



The COVID-19 green certificate's effect on vaccine uptake in French and Italian regions

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Abstract

The COVID-19 green certificates were introduced in many countries in 2021 to encourage vaccine uptake against the COVID-19 virus in order to reduce the spread of severe infection among the population, ensure the safety of cross-border movements, and facilitate the resumption of social life and economic activities. This study uses a single-group interrupted time series approach to examine the effect of the green certificate announcement on the first doses of the COVID-19 vaccine in 20 Italian and 18 French regions during the summer of 2021. The estimation results show that the green certificate announcement mitigated regional disparities in vaccine uptake. It persuaded undecided people to have their first doses of the COVID-19 vaccine, especially in regions lagging in the mass vaccination campaign. It was less effective in those regions where there was already a high level of vaccine protection. The announcement also proved to be an effective political strategy with which to increase the first-dose rates immediately, but not in the long term.

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1. Introduction

On 11 March 2020, a pandemic of coronavirus disease 2019 (COVID-19), caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), was announced by the World Health Organization (WHO, 2020). The first cases of the virus infection were documented in China and then rapidly spread to the rest of the world. Less than a year after the announcement of the pandemic, vaccines against COVID-19 were made available in many advanced economies, beginning a decisive phase in the fight against the global health emergency through mass vaccination. In most of the countries that launched the COVID-19 vaccination campaign, there was introduced a digital and/or paper document for domestic use to encourage vaccine uptake, to achieve herd immunity, and to restart the economy safely. The document was given various names: ‘green certificate’, ‘health pass’ or ‘green pass’, amongst others. It was issued to people who had been vaccinated against COVID-19, with a negative test for the SARS-CoV-2 virus, or with a certificate of recovery from a recent natural infection revealed by a positive molecular or antigen test.

Israel was one of the first countries to adopt the certificate for access to non-essential services (Waitzberg et al., 2021). A green digital certificate came into force later in the European Union (EU) countries, with the intention of ensuring safe cross-border travel during the pandemic and preventing discrimination between vaccinated and unvaccinated individuals (Lang, 2021). In most of the EU countries, also adopted was a domestic green certificate system for access to public events or to engage in recreational and cultural activities indoors in safety (Montanari Vergallo et al., 2022). Italy progressively extended the green certificate’s internal use for access to essential facilities such as schools, universities, and public transport, and to economic activities (including work). This decision was taken to increase the first-dose rates of the COVID-19 vaccine, which were below the herd immunity coverage of 80–90% at the time of the effective entry of the certificate. A reinforced version of the green certificate entered into force in both Italy and France in December 2021 and January 2022, respectively. These new certificates allowed only those who were vaccinated against COVID-19 and those who had a certificate of recovery from a recent natural infection to take part in social and sports activities and use transport services. In Italy, it was also used for entry to workplaces. Established with the launch of the reinforced version of the green certificate was a ‘soft’ lockdown for unvaccinated individuals, who were excluded *de facto* from social and working life. This raised ethical doubts concerning 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 the period of its entry into force (Drury et al., 2021).

The extension of the green certificate to many activities and services 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 & Rüttenauer, 2022). At the same time, it provoked protests (Ward et al., 2022), and 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 & Rüttenauer, 2022). More coercive measures to boost vaccine uptake created further ethical problems and refusal to be vaccinated in the long term (Drury et al., 2021; Wise, 2021). According to Montanari Vergallo et al. (2022), less stringent policies to persuade the hesitant to

get vaccinated could have been implemented just as successfully. Crystal-clear information about the COVID-19 vaccine and public debates with doctors could have strengthened citizens' trust in the public health system and increased first-dose rates as well. It is no coincidence that countries like Spain, where the green certificate was ruled out¹ at the time of the pandemic and there was high citizens' trust in public health authorities, the levels of uptake of the first doses of COVID-19 vaccines were very high (Antonini et al., 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 percentage 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, 2022) 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 points increase in first-doses administration compared to Poland, where the certificate was 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-70 s. Overall, these studies show that the certificate mandate, as well as its announcement, is an effective policy instrument with which to increase vaccine uptake. But this does not imply that by itself it reduced vaccine hesitancy. As shown by Ward et al. (2022), it may increase doubts among vaccinated people after its implementation.

