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Evaluation of COVID-19 containment measures in Spain

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Abstract

In the new normality brought by the COVID-19 pandemic, most governments have to adopt containment measures in order to control the spread of the virus. This paper addresses the adequacy and effectiveness of containment measures implemented by the 19 different autonomous regions in which Spain is subdivided. The study focuses on the heterogeneity and lack of simultaneity of measures applied by the regions, exploiting such differences in applying a panel data model with fixed effects. Using this approach, I find that the most effective containment measure applied in Spain is the perimeter confinement which consists of closing the border of a region. Moreover, the analysis of this paper highlights the importance of defining a specific time frame and objective when designing effective containment measures to control COVID-19 spread.

Keywords: COVID-19, containment measures, Spain, panel data analysis

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1 Introduction

During the first quarter of 2020, Spain was one of the most affected countries by SARS-CoV-2 (Severe Acute Respiratory Syndrome Coronavirus 2). The health system collapsed, and they reached around a 1000 deaths per day. The Spanish government was forced to implement a total confinement in order to flatten the curve of new cases, but the consequences and the impact of COVID-19 (Coronavirus Disease 2019) have been devastating.

The Spanish Government started to relax the total confinement and faced the new challenges of the new normality during the summer of 2020, which was calm in terms of COVID-19 cases. However, from October 2020 to March 2021, Spain suffered the effects of the second and third waves of COVID-19, which had a lower mortality than the first but was still public concern. The Spanish Constitution allows every autonomous region to take their own measures or laws in many ambits, being one of them health policies. The state of alarm, implemented during March of 2020, forces the autonomous communities to follow the guidelines of the Central Government when it comes to COVID-19 aspects, but the regions are "free" to adopt the most convenient containment measures.

The main goal of this study is to evaluate the effectiveness of the containment measures adopted by the 19 autonomous regions in which Spain is subdivided. I exploit the variations in such measures to find the relation, if any, between the containment measures and the registered cases of COVID-19 in every autonomous region. The most common containment measures in Spain were the implementation of a curfew during the night, a perimeter confinement consisting of closing the borders of the region, and hostelry or/and commerce restrictions. There has been a latent discussion on the adequacy of the many imposed restrictions and a general discontentment has been displayed in the public opinion of the Spanish population. However, the authority to impose some restrictions depends on the autonomous government of the regions, so there is not simultaneity on the application. The previous hypothesis is that there exists a negative relation between registered cases and containment measures, specifically mobility restrictions are expected to have a great impact reducing SARS-CoV-2 cases, given that politically it has been an extended measure.

Previous literature has been focused on evaluating policies and measures using simulations. The vast majority of COVID-19 evaluation papers use SIR (Susceptible, Infectious, Recovered) models and its refinements, such as SEIR or further enrichment, mainly to determine how the spread would have evolved without a lockdown ((Aleta & Moreno 2020), (Berlemann & Haustein 2020), (Di Giamberardino & Iacoviello 2021)) but not really demonstrate the effectiveness of other containment measures, which are explained in more detail below. This paper aims to use an econometric approach, particularly a panel data model, to capture the effect of restrictions in Spain from June 2020 to March 2021 while other variables are constant.

This paper differs or diverges from other studies on containment measures evaluation by using a not very common methodology. Particularly, a panel data approach with individual fixed effects in order to capture the effectiveness of the measures without the influence of time-invariant variables. The analysis focuses on exploiting the policy variations that took place in Spain during the second and third waves of COVID-19 in Spain at a regional level. In this way, it contributes to the recent literature of COVID-19 policy evaluation by presenting new empirical evidence. Some of the main findings of the paper are the significant effect of the curfew on the diminishment of registered SARS-CoV-2 cases, and the best explanatory model using an incubation period of 4 days.

The paper is structured as follows. Section 2 introduces the related literature. Section 3 describes the employed data and methodology. Section 4 presents the obtained results followed by the pertinent discussion. Section 5 concludes.

2 Previous Related Literature

Due to the recent study of COVID-19 and the difficulties obtaining data, there does not exist a vast literature on the evaluation of containment measures. Previous literature on COVID-19 containment measures evaluation has focused on using SIR (Susceptible, Infectious, Recovered) an SEIR (Susceptible, Exposed, Infectious, Recovered) simulations to evaluate how the application of containment measures of countries has decreased the contagion of SAR-CoV-2. The main objective of these papers is to find a better-fitting mathematical model to simulate the data and define the effectiveness of the measures based on the actual data and the simulated scenario. On the other hand, there exist a petite wing of the current literature that examines other aspects of the containment measures as the different types of consequences on the population, or the effect population mobility prior to the beginning of a lockdown on confirmed cases.

Berlemann & Haustein (2020) contribute to the recent COVID-19 literature by evaluating Germany's waves of containment policy during March 2020. They use a spatio-temporal endemic-epidemic model to find empirical evidence on the effectiveness of the measures adopted by the Federal Government. The authors use a SIR (Susceptible, Infectious, Recovered) model, that assumes population can be divided in these categories and consists on differential equation used to forecasting. They take both and ex-ante and ex-post perspective to evaluate the three waves of containment measures using data from RKI (Robert Koch Institute) to estimate their spatio-temporal model and subsequently, the likely development of new infections. They define carefully when every measure is adopted and find the difference between the predicted and factual new infections to estimate the effectiveness. Two main conclusions can be derived from Berlemann & Haustein (2020), the first one is that ex-post the latter German containment measures seem to be unnecessary but given the available information set (ex-ante approach) the decision of adopting additional measures does not seem irrational. The second conclusion is that a one-size-fits-all type of policy might not be the more effective given the differences on the incidence between regions.

