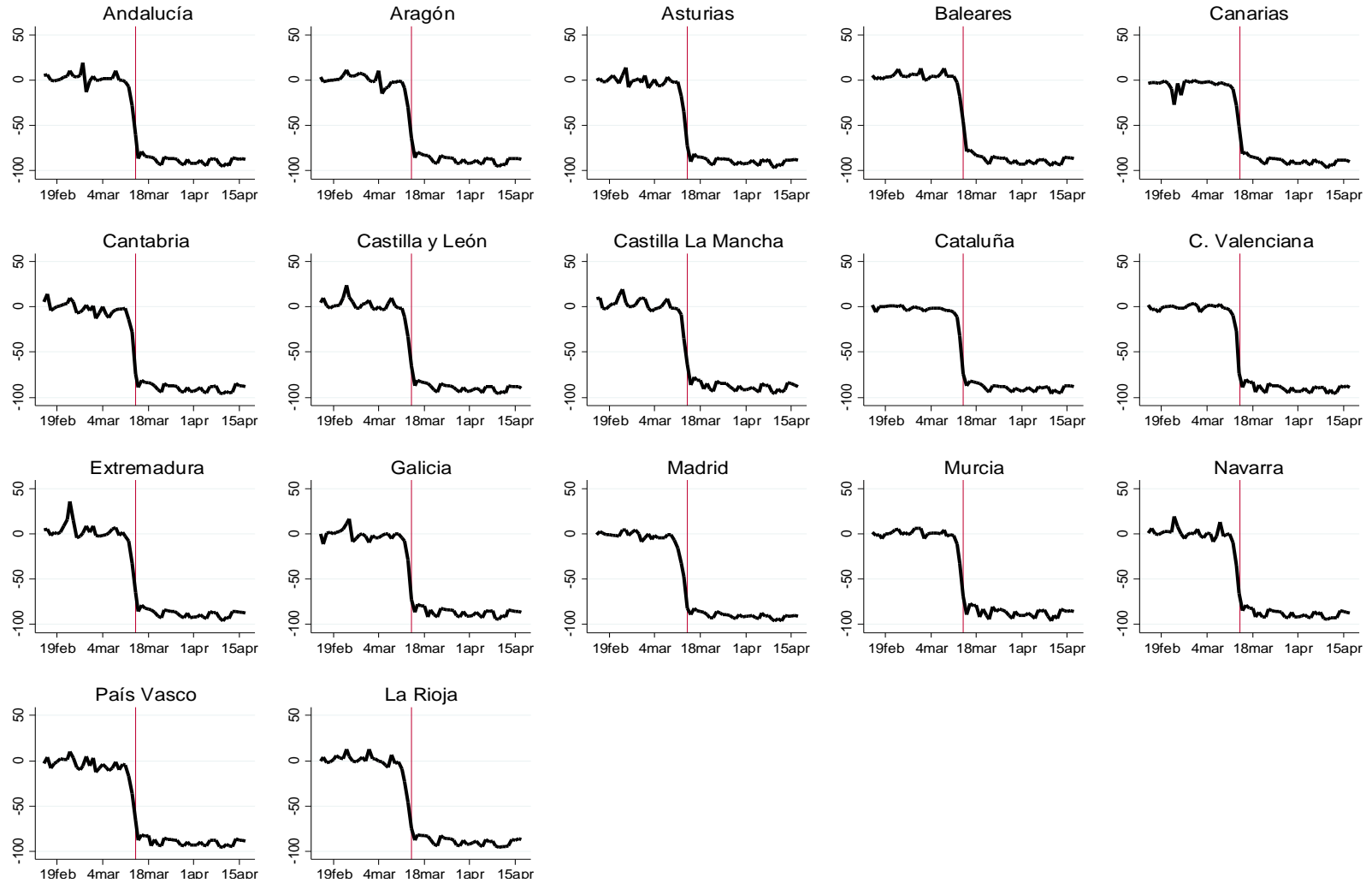
Table A.1
Descriptive Statistics

Variables	Obs.	Mean	Std. Dev	Min	Max
Panel A: Used in the Main Analysis					
Regional daily COVID-19 Mortality (per 100,000)	782	0.89	1.21	0	11.85
Regional daily COVID-19 Cases (per 100,000)	782	9.81	11.66	0	133.94
Regional daily Temperature (in °C)	782	11.97	3.37	2.54	24.80
Regional daily Sun exposure (hours)	782	6.41	3.47	0	11.80
Regional Speed 2 (outbreak defined as 2 cases per 100,000)	782	-4.59	3.07	-1	-11
Regional Speed 3 (outbreak defined as 3 cases per 100,000)	782	-3.35	2.81	0	-10
Regional Speed 4 (outbreak defined as 4 cases per 100,000)	782	-2.77	2.92	0	-10
Panel B: Used in Additional Analyses					
Regional daily Non-COVID-Mortality (per 100,000)	782	2.89	1.22	0	10.27
Regional daily Total Deaths (MoMo Data) (per 100,000)	782	3.77	1.87	0.96	12.78
Retail and recreation mobility (% change)	782	-68.49	36.17	-97	13
Grocery and pharmacy mobility (% change)	782	-36.72	30.86	-94	46
Parks mobility (% change)	782	-57.78	38.16	-93	58
Transit stations mobility (% change)	782	-62.01	34.22	-93	25
Workplaces mobility (% change)	782	-49.66	29.57	-92	12
Residential mobility (% change)	782	21.27	12.71	-6	46
Province daily COVID-19 Mortality (per 100,000)	2,240	0.94	1.45	0	12.51
Province Speed (outbreak defined as 2 cases per 100,000)	2,240	-3.40	3.41	0	-13
Province daily Temperature (in °C)	2,240	11.98	3.65	0	27
Province daily Sun exposure (hours)	2,240	6.57	3.63	0	12

Notes: The sample is March 4th to April 17th. Speed is measured by the number of days elapsed between the outbreak and the nationwide lockdown, multiplied by (-1) to ensure that higher values denote a faster response.