The original contribution of the present study is its empirical assessment of the short- and long-term effect of the green certificate announcement, which took place in summer 2021, on the daily administration of the first dose of the COVID-19 vaccine in 18 French and 20 Italian regions. It is plausible that there was an immediate increase in first-dose rates due to the announcement because hesitant people, worried about the announced policy's implications, promptly responded by rushing to get vaccinated. A long-term effect of the announcement may be less clear and/or evident due to the effective entry into force of the policy.

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. France and Italy are interesting case studies to analyse for several reasons. Firstly, they were hard hit by the COVID-19 pandemic in first waves (Hassenteufel, 2020; Beccia et al., 2022)

¹ Except for the Spanish regions of Galicia and the Canary Islands.

and adopted similar national policies against the outbreak (Berardi et al., 2020; Desson et al., 2020; Roques et al., 2020; Merkaj & Santolini, 2022). Secondly, they gradually introduced severe restrictive anti-COVID-19 measures through the green certificate. Thirdly, the two countries share similarities from a socio-economic point of view (Antonini et al., 2022) which make them comparable case studies. Finally, they have regional disparities in their public health systems (France et al., 2005; Chevreul et al., 2010; Ferré et al., 2014) that could produce a differentiated regional response to national anti-COVID-19 policies.

Italy was among the first European countries to introduce the green certificate as a measure to limit the spread of the virus and to encourage the gradual resumption of economic and social activities in the country. Its extension to most social, cultural and leisure activities was announced on 22 July 2021 by the Prime Minister Mario Draghi and entered into force on 6 August. In September, the green certificate became mandatory for the sectors of transport and public education, while in October it did so for the entire public and private sector. Analogous policy strategies were implemented in summer 2021 in France to contain the spread of the Delta variant. On 12 July 2021, President Emmanuel Macron announced that, starting on 21 July, the ‘health pass’ would be mandatory for access to leisure and cultural venues attended by more than 50 people. He also announced that, from the beginning of August, the health pass requirement would be extended to cafes, restaurants, hospitals, retirement homes, medical-social institutions, and long-distance transport (Ward et al., 2022). The announcement had the effect of incentivizing many people to receive the first dose of the vaccine in both countries (Karaivanov et al., 2021, 2022; Mills & Rüttenauer, 2022).

The impact of the green certificate announcement on the first-dose rates was analysed by means of a single-group interrupted time-series analysis (ITSA). This kind of analysis makes it possible to determine both the immediate and long-term effects of a policy intervention for a single entity such as a country or a region. The single-group ITS analysis conducted at the Italian regional level showed that the announcement effect produced a robust and immediate increase in the first-dose rates of the COVID-19 vaccine in the regions of Friuli-Venezia Giulia and Sicilia. The estimated average immediate increase was 199% and 67% in the daily first-dose rates for Friuli-Venezia Giulia and Sicilia, respectively.² Both Italian regions were characterized by a share of the first-dose vaccination rate below the national average at the time of the announcement (see Figure 1). For the Friuli-Venezia Giulia region, this delay may have been due to an already high percentage of people with a natural immunity to COVID-19. For the Sicily region, it can 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 (see Figure 2) and the mortality rate from the COVID-19 in this region were very low at the time of the announcement. Similar findings are observed for France where the announcement created a robust immediate increase in the daily first-dose rates in regions that were late with vaccinations: Auvergne-Rhône-Alpes (+97%), Corse (+404%), Guadeloupe (+116%), Guyane (+169%), La Réunion (+168%), Provence-Alpes-Côte d’Azur (+148%). Overall, these results demonstrate that the announcement had the effect desired by the national governments (i.e., the increase in first-dose rates to achieve herd immunity) especially in those regions lagging in the mass vaccination campaign (see Figure 3).

