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# THE COVID-19 GREEN CERTIFICATE'S EFFECT ON VACCINE UPTAKE IN ITALIAN REGIONS

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*The views expressed in the articles are those of the authors and do not involve the responsibility of the department.*

**Abstract**

The COVID-19 green certificates were introduced in many countries in 2021 to encourage vaccine uptake in order to limit severe symptoms and deaths from COVID-19. This study uses a single-group interrupted time series approach to examine the effect of the green certificate announcement on the first doses oftheCOVID-19 vaccine in 20 Italian regions during the summer of 2021. The estimation results show that the announcement caused a significant immediate increase in the first doses in most of the Italian regions. These results remain robust to a structural breaks analysis for the regions of Friuli-Venezia Giulia and Sicily, which had a share of unvaccinated people below the national average. For these regions, the announcement of the certificate mandate incentivized hesitant individuals to get vaccinated immediately. There were regions, like Lazio, Puglia and Sardinia, which were unaffected by the announcement, most likely because they already had high rates of first-dose COVID-19 vaccination.

**JEL Class.:** H11, H12, I18.

**Keywords:** COVID-19 green pass, COVID-19 vaccine, announcement effect, single-group ITSA, Italian regions.

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# The COVID-19 Green Certificate's Effect on Vaccine Uptake in Italian Regions

*Raffaella Santolini*

## 1 Introduction

In response to the coronavirus disease 2019 (COVID-19) pandemic, caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), many countries have adopted the COVID-19 green certificate to guarantee their citizens the ability to travel and move across territories safely. The certificate is a digital or paper document issued to people who satisfy one of the following health statuses: *i)* vaccinated against COVID-19; *ii)* with a negative test for the SARS-CoV-2 virus; *iii)* with a recovery certificate due to a recent natural infection revealed by a positive molecular or antigen test.

In Italy, the green certificate, known as the "basic green pass", was introduced in April 2021 in order to guarantee free movement of people across regions classified as being at medium and high risk of SARS-CoV-2 infection. Over time, the Italian government extended its use for access to many activities (including work) and its period of validity among vaccinated people. This created a strong incentive to get vaccinated, especially for young people and men, who recorded low COVID-19 vaccination rates because they perceived a lower risk of contracting severe symptoms from the COVID-19 disease (Mills and Rüttenauer, 2022). Moreover, young people had a greater need for socialization after the lockdown and other severe restrictions, making them more amenable to vaccination so that they could obtain the certificate and resume a "normal life".

The extension of the basic green pass to many activities and services was not without drawbacks. It raised many ethical, legal and privacy concerns due to the tracking of individuals' movements, the temporary suspension of civil liberties, social discrimination, documents falsification or unlawful obtaining of data (Drury et al., 2021). This led to a greater refusal to receive the vaccine, especially among ethnic and socioeconomic groups of the population characterized by poor institutional trust and low vaccine uptake (Drury et al., 2021; Mills and Rüttenauer, 2022).

The effects of the green certificate on the COVID-19 vaccine administration may be controversial, and they require further investigation. There are still few studies on its impact on individuals' vaccination decisions. A recent study conducted by Mills and Rüttenauer (2022) on six countries (Denmark, France, Germany, Israel, Italy, Switzerland) shows that a mandatory COVID-19 certificate has an anticipation effect, increasing the administration of the vaccine 20 days before its implementation, with an effect lasting up to 40 days later. They also find an anticipation effect on vaccine uptake for Italy due to the digital certificate announcement that occurred in July 2021, especially for young people aged 18-24 years. Oliu-Barton et al. (2022) find an increase in one-dose vaccine uptake of 9.7 percentage points of the total population in Italy and of 13.0 and 6.2 percentage points in France and Germany, respectively. Furthermore, they show that the digital certificate is effective in reducing pressure on intensive care units (ICUs) and deaths in these countries. Karaivanov et al. (2021) estimated a significantly large increase in the first-dose vaccine uptake in Canadian provinces in the first weeks after the announcement of the proof of vaccination mandate. They also found a similar effect for France, Germany, and Italy due to the green certificate announced in summer 2021. Walkowiak et al. (2021) examined the impact of the green certificate on first doses of the COVID-19 vaccine by age groups in Lithuania and Poland from 30 June to 31 October 2021. They found that in Lithuania the green certificate mandate, extended to restaurants, sports facilities, indoor events, supermarkets and most services, produced a 12.34 percentage point increase in first-doses administration compared to Poland, where the certificate is only required for international travel. The increase was markedly higher among young people than among the elderly, with a net increase in the first doses of 16.5 percentage points in the 15-17 age group and of 3.0 percentage points for the over 70s.

The aforementioned studies show that the certificate mandate is an effective means to increase vaccine uptake among the hesitant. The original contribution of the present study is its empirical assessment of the effect of the green certificate announcement, which took place on 22 July, 2021, on the daily administration of the first dose of the COVID-19 vaccine in 20 Italian regions. The regional analysis provides a more granular picture than the national one. It enables evaluation of the territorially heterogeneous responses to the announcement on first doses. A single-group interrupted time series analysis (ITSA) is conducted to investigate this issue empirically. This kind of analysis makes it possible to analyze both the immediate and long term effects of a policy intervention for a single entity such as a country or a region.

The baseline estimation results show that the announcement caused a significant immediate increase in the first dose vaccination rate in most of the Italian regions. Only the Tuscany region recorded a significant immediate reduction in the first doses after the announcement of the green certificate mandate. The long-term effect of the announcement is observed in the regions like Campania, Lombardy, Marche, Piedmont and Tuscany which (with the exception of Campania) were strongly affected by the pandemic in the first wave. No significant effect of the green certificate anticipation was observed in the baseline estimates for the regions of Aosta Valley, Lazio, Puglia, Sardinia and Trentino-Alto Adige.

A sensitivity analysis was conducted by extending the ending date of the time series until 2 September 2021. We found that the immediate increase in the first-doses after the announcement of the basic green pass remained statistically significant in most of the Italian regions. A robust immediate increase effect was observed for Abruzzo, Basilicata, Campania, Emilia-Romagna, Friuli-Venezia Giulia, Marche, Piedmont, Sicily and Veneto. The long-term effect remained robust only for the Marche region. Lazio, Puglia and Sardinia continued not to react significantly to the announcement of the green pass, most likely because they already had high rates of first-dose COVID-19 vaccination (see Figure 1). Some regions (e.g., Lombardy, Aosta Valley, Trentino-Alto Adige, Tuscany, Molise) are sensitive to date changes, revealing less reliable results.

On checking for structural breaks both in the announcement date (Karaivanov et al., 2021) and in the pre-intervention days (Linden and Arbor, 2015; Linden and Yarnold, 2016; Linden, 2020), we found that the immediate effect of the green certificate announcement on the first-dose rate of the COVID-19 vaccine remained robust for Friuli-Venezia Giulia and Sicily. We also found that both Emilia-Romagna and Veneto showed a significant immediate increase in first-doses; an increase which was robust to the structural breaks only when controls were included in the interrupted time series regression analysis. These regions were characterized by a high proportion of persons unvaccinated for COVID-19 compared to the national average in summer 2021. This suggests that the announcement of the extension of the basic green pass to cultural, sporting and recreational activities created a push to be vaccinated in those regions where the COVID-19 vaccination rate was already low due to a higher percentage of recovery from COVID-19 (e.g., Emilia-Romagna, Friuli-Venezia Giulia, and Veneto), lack of confidence in the efficacy of the vaccine and/or poor perception of the severity of the disease (e.g., Sicily).

The next section describes the experience of the green pass in Italy. Section 3 illustrates the data and variables used in the empirical analysis. Section 4 describes the single-group ITSA, setting out model specification, baseline results, sensitivity and structural break analysis. Section 5 concludes.

# 2 The experience of the COVID-19 green certificate in Italy

Italy was among the first European countries to introduce COVID-19 green certification as a measure to limit the spread of the SARS-Cov-2 virus and to encourage the gradual resumption of economic and social activities in the country. In April 2021, the basic version of the COVID-19 green certificate was introduced in Italy (Decree-law No. 52/2021) to guarantee the free movement of persons in regions classified as high (red zone) or medium (orange zone) risk zones of SARS-coV-2 infection.[1] The basic green pass could be issued in three circumstances: *i*) completion of the vaccination cycle; *ii*) a recovery certificate concerning a recent natural infection revealed by a molecular or antigen test; *iii*) conduct of a molecular test or rapid antigen test with a negative result. In origin, its duration was 6 months for both vaccinated and recently naturally immunized persons, and 48 hours for diagnostic tests.[2]

The basic green pass became operational only from mid-June, when technical aspects (e.g., the collection of personal data, the functioning of the national digital platform) were arranged. In June, its use was also extended to further activities by Law No. 87/2021. Possession of the basic green pass became mandatory to participate in civil or religious ceremonies and discretionary to attend fairs, conferences, public and sporting events in regions with low risk of the SARS-coV-2 virus infection, classified as yellow zones. Other activities were subject to the mandatory use of the digital certificate. In particular, this concerned persons who accompanied patients to hospital emergency rooms and patients in health facilities in the case of their temporary discharge. These restrictions most likely

[1]Since early November 2020, the Italian regions have been classified into three zones, red, orange and yellow, based on the risk of spread of the virus in the regional territory and the ability of hospitals to treat COVID-19 patients. The red zone corresponds to high risk, while the orange and yellow zones correspond to moderate and low risk respectively. The decree-law 2/2022 introduced a safe zone called "white zone" in which the risk of the virus spreading is very limited.