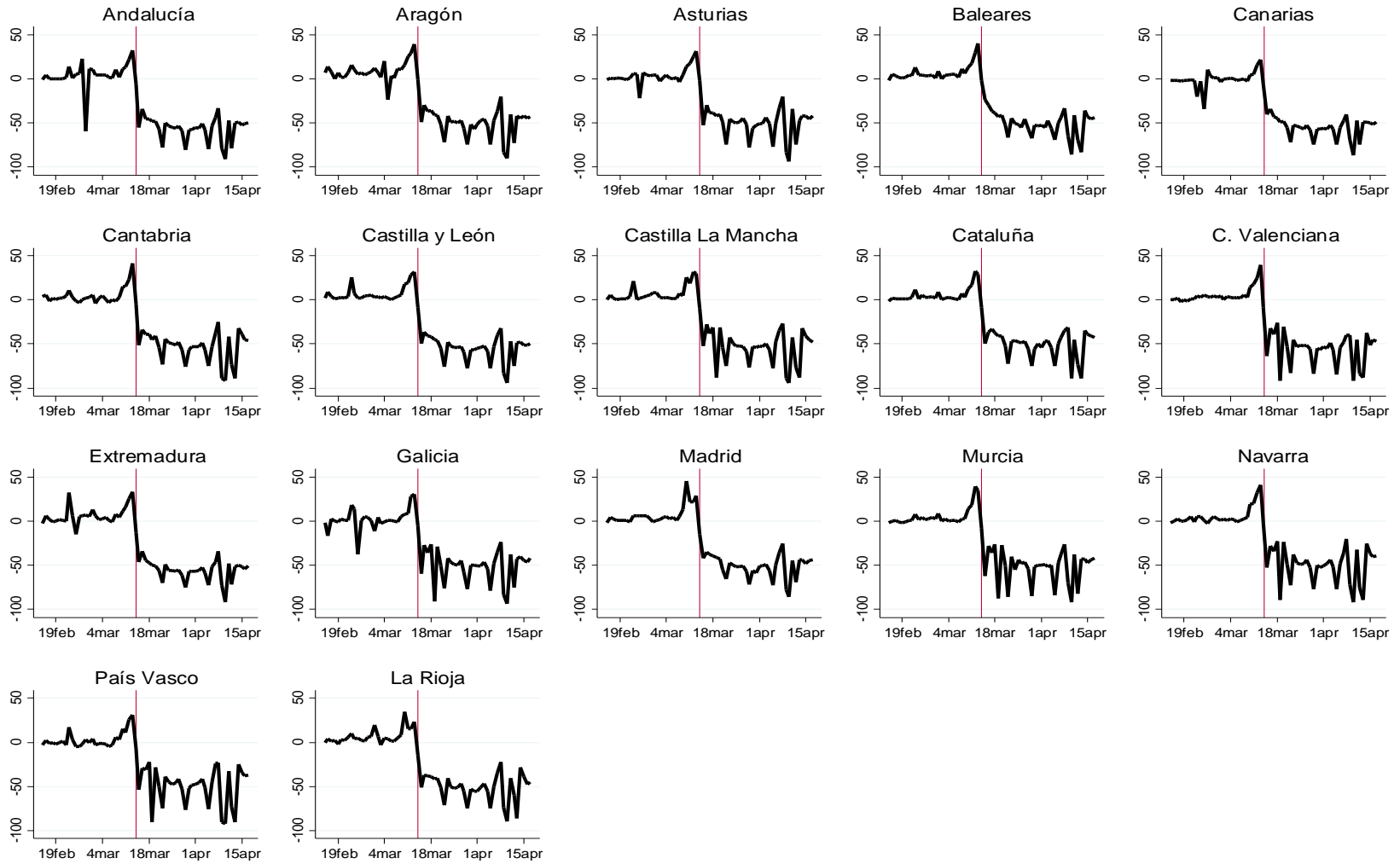
Sources: COVID-19 data are gathered from the Spanish Ministry of Health, whereas data on ‘Total Deaths’ are obtained from the Spanish System of Monitoring Mortality. Temperature and sun exposure data originate from the Spanish Meteorological Agency, and mobility data derive from Google Mobility Reports.