A study performed in Spain by Aleta & Moreno (2020) follows a similar methodology as Berlemann & Haustein (2020). They use a SEIR metapopulation model, which in addition to the previously mentioned groups above, includes exposed population. Through a stochastic simulation, the authors are able to trace the spatial spread of the virus. They evaluate the containment measures of the first wave in Spain, dating from February 28th of 2020 until the 13th of April of the same year (when the study was conducted). Aleta &

Moreno (2020) highlight the importance of coordinated measures to reduce the spreading of COVID-19. Moreover, they put an emphasis and recommend based on their results that strategies to delay the propagation of the disease should be further considered instead of focusing only on cutting down the cases. Therefore, the results from the SEIR model are in line with WHO (World Health Organisation), where the detection and isolation of individuals who present COVID-19 as well other public recommendations could be the key at reducing and delaying the spread.

Di Giamberardino & Iacoviello (2021) deliver a refinement of the typically used SEIR model to describe the spread of COVID-19 in absence of a vaccine. The authors use data from the Chinese Government for the Wuhan region, to prove the validity of the model on simulating the spread of the disease accounting for different control efforts. In addition, Di Giamberardino & Iacoviello (2021) find fitting simulation values when comparing the different containment policies in Italy and United Kingdom and the evolution of the spread. They conclude finding a correspondence between the containment policies adopted by a country and the future evolution of the virus and the possible application of this refined SEIR model on other diseases.

In addition, Di Giamberardino et al. (2021) deepens on the refinements of a SEIR model to include the effect of the containment measures on the positive COVID-19 cases in Italy. Through a mathematical model, the authors explore different possible scenarios depending on the measures that Italy applied or would hypothetically apply. They find that the repercussions of COVID-19 both in terms of infected patients and deaths depends on the containment measure, and they evidence the effectiveness and advantages that strict measures bring as in the case of a complete lockdown.

As a different approach to evaluate containment measures, Naumann et al. (2020) focus on psychological, social and political effects in Germany of those policies. To measure public contentment with containment measures the authors use data from the German Internet Panel, specifically two survey question to capture the support and evaluation. As an economic proxy, they explore the labour situation, distinguishing by status. Finally, psychological effects are measured by how threatened people feel by SARS-CoV-2. They focus on the consequences of a lockdown, so the data used dates from March 2020 to May 2020 in Germany. Naumann et al. (2020) find high approval rates at the beginning of the lockdown, given that the health system collapsed and propagation was very high in Germany. However, the support decreases as people feel a lower risk on the probability of being infected and severity of the disease, as well as the economic consequences illustrated by an increase of short-time jobs and unemployment aggravate the situation. The authors conclude stating that lockdown policies change political behaviour of individuals and their risk perception.

On the other hand, Jiang & Luo (2020) examine the influence that population mobility has on the transmission of the disease. The authors obtain data from multiple open-access sources on confirmed cases of Hubei province in China. The objective is to measure how the mobility produced in the wake of the lockdown in Wuhan influenced COVID-19 cases in the rest of the region. Jiang & Luo (2020) use a panel data model with random effects (RE) and explore different incubation periods, to achieve a good fitting model that explains the behaviour of the confirmed cases. The main findings of Jiang & Luo (2020) are that population mobility is a driver of COVID-19 and that the common period between the contact and the confirmation of the disease is around 11-12 days.

Lastly, Ouchetto et al. (2020) evaluate the effectiveness of containment measures in North Africa through the influence they had on the reproductive rate and the conditional probability of death, differing from the SIR models. They conclude that the early application of measures decreases the spread, but do not determine which measure could have a higher impact on decelerating the COVID-19 escalation.

This paper pays a major attention to this last aspect, but not using a SIR model or any typically medical method. It fits into the literature since it consists of determining the effectiveness of containment measures, but differentiating between them and using only an econometric approach. Therefore, the objective is not only on describing the differences on the spread of COVID-19 when containment measures are applied, but it is a normative paper on the more effective policymaking.

Thus, the existent literature consists mainly of SIR models that analyse the containment measures applied during the first wave, which in various countries was a total lockdown. This simulation models are valuable given that the refinements performed by the authors can describe the behaviour of the virus. The other branch of policy evaluation, which focus on estimating the effects of containment measures or the problems to tackle when designing measures, by utilising other methods give a a new grasp and comprehension inside the COVID-19 evaluation literature. However, in many cases they do not account for the effect of different specific measures and their interaction, and given the recent events there is a lack of the literature of the following waves of COVID-19.

3 Data and Methodology

3.1 Data

The data used in this study is obtained from the Spanish Health Department, which is an open source. All medical centres that take SARS-CoV-2 tests are obligated to inform the Spanish Health Department when the test is positive. Hence, the database includes all positive registered cases and the test through which the medical centre evaluated the patient. Moreover, the database includes the specific date the test was taken and then tested positive, but it is impossible to know exactly when did the individual get infected. The registered cases available start in March 2020, when the Spanish Government declared the total confinement. However, since the health system was surpassed and there were not enough COVID-19 tests in Spain at that time, some data from the first wave is missing.

This study uses data from June 2020 to March 2021 on registered cases by autonomous region. In addition, some other variables taken from the Spanish Institute of Statistics are used to complement the data. These other variables are daily mobility rates inside the region, the number of working physicians in 2019, and quarterly unemployment rates. Therefore, the analysis is performed with regional data o the previously commented variables to use a panel data approach, where the regions are used as individuals.

3.2 Descriptive Analysis

First, a descriptive analysis is performed to display the existence of the second and third waves and how these affected the different regions by graphical representations. In Figure 1 it is observable the existence of the second and third waves that Spain suffered during the fall and winter season, respectively. In the graph, the months and years of the sum of registered COVID-19 cases in all the autonomous regions is denoted under every bar.