[2]Law 133/2021 extended the validity of molecular PCR test for 72 hours.

had a very modest or almost nil effect on the containment of the virus because they concerned a small number of activities that, in some cases, involved a discretionary use of the certificate. Moreover, all Italian regions were classified as white zones (very low risk of contagion) a few days after the law came into force, so that such measures became inoperative.

Additional restrictions to fight the epidemiological emergency caused by COVID-19 and to support social and economic activities were announced on 22 July 2021 at a press conference held by the Prime Minister Mario Draghi with Justice Minister Marta Cartabia and Health Minister Roberto Speranza. Announced during the press conference, was the mandatory use of the basic green pass for most of the social, cultural and leisure activities carried out in the white zone regions. *De facto* this involved all the Italian regions.[3] The announcement had the effect of incentivizing many people to receive the first-dose of the vaccine so that they could engage in the aforementioned activities. Indeed, vaccination was still a more convenient means than diagnostic testing to obtain the basic green pass, because in June law 87/2021 extended its validity from 6 to 9 months for people vaccinated against COVID-19. Mass testing is still an important strategy with which to limit the spread of the infection because it helps to find positivity to COVID-19 especially among asymptomatic people, who represent about 40-45% of COVID-19 positive cases (Oran and Topol, 2020; Naimoli, 2022). However, its efficacy mainly depends on whether it ensures accurate diagnosis by limiting the number of false negatives. Recent studies do not clarify this issue because they report mixed evidence on the accuracy of rapid tests in tracking positives (Wang et al., 2021; Adamson et al., 2022).

With the decree-law no. 111 of 6 August 2021, the mandatory use of the basic green pass was further extended from 1 September until 31 December 2021 to the sectors of transport and public education. Severe penalties were applied to school and university staff who entered their workplaces without the basic green pass. They consisted in suspension from work without pay as well as the payment of a pecuniary fine. These measures and sanctions were also adopted in the entire public and private sector by decree-law 127 of 21 September 2021, which entered into force on 15 October 2021. They were preceded by the further extension of the validity of the green pass from 9 to 12 months for vaccinated people as an additional incentive to prefer vaccination to diagnostic testing (Law 126/2021).

A "reinforced" version of the basic green pass, called the "super green pass", en-

[3]The new measures announced entered in force on 6 August 2021 (Decree-law 105/2021).

tered into force on 6 December 2021 (Decree-law no. 172/2021). This new certificate allows only those who are vaccinated against COVID-19 and those who have a recovery certificate due to a recent natural infection to take part in social and sports activities, use transport services and enter workplaces. Established with the launch of the super green pass was a "soft" lockdown for unvaccinated individuals who were excluded *de facto* from social life. This raised ethical doubts as this kind of restriction and its impact on the progress of the pandemic, given a high increase in the number of positive cases and deaths in January and February 2022. The super green pass may have paradoxically contributed to this exponential increase, given that recent studies have pointed out that the COVID-19 green certificate could spread the virus by inducing people to deliberately become infected with SARS-CoV-2 in order to obtain the certificate (Drury et al., 2021).

The legislation concerning the basic green pass is summarized in Table 1. The table describes in greater detail the activities and services subject to the certificate and its temporal validity.

# 3 Data and variables

We examine the effect of the announcement of the basic green pass, which occurred on 22 July 2021, on first-doses of vaccine administration.[4] The empirical analysis exploits data on first-dose vaccine administration for a sample of 20 Italian regions from 2 July to 2 August 2021. These are open data provided by the Extraordinary Commissioner for the COVID-19 emergency.[5]

Figure 1 shows the percentage of individuals who received the first dose of COVID-19 vaccine out of the total inhabitants of Italian regions on 22 July 2021, i.e. on the day of announcement of the mandatory extension of the basic green pass. Lombardy was the region with the highest first-dose vaccination rate (65.7%). This success was most likely due to the higher number of vaccine doses received in the initial phase of the national vaccination campaign because this region had been hit hard by the pandemic in the first wave. Despite this evidence, the first-dose vaccination rate was not very high in Italy in summer 2021 because the national average was only around 60.7%. This situation most

[4]The implementation effect of the announcement is not examined because it overlaps with another announcement related to the extension of the basic green pass to schools, universities, and transport services (Decree-law No. 111/2021).

[5]They are available at the link: https://github.com/italia/covid19-opendata-vaccini.

likely motivated the Italian government to extend the basic green pass to many activities and services in order to encourage vaccine administration. Figure 1 also shows that the Piedmont and Veneto regions, which had been hardly affected by the first pandemic wave, had a percentage of first-dose vaccinated people lower than the national average. This may have been due to the presence of a high percentage of COVID-19 patients clinically cured and discharged from hospitals, as shown by Figure 2.[6] People cured of COVID-19 did not need to be vaccinated immediately thanks to the natural immunity acquired from the infection. Among the southern regions, Sicily had the lowest first-dose vaccination rate (55.2%). The higher percentage of unvaccinated persons in Sicily was probably due to the lower perception of the severity of the COVID-19 disease and/or greater distrust in the safety and efficacy of the COVID-19 vaccine, since the rate of discharge-cure from COVID-19 of this region was very low (3.9%).

The daily number of people vaccinated with the first dose per 100,000 inhabitants was used as the outcome variable since it reflects the individual's intention to be immunized after the announcement of the green pass (Karaivanov et al., 2021). It was transformed into natural logarithm to interpret the coefficients estimated in the regressions as percentage changes in the outcome variable.

Control variables were included in the regression analysis to check for robustness results. A dummy variable to control for the *weekend* effect was introduced since vaccine administration significantly diminishes at the week-ends. The dummy variable assumed value $1$ when the day of the week was Saturday and Sunday, and $0$ otherwise. Further controls were included to verify how the information about the risk of contracting the virus and developing severe symptoms of the disease affected the decision to get vaccinated (Karaivanov et al., 2021). Such variables were the daily change in deaths from COVID-19 per 100,000 inhabitants ($\Delta death$) and the share of intensive care unit (*ICU*) admissions due to COVID-19 in the total number of hospital admissions. Data on both variables are released by the Department of Civil Protection.[7]

In Table 2, we summarize descriptive statistics of the outcome and control variables used in the empirical analysis.

[6] The rate of recovery from COVID-19 over the total population may be overestimated because it could include cases of patients who have been infected by and recovered from COVID-19 more than once.

[7] They are open data available at the link: https://github.com/pcm-dpc/COVID-19.

# 4 Interrupted time series analysis

## 4.1 Model specification

Randomized trials are widely used to analyze health policy interventions becase they represent a valid design with which to identify the causal effect of the policy. However, they cannot always be implemented due to the absence of a control group. In this case, non-randomized designs, such as the single-group ITSA, can be a valid option (Linden and Arbor, 2015; Bernal et al., 2017; Hudson et al., 2019). The single-group ITSA makes it possible to estimate the impact of a policy intervention in the period immediately following its entry and in the long-run period in a single unit (e.g., country, region). In the research reported by this study, we used this design to estimate the announcement effect of the basic green pass extension, which took place on 22 July 2021, on the daily rate of first-dose vaccine administration.

Equation (1) illustrates the baseline model estimated in the empirical analysis. The outcome variable *firstdose* is the log of persons vaccinated with the first-dose per 100,000 inhabitants for the $i$-th municipality on day *t*. The variable *announce* is a dummy variable that assumes value 1 in the post-intervention period and zero otherwise. The variable $T$ is the time elapsing since the start of the analysis and *announce*T* is the interaction term. A constant and an error term $\epsilon$, assumed to be normally distributed, are introduced into the baseline model specification.

$$firstdose_{it} = \beta_0 + \beta_1 T_{it} + \beta_2 announce_{it} + \beta_3 announce_{it} * T_{it} + \epsilon_{it} \tag{1}$$

The coefficient $\beta_0$ measures the intercept of pre-intervention trend and represents the starting level of the outcome variable. $\beta_1$ corresponds to the slope of the pre-intervention trend of the outcome variable until the announcement. The coefficient $\beta_2$ is the level change in the outcome variable that occurs in the period immediately following the intervention. The coefficient $\beta_3$ captures the effect of the intervention over time (Linden and Adams, 2011; Linden and Arbor, 2015). It is the difference between the counterfactual pre-intervention slope and the post-intervention slope of the outcome variable. The interest coefficients are $\beta_2$ and $\beta_3$. They measure the immediate and subsequent effects of a policy intervention respectively, allowing analysis of the short- and long-term effects of that policy (Baicker and Svoronos, 2019).

Model (1) was estimated with the ordinary least squares (OLS) estimator correcting standard errors for autocorrelation[8] when they were detected with test developed by (Cumby and Huizinga, 1990, 1992). In the presence of autocorrelated and heteroskedastic standard errors, the model was estimated with the OLS by using Newey-West standard errors (Newey and West, 1987). The ITSA based on OLS method may be preferred to autoregressive integrated moving-average models since it "is often more flexible and broadly applicable in an interrupted time-series context" (Linden and Arbor, 2015, p. 481).