Figure A.1: Retail and Recreation Mobility



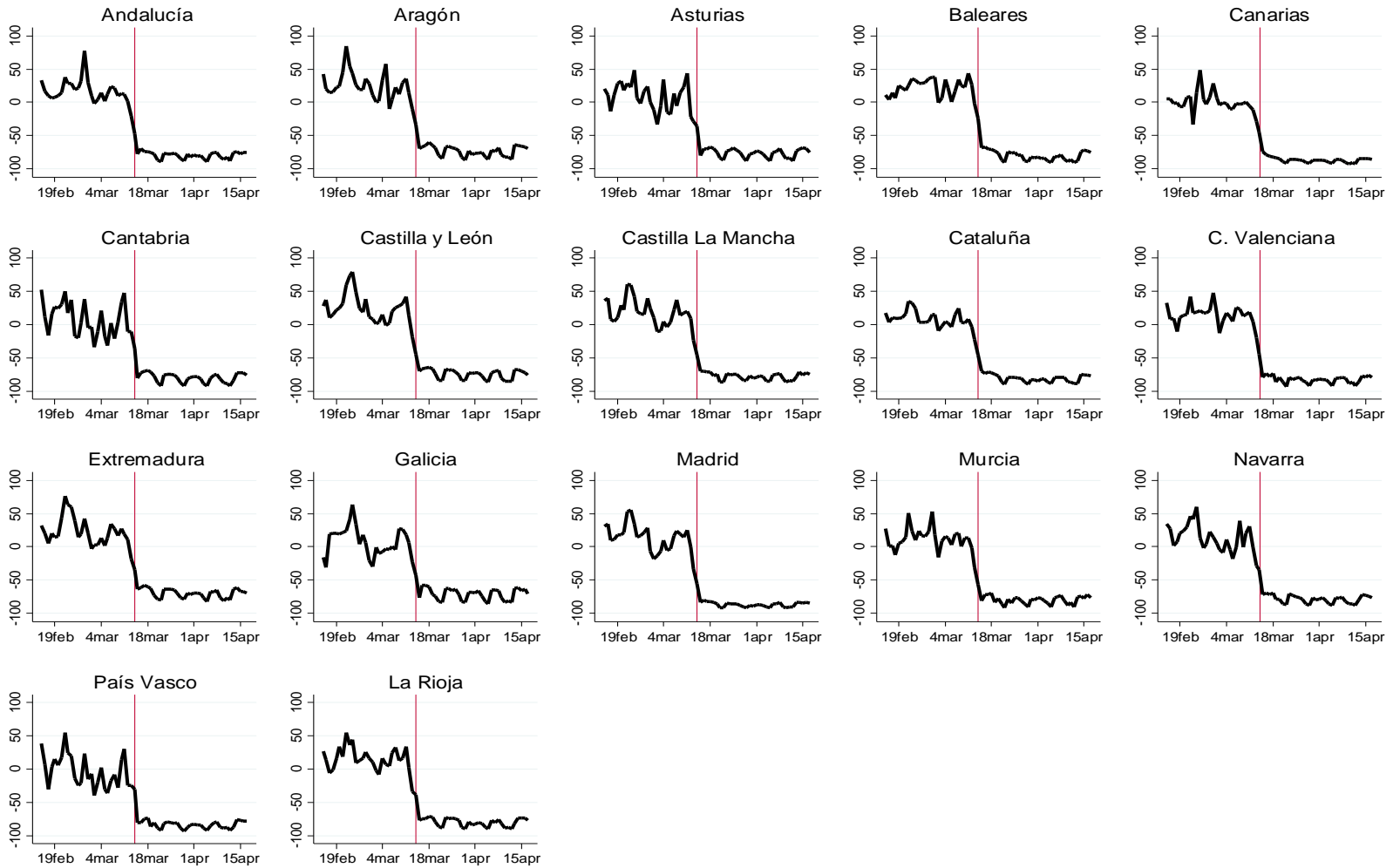
Source: Google Mobility Data February 15th to April 17th.