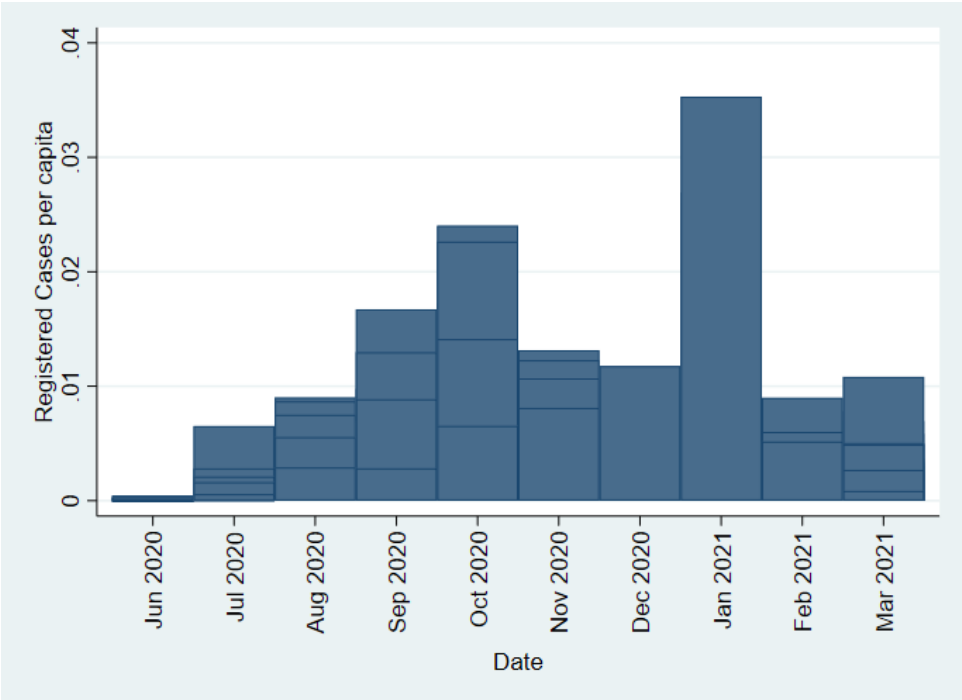

Figure 1: Registered Cases per capita per Month in Spain

It is notorious the progressive increase of registered cases from June to September 2020, reaching a peak in the last. The containment measures started to be applied by the 30th of October, consequently the effects should be observed in November. However, the decreasing trend already started in October and lasted until December of the same year. This is not surprising, given that many regions kept the restrictive measures. This would delimit the so called second wave. In January, the government observed the begging of the third wave, with the higher value of COVID-19 cases among all the studied months registering around 175,000 infections. This worrying phenomenon was produced by the gatherings during Christmas and the relaxation of measures in December 2020. After the last Christmas event in Spain on the 6th of January 2021, many new preventive actions took place in all the regions of Spain. Even if the registered infected people during February and March 2021 were low compared to the previous months, the health system was almost collapsed and the local governments, fearing a new health crisis, did not lift the measures as fast as they did before.

Figure 2 presents the per capita registered cases in every autonomous region of Spain. The graph uses the ISO codes of the regions, which can be consulted on the Appendix on Table A1.

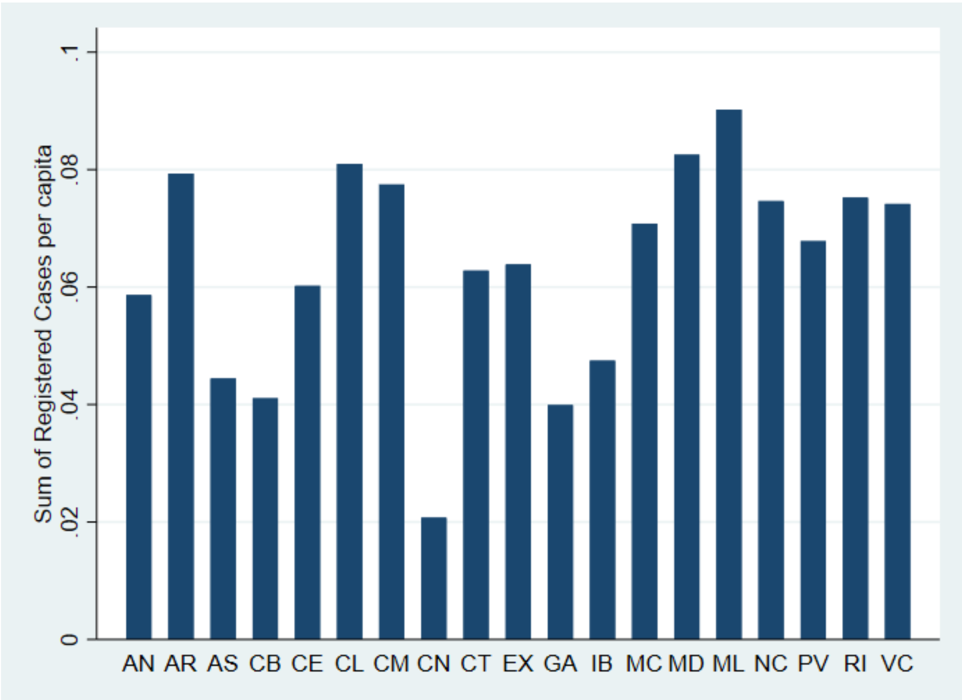

Figure 2: Registered Cases per capita by Autonomous Region (June 2020-March 2021)

As it can be observed, there exist great variation between the regions. The Canary Islands (CN) is the region with the lowest number of registered cases, which can be due to the geographical isolation of the regions. However, the Balearic Islands (IB) more than double the number of cases with respect to the Canary Islands. Melilla and Madrid show the highest totals among all the regions, with more than 0.08 COVID-19 cases per capita from June 2020 to March 2021. Most other regions show around 0.06 cases per capita. Nevertheless, all the regions mentioned above are some of the ones that applied less or more relaxed measures to fight the spread of COVID-19.