## 4.2 Baseline results

Table 3 displays the baseline OLS estimation results of model (1) for each Italian region. Standard errors are robust to heteroskedasticity and/or autocorrelation.[9] Checking for the presence of serial correlation in the error term structure is important in this kind of analysis because the causal identification depends on the assumptions about the functional form of the ITSA model (Linden and Arbor, 2015).

The baseline estimates show a significant increase in the first-dose vaccination rate immediately after the announcement of the mandatory use of the basic green pass in several activities and services in most of the Italian regions, specifically in Abruzzo, Basilicata, Calabria, Campania, Emilia-Romagna, Friuli-Venezia Giulia, Marche, Piedmont, Sicily, Umbria and Veneto. Indeed, the coefficient $\beta_2$, which captures the immediate effect of policy intervention, is statistically significant in those regions. The immediate effect is negative and significant in the Tuscany region.

The long-term effect of the announcement, measured by the coefficient $\beta_3$, is reliable in those regions where the post-intervention trend coefficient, measured as the sum of $\beta_1$ and $\beta_3$, is statistically significant. Accordingly, a positive and significant long term effect is found for Campania, Lombardy, Marche, Piedmont and Tuscany. This result is interesting because the northern regions of Lombardy and Piedmont were hard hit by the first wave of the pandemic, with a great loss of human life.

There are regions that show no effect by the announcement of the mandatory green certificate. They are Aosta Valley, Liguria, Lazio, Molise, Puglia, Sardinia and Trentino-Alto Adige. The absence of a significant announcement effect in regions like Lazio, Molise, Puglia, and Sardinia could be explained by the fact that they already had high

[8]The ITSA model is estimated by using the Stata command "itsa" developed by Linden and Arbor (2015).

[9]the Cumby–Huizinga (1992) general test for autocorrelation has been performed by using the Stata command "actest" implemented by Baum and Schaffer (1990).

rates of first-dose vaccination, which made the basic green pass a tool less effective in inducing vaccination in hesitant individuals (see Figures 1 and 2). The lack of reaction in Aosta Valley and Trentino-Alto Adige could be explained by high rates of natural immunity as shown in Figure 2.

Figure 3 provides a graphical representation of the actual and predicted daily change in the first-dose vaccination rate in Italian regions from 2 July to 2 August 2021. The day of the announcement (22 July) is indicated by the vertical dashed line. With the exception of Aosta Valley, Lazio, Puglia, Sardinia and Trentino-Alto Adige, the regions show a jump immediately after the announcement. It should be noted that in some of them (e.g., Campania, Marche, Lombardy and Tuscany), the post-intervention treatment period has a reverse trend after the announcement.

A set of control variables were introduced into the right side of equation (1) to verify whether the results remained robust to confounding factors (Bottomley et al., 2019). The controls included among the regressors were: the daily change in deaths from COVID-19 per 100,000 inhabitants ($\Delta death$), the *ICU* admission rate, and a dummy variable measuring the *weekend* effect. Table 4 displays estimation results with the inclusion of controls in ITSA. The results remain quite similar to those displayed in Table 3. The main difference is that the immediate effect of the announcement measured by the coefficient $\beta_2$ is no longer significant in the Calabria and Umbria regions. The immediate effect of the announcement becomes statistically significant at 1% level in Liguria.

As regards the controls, Table 4 shows that, during the weekend, the first-dose rate decreases significantly in most regions. An increase in deaths per inhabitant prompts hesitant people to get vaccinated in the Liguria region. The increase in the daily variation in deaths due to COVID-19 decreases the administration rate of the first doses in Piedmont. Although this result appears counter-intuitive, it is also likely that increasing deaths from COVID-19 are be perceived as a low vaccine efficacy signal that discourages the undecided from being vaccinated. An increase in *ICU* admissions significantly increases the first-dose vaccination rate in the regions of Calabria and Emilia-Romagna. The higher the risk of contracting the severe symptoms of COVID-19 and being admitted to the ICU, the more hesitant people tend to choose vaccinations to protect themselves from infection. We note that in Basilicata and Lombardy, the impact of *ICU* is negative and statistically significant. This finding could be consistent with the explanation that the increase in ICU cases creates a climate of distrust among individuals about the effectiveness of vaccines in protecting against severe disease symptoms and death by discouraging vaccine administration. The variable *ICU* was dropped in the interrupted time-series regression for the Aosta Valley region since it was time invariant over the period examined, assuming value zero.[10]

## 4.3 Sensitivity analysis

A sensitivity analysis was carried out to check whether the results in Table 4 could depend on the ending date. Accordingly, the time period of the sample was extended until to 2 September 2021. This is not without concerns because a longer time span involves further announcement and effective entry effects due to green pass reforms as summarized in Table 1. For this reason, the results should be interpreted with caution. An additional control variable, called *holiday*, was added among the regressors. It was a dummy variable that captured the national holiday which falls on August 15. The dummy variable assumed value 1 on 15 August and zero otherwise.

On comparing the results in Tables 4 and 5, the immediate effect of the announcement on first doses is confirmed for many regions. It now becomes statistically significant for Aosta Valley, Molise, Trentino-Alto Adige, and Umbria. A negative long-term effect of the announcement is now statistically significant for Aosta Valley, Liguria, Molise and Sicily. In the specific case of Lombardy, the long-term effect on the first daily dose vaccination rate becomes irrelevant as the post-trend intervention coefficient loses statistical significance. On extending the ending date, the announcement no longer has an effect in the Tuscany region.

When all the results of the empirical analysis are compared, an immediate impact of the announcement is apparent in the regions of Abruzzo, Basilicata, Campania, Emilia-Romagna, Friuli-Venezia Giulia, Marche, Piedmont, Veneto and Sicily. The long-term effects of the announcement are robust only for the Marche region. No announcement effect is observed for Lazio, Puglia and Sardinia.

Table 5 shows that, among the controls, *weekend* is again statistically significant and negative for most regions. Both the *ICU* and the *holiday* variables show an ambiguous impact on the first-dose rate depending on the region. The daily variation in the death rate from COVID-19 has a significant and positive impact only in the estimates on the Sicily region.

[10] The variable *ICU* is set to 0 when both numerator and denominator are zero.

## 4.4 Structural breaks analysis

Identification of the causal effect due to the policy intervention in the single-group interrupted time series analysis is reliable if the pre-intervention trend is flat (Linden and Arbor, 2015; Linden, 2020) and there is a significant change in the outcome variable immediately after the policy intervention, which persists over time (Baicker and Svoronos, 2019). This implies that there should be no other break points in the pre-intervention period and that the break point identified with the date of policy announcement should be not artificial.

The cumulative sum (CUSUM) test based on the sum of recursive residuals (Brown et al., 1975) is used to verify if there are structural breaks due to changes in the coefficients of the regressions during the pre-intervention period (Linden and Arbor, 2015; Linden, 2020). The null hypothesis of the test is that all parameters are stable over time. The CUSUM test statistic is compared with three critical values computed at the 1% (1.143), 5% (0.948), and 10% (0.850) significance level.

Table 6 displays the results of the CUSUM test for all regions with and without control variables in the ITSA. The CUSUM test statistic accepts the null hypothesis of parameters stability for the regions of Aosta Valley, Friuli-Venezia Giulia, Lazio, Liguria, Molise, Sardinia, Sicily Trentino-Alto Adige, since its value is lower than the 10% critical level of 0.850. In the regions of Emilia-Romagna, Calabria, Puglia and Veneto, the test statistic rejects the null hypothesis only when the control variables are included in the ITSA. For the remaining regions, the null hypothesis of a constant mean is accepted.

We tested if the date of the announcement was a structural breaking point by performing the Wald test. We verified whether if the coefficients estimated in the time series regressions remained stable over the periods defined by the announcement date. If error terms are independent and identically distributed, this test corresponds to the Chow (1960) test.[11]

Table 6 displays the Wald test results for all Italian regions. We find that the announcement date represents a structural break for the regions of Campania, Emilia-Romagna, Friuli-Venezia Giulia, Molise, Piedmont, and Sicily, Umbria, and Veneto. For some regions, the test shows ambiguous results that depend on whether or not controls were included in the time series regression analysis. The test shows that the announcement date does not represent a structural break for Liguria and Sardinia.

[11] The test was performed by using the Stata command "estat sbknown".

In light of the results of the structural break tests and those of the estimates of model (1), here emerges a robust immediate increase in first-doses after the announcement for Friuli-Venezia Giulia and Sicily. The estimated average immediate increase is 199 and 67 percent in the daily first doses for Friuli-Venezia Giulia and Sicily, respectively.[12] Emilia-Romagna and Veneto show a significant immediate increase in first doses, robust to the structural breaks, when controls are included in the interrupted time series regression analysis. A significant long-term effect due to the announcement is robust to structural breaks for Sicily only in the regressions with the ending date extended to 2 September. Although the tests suggest that the announcement date is a possible structural break for Lazio and Puglia, the estimation results of model (1) do not show any significant short- or long-term effect of the announcement for both regions.

