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Shutting down to save lives: A regression discontinuity analysis of non-essential business closure

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ABSTRACT

This article quantifies the impact of the non-essential business closure policy implemented in the Spanish region of Andalusia during the COVID-19 pandemic between January and May 2021. Taking advantage of the fact that municipalities were assigned a two-week closure of non-essential businesses on the basis of whether the 14-day infection rate (per 100,000 inhabitants) was above a predetermined cutoff value of 1,000, we use a regression discontinuity design to estimate the causal impact of the policy on new COVID-19 cases and deaths. Using weekly administrative data, the estimates suggest that, on average, the policy produced a 23 percent reduction in new COVID-19 cases and a 2 percent decrease in new COVID-19 deaths. Notably, the heterogeneity analysis reveals that the policy was more effective in rural areas than in urban areas. Overall, this study provides compelling evidence that shutting down businesses served as an effective tool to counter the COVID-19 pandemic.

1. Introduction

Since it first emerged in late 2019, the Coronavirus disease 2019 (COVID-19) pandemic has presented an unprecedented challenge to healthcare systems worldwide. The highly lethal and contagious nature of the virus, coupled with the initial absence of vaccines, compelled national governments to promptly implement extreme non-pharmaceutical interventions (NPIs) to slow the spread of the disease and reduce its impact on population health, including social distancing, mask mandates, travel restrictions, lockdowns, and non-essential business closures [1–4].[1] Given the ongoing debate about the efficacy of these NPIs, there is a profound need for empirical evidence to inform decisions about their use. This is particularly important for future pandemics and new COVID-19 variants, as understanding the effectiveness of NPIs in reducing infections and deaths can help guide policymakers in implementing effective and efficient responses to these outbreaks.[2]

This paper evaluates the effectiveness of one of the most widely implemented NPIs during the COVID-19: the non-essential businesses closure (NEBC). While it may seem intuitive that shutting down businesses would help to reduce the spread of the virus, there is a dearth of reliable estimates quantifying the population-level effects of this intervention. This is crucial from a policy perspective, given the significant economic and social costs associated with business closures.

In an ideal experiment, we would randomly assign certain municipalities to implement non-essential business closures, while allowing other similar municipalities to continue operations without interruption. The empirical design in this paper mimics this ideal experiment by examining the real-world implementation of the NEBC policy in the

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[1] While the primary objectives of these interventions were to reduce the spread of the virus and prevent unnecessary deaths, they had significant impacts on other outcomes, including the environment (Gao et al., 2022), mental health (Gaggero et al., 2022; García-Prado et al., 2022; Hyland et al., 2020; Serrano-Alarcón et al., 2022), subjective well-being (Cheng et al., 2020), domestic violence (Bullinger et al., 2021), substance use (Emery et al., 2021), unemployment (Fairlie et al., 2020), supply chains ([27]; Mosallanezhad et al., 2023), and healthcare system performance (Henriques & Gouveia, 2022; Mesnier et al., 2020).

[2] A recent editorial in The Lancet observed that the COVID-19 pandemic is ongoing (Lancet, 2023). Data from the World Health Organization (WHO) COVID-19 weekly epidemiological report for the week of 1 September 2023 (WHO, 2023) revealed a notable increase in new cases per 100,000 residents in countries within the Western Pacific Region, including China, Japan, and the Republic of Korea.

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Spanish region of Andalusia, beginning on 17 January 2021. This policy mandated a two-week shutdown of non-essential businesses in municipalities with a 14-day infection rate (per 100,000 inhabitants) above the cutoff of 1000. The empirical approach implemented here makes it possible to obtain reliable estimates of the NEBC policy's impact by comparing municipalities located just below and just above this predetermined cutoff in the framework of a regression discontinuity (RD) design.

Using weekly administrative data for the 785 municipalities that comprise the Spanish region of Andalusia from January to May 2021, our findings suggest that the NEBC policy significantly reduced new COVID-19 cases and deaths. Specifically, our RD estimates suggest that, on average, the policy led to a 23 percent reduction in new COVID-19 cases and a 2 percent decrease in new COVID-19 deaths. The heterogeneity analysis suggests that the policy was more effective in rural areas (municipalities with fewer than 5000 inhabitants) than in urban areas.

This paper contributes to the literature in two important ways. Firstly, this is the first study to examine the effectiveness of the NEBC policy in Spain, as well as one of the few to analyse this type of NPI in the literature [5].[3] Secondly, since governments often implemented packages of restrictions simultaneously, as opposed to one restriction at the time, prior research has struggled to isolate the impact of one specific intervention from pre-existing interventions [3,4,6]. By employing a regression discontinuity (RD), this study specifically isolates the impact of the NEBC by comparing municipalities identical in all aspects, including pre-existing interventions, and differing solely in the implementation of the NEBC policy.

The rest of the paper proceeds as follows. Section 2 provides a review of the literature; section 3 outlines the institutional setting; section 4 describes the data, variables, and empirical strategy, and section 5 reports the results. Sections 6 and 7 provide, respectively, the discussion and conclusion.

2. Literature review

Since governments first began implementing non-pharmaceutical interventions to control the spread of COVID-19, a substantial body of research has emerged aimed at evaluating their effectiveness [5,7]. The literature overwhelmingly reports significant positive effects of NPIs in reducing COVID-19 infections and deaths. For example, Alfano & Ercolano [8] analysed the role played by the lockdown policy using data from 202 countries around the world. They found that countries implementing lockdowns had significantly fewer COVID-19 cases than countries that did not. Similar results were found by Born et al. [9] and Orea & Álvarez [10] for the case of Sweden and Spain, respectively. Born et al. [9] estimated that if Sweden had implemented a 9-week lockdown during the first wave of COVID-19 pandemic, the number of infections and deaths would have been reduced by around 75 percent and 38 percent, respectively. Orea & Álvarez [10] observed that the lockdown implemented in Spain during the first wave of pandemic prevented around 600,000 COVID-19 infections.