3.3 Containment measures in Spain

This study aims to exploit the variations in containment measures in every region, taking advantage of the independence of the autonomous governments. The objective is to observe the relation, if any, between the registered cases and the adopted measures.

As it was previously mentioned, there were three main types of containment measures implemented by the governments:

- Curfew: The Spanish government adopted a curfew during the night by the end of October. However, even if it was a measure implemented by the Central Government, some regions delayed it. That is why, it is considered in the panel data analysis, as well as in the OLS regressions. The curfew was mainly imposed between 10 or 11 pm to 6 am in most cases. It must be mentioned that this measure was relaxed the most celebrated days by tradition in Spain during Christmas.
- Perimeter confinement: This measure depends fully on the autonomous government. This consists of limiting mobility by not allowing he entrance or exit of the region without a demonstrate major legal excuse. This includes non-resident visitors from outside the country but also from other regions of Spain. Moreover, some Spanish regions adopted other types of confinement at a county, municipality or other spatial division level. In many cases as an additional measure like Catalonia or the Community of Valencia, but in others as partial confinement of affected areas which is the case of the Community of Madrid or the Balearic Islands. To avoid possible discrepancies, only the perimeter confinement of the whole region is considered.
- Hostelry and commerce restrictions: These are the type of measures that vary he most among autonomous regions. The vast majority consist of capacity limitations and in some cases even closing completely hostelry and commerce in the region. However, it is important to mention that these kinds of restrictions were also the most variant within the regions, many measures were adopted and given the difficulty of the matter, in some cases the new rules were ambiguous.

The containment measures were published by the local autonomous governments, but when the measures lose their validity, they are removed from the official government documents. To collect all the applied measures in every region, I used some of the most important newspapers of the country together with the government documents in order to be able to account for any policy variations.

3.4 Methodology

The 19 autonomous regions of Spain are considered, and all the mentioned months (June 2020 – March 2021) are analysed. The daily observations on COVID-19 are collapsed to obtain monthly registered cases by region, and then divided by the population in the autonomous region. Also, different incubation periods are constructed, based on previous literature that suggest that the time interval between the contact and the tested positive case could be between 3-12 days ((Aleta & Moreno 2020), (Berlemann & Haustein 2020), (Jiang & Luo 2020)). I explored incubation periods between 3 and 7 days, and as a control I also use 14 days of incubation to observe if any effect is still present. I expect 3 and 7 day incubation periods to be better suiting, since many studies as McAloon et al. (2020) suggest an incubation period of 5.8 days i explore various specifications.

When working with the mobility rates, I obtained daily mobility rates from June 2020 to March 2021. Therefore, I calculated the monthly average for every autonomous region. On the other hand, for the unemployment rates the information provided by the National Institute of Statistics is divided by trimesters, so I assume that the regions have the same rate during three months in a row. It is not the most realistic assumption, but given the data available it is the only method to include an economic variable in the analysis.

Moreover, I create dummy variables that represent the containment measures. The dummies take value of 0 if the restrictions are non-existent in that aspect or if they have been relaxed. That is, if there were very harsh restrictions for the hostelry and commerce then the dummy would take the value of 1 for that specific month. But, if the following month the restrictions are partially removed or relaxed, then the dummy will be equal to 0.

The dummies of the containment measures have been constructed reviewing all the policies adopted by all the autonomous governments. When it comes to perimeter confinement, the respective dummy takes value of 1 if and only if the confinement closes the whole region. Regarding the hostelry and commerce restrictions, when the region adopts "loose" measures compared to the other Spanish regions, the dummy is equal to 0. A table with all the constructed dummies is included in the Appendix as Table A2.

The regression analysis starts with OLS regression to observe the interaction between the previously described variables. Where the regression is the following:

$$y_i = \beta_0 + \beta_1 p_i + \beta_2 h_i + \beta_3 c_i + \beta_4 m_i + \gamma u_i + \pi r_i + \delta_t + \epsilon_i \tag{1}$$

In Eq. 1 y stands for per capita registered COVID-19 cases, and i is the autonomous region used as an individual in this analysis. The letters p, h, and c represent the perimeter confinement, the hostelry restriction and the existence of curfew respectively. The mobility rates are symbolised by the m, and unemployment and physicians rate (the controls) are the u and r in Eq. 1. The time trends controls are the letter δ, which is a matrix of dummies for all the considered months. Lastly, ϵ stands for the error term.

Next, the panel data approach follows, using autonomous regions as individuals and months as the time variable the regressions are estimated with fixed effects (FE) as the following:

$$\tilde{y_{it}} = \beta_0 + \beta_1 \tilde{p_{it}} + \beta_2 \tilde{h_{it}} + \beta_3 \tilde{c_{it}} + \beta_4 \tilde{m_{it}} + \gamma \tilde{u_i} + \delta_t + \tilde{\epsilon_{it}} \tag{2}$$

Where $\tilde{y}_{it}$ is the difference between the individual specific value and the individual specific average. So are all the variables that include a *tilde*. All the previously defined letters stand for the same variables in Eq. 2 as in Eq. 1

I decide to use FE after performing a Hausman test, for which the null hypothesis is that a random effects (RE) regression is consistent with the data. Since the p-value was equal to 0, therefore lower than 0.05, the null hypothesis was rejected. An example of a factor that might be affected by containment measures and could be captured by regional fixed effects is public expenditure, since there are more control mechanisms of the measures needed but the public revenue decreases as a consequence of COVID-19 and restrictions. Both OLS and panel data regressions are estimated for the various incubation periods.