Figure A.2: Grocery and Pharmacy Mobility



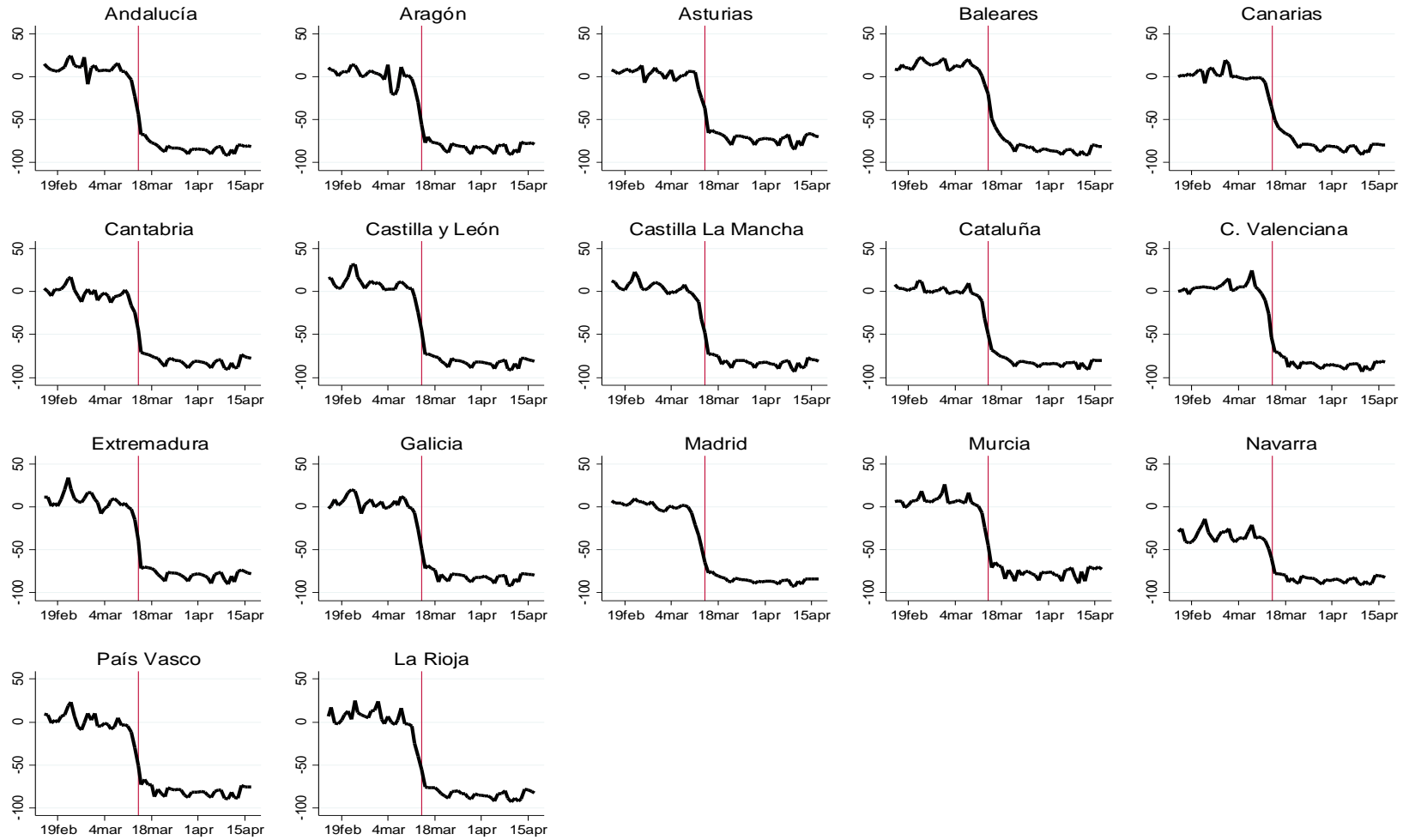
Source: Google Mobility Data February 15th to April 17th