Alfano [11] also investigated the effectiveness of school closures across Europe and found a positive impact, particularly 40 days after the intervention. Furthermore, Hansen & Mano [12] and Chernozhukov et al. [13] analysed the effect of state-wide mask mandates in the United States during the first wave of the pandemic, finding that mandating face masks seems to have reduced the rate of infections, hospital admissions, and deaths, potentially saving around 87,000 lives. The impact of night-time curfews was also analysed by Apel et al. [1], who found that when individuals were banned from leaving their homes between 9 p.m. and 5 a.m. in Hamburg between April and May 2021, nearly 3000 people avoided COVID-19 infection.

Our investigation parallels other studies that evaluated the impact of the non-essential business closure (NEBC) on the COVID-19 pandemic [4,6,14,15]. Song et al. [15] examine the extent to which being designated as an essential worker impacted one's risk of being diagnosed with COVID-19 in Pennsylvania. Using a difference-in-differences approach, they found that, as a result of the NEBC policy, essential workers were 55 percent more likely to be diagnosed with COVID-19 with respect to non-essential workers. Our article takes a more general approach compared to Song et al. [15] in that it studies the effects of the NEBC policy on overall COVID-19 cases and deaths (at the aggregate municipal level), rather than its effects on a specific category of workers.

Bongaerts et al. [6] and Ciminelli & Garcia-Mandicó [4] analysed the effectiveness of business closure during the first wave of the pandemic in Italy for a sample of over 2000 and 4000 municipalities, respectively, finding a clear positive effect, with business closures preventing an estimated 9500 [6] and 78,000 [4] deaths. In the United States, Courtemanche et al. (2020) found that the closure of restaurant dining rooms, bars, and entertainment centres significantly reduced the growth rate of COVID-19 cases in 3138 counties from 1 March 2020 to 27 April 2020. All these studies suggest a positive effect of NEBC policies on COVID-19 cases and deaths. However, since business closures were mandated simultaneously across the entire country in these studies, they face a potential limitation in that there is no true control group against which to compare [4]. Our article is the first study that identifies a reliable control group to be used as a counterfactual outcome in the absence of the policy.[4]

3. Institutional setting

The Spanish central government imposed a state of alarm on 14 March 2020, a mere three days after the World Health Organization declared COVID-19 a global pandemic (BOE, 2020a). This declaration imposed stringent nationwide restrictions, including stay-at-home orders, school and business closures, mandatory mask usage, and the suspension of non-essential businesses. The first state of alarm ended in June, when a significant decline in infections and deaths was observed. A second state of alarm was enacted on 25 October 2020, due to a resurgence of infections and worsening epidemiological indicators (BOE, 2020b). In this instance, the management of the pandemic was delegated to the regional governments (Angelici et al., 2023), which were granted the authority to implement a range of restrictions, including curfews, school closures, and regional, provincial, and municipal lockdowns.

From 25 October 2020 to 9 May 2021, the Andalusian government had to handle two distinct COVID-19 waves. During the first, from October to December 2020, the government established a curfew from 11 p.m. to 6 a.m., limited gatherings to a maximum of six people, and

[3] In their systematic review of empirical studies on NPIs, Mendez-Brito et al. (2021) discovered that out of the 34 studies found, only six examined the effectiveness of closing businesses or venues on variables like the COVID-19 reproduction number, incidence, and mortality rates. Most of them focused on measuring the impact of school closings, lockdowns, or social gathering restrictions.

[4] Despite the positive effects reported by these authors, recent studies suggest that NEBC policies might not be the most effective NPIs. After analysing several NPIs in 41 countries during the first wave of the pandemic, Brauner et al. [2] suggest that the closure of face-to-face businesses such as restaurants, bars, and nightclubs, as well as other non-essential businesses delivering personal services were not the most effective measures in reducing COVID-19 transmission. Instead, limiting the number of people in gatherings or closing schools and universities appear to have been more effective. Similar conclusions were also reached by other authors, including Banholzer et al. (2021), Dreher et al. (2021), and Hunter et al. (2021). Other studies suggest that a combination of NPIs could be the most appropriate way to more effectively reduce the COVID-19 reproduction number [25,28].

restricted mobility, prohibiting movement across municipalities. These restrictions were applied uniformly across the region (except for a temporary relaxation during the Christmas holidays).

In response to a post- Christmas surge in COVID-19 cases and fatalities,[5] coupled with the absence of widespread vaccination,[6] on 17 January 2021, the government not only reintroduced the previous restrictions, but also included the closure of non-essential businesses. Notably, this closure was not uniformly applied throughout the region, but was contingent on each municipality's epidemiological status. Specifically, municipalities with a 14-day infection rate exceeding 1000 cases per 100,000 inhabitants were mandated to close non-essential businesses for two weeks.[7] This policy, referred to as the non-essential business closure (NEBC), remained in effect until 14 May 2021.

Table 1 presents a summary of the NEBC policy. The Table shows that while the policy applied only to municipalities that exceeded the infection rate cutoff, a set of pre-existing limitations were in place in all the municipalities. This is a crucial component for the identification strategy used in this study; by comparing municipalities just above and below the cutoff, which are identical in every aspect – including pre-existing mobility limitations like curfews, restrictions on places of worship, and group size constraints – it is possible to isolate the impact of the NEBC policy.