# 5 Conclusions

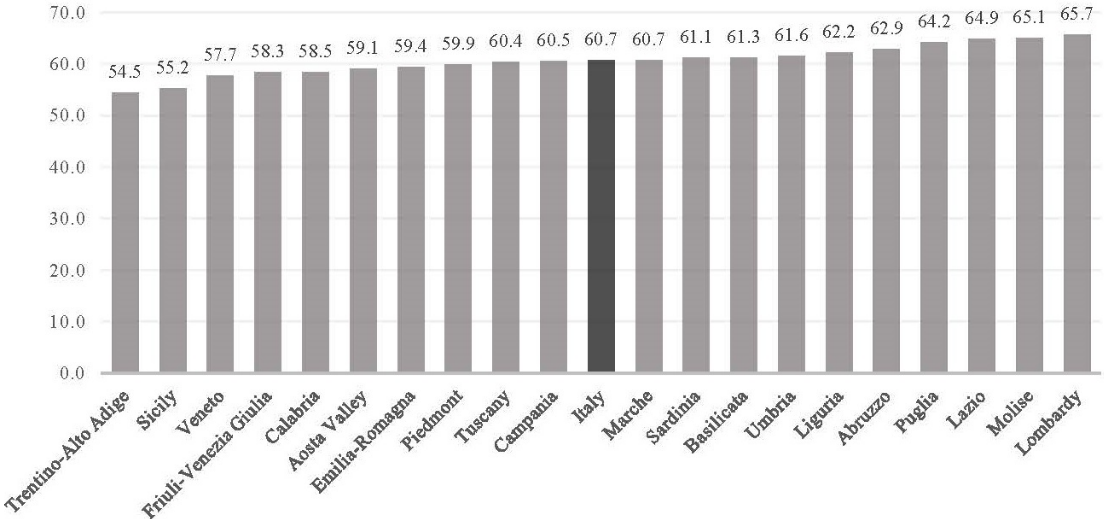
The ITS analysis at the Italian regional level showed that the announcement effect of the extension in July 2021 of the basic green pass produced a robust and immediate increase in the first-doses of the COVID-19 vaccine in the regions of Friuli-Venezia Giulia and Sicily. These regions were characterized by first-dose vaccination rates below the national average. The single-group ITS analysis also showed that some regions did not react to the announcement. They were characterized by relatively high vaccination rates or in any case ones above the national average. Overall, these results are interesting because they demonstrate that the announcement of the extension of the basic green pass had the effect desired by the Italian government, i.e. the increase in first-dose rates, particularly in the regions lagging behind in the mass vaccination campaign. For the Friuli-Venezia Giulia region, this delay may have been motivated by an already high percentage of people with a natural immunity to COVID-19. For the Sicily region, this delay could be attributed to a lack of confidence in the efficacy of the vaccine and/or a poor perception of the severity of the COVID-19 disease because the level of natural immunity in this region is very low.

The mandatory extension of the basic green pass certainly played a role in increasing the daily first-dose vaccination rate at the Italian regional level, but the fact that even more restrictive measures, such as the introduction of the vaccination obligation and the super green pass, were added over time suggests that its impact in terms of increased first-doses

[12]The increase was computed as $100(e^x - 1)$, where $x$ is the estimated coefficient (Karaivanov et al., 2021).

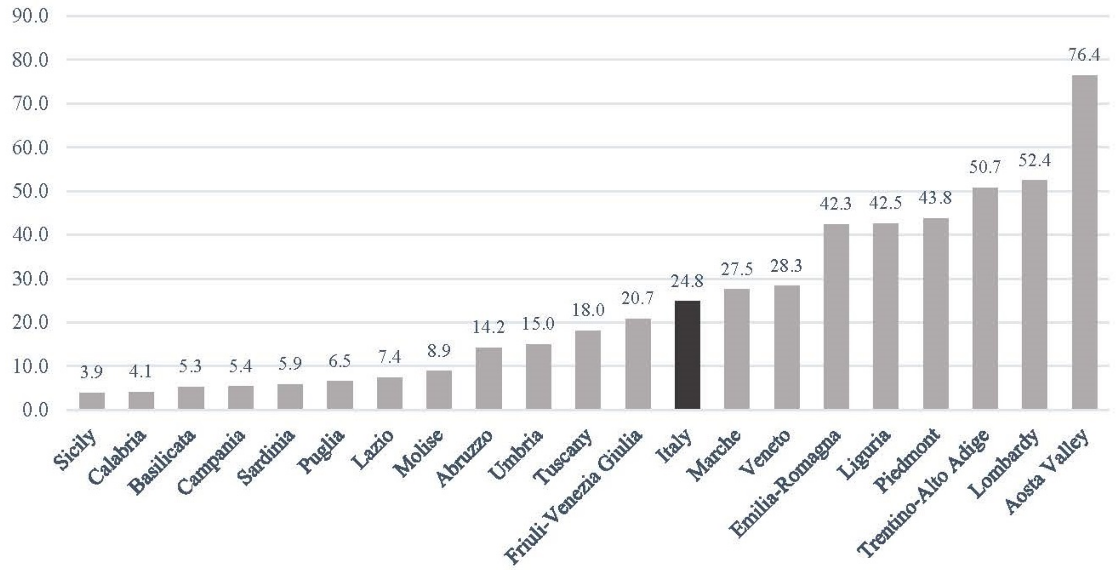
was perhaps more modest than what the Italian government expected to achieve. The green certificate, both in its basic and reinforced form, has raised many ethical doubts about its use and provoked many street protests because it is considered a measure that excessively limits personal freedoms because of the national health system's inability to respond promptly to health emergencies. Strengthening national health systems through the increase of healthcare workers and intensive care units per inhabitant will be the priority in the years to come for any country, including Italy, in order to ensure adequate health protection and to avoid excessive restrictions on personal freedoms in times of pandemic.

Figure 1: The daily COVID-19 first-dose vaccination rate (%) in Italian regions on 22 July 2021



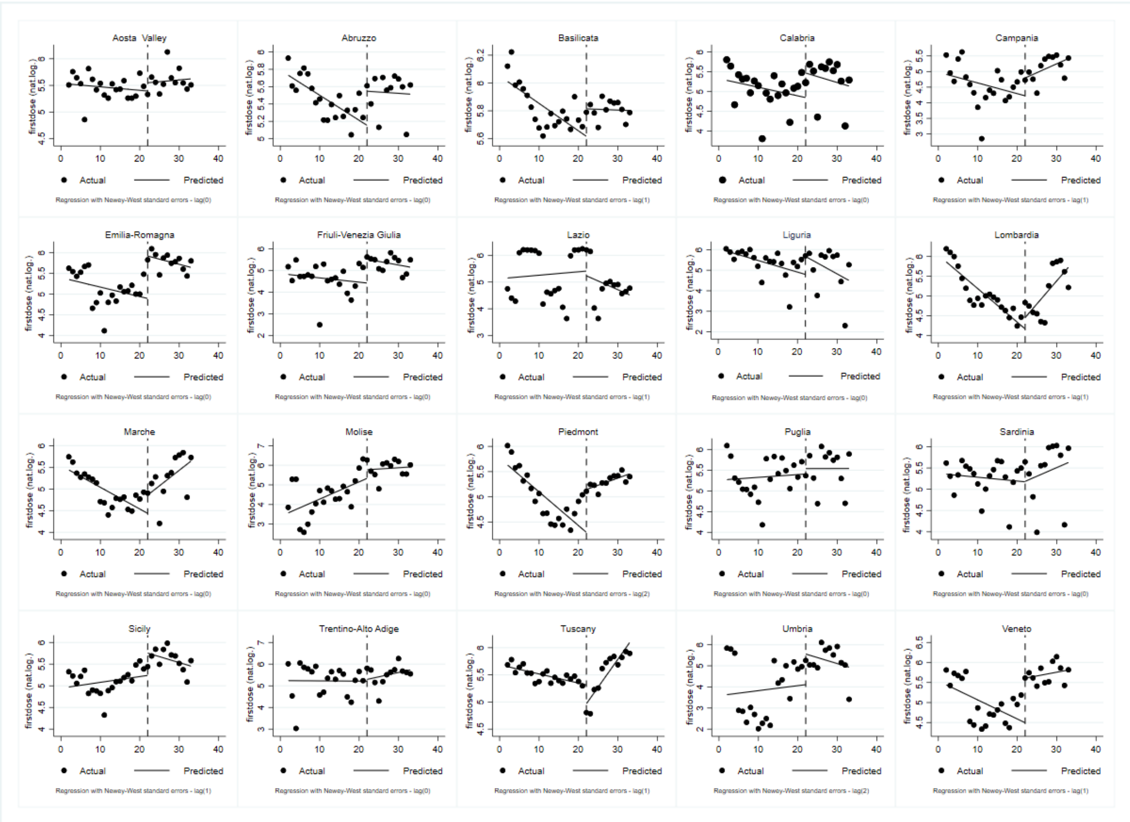

Source: Author's elaboration on data provided by Extraordinary Commissioner for the COVID-19 emergency - Presidency of the Council of Ministers.

Figure 2: Rate of persons discharge-cured from COVID-19 (%) in Italian regions on 22 July 2021




Source: Author's elaboration on data provided by Department of Civil Protection - Presidency of the Council of Ministers.

Figure 3: The daily COVID-19 first-dose vaccination rate (per 100,000 inhabitants) in Italian regions from 2 July to 2 August 2021




Source: Author's elaboration on data provided by Extraordinary Commissioner for the COVID-19 emergency - Presidency of the Council of Ministers. The ITSA is performed without controls.