The single-group ITS analysis also showed that some regions (i.e., Lazio, Puglia, Sardegna, for Italy, and Bretagne, Martinique and Mayotte for France) did not react to the announcement. Most of them were characterized by high first dose-rates, or in any case ones above the national

² The increase was computed as $100(e^x - 1)$ where x is the estimated coefficient (Karaivanov et al., 2021).

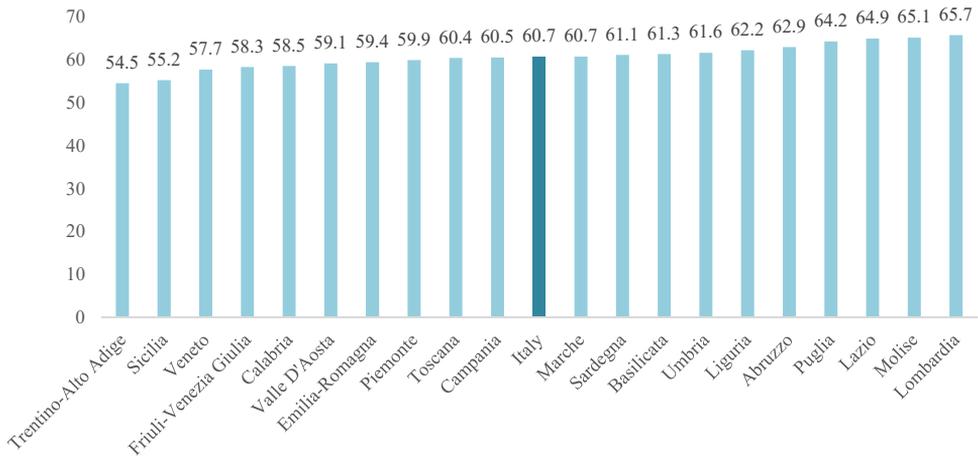


Fig 1. The daily COVID-19 first-dose vaccination rate (%) in Italian regions on 22 July 2021

Source: Author's elaboration on data provided by Extraordinary Commissioner for the COVID-19 emergency - Presidency of the Council of Ministers. Data coverage: 27 December 2020–22 July 2021.

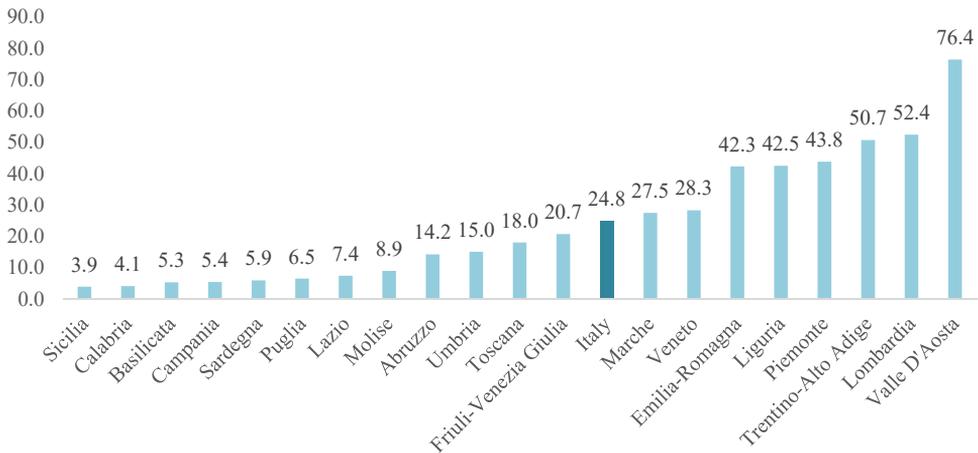


Fig 2. Rate of persons discharge-cured from COVID-19 (%) in Italian regions on 22 July 2021.