4. Methods

4.1. Data

The study uses administrative data provided by the Institute of Statistics and Cartography of Andalusia (ISCA) in conjunction with the Health and Consumption Department of Andalusia data related to the COVID-19 situation in the region.[8] Our dataset includes weekly data for every Friday from 15 January to 7 May 2021, spanning 17 weeks and covering all 785 municipalities in the region of Andalusia. After removing missing data, the final sample comprises 13,242 observations. This comprehensive dataset provides detailed information for each municipality on the following key metrics: (1) the accumulated number of confirmed COVID-19 cases after 26 February 2020; (2) the accumulated number of confirmed COVID-19 deaths after 26 February 2020; and (3) the 14-day infection rate per 100,000 inhabitants.[9]

The 14-day infection rate is calculated by dividing the accumulated number of confirmed COVID-19 cases in the preceding 14 days by the population in the municipality and multiplying this by 100,000 to express the number per 100,000 inhabitants.[10] This study considers a person infected or deceased from COVID-19 if this condition was confirmed by a positive polymerase chain reaction (PCR) or rapid antigen test.[11]

Fig. 1 shows a map illustrating the municipalities within Andalusia as of 17 January 2021 that uses colour-coded markers to distinguish between the municipalities based on two key criteria: the 14-day infection rate (per 100,000 inhabitants) and the population size. For the 14-day infection rate, municipalities are categorized as either above or below the cutoff of 1000 cases per 100,000 inhabitants, with white depicting 'below' and red 'above'. The population size is also categorized as above or below 5000 inhabitants, with a larger marker size designating 'above' and a smaller 'below'.

Table 2 shows the descriptive statistics for the sample of interest.[12] Column 1 provides statistics for the entire sample, while Columns 2 and 3 distinguish between municipalities with infection rates below and above the cutoff point of 1,000, respectively. The Table reveals that, on average, each municipality recorded approximately 600 new weekly COVID-19 cases, with an average of 10 COVID-19 deaths. At the height of the pandemic, the maximum number of deaths reached 744. The average 14-day infection rate stands at 356 cases per 100,000 inhabitants, and the mean population size is approximately 10,730 residents.

Table 1
COVID-19 restrictions in Andalusian municipalities, by infection rate.

Restrictions implemented:	14-day infection rate	
	$< 1,000$	$\geq 1,000$
NEBC policy	No	Yes
Curfew	Yes	Yes
Place of worship restrictions	Yes	Yes
Group restrictions	Yes	Yes
Regional lockdown	Yes	Yes
Provincial lockdowns	Yes	Yes
Schedule restrictions	Yes	Yes
Municipal lockdown	Yes	Yes

4.2. Econometric model

This study employs a regression discontinuity (RD) design to estimate the impact of the NEBC policy on COVID-19 cases and deaths. This method, first introduced by Thistlethwaite & Campbell [16], has since become one of the most credible non-experimental approaches for the analysis of causal effects in observational settings [17]. In the RD design, all units have a running variable, and treatment is assigned to those units with a value of the running variable exceeding a specific cutoff point. The key feature of the design is the sudden change in the probability of receiving treatment at the known cutoff value of the running variable. This characteristic effectively emulates a randomized evaluation, as units near the cutoff value can be considered as receiving treatment almost randomly.

The RD design is perfectly suited for our context. Each municipality has a 14-day infection rate (the running variable), and only those exceeding the predetermined cutoff value of 1000 were assigned to the NEBC policy (the treatment group). Accordingly, thanks to the discontinuous change in the probability of being assigned to the NEBC policy, the (local) causal effect can be gauged by using municipalities with a

[5] The SARS-CoV-2 variant during the study period was B.1.1.7. This variant, which emerged from London (England), was characterized by its higher transmissibility, but was effectively controlled using the Moderna and Pfizer-BioTech vaccines (CMAJ, 2021).

[6] Spain initiated the first stage of its vaccination campaign in January 2021, prioritizing high-risk groups, particularly the elderly and healthcare workers. The first vaccines used were Pfizer-BioNTech and Moderna. By the end of the study period, the AstraZeneca and Janssen vaccines had also become available. As of 14 May 2021, approximately 1 million people (14.4 % of the population) had received the full vaccination course.

[7] The selection of the 14-day infection rate cutoff of 1,000, as determined by regional health authorities, aligns with established public health guidelines that identify a high level of virus transmission necessitating immediate and stringent measures. It is noteworthy, however, that this cutoff inherently carries an element of arbitrariness. In our study, we deliberately leverage the arbitrary nature of this cutoff point as a methodological advantage via a regression discontinuity design.

[8] Appendix A2 provides an extensive description of Spain and the region of Andalusia and their policy backgrounds.

[9] For the municipalities in the province of Málaga, there is no information for the week of 5 March 2021. Therefore, this study only includes 16 weeks' data for the municipalities in this province.

[10] The term 'infection rate' may create confusion, as it is not a rate in the traditional sense, but rather a measure of COVID-19 cases standardized by population size.

[11] Although we use the official variable provided by the ISCA, we confirmed the accuracy of our results by independently creating the 14-day infection rate variable.

[12] Table A3 in Appendix A1 presents the statistics for the entire sample (from 30 October 2020 to 7 May 2021) and Table A4 shows the statistics by province.