Figure A.3: Parks Mobility



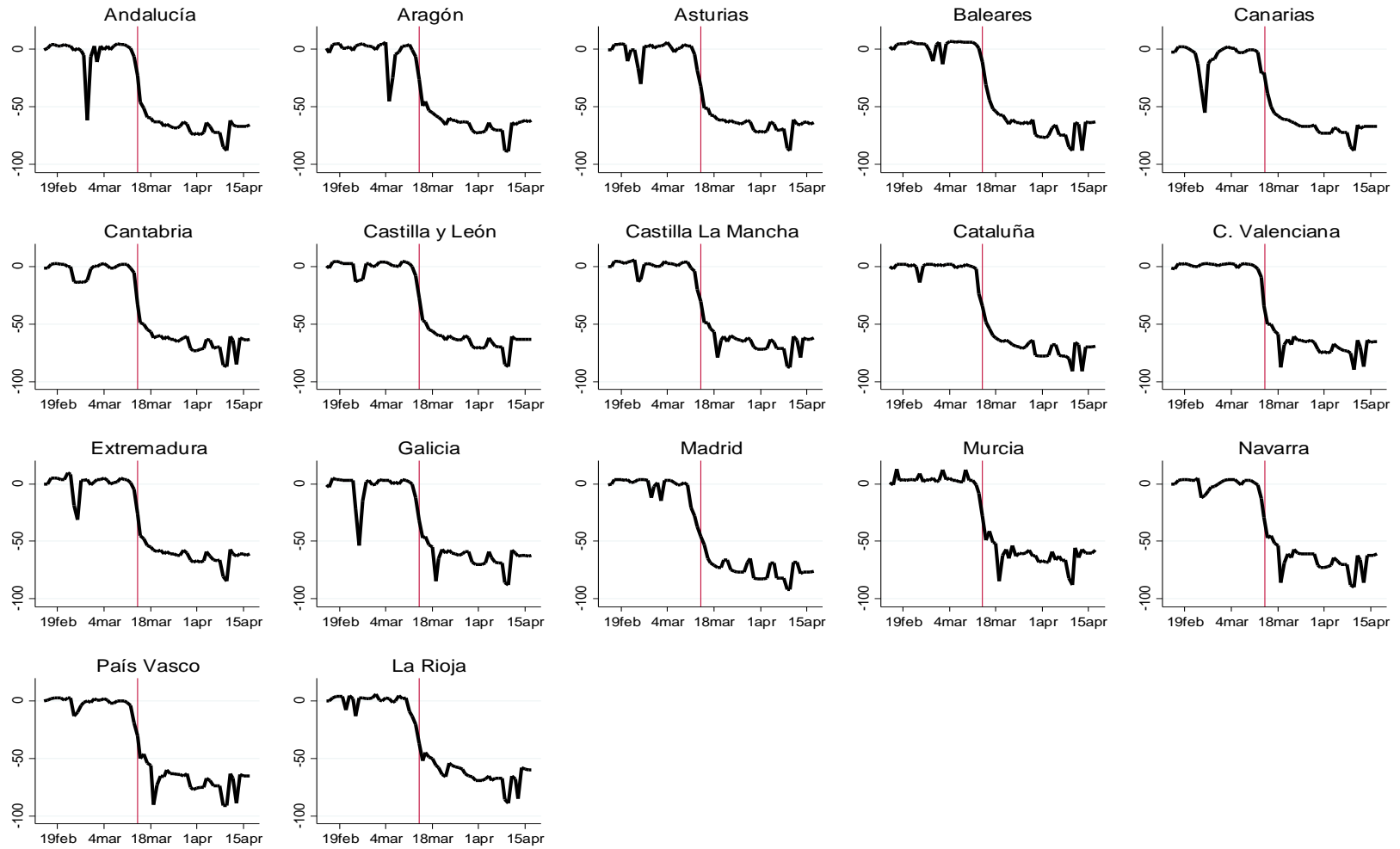
Source: Google Mobility Data February 15th to April 17th