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

average, which rendered the announcement effect ineffective. An explanation for this good performance in the administration of the first-doses could be a greater level of citizens' confidence in the efficacy of the vaccine. Indeed, these regions proved to be less severely affected by COVID-19 in terms of mortality rate and virus spread (see [Figures 2 and 4](#)). Thus, citizens' perceptions of the disease's severity may have been lower in these regions to justify a rush to get vaccinated voluntarily during the pandemic.

Overall, the estimation results showed that the green certificate announcement mitigated regional disparities in vaccine uptake. It persuaded undecided people to have their first doses of COVID-19 vaccine, especially in regions lagging behind in the mass vaccination campaign. It was less effective in those regions where there was already a high level of vaccine protection.

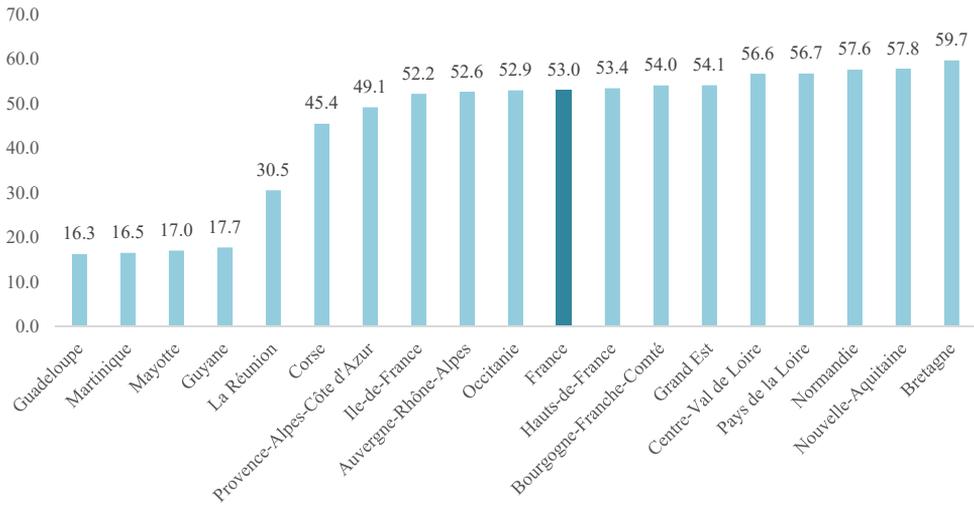


Fig 3. The daily COVID-19 first-dose vaccination rate (%) in French regions on 12 July 2021.

Source: Author's elaboration on data provided by Santé publique France - Données relatives aux personnes vaccinées contre la Covid-19. Data coverage: 1 January 2021–12 July 2021.