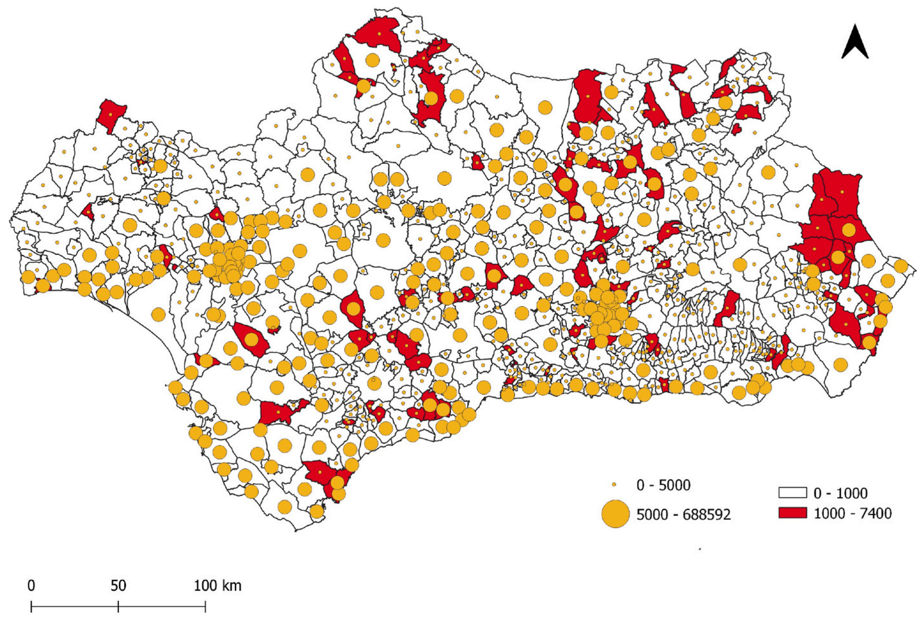

Fig. 1. Map of Andalusia.

Table 2
Summary statistics.

	(1)	(2)	(3)
		14-day infection rate	
	Overall	< 1000	≥ 1000
Total COVID-19 cases	600.88	604.83	584.19
	(2203.073)	(2282.560)	(1829.280)
Total COVID-19 deaths	10.51	10.75	9.50
	(40.477)	(42.092)	(32.765)
14-day infection rate (per 100,000 inhabitants)	356.54	220.21	1759.53
	(579.451)	(249.528)	(995.683)
Population	10731.67	10835.66	10297.75
	(39494.738)	(41099.609)	(31942.825)
No. of Municipalities	115.87	120.09	98.25
	(37.640)	(37.370)	(33.420)
Observations	13242	10682	2560

Note: The table shows the summary statistics of the main variables of interest.

running variable score just below the cutoff as counterfactuals for those with a score barely above it.[13]

Formally, let $Z_{i,t}$ be the running variable which identifies the 14-day infection rate for municipality *i* at time *t*. The cutoff point of interest is set as $z_0 = 1,000$, since municipalities with a 14-day infection rate greater than, or equal to, 1000 were assigned to the NEBC policy. Finally, let the treatment variable, denoted $P_{i,t}$, take the value of one for municipalities with an infection rate greater than 1000 and hence assigned to the NEBC policy, namely $P_{i,t} = 1[Z_{i,t} \geq z_0]$. In this study, since the NEBC policy was strictly assigned on the basis of the 14-day infection rate, the simplest version of an RD design, the sharp design, is used.[14] Following Hahn et al. [18], a regression framework for a sharp RD design is as follows:

$$Y_i = \alpha + \beta P_{i,t} + \varphi g(Z_{i,t}) + \delta P_{i,t} \bullet g(Z_{i,t}) + \boldsymbol{X}_{i,t}^{'}\gamma + \varepsilon_{i,t} \quad (1)$$

Here, Y_i is the outcome of interest, namely the log of new COVID-19 infections and deaths, enabling the coefficients to be interpreted in terms of percentage change.[15] As described above, $P_{i,t}$ is the treatment dummy variable, taking the value of one for municipalities assigned to the NEBC policy, and $Z_{i,t}$ the running variable. The function $g(.)$ is a polynomial of the running variable. Following the recommendations of Gelman and Imbens (2018), a quadratic function of the running variable is used in the baseline specification. Additionally, an interaction term is included in the baseline model between the policy indicator and the running variable, to allow the function to have different slopes at the two sides of the cutoff, which is a standard assumption in RD design. X_i is a vector of control variables, namely, date, province, and municipality fixed effects (FE), and γ is the vector of associated coefficients. Notably, the inclusion of municipality fixed effects in the model strengthens its ability to capture unobserved heterogeneity at the municipality level. Finally, $\varepsilon_{i,t}$ is a random disturbance. β is the main parameter of interest, which represents the effect of NEBC policy around the cutoff point.[16] Standard errors are clustered on the running variable as per Lee & Card [19].[17]

[13] Specifically, upon reaching or surpassing this infection rate, a municipality is designated a 'treatment' group for a period of two weeks. After this period, the municipality's treatment status is re-evaluated. This re-evaluation is based on the latest infection rate data: if the rate remains at or above the 1000-case threshold, the municipality continues to be classified as under treatment and undergoes another two-week lockdown. Conversely, if the infection rate falls below this threshold, the municipality reverts to 'control' status and the lockdown measures are lifted.

[14] Alternatively, in the fuzzy design, the probability of receiving the treatment is known to be discontinuous in the cutoff point, but not in a deterministic way.

[15] R0, or the basic reproduction number, is the standard metric for monitoring the spread of an infectious disease such as COVID-19 [27,29]. However, due to the lack of specific epidemiological data required for its calculation, we were unable to incorporate it into our analysis.