Table 1: Italian legislation on the basic green pass

| Legislation | Date of entry | Validity | Activities and personnel involved |
|---|---|---|---|
| DL No. 52 Apr 22, 2021 | No | 6 months | – Free movements of persons in regions classified as high (red zone) or medium (orange zone) risk zones of SARS-coV-2 infection.<br>– Access to particular public events, sporting events, fairs, conferences and congresses. |
| L No. 87 Jun 17, 2021 | Jun 15, 2021 | 9 months | – Accompanying patients in the waiting rooms of the emergency, admission departments and first aid departments.<br>– Temporary exits of people housed in hospitals and long term care facilities, assisted healthcare residences, hospices, rehabilitation facilities and residential facilities for the elderly, self-sufficient and non-self-sufficient, residential socio-assistance facilities and other residential facilities.<br>– Civil or religious ceremonies carried out in regions with low-risk of SARS-CoV-2 infection (yellow zone).<br>– Fairs, conferences, public and sporting events (discretionary use of GP). |
| DL No. 105 Jul 23, 2021 | Aug 6, 2021 | 9 months | In white zones (very low risk of SARS-CoV-2 infection)(*):<br>– Catering services for indoor table consumption.(*)<br>– Public events, sporting events and competitions.(*)<br>– Museums, other institutes and places of culture and exhibitions.(*)<br>– swimming pools, swimming centers, gyms, team sports, well-being centers limited to indoor activities.(*)<br>– Festivals and fairs, conferences and congresses.(*)<br>– Spas, theme and amusement parks.(*)<br>– Cultural centers, social and recreational centers, limited to indoor activities, (exclusion of educational centers for infanis, including summer centers, and related catering activities).(*)<br>– Gaming rooms, betting rooms, bingo halls, casinos<br>– Public competitions.(*)<br>– Public events open to audiences in theatrical halls, concert halls, cinemas, entertainment venues and live music and other places or spaces even outdoors.(**)<br>– Sporting events of pre-eminent national interest recognized by the Italian National Olympic Committee (CONI) and the Italian Paralympic Committee (CIP). |
| DL No. 111 Aug 6, 2021 | Sep 1, 2021 | 9 months | – The school staff of the national education and university system, as well as university students.<br>– Means of transport: a) aircraft engaged in commercial passenger transport services; b) ships and ferries used for interregional transport services, with the exception of those used for maritime connections in the Strait of Messina area; c) trains used in passenger rail transport services of Intercity, Intercity Night and Speed type; d) buses used for passenger transport services carried out by road and on routes that connect more than two regions and having pre-established itineraries, timetables, frequencies and prices; e) buses and rental services with driver, with the exception of those used in additional local and regional public transport services. |

Table 1: Italian legislation on the basic green pass (*continue*)

| Legislation | Date of entry | Validity | Activities and personnel involved |
|---|---|---|---|
| L No. 126 Sep 16, 2021 | Sep 19, 2021 | 12 months | – Catering services carried out in hotels and other accommodation facilities reserved exclusively for customers staying there are exempt.<br>– Diagnostic centers and specialist outpatient clinics.<br>– Access to spas for services relating to essential levels of assistance, rehabilitation and therapeutics are exempt.<br>– Local festivals and fairs that take place outdoors and in spaces without access gates.<br>– Parties following a civil or religious ceremony. |
| DL No. 127 Sep 21, 2021 | Oct 15, 2021 | 12 months | – Staff of public administrations, independent administrative authorities, as well as public economic and constitutional bodies, for the purpose of access to the workplace.<br>– Magistrates, administrative, accounting and military personnel, the members of the tax commissions, for the purpose of access to the workplace.<br>– Anyone who works and carrying out training and voluntary activities in the private sector. |
| L No. 133 Sept 24, 2021 | Oct 2, 2021 | 12 months | – The staff of non-peer schools, educational services for children, provincial centers for adult education, regional education and professional training systems, of the regional systems that implement higher education and technical training courses and higher technical institutes.<br>– Anyone who accesses the permises of schools, education and training institutions (except for children, pupils and students), universities and higher education institutions in art and music, as well as other higher education institutions connected to universities.<br>– Means of transport: cable cars, gondola lifts and chairlifts, if used closing the screen domes, with tourist-commercial purposes and also when located in ski areas, without limitations on the sale of travel tickets; ships and ferries used in maritime connections to and from the archipelago of the Tremiti Islands are exempt. |
| L No. 165 Nov 19, 2021 | Nov 21, 2021 | 12 months | – Universal civil service volunteers. |

Note: (*) The basic green pass also applies in the yellow (low-risk), orange (medium-risk) and red (high-risk) zones, where the services and activities are permitted and under the conditions provided for individual zones. (**) In yellow zone too.

Table 2: Descriptive statistics

| Region | First dose% | | | | | ICU | | | | | $\Delta death$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Obs | Mean | Std.dev. | Min | Max | Obs | Mean | Std.dev. | Min | Max | Obs | Mean | Std.dev. | Min | Max |
| Abruzzo | 32 | 247.09 | 55.09 | 155.21 | 375.93 | 32 | 0.03 | 0.02 | 0.00 | 0.05 | 32 | 0.01 | 0.02 | 0.00 | 0.08 |
| Aosta Valley | 32 | 253.13 | 58.31 | 128.80 | 458.50 | – | – | – | – | – | 32 | 0.01 | 0.21 | -0.81 | 0.81 |
| Basilicata | 32 | 339.44 | 49.69 | 275.70 | 504.22 | 32 | 0.00 | 0.02 | 0.00 | 0.07 | 32 | 0.01 | 0.03 | 0.00 | 0.18 |
| Calabria | 32 | 192.62 | 76.05 | 45.17 | 331.85 | 32 | 0.08 | 0.02 | 0.04 | 0.11 | 32 | 0.05 | 0.10 | 0.00 | 0.48 |
| Campania | 32 | 138.2623 | 70.50 | 17.33 | 277.44 | 32 | 0.06 | 0.01 | 0.04 | 0.09 | 32 | 0.06 | 0.07 | 0.00 | 0.28 |
| Emilia-Romagna | 32 | 238.01 | 97.31 | 61.23 | 443.96 | 32 | 0.08 | 0.02 | 0.05 | 0.12 | 32 | 0.01 | 0.02 | -0.02 | 0.09 |
| Friuli-Venezia Giulia | 32 | 157.45 | 78.43 | 12.12 | 336.30 | 32 | 0.11 | 0.09 | 0.00 | 0.25 | 32 | 0.00 | 0.02 | -0.03 | 0.08 |
| Lazio | 32 | 239.35 | 189.48 | 37.89 | 516.34 | 32 | 0.16 | 0.03 | 0.12 | 0.21 | 32 | 0.04 | 0.03 | 0.00 | 0.12 |
| Liguria | 32 | 242.70 | 112.35 | 9.99 | 420.89 | 32 | 0.30 | 0.10 | 0.14 | 0.50 | 32 | 0.03 | 0.04 | 0.00 | 0.13 |
| Lumbardy | 32 | 188.17 | 119.08 | 69.56 | 490.07 | 32 | 0.18 | 0.04 | 0.11 | 0.24 | 32 | 0.01 | 0.01 | 0.00 | 0.05 |
| Marche | 32 | 175.30 | 78.62 | 66.99 | 343.64 | 32 | 0.18 | 0.04 | 0.10 | 0.29 | 32 | 0.01 | 0.02 | 0.00 | 0.07 |
| Molise | 32 | 217.65 | 175.82 | 13.24 | 555.90 | 32 | 0.06 | 0.25 | 0.00 | 1.00 | 32 | 0.01 | 0.06 | 0.00 | 0.34 |
| Piedmont | 32 | 181.17 | 77.93 | 76.71 | 409.43 | 32 | 0.06 | 0.02 | 0.04 | 0.10 | 32 | 0.00 | 0.01 | 0.00 | 0.07 |
| Puglia | 32 | 246.70 | 101.03 | 65.42 | 443.20 | 32 | 0.10 | 0.01 | 0.08 | 0.13 | 32 | 0.02 | 0.03 | -0.03 | 0.13 |
| Sardinia | 32 | 229.23 | 96.86 | 53.97 | 413.73 | 32 | 0.08 | 0.05 | 0.02 | 0.20 | 32 | 0.03 | 0.04 | 0.00 | 0.13 |
| Sicily | 32 | 210.80 | 74.69 | 75.62 | 396.75 | 32 | 0.12 | 0.01 | 0.09 | 0.14 | 32 | 0.05 | 0.05 | 0.00 | 0.21 |
| Trentino-Alto Adige | 32 | 243.93 | 115.30 | 20.75 | 522.04 | 32 | 0.11 | 0.09 | 0.00 | 0.25 | 32 | 0.01 | 0.03 | -0.01 | 0.09 |
| Tuscany | 32 | 254.56 | 62.30 | 119.67 | 376.37 | 32 | 0.16 | 0.03 | 0.10 | 0.21 | 32 | 0.04 | 0.05 | 0.00 | 0.22 |
| Umbria | 32 | 148.18 | 128.30 | 7.55 | 449.03 | 32 | 0.10 | 0.05 | 0.00 | 0.20 | 32 | 0.02 | 0.05 | 0.00 | 0.23 |
| Veneto | 32 | 221.33 | 109.35 | 76.37 | 465.71 | 32 | 0.15 | 0.03 | 0.10 | 0.21 | 32 | 0.01 | 0.03 | -0.07 | 0.14 |