4 Results and Discussion

4.1 Regression Analysis

As it was previously mentioned, the regression analysis consists of linear and panel data models, using fixed effects (FE) in the latter. During the regression analysis various incubation periods are considered, in line with the previous literature, I estimate the regressions using from 3 to 7 days of incubation since the contact ((Aleta & Moreno 2020), (Berlemann & Haustein 2020), and (Jiang & Luo 2020)).

However, on the analysis only the results for a 7-day incubation period are shown due to the higher value of the R-squared when using the shortest incubation period available. The results for other incubation periods can be consulted on tables A3, which shows the OLS regressions, and A4, for panel data FE coefficients.

Prior to the results, I would expect to observe negative coefficients on the containment measures variables. The reasoning behind this premise is that the more restrictions the more difficult is to meet and be in contact with someone who is infected for people. Unemployment and physicians' rates are included to capture possible economic or health system effects that might be correlated with COVID-19 spread. Therefore, there are no previous premises with them. These are not included on Table 1 as variables, but as 'Controls' of the regressions. On the other hand, mobility rates within the autonomous regions are expected to have a positive effect on registered cases. Since the only confinement included in the analysis consists of closing the borders of the regions, the mobility within the same areas is supposed to increase the infections, given that it could facilitate the contact between people.

Table 1: OLS and Panel Data FE Models with 7-day incubation period

VARIABLES	(1) 7-day OLS	(2) 7-day FE	(3) 7-day OLS	(4) 7-day FE
Perimeter Confinement	0.000	-0.005**		
	(0.001)	(0.002)		
Hostelry and Commerce Restrictions	-0.001	-0.001		
	(0.001)	(0.001)		
Curfew	0.003	-0.003		
	(0.005)	(0.004)		
Mobility rate	-0.000	-0.001**	-0.001***	-0.001***
	(0.000)	(0.001)	(0.000)	(0.000)
All Measures			-0.002	-0.003**
			(0.001)	(0.002)
Constant	0.027***	0.038**	0.017***	0.025***
	(0.007)	(0.016)	(0.005)	(0.005)
Observations	114	114	114	114
Controls*	Yes	Yes	Yes	Yes
R-squared	0.606	0.700	0.067	0.118
Number of Regions		19		19

*Time trends, unemployment and physicians rates (the latter is dropped in panel data)

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

When analysing the coefficients of the first OLS regression which is shown in Table 1 column (1), I find no significant variables at any confidence level. The curfew has a negative and significant effect when there are no time trend controls, but when adding them, this effect is absorbed by the variable representing the monthly trends. Mobility, as the containment measures variables, was expected to be significant, but it is observable that the coefficient is 0. Despite finding a high R-squared of the model, it seems surprising not to obtain any significance in containment measures.

In Table 1 column (2), the coefficients for the panel data fixed effects are shown. It is clearly observable a great increase of the R-squared of this approach compared to the OLS regression (column (1)), reaching a determination coefficient of 0.700. However, the other incubation periods (Table A4) present also high values of the R-squared with not significant differences between them, as it occurs on the OLS analysis (Table A3). The pattern described indicates that the results are not highly sensitive to the choice of incubation period. The expected coefficients also do not coincide with the previous premises of the OLS regressions, but obtaining an increment of the significance levels and probably more significant coefficients of at least some variables.

The only time-invariant variable (physicians rate), which is used a a control in the analysis, is dropped when estimating panel data with fixed effects, since this method 'controls' for time-invariant characteristics of the individuals, in this case autonomous regions. Therefore, the only remaining control variables that was included on the FE regression are unemployment rates, which suffer quarterly variations, and time trends. This is the case because unemployment rates are a socioeconomic proxy, but at the same time unemployed population has more leisure or time employed on job searching which could potentially increase the number of infections or could decrease the registered cases given those citizens can stay at home and keep social distance.

The coefficients of these regressions using panel data are the 'within' estimators, getting rid of the external time-invariant noise. On the other hand, one variable becomes significant on the analysis when using FE. The perimeter confinement (closing the region border) is significant at the 5% confidence level, being the only containment measure that shows a significant effect on COVID-19 registered cases with a coefficient of -0.005.

However, it is highly significant at the 1% when the specification is made for a 14-day incubation period, as it can be seen i Table 2. In addition, the coefficient of curfew, which was expected to be a significant measure both on the OLS and FE regressions, remains being irrelevant in the analysis of registered cases. While perimeter confinement has increased from 0 to -0.005. This coefficient increases in value when the incubation period increases, phenomenon that will be further discussed.

The mobility rates show a negative and significant coefficient at a 5% level when using FE. The estimate is rather counter-intuitive, showing the opposite effect than expected. However, since it is negative and significant at a 5% level it might be capturing other effects, or it could be a result of a confounding problem. This will be further analysed on the next Section (Discussion and Limitations). However, as it can be observed in Table A4, the coefficient of internal mobility suffers a constant decrease in significance level and value if the incubation period increases.

In addition, two other specifications are estimated for a 7-day incubation period, which are shown in Table 1 columns (3) and (4). A new variable ('All measures') is created through the multiplication of the containment measures dummies, to represent the application of all the possible measures. It might be the case that the combination of measures has a greater effect on registered cases, given that it would be positive only for the regions that were more restrictive. Nonetheless, it is observable in the last two columns that all coefficients suffer a clear decrease, so does the R-squared. Note that the coefficient of perimeter confinement is -0.005 when using FE, but 'All measures' does not even reach these value, not in an OLS specification nor with panel data. The presented results could imply that the combination is not as effective as the independent application of containment measures.