Figure A.4: Transit Stations Mobility



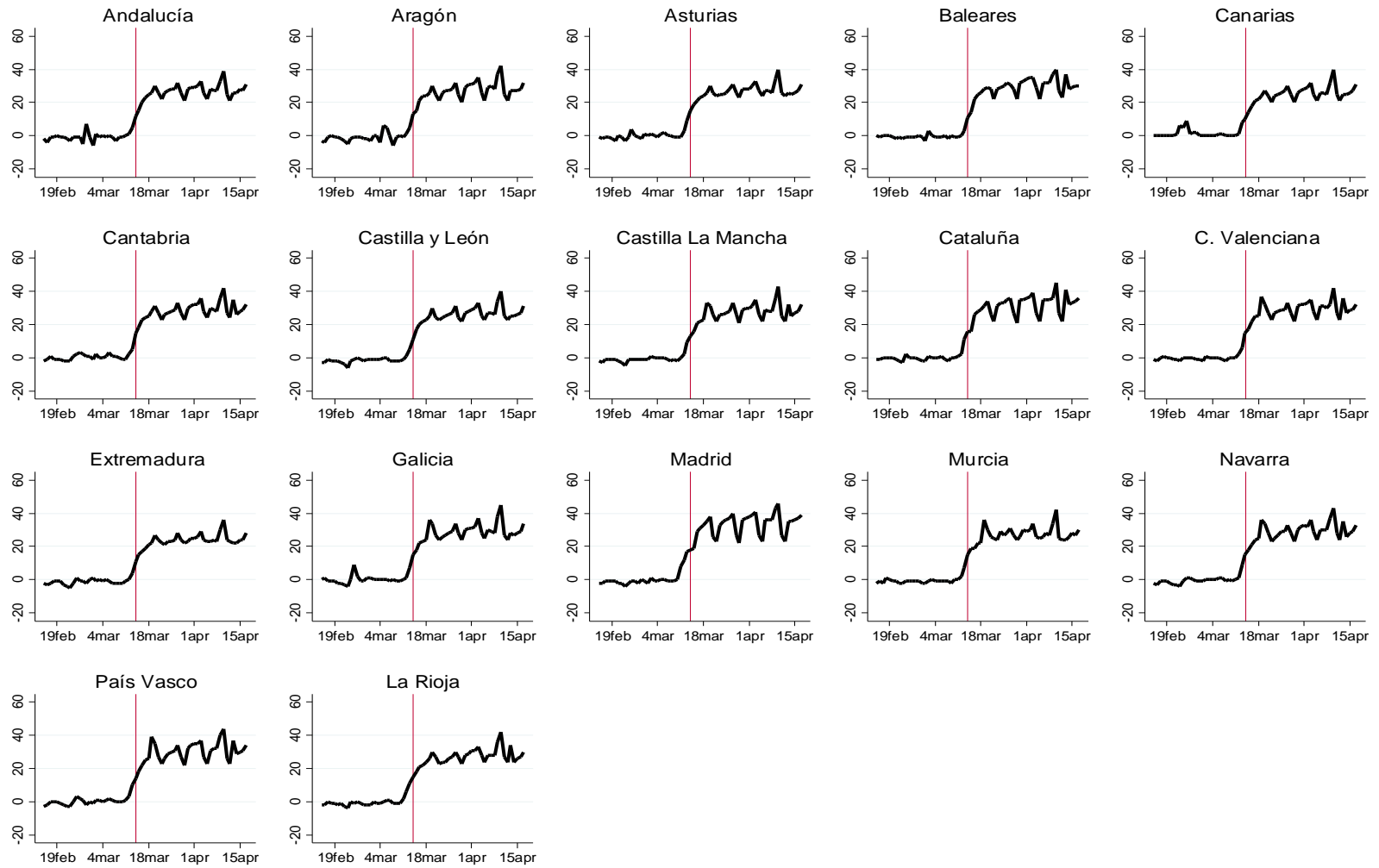
Source: Google Mobility Data February 15th to April 17th