Table 3: Baseline estimation results

| | Liguria | | | Lombardy+ | | | Piedmont++ | | | Aosta Vally | | | Friuli-Venezia Giulia | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value |
| $\beta_1$ | -0.057 | -2.43 | 0.022 | -0.085 | -7.04 | 0.000 | -0.067 | -3.36 | 0.002 | -0.007 | -0.73 | 0.474 | -0.020 | -0.86 | 0.396 |
| $\beta_2$ | 0.878 | 1.58 | 0.125 | 0.283 | 1.18 | 0.249 | 0.849 | 3.17 | 0.004 | 0.155 | 1.10 | 0.279 | 1.096 | 3.36 | 0.002 |
| $\beta_3$ | -0.050 | -0.52 | 0.606 | 0.201 | 5.14 | 0.000 | 0.095 | 4.62 | 0.000 | 0.013 | 0.79 | 0.436 | -0.013 | -0.39 | 0.697 |
| $\beta_0$ | 5.991 | 35.36 | 0.000 | 5.949 | 31.80 | 0.000 | 5.699 | 29.27 | 0.000 | 5.532 | 45.30 | 0.000 | 4.836 | 17.92 | 0.000 |
| $\beta_1 + \beta_3$ | -0.107 | -1.15 | 0.259 | 0.116 | 3.18 | 0.004 | 0.028 | 4.50 | 0.000 | 0.007 | 0.47 | 0.639 | -0.033 | -1.30 | 0.204 |
| | Trentino-Alto Adige | | | Veneto+ | | | Emilia-Romagna | | | Marche | | | Tuscany+ | | |
| | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value |
| $\beta_1$ | -0.001 | -0.03 | 0.973 | -0.047 | -2.40 | 0.023 | -0.023 | -1.84 | 0.076 | -0.050 | -4.90 | 0.000 | -0.017 | -5.10 | 0.000 |
| $\beta_2$ | 0.082 | 0.19 | 0.848 | 1.112 | 4.49 | 0.000 | 1.025 | 5.70 | 0.000 | 0.422 | 1.72 | 0.096 | -0.347 | -2.63 | 0.014 |
| $\beta_3$ | 0.041 | 0.81 | 0.424 | 0.066 | 2.58 | 0.015 | -0.002 | -0.10 | 0.920 | 0.121 | 3.39 | 0.002 | 0.119 | 6.68 | 0.000 |
| $\beta_0$ | 5.239 | 10.46 | 0.000 | 5.492 | 22.65 | 0.000 | 5.377 | 32.08 | 0.000 | 5.490 | 50.98 | 0.000 | 5.669 | 125.07 | 0.000 |
| $\beta_1 + \beta_3$ | 0.040 | 1.10 | 0.279 | 0.019 | 1.15 | 0.260 | -0.025 | -1.64 | 0.113 | 0.071 | 2.08 | 0.047 | 0.103 | 5.87 | 0.000 |

Table 3: Baseline estimation results (*continued*)

| | Lazio+ | | | Umbria++ | | | Molise | | | Abruzzo | | | Basilicata+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value |
| $\beta_1$ | 0.013 | 0.29 | 0.776 | 0.024 | 0.29 | 0.770 | 0.088 | 2.13 | 0.042 | -0.029 | -4.27 | 0.000 | -0.020 | -3.44 | 0.002 |
| $\beta_2$ | -0.175 | -0.22 | 0.831 | 1.449 | 1.73 | 0.095 | 0.437 | 0.92 | 0.364 | 0.393 | 2.82 | 0.009 | 0.198 | 2.83 | 0.008 |
| $\beta_3$ | -0.078 | -0.87 | 0.390 | -0.080 | -0.75 | 0.459 | -0.075 | -1.41 | 0.170 | 0.026 | 1.23 | 0.228 | 0.019 | 2.52 | 0.018 |
| $\beta_0$ | 5.142 | 9.99 | 0.000 | 3.611 | 3.15 | 0.004 | 3.486 | 6.39 | 0.000 | 5.761 | 76.43 | 0.000 | 6.031 | 80.48 | 0.000 |
| $\beta_1 + \beta_3$ | -0.065 | -0.88 | 0.387 | -0.057 | -0.77 | 0.448 | 0.013 | 0.38 | 0.704 | -0.003 | -0.16 | 0.878 | -0.001 | -0.23 | 0.819 |
| | Calabria | | | Campania+ | | | Puglia | | | Sardinia | | | Sicily+ | | |
| | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value |
| $\beta_1$ | -0.022 | -1.23 | 0.228 | -0.034 | -1.54 | 0.136 | 0.007 | 0.39 | 0.698 | -0.009 | -0.57 | 0.574 | 0.013 | 1.08 | 0.288 |
| $\beta_2$ | 0.620 | 1.87 | 0.072 | 0.570 | 1.79 | 0.085 | 0.131 | 0.45 | 0.656 | 0.009 | 0.02 | 0.982 | 0.514 | 2.57 | 0.016 |
| $\beta_3$ | -0.008 | -0.18 | 0.862 | 0.091 | 2.72 | 0.011 | -0.006 | -0.15 | 0.881 | 0.049 | 0.78 | 0.444 | -0.041 | -1.80 | 0.083 |
| $\beta_0$ | 5.306 | 25.28 | 0.000 | 4.944 | 16.06 | 0.000 | 5.268 | 21.92 | 0.000 | 5.363 | 35.57 | 0.000 | 4.959 | 30.86 | 0.000 |
| $\beta_1 + \beta_3$ | -0.030 | -0.69 | 0.497 | 0.057 | 2.22 | 0.035 | 0.000 | 0.00 | 0.996 | 0.040 | 0.66 | 0.517 | -0.027 | -1.38 | 0.178 |

Note: Standard errors robust to heteroskedasticity. $+(++)$ Newey-West standard errors robust to first-order (second-order) autocorrelation.

Table 4: Estimation results with controls

| | Liguria+ | | | Lombardy+ | | | Piedmont+ | | | Aosta Vally | | | Friuli-Venezia Giulia | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value |
| ICU | -0.908 | -0.76 | 0.452 | -12.122 | -6.28 | 0.000 | 4.005 | 1.25 | 0.222 | – | – | – | -1.346 | -0.92 | 0.364 |
| $\Delta death$ | 8.460 | 2.71 | 0.012 | 3.264 | 1.11 | 0.276 | -4.568 | -1.74 | 0.094 | 0.033 | 0.95 | 0.350 | 3.046 | 1.33 | 0.197 |
| weekend | -1.214 | -6.05 | 0.000 | -0.085 | -0.84 | 0.411 | -0.039 | -0.44 | 0.665 | -0.078 | -1.03 | 0.313 | -0.522 | -1.77 | 0.089 |
| $\beta_1$ | -0.091 | -6.39 | 0.000 | -0.104 | -20.84 | 0.000 | -0.061 | -2.96 | 0.007 | -0.007 | -0.74 | 0.464 | -0.026 | -1.33 | 0.196 |
| $\beta_2$ | 1.231 | 4.12 | 0.000 | 0.049 | 0.19 | 0.851 | 0.821 | 3.29 | 0.003 | 0.159 | 1.12 | 0.271 | 1.110 | 3.54 | 0.002 |
| $\beta_3$ | -0.061 | -1.17 | 0.251 | 0.159 | 5.71 | 0.000 | 0.093 | 3.46 | 0.002 | 0.015 | 0.84 | 0.409 | 0.012 | 0.36 | 0.725 |
| $\beta_0$ | 6.837 | 13.73 | 0.000 | 8.581 | 21.39 | 0.000 | 5.404 | 15.26 | 0.000 | 5.562 | 38.84 | 0.000 | 5.182 | 21.76 | 0.000 |
| $\beta_1 + \beta_3$ | -0.152 | -2.62 | 0.015 | 0.055 | 1.99 | 0.057 | 0.032 | 2.57 | 0.017 | 0.007 | 0.52 | 0.610 | -0.014 | -0.53 | 0.600 |
| | Trentino-Alto Adige | | | Veneto+ | | | Emilia-Romagna | | | Marche | | | Tuscany+ | | |
| | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value |
| ICU | 0.943 | 0.84 | 0.410 | -0.627 | -0.29 | 0.772 | 13.591 | 1.99 | 0.058 | 0.191 | 0.12 | 0.907 | 0.924 | 0.62 | 0.543 |
| $\Delta death$ | 0.400 | 0.21 | 0.834 | -0.123 | -0.08 | 0.940 | 0.424 | 0.17 | 0.866 | -0.132 | -0.04 | 0.970 | 0.428 | 0.87 | 0.395 |
| weekend | -1.093 | -4.91 | 0.000 | -0.234 | -1.86 | 0.075 | -0.131 | -1.11 | 0.278 | -0.255 | -1.63 | 0.116 | 0.005 | 0.11 | 0.911 |
| $\beta_1$ | -0.003 | -0.14 | 0.892 | -0.046 | -2.10 | 0.046 | -0.003 | -0.15 | 0.879 | -0.052 | -4.77 | 0.000 | -0.016 | -3.86 | 0.001 |
| $\beta_2$ | 0.257 | 1.06 | 0.299 | 1.108 | 4.65 | 0.000 | 1.292 | 4.44 | 0.000 | 0.430 | 1.78 | 0.088 | -0.313 | -2.13 | 0.043 |
| $\beta_3$ | 0.042 | 0.93 | 0.363 | 0.064 | 2.16 | 0.040 | -0.033 | -0.93 | 0.360 | 0.127 | 3.90 | 0.001 | 0.119 | 6.00 | 0.000 |
| $\beta_0$ | 5.438 | 12.51 | 0.000 | 5.644 | 16.31 | 0.000 | 3.906 | 4.65 | 0.000 | 5.557 | 19.55 | 0.000 | 5.468 | 18.83 | 0.000 |
| $\beta_1 + \beta_3$ | 0.039 | 1.03 | 0.312 | 0.018 | 1.09 | 0.285 | -0.036 | -1.46 | 0.158 | 0.075 | 2.43 | 0.023 | 0.103 | 5.21 | 0.000 |