Lastly, in Table 2 the results for regressions using a 14-day incubation period are shown. The selected incubation period is discarded by the literature, so it should not be considered as an incubation of COVID-19 in infected individuals, but as a mechanism to observe if containment measures effects are not immediate. The same regressions that were previously estimated with for a 7-day incubation period, are estimated with a 14-day delay in registered cases as the dependent variable.

There is a small increase in the coefficient of determination of the 14-day incubation period if the method applied is panel data column (2), when comparing Table 1 and 2. Even if it is not in line wit the previous literature, and it is not a large variation of the R-squared, it is interesting to notice it. As it has been mentioned, the scientific COVID-19 recent literature has found incubation periods of 3-7 days. However, this could mean that the effect of containment measures has a longer delay than the incubation of the virus found in the literature. Thus, I consider that the presented results should not be disregarded.

The coefficients for the OLS specification shown in column (1), when containment measures are analysed separately coincide with all the other regressions with shortest incubation periods. In fact, all coefficients are similar. Hence, the non-sensitivity of coefficients is again observable. On the other hand, the results when applying a panel data with fixed effects approach show a small increase in the perimeter confinement significance level at the expense of the mobility rates, which decreases in value and is not significant. The mobility rates seem sensitive to a greater 'incubation' period, that was already observable from the previously mentioned tables. If the analysis is performed for the combination of measures, through 'All measures', there are no significant variables with this specification (but the constant) and the R-squared for both a OLS and panel data has completely sunken.

Table 2: OLS and FE Models with 14-day incubation period

VARIABLES	(1) 14-day OLS	(2) 14-day FE	(3) 14-day OLS	(4) 14-day FE
Perimeter Confinement	0.000	-0.005***		
	(0.001)	(0.002)		
Hostelry and Commerce Restrictions	-0.001	-0.000		
	(0.001)	(0.001)		
Curfew	0.002	-0.003		
	(0.004)	(0.004)		
Mobility rate	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.001)	(0.000)	(0.000)
All Measures			-0.001	-0.002
			(0.001)	(0.002)
Constant	0.026***	0.031**	0.012***	0.012**
	(0.006)	(0.015)	(0.005)	(0.005)
Observations	114	114	114	114
Controls*	Yes	Yes	Yes	Yes
R-squared	0.617	0.713	0.010	0.015
Number of Regions		19		19

*Time trends, unemployment and physicians rates (the latter is dropped in panel data)

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

4.2 Discussion and Interpretation

The results from the regression analysis suggest that a 7-day incubation period is the best fitting model, in line with COVID-19 literature, by showing the greatest coefficients of determination in all specifications. On the other hand, the 14-day 'incubation' period should be interpreted differently. Previous research has identified time lags on the actual effectiveness of measures. As I mentioned earlier, it should not be considered a proper 'incubation' but a delay on the effectiveness. A report by the OECD (2020) o containment and mitigation policies has found that some measures can flatten the COVID-19 infection curve, but the effect can be no immediate. Some of the strategies that imply a delay on its effect are related to schools' closure. Therefore, when I explore the option of a longer delay o the effectiveness of the containment measures applied in Spain, the only measure that maintains a great degree of significance in panel data is perimeter closure. This could validate that depending on the type of measure the effectiveness might present a time lag. Thus, the debate on the adequacy of containment measures can be enriched by accounting the objective and time frame available.

The negative coefficient of mobility rate is counter-intuitive, not validating he initial hypothesis. One of the causes, mentioned in the regression analysis, is hat it might be capturing other variables. However, a possible explanation to the behaviour of the mobility rates in the models is that the only mobility considered is intra-regional, which I consider coherent given that during many months there exist a perimeter confinement. Thus, the variable might negative given that the vast majority of the displacements can be caused by labour reasons. This could be one possible explanation of the coefficient not being positive, but the negativity is probably generated by a confounding or reverse causality problem.

Moving into which containment measures that are effective, through the regressions shown above I found that the perimeter confinement has a more significant effect in a longer time frame. The coefficient of the curfew is negative but insignificant both in a linear regression and when accounting for regional fixed effects. Thus, it does seem surprising that in order to control the spread of COVID-19 during the summer of 2021, the government of autonomous regions has once more implemented a curfew. However, the perimeter confinement and mobility rates could indicate that the effectiveness of controlling COVID-19 registered cases could come from the limitations in long distance mobility. This result would support the finding from Jiang & Luo (2020), that determined that mobility was a major driver of COVID-19, but adding some evidence on the subject, since given the shown results not all types of mobility cause an increase of COVID-19 positive cases.

On the other hand, the combination of all possible measures that was tested though the variables ‘All measures’ consisting of the multiplication of the containment measures dummies, did not have a significant effect. In fact, the coefficients suffered a reduction compared to when the policies are regressed separately. I assume this is due to the behaviour of hostelry and commerce restriction, many autonomous regions did not apply severe restrictions in this ambit, thus the value of the dummy is equal to 0, resulting in a reduction of the estimated efficiency, implying that in this case ‘the more the merrier’ criteria is not accurate.

Therefore, the scrutiny and implementation of relevant and appropriate containment measures should be effectuated with consideration of the time frame available, which depends on the stage of the contagion curve of COVID-19. The planning and prevision of the future behaviour of the virus, of seasonal trends on infections is of major importance to implement looser containment measures that might have a less harmful economic impact.

4.3 Limitations

The lack of previous literature has been broadly reported through this paper. Despite the absence of preceding recent pandemics and therefore management experience, I consider that a tremendous limitation to the research is the scarcity of data. One major problem of the paper has been the various obstacles when looking for official and specific data. Moreover, the vast number of containment measures modification and the non-existence of an official resume of the implemented policies in Spain at a regional level, is a major impediment of research and has been a noticeable limitation to the development of this paper.