[16] Our analysis is based on weekly data, collected each Friday. However, there is a possibility that the NEBC status of the municipalities changed during the week, which could lead to the misclassification of the actual treatment status. As a result, our presented results should be interpreted as intention-to-treat estimates of the NEBC policy. This means that our estimates represent the effect of the policy assignment rule, rather than the effect of the actual non-essential business closure.

[17] Following Kolesár & Rothe [30], we also estimate our models using Eicker-Huber-White (EHW) heteroskedasticity-robust standard errors. These are recommended when the number of support points around the cutoff is sufficiently large and are based on a smaller bandwidth. The results are very similar.

5. Results

5.1. Primary results

We first examine the effect of the NEBC policy on new COVID-19 cases and deaths using a graph. Fig. 2 presents clear evidence of a discontinuity at the predetermined cutoff point of the running variable, both on COVID-19 cases and deaths. Specifically, the plots indicate that municipalities with a 14-day infection rate just above the 1000 cutoff, and hence assigned to the NEBC, show a reduction in new COVID-19 cases and deaths relative to their counterparts just below the cutoff. We next test the statistical significance of these findings in a regression framework while controlling for a number of potential confounding factors, as described above.

Table 3 presents the main findings of this paper, along with the robustness of the results across various specifications. Column 1 provides the basic RD specification, which includes only the running variable and the interaction term between the policy indicator and the running variable as covariates. Column 2 includes time fixed effects (FE), namely a complete set of weekly dummies. Column 3 includes province fixed effects to account for time-invariant characteristics at the provincial level. Finally, Column 4 presents our preferred specification, which also includes municipality fixed effects to address unobserved heterogeneity at the municipality level. The results are presented in two panels: Panel A provides RD estimates of the impact of the NEBC policy on COVID-19 cases, while Panel B focuses on the impact on COVID-19 deaths.

The results in Panel A show that the NEBC policy had a statistically significant and positive effect on reducing the COVID-19 case rate. Specifically, the estimated coefficient in Column 4, our preferred specification, implies that, on average, municipalities assigned a two-week closure of non-essential businesses experienced a roughly 23 percent reduction in new COVID-19 cases. While the adjusted R-squared increases considerably, the average effect remains positive and relatively stable. Similarly, the estimates in Panel B suggest a significant and beneficial effect of the NEBC policy on COVID-19 deaths. Specifically, the estimated coefficient in Column 4 suggests that, on average, municipalities assigned a two-week closure of non-essential businesses experienced roughly a 2.5 percent reduction in new COVID-19 deaths relative to their counterparts.

To strengthen the validity of these findings, Table A3, the Appendix, presents the results obtained by estimating the RD design when employing different polynomial orders of the running variable, ranging from a polynomial of order 1 (Column 1) to a polynomial of order 4 (Column 4). Overall, the RD estimates confirm the findings in Fig. 2 and provide evidence of the significant and positive effects of the NEBC policy on reducing COVID-19 cases and deaths.

In order to better understand the condition under which policy effects are strongest, heterogeneous effects were investigated to explore whether, and to what extent, the estimated impact of the NEBC policy differed by population size. To that end, we divide the municipalities into two groups: 1) urban areas (municipalities with more than 5000 inhabitants), and 2) rural areas (municipalities with fewer than 5000 inhabitants).[18] The results of this analysis are presented in Table 4. Interestingly, the RD estimates report that the effects of the NEBC policy are stronger in rural areas than in urban areas. Specifically, a two-week closure of non-essential businesses in rural municipalities led to a reduction in new COVID-19 cases of roughly 30 percent, compared to an 18 percent reduction in urban municipalities. Similarly, with respect to COVID deaths, a two-week closure of non-essential businesses in rural municipalities led to a reduction of new COVID-19 deaths of roughly 6 percent, while the same number for municipalities in urban areas is not statistically different from zero.[19]

5.2. Validity and sensitivity checks

The main threat to identification is the possibility of manipulation of the running variable McCrary [20]. In our context, this would mean that a municipality finely manipulated its 14-day infection rate in order to narrowly avoid non-essential business closures. Theoretically, this is plausible because the NEBC threshold is publicly known, and a municipality could potentially find a way to manipulate the 14-day infection rate. However, such manipulation is highly unlikely in this case, as the infection rate data were collected and reported by independent health authorities, not by the municipalities themselves. In order to test for this threat, a manipulation testing procedure proposed by McCrary [20] and Cattaneo et al. [21] was performed, specifically designed to check for discontinuities in the density of the running variable (in our case, the 14-day infection rate) around the cutoff. Fig. 3 presents the results of this test and does not reveal any significant discontinuity in the density of the running variable at the cutoff (discontinuity size: 0.347; p-value: 0.728).

Additionally, in order to dispel any potential concerns about municipalities sorting around the running variable, we implement the donut hole approach suggested by Barreca et al. [22]. The main idea behind this approach is that the municipalities closest to the cutoff are most likely to have engaged in manipulation. Consequently, excluding such municipalities from the analysis would eliminate any potential concern. Table 5 reports the RD estimates of the NEBC policy on new COVID-19 cases and deaths, excluding municipalities with a 14-day infection rate of 5, 10, and 20 points around the cutoff. These ranges were selected to create donut holes of varying sizes, making it possible to test the sensitivity of the results to the exclusion of municipalities immediately adjacent to the threshold. Table 5 confirms the validity of our approach, showing that the results are virtually unchanged when municipalities nearest to the cutoff are excluded.