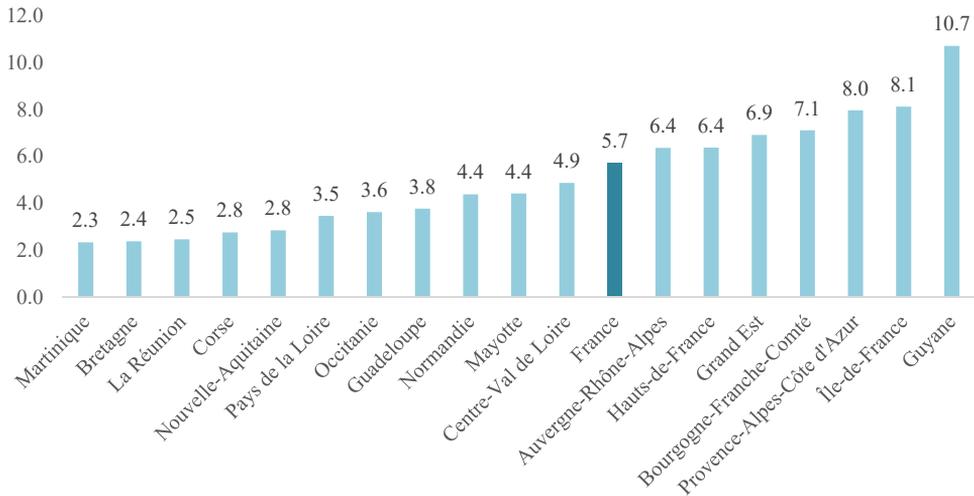


Fig 4. Rate of persons discharge-cured after a diagnosis of COVID-19 per 1000 inhabitants in French regions on 12 July 2021
Source: Author's elaboration on data provided by Santé Publique France, Préfectures, Agences Régionales de Santé, Ministère des Solidarités et de la Santé - Chiffres-clés concernant l'épidémie de COVID19 en France. Data coverage: 5 April 2020 – 12 July 2021.

The announcement also proved to be an effective political strategy with which to increase the first dose-rates immediately, but not in the long-term. Without it, the increase in the first doses would have been much smaller.

The next section describes 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 by discussing policy implications.

2. Data

We examine the effect of the announcement of the mandatory extension of the basic green pass, which occurred on 22 July 2021 in Italy and 12 July 2021 in France, on first doses of vaccine administration. The empirical analysis exploits data on first-dose vaccine administration for a sample of 20 Italian and 18 French regions from 2 July to 2 August 2021. These are open data provided by the Italian Extraordinary Commissioner for the COVID-19³ emergency and Santé Publique France.⁴

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. 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 likely motivated the Italian government to extend the basic green pass to many activities and services to encourage vaccine administration. Figure 1 also shows that the Piemonte 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 2.⁵ 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, Sicilia had the lowest first-dose vaccination rate (55.2%). The higher percentage of unvaccinated persons in Sicilia 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%).

Figure 3 shows the first-dose coverage in the French regions at the time of the announcement of the health pass extension. The high first-dose rates in the Grand Est, Bourgogne-Franche-Comté and Hauts-de-France regions could be explained by the remarkable loss of human life due to COVID-19 in those regions during the first waves of the pandemic. This may have increased the willingness of the population to get vaccinated in order to protect themselves against the virus and serious illness. Interestingly, there are four regions, Guadeloupe, Guyane, Martinique, and Mayotte, with first dose rates below 20%. Among the reasons that could explain the small amounts of the first doses, there may have been a lower perception of the severity of the COVID-19 disease due to smaller COVID-19 mortality rates in the first waves in those French regions than in the others.

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, 2022). It was transformed into natural logarithm to interpret the coefficients estimated in the regressions as percentage changes in the

³ Available at the link: github.com/italia/covid19-opendata-vaccini.

⁴ Available at the link: www.data.gouv.fr/en/datasets/donnees-relatives-aux-personnes-vaccinees-contre-la-covid-19-1/.

⁵ 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.

Table 1

Descriptive statistics of the first-doses COVID-19 vaccines per 100,000 inhabitants in Italian and French regions over the period 2 July-2 August 2021.