Table 4: Estimation results with controls (*continued*)

| | Lazio+ | | | Umbria++ | | | Molise | | | Abruzzo+ | | | Basilicata++ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value |
| ICU | -6.708 | -0.45 | 0.658 | 6.503 | 1.25 | 0.222 | -0.268 | -0.70 | 0.488 | 4.838 | 1.49 | 0.148 | -2.028 | -4.19 | 0.000 |
| $\Delta death$ | 8.161 | 1.35 | 0.190 | 3.664 | 0.94 | 0.358 | 0.986 | 0.53 | 0.598 | -1.856 | -0.89 | 0.383 | 0.178 | 0.33 | 0.747 |
| weekend | -0.674 | -2.03 | 0.053 | -0.113 | -0.22 | 0.827 | 0.033 | 0.10 | 0.924 | -0.214 | -3.70 | 0.001 | -0.076 | -1.46 | 0.157 |
| $\beta_1$ | 0.033 | 0.62 | 0.540 | 0.004 | 0.04 | 0.969 | 0.093 | 1.81 | 0.082 | -0.031 | -7.56 | 0.000 | -0.021 | -2.90 | 0.008 |
| $\beta_2$ | -0.416 | -0.54 | 0.596 | 1.508 | 1.69 | 0.104 | 0.346 | 0.62 | 0.541 | 0.447 | 4.42 | 0.000 | 0.186 | 2.43 | 0.023 |
| $\beta_3$ | -0.124 | -1.28 | 0.212 | -0.055 | -0.42 | 0.675 | -0.063 | -0.85 | 0.403 | 0.050 | 2.57 | 0.016 | 0.024 | 3.10 | 0.005 |
| $\beta_0$ | 5.983 | 1.94 | 0.064 | 3.163 | 3.00 | 0.006 | 3.405 | 5.04 | 0.000 | 5.656 | 39.02 | 0.000 | 6.068 | 71.35 | 0.000 |
| $\beta_1+\beta_3$ | -0.091 | -1.20 | 0.242 | -0.051 | -0.71 | 0.483 | 0.030 | 0.57 | 0.574 | 0.019 | 0.99 | 0.333 | 0.004 | 1.35 | 0.189 |

| | Calabria+ | | | Campania+ | | | Puglia+ | | | Sardegna | | | Sicilia+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value |
| ICU | 6.095 | 2.13 | 0.044 | -3.458 | -0.26 | 0.800 | 3.344 | 0.44 | 0.665 | -6.315 | -1.57 | 0.130 | -5.426 | -1.23 | 0.231 |
| $\Delta death$ | -0.430 | -0.67 | 0.508 | 0.729 | 0.58 | 0.567 | 0.796 | 0.30 | 0.766 | 1.926 | 0.93 | 0.359 | 0.058 | 0.09 | 0.927 |
| weekend | -0.635 | -4.46 | 0.000 | -0.638 | -3.51 | 0.002 | -0.520 | -2.62 | 0.015 | -0.721 | -3.97 | 0.001 | -0.177 | -1.50 | 0.145 |
| $\beta_1$ | -0.021 | -1.68 | 0.105 | -0.040 | -1.30 | 0.204 | -0.006 | -0.23 | 0.823 | -0.002 | -0.11 | 0.914 | 0.016 | 1.38 | 0.180 |
| $\beta_2$ | 0.543 | 1.57 | 0.130 | 0.584 | 1.90 | 0.069 | 0.238 | 1.03 | 0.315 | 0.240 | 0.95 | 0.351 | 0.493 | 2.14 | 0.042 |
| $\beta_3$ | 0.003 | 0.07 | 0.948 | 0.102 | 3.35 | 0.003 | 0.014 | 0.38 | 0.706 | 0.088 | 1.59 | 0.124 | -0.056 | -2.00 | 0.056 |
| $\beta_0$ | 5.048 | 19.39 | 0.000 | 5.384 | 4.50 | 0.000 | 5.195 | 6.43 | 0.000 | 5.744 | 36.35 | 0.000 | 5.636 | 10.14 | 0.000 |
| $\beta_1+\beta_3$ | -0.018 | -0.44 | 0.663 | 0.062 | 2.29 | 0.031 | 0.009 | 0.38 | 0.706 | 0.087 | 1.43 | 0.165 | -0.040 | -1.61 | 0.120 |

Note: Standard errors robust to heteroskedasticity. $+(++)$ Newey-West standard errors robust to first-order (second-order) autocorrelation.

Table 5: Estimation results with control variables and extended ending date

| | Liguria | | | Lombardy+ | | | Piedmont+++ | | | Aosta Valley | | | Friuli-Venezia Giulia | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value |
| ICU | -0.417 | -0.41 | 0.682 | -10.95 | -3.990 | 0.000 | -1.50 | -0.450 | 0.657 | – | – | – | -1.461 | -1.21 | 0.231 |
| $\Delta death$ | 1.292 | 1.25 | 0.216 | -1.08 | -0.390 | 0.701 | -1.71 | -1.130 | 0.262 | 0.12 | 0.890 | 0.376 | 0.514 | 0.45 | 0.651 |
| weekend | -1.521 | -7.19 | 0.000 | -0.22 | -1.740 | 0.087 | -0.12 | -1.680 | 0.098 | -0.51 | -2.210 | 0.031 | -0.747 | -3.29 | 0.002 |
| holiday | 0.230 | 0.97 | 0.335 | -1.67 | -10.370 | 0.000 | -0.50 | -5.670 | 0.000 | 0.23 | 0.850 | 0.401 | – | – | – |
| $\beta_1$ | -0.074 | -3.44 | 0.001 | -0.10 | -17.850 | 0.000 | -0.07 | -3.390 | 0.001 | -0.01 | -0.810 | 0.421 | -0.028 | -1.50 | 0.140 |
| $\beta_2$ | 0.644 | 2.35 | 0.022 | 0.22 | 1.300 | 0.199 | 1.18 | 3.710 | 0.000 | 0.62 | 3.220 | 0.002 | 1.238 | 4.86 | 0.000 |
| $\beta_3$ | 0.056 | 2.57 | 0.013 | 0.11 | 12.600 | 0.000 | 0.07 | 3.210 | 0.002 | -0.04 | -2.430 | 0.018 | 0.014 | 0.69 | 0.493 |
| $\beta_0$ | 6.751 | 13.12 | 0.000 | 8.44 | 14.960 | 0.000 | 5.88 | 16.680 | 0.000 | 5.73 | 26.980 | 0.000 | 5.283 | 20.80 | 0.000 |
| $\beta_1+\beta_3$ | -0.019 | -2.81 | 0.007 | 0.00 | 0.476 | 0.636 | 0.00 | -0.522 | 0.604 | -0.05 | -5.335 | 0.000 | -0.014 | -1.87 | 0.067 |
| | Trentino-Alto Adige | | | Veneto | | | Emilia-Romagna | | | Marche | | | Tuscany++ | | |
| | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value |
| ICU | 2.320 | 2.30 | 0.025 | -4.14 | -4.780 | 0.000 | 10.606 | 2.52 | 0.015 | -1.375 | -1.02 | 0.314 | -6.158 | -2.55 | 0.014 |
| $\Delta death$ | -0.471 | -0.47 | 0.643 | 0.16 | 0.190 | 0.847 | -0.360 | -0.49 | 0.624 | 1.400 | 0.60 | 0.553 | 0.498 | 0.89 | 0.377 |
| weekend | -1.046 | -7.47 | 0.000 | -0.28 | -3.390 | 0.001 | -0.154 | -1.82 | 0.074 | -0.723 | -2.85 | 0.006 | -0.095 | -1.07 | 0.290 |
| holiday | 0.611 | 4.44 | 0.000 | -1.22 | -16.960 | 0.000 | -1.168 | -15.06 | 0.000 | -1.889 | -5.97 | 0.000 | -0.684 | -6.44 | 0.000 |
| $\beta_1$ | 0.009 | 0.36 | 0.719 | -0.03 | -1.580 | 0.121 | -0.008 | -0.56 | 0.578 | -0.058 | -3.81 | 0.000 | -0.012 | -1.61 | 0.114 |
| $\beta_2$ | 0.666 | 3.37 | 0.001 | 1.12 | 5.370 | 0.000 | 1.322 | 7.03 | 0.000 | 1.092 | 4.94 | 0.000 | -0.112 | -0.44 | 0.664 |
| $\beta_3$ | -0.032 | -1.23 | 0.222 | 0.01 | 0.720 | 0.474 | -0.026 | -1.30 | 0.198 | 0.038 | 2.20 | 0.032 | 0.011 | 1.08 | 0.286 |
| $\beta_0$ | 5.101 | 12.16 | 0.000 | 5.98 | 27.440 | 0.000 | 4.258 | 7.86 | 0.000 | 6.007 | 24.84 | 0.000 | 6.765 | 15.32 | 0.000 |
| $\beta_1+\beta_3$ | -0.023 | -4.80 | 0.000 | -0.01 | -4.401 | 0.000 | -0.034 | -4.17 | 0.000 | -0.020 | -2.27 | 0.027 | -0.001 | -0.16 | 0.875 |