Lastly, the study includes a falsification test that employs placebo cutoffs to validate the estimated effects of the intervention. This test involves selecting arbitrary cutoff points, distinct from the actual cutoff, and analysing them as if they were the true intervention points. The aim of examining the outcomes at these placebo cutoffs is to determine if there are systematic differences in the outcome variable where no real intervention occurred. The absence of significant effects at these placebo points serves as a strong indicator of the validity of the findings, confirming that the observed effects are, indeed, due to the intervention and not to other factors.

In this case, we employed a randomized inference approach and performed a thorough analysis by randomly selecting placebo cutoffs ranging from 100 to 700, a range indicative of the municipalities likely unaffected by the policy. This approach was repeated 10,000 times. For each placebo cutoff, coefficients and standard errors were estimated and compiled to assess the distribution and significance across all the cutoffs. The results presented in Fig. 4 show that the coefficients at each randomly chosen cutoff do not significantly deviate from zero. This outcome corroborates the absence of significant effects in untreated municipalities, reinforcing the genuine causal effect at the true cutoff

[18] Different approaches exist to classify a municipality as urban or rural. We have followed the approach of the Ministry of Agriculture, Fisheries, and Food, which designates municipalities with fewer than 5000 inhabitants in its 2020 demographic report of the rural population as 'rural' (MAFF, 2021). Following this, 67 percent of Andalusian municipalities (527 out of 785) would be considered rural, comprising around 900,000 inhabitants.

[19] The results are robust when choosing different definitions for rural and urban areas.

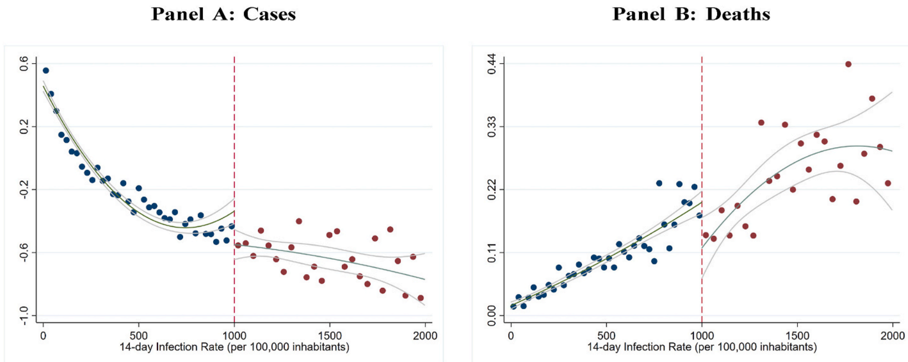

Fig. 2. Graphical evidence: Effect of NEBC policy on COVID-19 cases and deaths.

Table 3
RD estimates of NEBC policy on COVID-19 cases and deaths.

	(1)	(2)	(3)	(4)
Panel A: COVID-19 cases				
NEBC policy [0,1]	−0.186***	−0.178***	−0.178***	−0.233***
	(0.050)	(0.049)	(0.049)	(0.053)
$P_{i,t} \cdot Z_{i,t}$	✓	✓	✓	✓
Time FE		✓	✓	✓
Province FE				✓
Municipality FE				✓
Observations:	5840	5840	5840	5799
Adjusted R^2:	0.245	0.305	0.307	0.316
Panel B: COVID-19 deaths				
NEBC policy [0,1]	−0.029*	−0.030*	−0.029*	−0.026*
	(0.016)	(0.016)	(0.016)	(0.016)
$P_{i,t} \cdot Z_{i,t}$	✓	✓	✓	✓
Time FE		✓	✓	✓
Province FE				✓
Municipality FE				✓
Observations:	7207	7207	7207	7204
Adjusted R^2:	0.119	0.140	0.144	0.207

Note: The table shows RD estimates of NEBC Policy. Panels A and B present RD estimates of NEBC policy on COVID-19 cases and deaths respectively. Key regressor: NEBC policy [0 1]. This is a dummy variable for whether a municipality has a 14-day infection rate (per 10000 inhabitants) greater than 1000. Column (1) provides the basic RD specification which includes only the running variable and the interaction term between the policy indicator and the running variable as covariates. Column (2) includes time fixed effects (FE) a complete set of weekly dummies. Column (3) includes province fixed effects to account for time-invariant characteristics at the provincial level. Column (4) presents the preferred specification which includes municipality fixed effects to address unobserved heterogeneity at the municipality level. Robust standard errors are clustered on the running variable. *$p < 0.1$ **$p < 0.05$ ***$p < 0.01$.

point in the findings.[20]

6. Discussion

This study analyses the impact of the NEBC policy implemented in Andalusia, Spain from 17 January 2021 on new COVID-19 cases and deaths. We carry out a municipal level analysis by using ISCA data and applying a regression discontinuity approach. The findings indicate that the policy effectively reduced the number of new COVID-19 cases and deaths by 23 percent and 2.5 percent, respectively. These findings are consistent with previous estimates on the impact of business shutdown policies in other published studies. The heterogeneity analysis found that the population size of the municipality is relevant when guaranteeing the effectiveness of the policy. In this case, the NEBC policy was more effective in rural (municipalities with fewer than 5000 inhabitants) than urban areas, both in the reduction of the number of COVID-19 cases (30 percent in rural areas versus 18 percent in urban areas) and COVID-19 deaths (6 percent in rural areas and not statistically significant in urban areas).

[20] Another effective falsification test would be the application of the regression discontinuity (RD) design model to the Spanish municipalities that, during this time period, did not implement the NEBC policy at the cutoff of 1000. However, due to data limitations, this test could not be performed.

Table 4
RD estimates of NEBC policy - heterogeneity analysis.