	first-dose				
	Obs	Mean	Std.dev.	Min	Max
<i>Italian</i>					
Abruzzo	32	247.09	55.09	155.21	375.93
Valle D'Aosta	32	253.13	58.31	128.80	458.50
Basilicata	32	339.44	49.69	275.70	504.22
Calabria	32	192.62	76.05	45.17	331.85
Campania	32	138.26	70.50	17.33	277.44
Emilia-Romagna	32	238.01	97.31	61.23	443.96
Friuli-Venezia Giulia	32	157.45	78.43	12.12	336.30
Lazio	32	239.35	189.48	37.89	516.34
Liguria	32	242.70	112.35	9.99	420.89
Lumbardy	32	188.17	119.08	69.56	490.07
Marche	32	175.30	78.62	66.99	343.64
Molise	32	217.65	175.82	13.24	555.90
Piemonte	32	181.17	77.93	76.71	409.43
Puglia	32	246.70	101.03	65.42	443.20
Sardinia	32	229.23	96.86	53.97	413.73
Sicilia	32	210.80	74.69	75.62	396.75
Trentino-Alto Adige	32	243.93	115.30	20.75	522.04
Toscana	32	254.56	62.30	119.67	376.37
Umbria	32	148.18	128.30	7.55	449.03
Veneto	32	221.33	109.35	76.37	465.71
<i>France</i>					
Guadeloupe	32	146.1	70.9	28.2	317.8
Martinique	32	182.9	117.4	8.7	421.6
Guyane	32	144.4	61.3	29.3	230.6
La Réunion	32	441.9	216.5	86.0	832.0
Mayotte	32	193.9	143.7	2.1	394.7
Ile-de-France	32	409.2	169.2	104.4	658.1
Centre-Val de Loire	32	374.0	238.3	22.5	813.9
Bourgogne-Franche-Comté	32	408.1	232.6	19.8	762.1
Normandie	32	399.4	185.7	87.0	784.5
Hauts-de-France	32	431.0	184.0	129.2	718.5
Grand Est	32	382.1	195.6	56.1	748.1
Pays de la Loire	32	371.5	190.0	47.7	753.7
Bretagne	32	346.6	162.6	69.6	627.2
Nouvelle-Aquitaine	32	353.2	186.8	55.6	721.7
Occitanie	32	389.3	183.5	89.2	729.9
Auvergne-Rhône-Alpes	32	407.7	199.8	98.6	710.7
Provence-Alpes-Côte d'Azur	32	365.2	208.1	37.5	692.4
Corse	32	334.8	204.2	23.4	649.4

outcome variable. In [Table 1](#), we summarize descriptive statistics of the outcome variable used in the empirical analysis.

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. For French regions, also included was a

dummy variable for Bastille Day celebrations, assuming value 1 in date 14 July 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, 2022). Such variables were the daily change in deaths⁶ 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 Italian Department of Civil Protection and Santé Publique France.⁷

3. Interrupted time series analysis

3.1. Model specification

Randomized trials are widely used to analyze health policy interventions because 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 & 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 for Italy and 12 July 2021 for France, on the daily rate of first-dose vaccine administration.

Equation (1) illustrates the baseline model estimated in the empirical analysis. The outcome variable $firstdose_{it}$ is the log of persons vaccinated with the first-dose per 100,000 inhabitants for the i -th region on day t . The variable $announce_{it}$ 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 $announce_{it} * T$ is the interaction term. A constant and an error term e assumed to be normally distributed, are introduced into the baseline model specification.

$$first-dose_{it} = \beta_0 + \beta_1 T_{it} + \beta_2 announce_{it} + \beta_3 announce_{it} * T_{it} + e_{it} \quad (1)$$

The coefficient β_0 measures the intercept of pre-intervention trend and represents the starting level of the outcome variable. β_1 corresponds to the slope of the pre-intervention trend of the outcome variable until the announcement. The coefficient β_2 is the level change in the outcome variable that occurs in the period immediately following the intervention. The coefficient β_3 captures the effect of the intervention over time (Linden & Adams, 2011; Linden & 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 β_2 and β_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 & Svoronos, 2019).

Model (1) was estimated with the ordinary least squares (OLS) estimator correcting standard errors for autocorrelation⁸ when they were detected with the test developed by (Cumby &

⁶ For France, the number of deaths in hospitals is considered.

⁷ They are open data available at the links: <https://github.com/pcm-dpc/COVID-19> (Italy), <https://www.data.gouv.fr/en/datasets/synthese-des-indicateurs-de-suivi-de-lepidemie-covid-19/> (France).

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

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 & 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 & Arbor, 2015, p. 481).

3.2. Baseline results

Table 2 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 & Arbor, 2015).