Besides, another limitation that this paper might face is reverse causality. In the case of policy evaluation, and specifically for COVID-19 containment policies, it is impossible to avoid simply a reverse causality problem, given the nature of containment policies. When COVID-19 registered cases are low, the less indispensable measures are. Therefore, it is undeniable that the presence of containment or mitigation policies surges from an increase in infected individuals. It was mentioned in the paper that the curfew, hostelry and commerce restriction ad the perimeter closure were applied in Spain and its autonomous regions when the registered COVID-19 cases were rapidly escalating. Nonetheless, it is also undeniable that the implementation of containment strategies by the autonomous governments has had the desirable effect expected. Therefore, the problem faced by the analysis could be considered of simultaneity, where the registered cases support the application of restriction policies and at the same time, the implementation causes variations on registered COVID-19 cases.

A set of variables were impossible to account given the lack of data. Firstly, COVID-19 contact trackers are a common strategy used that could be considered a containment measure in order to isolate people that were directly exposed to SARS-CoV-2, or as it is commonly known, a “close contact”. The Spanish government has used this method to track possible positive cases, but the data is not available at a regional level and could have bias the results of the paper.

Moreover, the vaccination process in Spain started by the end of December, that might produce a decrease on the spread of the virus. However, the vaccination started on population groups that are relatively small compared to the Spanish population. In addition, the vaccination rhythm was slower than in other countries, and mainly did not reach the whole pattern of vaccination for the first vaccinated groups during the analysed months due to logistic problems. Also, the case of Chile should be mentioned, since the Latin American country had one of the best vaccination rates but could not decrease the number of positive cases.

Multicollinearity is a problem that the selected containment measures could show. However, it is graphically tested through a dispersion graph, that this is not the case. The curfew was partially imposed to all the autonomous regions in the peninsula, but the islands and the autonomous cities in Africa did not necessary apply it. On the other hand, the perimeter closure was the most widely imposed measure, but hostelry and commerce limitations were inequivalent between regions and the first measures to be relaxed when the spread was partially controlled. Therefore, this data does not present multicollinearity signs.

Despite avoiding a possible multicollinearity problem, there exists a lack of comparability between containment measures. Curfew and perimeter closure are evident and straightforward to detect when applied. However, when it comes to hostelry and commerce limitations it is difficult to determine and to manage as a simple dummy. Therefore, a limitation to this paper and a possible future improvement would be to determine degrees on some containment measures. Some regions that have a 1 on hostelry restrictions could have looser or stricter limitations. This was partially treated as loosening restrictions was evaluated as dummy with value of 0, but it is still a petite disadvantage of the analysis.

5 Conclusion

The goal of this paper is to evaluate the effectiveness of the containment measures implemented in Spain during the second and third waves of COVID-19. The containment policies consisted of the application of a night curfew, perimeter confinement and hostelry and commerce restrictions. The Spanish situation during those months was alarming, due to the precedents of possible collapse of the health system, which occurred during the first wave of the pandemics. The legal possibility of the regional governments to apply and manage the containment measures applied in the various autonomous regions that conform Spain is exploited in this paper, in order to apply a panel data approach using fixed effects, considering the regions as individuals.

All the containment measures and their variations served to construct dummies, which were included in the regressions to observe if the initial hypothesis of a negative effect of containment policies on COVID-19 registered cases was valid. Through the regression analysis it is observed that a 7-day incubation period is the most accurate model to use, in line with the previous related literature. Moreover, it is shown that the effect of a curfew and hostelry and commerce restrictions are not significant in any of the estimated regressions. On the other hand, the perimeter confinement is only significant when using a panel data approach and gains significance when using a delay of the efficiency of the policy of 14 days. Even if 'all the measures' does not show the same behaviour, it has a negative coefficient as it was initially expected.

Nonetheless, the analysis of the paper has been limited by the availability of data as well as the lack of existence of official reports of applied measures. In addition, give that it is a recent evaluated scenario, there is not a vast literature. In an econometric ambit, there are simultaneity and confounding problems that are not simple to discern due to the nature of containment measures, which in many cases are not preventive but a cause of the increase in COVID-19 infections.

The paper contributes to the current debate on the adequacy of containment measures bringing to the fore a not very contemplated aspect of such policies, which is the time frame. Through the performed regression analysis, the difference in time effectiveness of the different types of measures noticeable. Moreover, the decrease of the coefficient when estimating a model with a variable that incorporates all the measures together, suggests that the efficacy in controlling the spread of COVID-19 comes from the analysis of independent strategies. Therefore, the adoption of containment measures should be carried out with special emphasis on the time frame and the objective to tackle. The effectiveness in the analysis was only measured through the influence of the policies on the registered cases, but there is a wide and broad path of for future research that will bring light to many of the questions that COVID-19 has left, as the inclusion of vaccines to the analysis, that will be useful to determine the best policies to control the spread of the pandemics.