Table 5: Estimation results with control variables and extended ending date (*continued*)

| | Lazio++ | | | Umbria++ | | | Molise | | | Abruzzo | | | Basilicata+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value |
| ICU | -0.595 | -0.05 | 0.964 | -2.371 | -0.68 | 0.499 | 0.289 | 1.18 | 0.241 | -0.959 | -0.75 | 0.455 | -0.928 | -1.14 | 0.261 |
| $\Delta death$ | -2.021 | -0.52 | 0.603 | 0.688 | 0.50 | 0.618 | -0.273 | -0.36 | 0.717 | -0.295 | -0.25 | 0.805 | 0.235 | 0.88 | 0.385 |
| weekend | -0.701 | -2.42 | 0.019 | -0.184 | -0.64 | 0.524 | -0.330 | -0.91 | 0.369 | -0.651 | -3.49 | 0.001 | -0.069 | -1.55 | 0.126 |
| national holiday | -1.880 | -5.58 | 0.000 | 0.457 | 1.92 | 0.060 | 0.635 | 1.61 | 0.112 | -0.077 | -0.32 | 0.747 | -0.133 | -2.12 | 0.038 |
| $\beta_1$ | -0.002 | -0.04 | 0.965 | 0.039 | 0.43 | 0.669 | 0.084 | 1.57 | 0.123 | -0.034 | -3.77 | 0.000 | -0.020 | -4.08 | 0.000 |
| $\beta_2$ | -0.183 | -0.28 | 0.781 | 1.465 | 1.82 | 0.075 | 0.885 | 1.85 | 0.070 | 0.559 | 3.34 | 0.002 | 0.235 | 3.85 | 0.000 |
| $\beta_3$ | -0.004 | -0.07 | 0.946 | -0.052 | -0.57 | 0.572 | -0.128 | -2.32 | 0.024 | 0.011 | 1.06 | 0.294 | 0.009 | 1.61 | 0.114 |
| $\beta_0$ | 5.704 | 2.10 | 0.040 | 3.695 | 3.21 | 0.002 | 3.634 | 4.89 | 0.000 | 6.055 | 42.00 | 0.000 | 6.057 | 97.46 | 0.000 |
| $\beta_1 + \beta_3$ | -0.006 | -0.56 | 0.577 | -0.013 | -1.50 | 0.140 | -0.044 | -4.23 | 0.000 | -0.024 | -4.54 | 0.000 | -0.011 | -5.54 | 0.000 |
| | Calabria | | | Campania+++ | | | Puglia | | | Sardegna+ | | | Sicilia+ | | |
| | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value | coeff | t | p-value |
| ICU | 3.530 | 1.30 | 0.200 | -5.187 | -0.61 | 0.546 | -4.241 | -1.10 | 0.275 | 4.049 | 2.39 | 0.020 | -0.167 | -0.04 | 0.967 |
| $\Delta death$ | -0.094 | -0.25 | 0.807 | 0.207 | 0.30 | 0.767 | -2.232 | -0.88 | 0.384 | 1.237 | 1.60 | 0.115 | 0.635 | 1.84 | 0.071 |
| weekend | -0.789 | -5.21 | 0.000 | -0.749 | -6.16 | 0.000 | -1.242 | -5.31 | 0.000 | -1.056 | -6.11 | 0.000 | -0.317 | -3.44 | 0.001 |
| national holiday | -4.381 | -27.91 | 0.000 | -3.131 | -19.55 | 0.000 | -3.647 | -12.50 | 0.000 | -5.521 | -24.03 | 0.000 | -1.534 | -14.01 | 0.000 |
| $\beta_1$ | -0.025 | -1.76 | 0.084 | -0.047 | -1.78 | 0.081 | 0.006 | 0.23 | 0.821 | -0.028 | -2.20 | 0.032 | 0.010 | 0.74 | 0.464 |
| $\beta_2$ | 0.590 | 3.13 | 0.003 | 1.057 | 3.09 | 0.003 | 0.215 | 0.69 | 0.491 | 0.152 | 0.62 | 0.538 | 0.447 | 2.06 | 0.044 |
| $\beta_3$ | 0.005 | 0.34 | 0.737 | 0.035 | 1.35 | 0.184 | -0.027 | -0.97 | 0.336 | 0.021 | 1.48 | 0.145 | -0.029 | -2.20 | 0.032 |
| $\beta_0$ | 5.316 | 18.80 | 0.000 | 5.648 | 7.33 | 0.000 | 6.131 | 11.64 | 0.000 | 5.700 | 36.26 | 0.000 | 5.084 | 10.05 | 0.000 |
| $\beta_1 + \beta_3$ | -0.020 | -4.15 | 0.000 | -0.011 | -1.90 | 0.063 | -0.021 | -3.09 | 0.003 | -0.008 | -1.16 | 0.252 | -0.020 | -3.52 | 0.001 |

Note: Standard errors robust to heteroskedasticity. $+(++/+++)$ Newey-West standard errors robust to first-order (second-/third-order) autocorrelation.

## Table 6: Results of structural break tests

| | Liguria | | | Lombardia | | | Piemonte | | | Aosta Vally | | | Friuli-Venezia Giulia | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CUSUM test statistic (Jul 2-Jul 21, 2021) | 0.844 | 0.830 | | 3.290 | 1.718 | | 2.647 | 1.581 | | 0.447 | 0.212 | | 0.534 | 0.207 | |
| Wald test structural break (Jul 22, 2021) p-value | 0.376 | 0.500 | 0.167 | 0.885 | 0.000 | 0.003 | 0.011 | 0.000 | 0.000 | 0.122 | 0.249 | 0.007 | 0.000 | 0.000 | 0.000 |
| Controls | no | yes | yes | no | yes | yes | no | yes | yes | no | yes | yes | no | yes | yes |
| Ending date extended up to Sep 2, 2021 | no | no | yes | no | no | yes | no | no | yes | no | no | yes | no | no | yes |
| | Trentino-Alto Adige | | | Veneto | | | Emilia-Romagna | | | Marche | | | Toscana | | |
| CUSUM test statistic (Jul 2-Jul 21, 2021) | 0.703 | 0.496 | | 1.421 | 0.764 | | 1.058 | 0.432 | | 2.370 | 1.471 | | 1.596 | 1.320 | |
| Wald test structural break (Jul 22, 2021) p-value | 0.184 | 0.000 | 0.123 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.079 | 0.111 | 0.000 | 0.739 | 0.042 | 0.002 |
| Controls | no | yes | yes | no | yes | yes | no | yes | yes | no | yes | yes | no | yes | yes |
| Ending date extended up to Sep 2, 2021 | no | no | yes | no | no | yes | no | no | yes | no | no | yes | no | no | yes |
| | Lazio | | | Umbria | | | Molise | | | Abruzzo | | | Basilicata | | |
| CUSUM test statistic (Jul 2-Jul 21, 2021) | 0.659 | 0.345 | | 1.121 | 0.953 | | 0.488 | 0.856 | | 1.678 | 1.286 | | 2.104 | 1.401 | |
| Wald test structural break (Jul 22, 2021) p-value | 0.179 | 0.000 | 0.062 | 0.000 | 0.006 | 0.000 | 0.000 | 0.000 | 0.000 | 0.378 | 0.416 | 0.006 | 0.709 | 0.000 | 0.000 |
| Controls | no | yes | yes | no | yes | yes | no | yes | yes | no | yes | yes | no | yes | yes |
| Ending date extended up to Sep 2, 2021 | no | no | yes | no | no | yes | no | no | yes | no | no | yes | no | no | yes |
| | Calabria | | | Campania | | | Puglia | | | Sardegna | | | Sicilia | | |
| CUSUM test statistic (Jul 2-Jul 21, 2021) | 0.852 | 0.388 | | 1.020 | 1.047 | | 1.133 | 0.580 | | 0.395 | 0.539 | | 0.772 | 0.539 | |
| Wald test structural break (Jul 22, 2021) p-value | 0.216 | 0.022 | 0.121 | 0.004 | 0.003 | 0.001 | 0.229 | 0.021 | 0.001 | 0.535 | 0.540 | 0.110 | 0.000 | 0.000 | 0.035 |
| Controls | no | yes | yes | no | yes | yes | no | yes | yes | no | yes | yes | no | yes | yes |
| Ending date extended up to Sep 2, 2021 | no | no | yes | no | no | yes | no | no | yes | no | no | yes | no | no | yes |

Note: Controls: *ICU*, $\Delta$*death*, *weekend*. *ICU* is dropped in Aosta Valley. *ICU* and $\Delta$*death* are dropped in the CUSUM test for Molise and Friuli-Venezia Giulia, respectively. The CUSUM test critical values: 1% (1.143), 5% (0.948), 10% (0.850).

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