The baseline estimates for Italian regions 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 them, specifically in Abruzzo, Basilicata, Calabria, Campania, Emilia-Romagna, Friuli-Venezia Giulia, Marche, Piemonte, Sicilia, Umbria and Veneto. Indeed, the coefficient β_2 , which captures the immediate effect of policy intervention, is statistically significant in those regions. The immediate effect is negative and significant in the Toscana region.

The long-term effect of the announcement, measured by the coefficient β_3 , is reliable in those regions where the post-intervention trend coefficient, measured as the sum of β_1 and β_3 , is statistically significant. Accordingly, a positive and significant long-term effect is found for Campania, Lombardia, Marche, Piemonte and Toscana. This result is interesting because the northern regions of Lombardia and Piemonte 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 Valle D’Aosta, Liguria, Lazio, Molise, Puglia, Sardegna and Trentino-Alto Adige. The absence of a significant announcement effect in regions like Lazio, Molise, Puglia, and Sardegna could be explained by the fact that they already had high 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 Valle D’Aosta and Trentino-Alto Adige could be due to high rates of natural immunity as shown in Figure 2.

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 2. The main difference is that the immediate effect of the announcement measured by the coefficient β_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.

⁹ The Cumby and Huizinga (1992) general test for autocorrelation has been performed by using the Stata command “actest” implemented by Baum and Schaffer (1990).

Table 2
Baseline results for Italian regions.

	β_1	β_2	β_3	β_0	$\beta_1 + \beta_3$
	(1)	(2)	(3)	(4)	(5)
Liguria	-0.057 * * (-2.43)	0.878 (1.58)	-0.050 (-0.52)	5.991 * * * (35.36)	-0.107 (-1.15)
Lombardia	-0.085 * * * (-7.04)	0.283 (1.18)	0.201 * * * (5.14)	5.949 * * * (31.80)	0.116 * * (3.18)
Piemonte	-0.067 * * (-3.36)	0.849 * * (3.17)	0.095 * * * (4.62)	5.699 * * * (29.27)	0.028 * * * (4.50)
Valle D'Aosta	-0.007 (-0.73)	0.155 (1.10)	0.013 (0.79)	5.532 * * * (45.30)	0.007 (0.47)
Friuli-Venezia Giulia	-0.020 (-0.86)	1.096 * * (3.36)	-0.013 (-0.39)	4.836 * * * (17.92)	-0.033 (-1.30)
Trentino-Alto Adige	-0.001 (-0.03)	0.082 (0.19)	0.041 (0.81)	5.239 * * * (10.46)	0.040 (1.10)
Veneto	-0.047 * * (-2.40)	1.112 * * * (4.49)	0.066 * * (2.58)	5.492 * * * (22.65)	0.019 (1.15)
Emilia-Romagna	-0.023 * (-1.84)	1.025 * * * (5.70)	-0.002 (-0.10)	5.377 * * * (32.08)	-0.025 (-1.64)
Marche	-0.05 * * * (-4.90)	0.422 * (1.72)	0.121 * * (3.39)	5.49 * * * (50.98)	0.071 * * (2.08)
Toscana	-0.017 * * * (-5.10)	-0.347 * * (-2.63)	0.119 * * * (6.68)	5.669 * * * (125.07)	0.103 * * * (5.87)
Lazio	0.013 (0.29)	-0.175 (-0.22)	-0.078 (-0.87)	5.142 * * * (9.99)	-0.065 (-0.88)
Umbria	0.024 (0.29)	1.449 * (1.73)	-0.080 (-0.75)	3.611 * * (3.15)	-0.057 (-0.77)
Molise	0.088 * * (2.13)	0.437 (0.92)	-0.075 (-1.41)	3.486 * * * (6.39)	0.013 (0.38)
Abruzzo	-0.029 * * * (-4.27)	0.393 * * * (2.82)	0.026 (1.23)	5.761 * * * (76.43)	-0.003 (-0.16)
Basilicata	-0.020 * * (-3.44)	0.198 * * * (2.83)	0.019 * * (2.52)	6.031 * * * (80.48)	-0.001 (-0.23)
Calabria	-0.022 (-1.23)	0.620 * (1.87)	-0.008 (-0.18)	5.306 * * * (25.28)	-0.030 (-0.69)
Campania	-0.034 (-1.54)	0.570 * (1.79)	0.091 * * (2.72)	4.944 * * * (16.06)	0.057 * * (2.22)
Puglia	0.007 (0.39)	0.131 (0.45)	-0.006 (-0.15)	5.268 * * * (21.92)	0.000 (0.00)
Sardegna	-0.009 (-0.57)	0.009 (0.02)	0.049 (0.78)	5.363 * * * (35.57)	0.040 (0.66)
Sicilia	0.013 (1.08)	0.514 * * (2.57)	-0.041 * (-1.80)	4.959 * * * (30.86)	-0.027 (-1.38)