	Rural Areas		Urban Areas	
	(1)	(2)	(3)	(4)
	COVID-19 cases	COVID-19 deaths	COVID-19 cases	COVID-19 deaths
NEBC policy [0,1]	−0.291***	−0.063***	−0.177***	−0.028
	(0.082)	(0.024)	(0.055)	(0.023)
Observations	3063	4063	2736	3141

Note: The table presents RD estimates of NEBC policy on COVID-19 cases and deaths respectively. Key regressor: NEBC policy [0 1]. This is a dummy variable for whether a municipality has a 14-day infection rate (per 10,000 inhabitants) greater than 1000. Columns (1) and (2) report RD estimates for the sample of municipalities with fewer than 5000 inhabitants (rural areas) whereas Columns (3) and (4) report RD estimates for municipalities with more than 5000 inhabitants. Each specification controls for the set of covariates as described in Section 4.2. Robust standard errors are clustered on the running variable. *$p < 0.1$ **$p < 0.05$ ***$p < 0.01$.

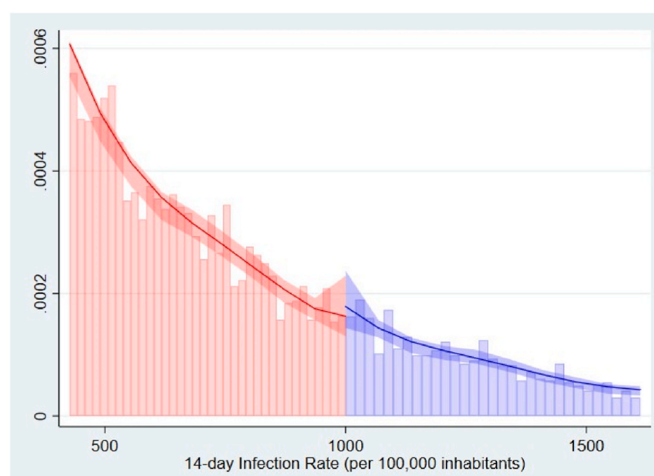

Fig. 3. Manipulation test.

Table 5
RD estimates of NEBC policy - donut approach.

	COVID-19 cases			COVID-19 deaths		
	(1)	(2)	(3)	(4)	(5)	(6)
	Donut	Donut	Donut	Donut	Donut	Donut
	5	10	20	5	10	20
NEBC policy [0,1]	−0.236*** (0.054)	−0.244*** (0.054)	−0.276*** (0.056)	−0.029* (0.016)	−0.027* (0.016)	−0.028* (0.017)
Observations	5786	5775	5749	7193	7181	7155

Note: The table reports RD estimates of NEBC policy on COVID-19 cases and deaths respectively. Key regressor: NEBC policy [0 1]. This is a dummy variable for whether a municipality has a 14-day infection rate (per 10000 inhabitants) greater than 1000. Each specification controls for the set of covariates as described in Section 4.2. Robust standard errors are clustered on the running variable. *$p < 0.1$ **$p < 0.05$ ***$p < 0.01$.

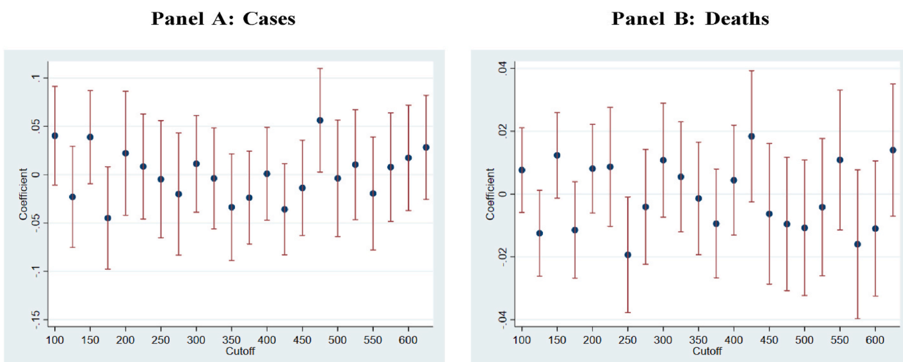

Fig. 4. Falsification test results: Estimated effects by cutoffs.

The effectiveness of this policy most likely results from minimizing the exposure of people to SARS-CoV-2. The closure of the non-essential businesses prevented physical contact with both people and things as well as the air transmission of the virus, thereby reducing the risk of COVID-19 infection and, consequently, death. The closures also reduced the risk of intrahousehold transmission. This hypothesis contrasts with the study by Song et al. [15] in Pennsylvania, which observed that implementation of the (NEBC) policy reduced the likelihood of testing positive for COVID-19 for workers in businesses designated as non-essential, compared with workers in essential jobs. In the case of the NEBC policy implemented in Andalusia, the main non-essential businesses affected by the intervention were related to the hostelry (hotels, hostels, inns, bed and breakfasts, camps), catering (bars, restaurants, nightclubs), and sports (gyms, sports facilities) sectors with a high risk of superspreading events, given the elevated level of close physical contact in crowded and/or poorly ventilated spaces [23]. As these types of businesses make up a high ratio of the Andalusian economy, the NEBC policy quite likely reduced new COVID-19 cases and deaths.

The differences observed in the impact of the NEBC policy between rural and urban areas can be attributed to several factors. Urban areas typically have higher population densities, leading to more frequent and close contact interactions, which are conducive to the spread of COVID-19. This increased interaction could dilute the impact of non-essential business closures. Rural areas, with lower population densities and less frequent social interactions, experience more pronounced effects from such closures, as there are inherently fewer opportunities for virus transmission. Additionally, the nature and scale of businesses in rural areas can differ significantly from those in urban settings, potentially making closures more effective in reducing contact rates. Rural areas can also have different patterns of compliance and mobility, which could further influence the effectiveness of the NEBC policy in reducing COVID-19 cases and deaths.