Figure A.5: Workplaces Mobility



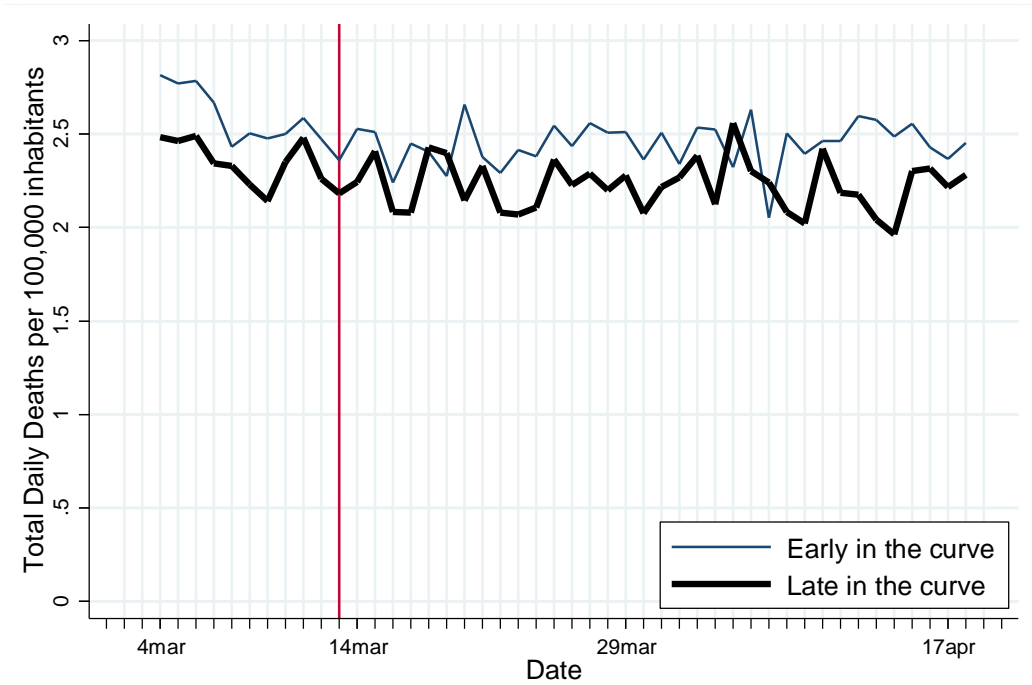
Source: Google Mobility Data February 15th to April 17th