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Appedix

Table A1: Autonomous Regions and ISO codes

ISO	Autonomous Region
AN	Andalusia
AR	Aragon
AS	Principality of Asturias
CB	Cantabria
CE	Ceuta
CL	Castile and León
CM	Castilla-La Mancha
CN	Canary Islands
CT	Catalonia
EX	Extremadura
GA	Galicia
IB	Balearic Islands
MC	Region of Murcia
MD	Community of Madrid
ML	Melilla
NC	Chartered Community of Navarre
PV	Basque Country
RI	La Rioja
VC	Valencian Community

Table A2: Containment Measures

CCAA	Date	Curfew	Perimeter clousure	Hostelry/Commerce
AN	oct-20	0	0	0
AN	nov-20	1	1	0
AN	dec-20	1	1	0
AN	jan-21	1	1	0
AN	feb-21	1	1	0
AN	mar-21	1	1	0
AR	oct-20	0	0	0
AR	nov-20	1	1	0
AR	dec-20	1	1	1
AR	jan-21	1	1	1
AR	feb-21	1	1	1
AR	mar-21	1	1	0
AS	oct-20	0	0	0
AS	nov-20	1	1	1
AS	dec-20	1	1	0
AS	jan-21	1	1	1
AS	feb-21	1	1	1
AS	mar-21	1	1	1
CB	oct-20	0	0	0
CB	nov-20	1	1	0
CB	dec-20	1	1	1
CB	jan-21	1	1	1
CB	feb-21	1	1	1
CB	mar-21	1	1	1
CL	oct-20	0	0	0
CL	nov-20	1	1	1
CL	dec-20	1	1	1
CL	jan-21	1	1	0
CL	feb-21	1	1	1
CL	mar-21	1	1	0

CCAA	Date	Curfew	Perimeter clousure	Hostelry/Commerce
CM	oct-20	0	0	0
CM	nov-20	1	1	0
CM	dec-20	1	1	1
CM	jan-21	1	1	0
CM	feb-21	1	1	1
CM	mar-21	1	1	1
CT	oct-20	0	0	0
CT	nov-20	1	1	1
CT	dec-20	1	1	1
CT	jan-21	1	1	1
CT	feb-21	1	1	1
CT	mar-21	1	1	0
NC	oct-20	0	0	0
NC	nov-20	1	1	1
NC	dec-20	1	1	0
NC	jan-21	1	1	1
NC	feb-21	1	1	0
NC	mar-21	1	1	0
VC	oct-20	0	0	0
VC	nov-20	1	1	0
VC	dec-20	1	1	1
VC	jan-21	1	1	1
VC	feb-21	1	1	1
VC	mar-21	1	1	0
EX	oct-20	0	0	0
EX	nov-20	1	0	0
EX	dec-20	1	0	0
EX	jan-21	1	0	1
EX	feb-21	1	0	1
EX	mar-21	1	0	0

CCAA	Date	Curfew	Perimeter clousure	Hostelry/Commerce
GA	oct-20	0	0	0
GA	nov-20	1	0	1
GA	dec-20	1	0	0
GA	jan-21	1	0	0
GA	feb-21	1	1	1
GA	mar-21	1	1	0
IB	oct-20	0	0	0
IB	nov-20	1	0	0
IB	dec-20	1	0	0
IB	jan-21	1	0	1
IB	feb-21	1	0	1
IB	mar-21	1	0	1
CN	oct-20	0	0	0
CN	nov-20	0	0	0
CN	dec-20	1	0	0
CN	jan-21	1	0	1
CN	feb-21	1	0	0
CN	mar-21	1	0	1
RI	oct-20	0	0	0
RI	nov-20	1	1	0
RI	dec-20	1	1	0
RI	jan-21	1	1	1
RI	feb-21	1	1	1
RI	mar-21	1	1	0
MD	oct-20	0	0	0
MD	nov-20	1	0	0
MD	dec-20	1	0	0
MD	jan-21	1	0	0
MD	feb-21	1	0	0
MD	mar-21	1	0	0

CCAA	Date	Curfew	Perimeter clousure	Hostelry/Commerce
MC	oct-20	0	0	0
MC	nov-20	1	1	1
MC	dec-20	1	1	1
MC	jan-21	1	1	0
MC	feb-21	1	1	0
MC	mar-21	1	1	0
PV	oct-20	0	0	0
PV	nov-20	1	1	1
PV	dec-20	1	1	1
PV	jan-21	1	1	0
PV	feb-21	1	1	0
PV	mar-21	1	1	0
CE	oct-20	0	0	0
CE	nov-20	1	1	0
CE	dec-20	1	1	0
CE	jan-21	1	1	0
CE	feb-21	1	1	0
CE	mar-21	1	1	0
ML	oct-20	0	0	0
ML	nov-20	1	1	0
ML	dec-20	1	1	0
ML	jan-21	1	1	0
ML	feb-21	1	1	0
ML	mar-21	1	1	1

Table A3: OLS models with various incubation periods

	(1)	(2)	(3)	(4)
VARIABLES	3-day	4-day	5-day	6-day
Perimeter Confinement	0.001	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Hostelry and Commerce Restrictions	-0.001	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Curfew	0.004	0.003	0.003	0.003
	(0.005)	(0.005)	(0.005)	(0.005)
Mobility rate	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Constant	0.027***	0.027***	0.027***	0.027***
	(0.007)	(0.007)	(0.007)	(0.007)
Observations	114	114	114	114
Controls*	Yes	Yes	Yes	Yes
R-squared	0.591	0.595	0.601	0.605

*Time trends, unemployment and physicians rates

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table A4: Panel data with FE models for various incubation periods

VARIABLES	(1) 3-day	(2) 4-day	(3) 5-day	(4) 6-day
Perimeter Confinement	-0.004**	-0.004**	-0.005**	-0.005**
	(0.002)	(0.002)	(0.002)	(0.002)
Hostelry and Commerce Restrictions	-0.001	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Curfew	-0.002	-0.002	-0.002	-0.003
	(0.005)	(0.005)	(0.005)	(0.004)
Mobility rate	-0.002***	-0.002**	-0.001**	-0.001**
	(0.001)	(0.001)	(0.001)	(0.001)
Constant	0.041**	0.040**	0.039**	0.039**
	(0.017)	(0.017)	(0.016)	(0.016)
Observations	114	114	114	114
Controls*	Yes	Yes	Yes	Yes
R-squared	0.682	0.687	0.692	0.698
Number of Regions	19	19	19	19

*Time trends and unemployment

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1