However, while our findings indicate the effectiveness of the NEBC policy in reducing COVID-19 cases and deaths, it may have had a substantial negative impact on the economy and overall welfare. Specifically, the mandatory closure of non-essential businesses could have led to significant income loss, limiting economic potential and possibly obstructing business reopening post-policy. Such economic constraints might have also had adverse effects on mental health and life satisfaction, as seen in studies of similar non-pharmaceutical interventions elsewhere (García-Prado et al., 2022; Serrano-Alarcón et al., 2022). Although studies specifically evaluating the NEBC policy's effects on these aspects are lacking, data from the Economic Observatory of Andalusia report a 4.3 percent interannual decline in Andalusian GDP during this period. Additionally, a reduction in the labour force impeded the full recovery of jobs lost during the first COVID-19 wave in 2020 (OEA, 2021).

This study is not without limitations. Firstly, while the findings indicate a positive impact of the NEBC policy on controlling COVID-19 cases and deaths, the study does not differentiate between the direct effects of reduced virus transmission and potential indirect effects, such as increased mortality from other causes related to the policy. The unavailability of detailed data on all-cause mortality at the municipality level precludes this level of analysis. Future research with access to more granular data will be able to address this gap.[21]

Secondly, our analysis is based on weekly data, which may not accurately capture the dynamic nature of policy implementation, especially if the status of municipalities regarding non-essential business closures changed during the week. While some municipalities were identified as controls, they might have been subject to the NEBC policy, leading to potential misclassification. To mitigate this possibility, we conducted sensitivity analyses and robustness checks, which, despite their effectiveness, cannot fully account for these unobserved changes.

[21] We acknowledge the importance of considering mobility data when assessing the impact of the NEBC policy. Unfortunately, we could not find mobility data at the municipal level, which is the level of granularity required for our analysis.

Furthermore, while the internal validity of the study is robust, its external validity is limited. The data represents only a single region of Spain, making it potentially non-representative of other regions with different characteristics. Additionally, the findings are specific to municipalities with a 14-day infection rate of around 1000 and may not apply to areas with different epidemiological contexts. Moreover, our analysis does not distinguish between the direct effects of reduced virus transmission and potential indirect effects, like increased mortality from other causes related to the policy, due to data constraints.

An additional limitation is the potential for delayed effects, especially regarding mortality outcomes. The nature of the disease, including its incubation period and the progression to severe cases, suggests a temporal lag between intervention implementation and observable impacts on death rates. This limitation underlines the importance of future research aimed at unraveling the complex temporal dynamics between public health interventions and their varied effects over time.

Lastly, the significant discrepancy between the reduction in COVID-19 cases and deaths within our study merits further discussion. This observation is consistent with the findings of Flaxman et al. [24], Haug et al. [25], Islam et al. [26] and Hansen & Mano [12], which suggest that a combination of factors—including increased testing and reporting, advancements in treatments, and shifts in the demographics of the infected population—may account for such disparities. Specifically, the pandemic's evolution led to significant demographic changes, particularly as earlier waves disproportionately impacted the most vulnerable groups. By the time of the third wave in January 2021, these shifts likely played a crucial role in shaping the outcomes we observed. The alignment of our findings with these studies underscores the complexity of assessing public health interventions' impacts, highlighting the need to consider the multifaceted influences on case and death statistics over time.

7. Conclusion

This study is one of the few that reliably quantifies the role played by the non-essential business closure policies to reduce the number of new COVID-19 cases and deaths. To that end, we specifically assessed the policy implemented at the municipal level in Andalusia, Spain, during the third wave of the pandemic starting on 17 January 2021. The design of this policy made it possible to isolate the influence of other interventions on our variables of interest and obtain causal estimates by means of a regression discontinuity approach.

These results advocate for the strategic use of NEBC policies. They provide evidence for policymakers, that closing non-essential businesses during a pandemic can be an effective way to prevent new infections and deaths, especially when vaccines or medicines are unavailable. However, they also emphasize the need for a targeted approach that considers regional and socioeconomic characteristics. In this respect, our findings suggest the need to distinguish between rural and urban areas when applying NEBC policies. Given the lower impact of the policy in reducing both infections and deaths in urban areas, it could be useful to apply more restrictions in these zones in order to better contain the virus.

Our analysis highlights how the effectiveness of the Andalusian NEBC policy varied depending on the population size of the municipality where it was implemented. However, due to the lack of municipal-level data, it was not possible to investigate this issue further. Future research should focus on identifying the mechanisms that underlie the differential impact of NEBC policies in rural and urban areas, a crucial consideration for effective policymaking. This entails exploring why rural areas, as indicated by our study, show limited responsiveness to such policies, possibly due to factors like lower population density, unique social interaction patterns, and distinct economic and business structures. At the same time, it is essential to understand the factors that contribute to the higher effectiveness of these policies in urban settings, such as higher population density and different social dynamics. Investigating these variances through detailed case studies, considering elements like community mobility, healthcare accessibility, and policy compliance, will provide critical insights for the future.

Declarations of competing interest

None.

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CRediT authorship contribution statement

Alessio Gaggero: Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Ángela Mesa-Pedrazas:** Data curation, Visualization. **Ángel Fernández-Pérez:** Conceptualization, Data curation, Funding acquisition, Methodology, Writing – original draft, Writing – review & editing.

Data availability

Data will be made available on request.

Appendix: Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.seps.2024.101925.

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