Figure A.6: Residential Mobility



Source: Google Mobility Data February 15th to April 17th

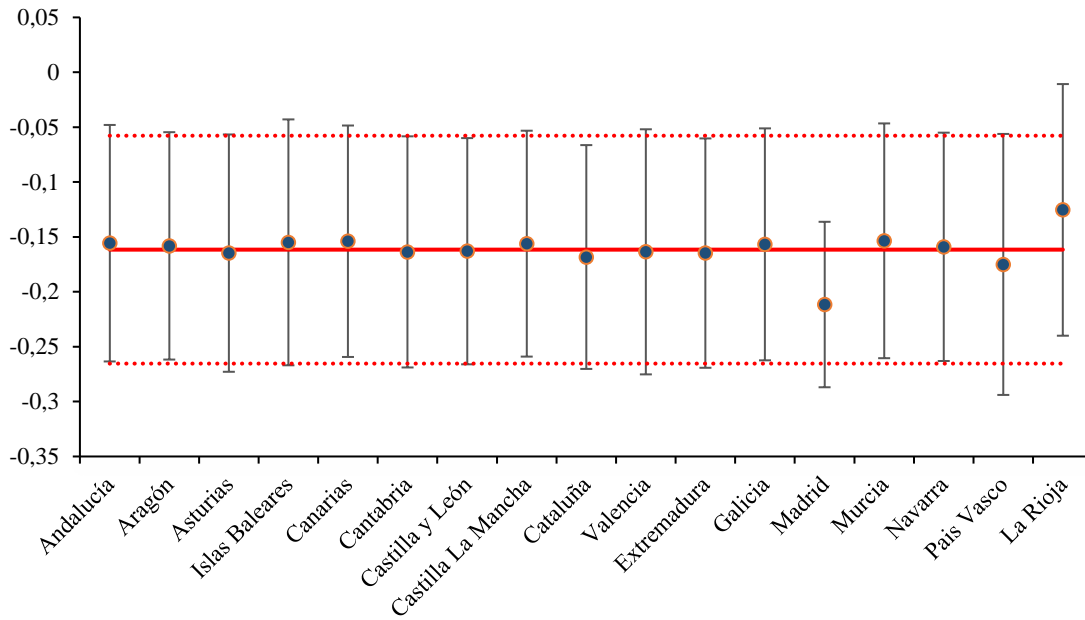
Figure A.7
Daily 2019 Deaths per 100,000 Inhabitants



Notes: *Early-on-the-curve* refers to regions for which the lockdown occurred 2 days or less after the pandemic outbreak [*i.e.* Andalucía (1), Baleares (0), Canarias (2), Cantabria (2), C. Valenciana (0), Extremadura (2), Castilla-León (2), Galicia (2) and Murcia (2)]. *Late-on-the-curve* refers to regions for which the lockdown took place 3+ days after the outbreak [*i.e.* Aragón (4), Asturias (4), Madrid (6), País Vasco (7), Castilla La Mancha (4), Cataluña (3), Navarra (4) and La Rioja (10)].

Source: MoMo data from March 4th, 2019 to April 17th, 2019.

Figure A.8
The Impact of Accelerating the Implementation of the Lockdown on Daily COVID-19 Mortality when Removing One Region at a Time



Note: The horizontal red line represents the impact of accelerating the lockdown implementation on daily COVID-19 mortality when using all regions, and the dotted lines the corresponding confidence intervals. Each one of the thicker dots represents the effect of accelerating the implementation of the lockdown on daily COVID-19 mortality when we exclude one region at a time.