Note: Control variables are not included in the ITSA regressions. Newey-West standard errors are robust to autocorrelation of: first order for Basilicata, Campania, Lazio, Lombardia, Sicilia, Veneto, and Toscana; second order for Piemonte and Umbria. Time period: 2 July-2 August 2021. Date of announcement: 22 July 2021.

Baseline estimates of the impact of the extension of the health pass on the first-dose rates in the French regions are reported in [Table 3](#). They reveal a significant immediate impact of the extension of the health pass on the first dose-rates after its announcement among the regions hard hit by the pandemic, such as Auvergne-Rhône-Alpes, Grand Est, Ile-de-France, Occitanie,

Table 3
Baseline results for French regions.

	β_1	β_2	β_3	β_0	$\beta_1 + \beta_3$
	(1)	(2)	(3)	(4)	(5)
Guadeloupe	-0.012 (-0.30)	0.771 ** (3.11)	0.017 (0.41)	4.398 *** (18.85)	0.005 (0.58)
Martinique	0.082 (0.65)	0.712 (0.77)	-0.104 (0.77)	3.752 *** (5.33)	-0.022 (0.481)
Guyane	-0.048 (-0.68)	0.990 ** (2.38)	0.028 (0.39)	4.755 *** (9.99)	-0.020 (-1.33)
La Réunion	-0.026 (-0.43)	0.986 ** (2.50)	0.029 (0.44)	5.486 *** (16.42)	0.003 (0.86)
Mayotte	-0.024 (-0.11)	0.296 (0.19)	0.050 (0.22)	4.386 *** (3.46)	0.026 (0.45)
Ile-de-France	-0.009 (-0.23)	0.612 ** (2.60)	0.011 (0.25)	5.558 *** (26.65)	0.002 (0.15)
Centre-Val de Loire	-0.064 (-0.66)	0.899 (1.39)	0.077 (0.78)	5.465 *** (10.51)	0.014 (0.63)
Bourgogne-Franche-Comté	-0.077 (-0.57)	1.230 (1.36)	0.083 (0.6)	5.536 *** (7.06)	0.0061 (0.24)
Normandie	-0.018 (-0.31)	0.462 (1.17)	0.040 (0.67)	5.547 *** (15.55)	0.022 (1.47)
Hauts-de-France	0.007 (0.15)	0.489 (1.68)	0.014 (0.28)	5.416 *** (21.86)	0.020 (1.33)
Grand Est	-0.027 (-0.48)	0.648 * (1.77)	0.051 (0.84)	5.417 *** (17.35)	0.024 * (1.89)
Pays de la Loire	-0.036 (-0.53)	0.645 (1.46)	0.053 (0.73)	5.516 *** (14.22)	0.016 (1.13)
Bretagne	-0.056 (-0.84)	0.584 (1.17)	0.065 (0.93)	5.744 *** (15.75)	0.009 (0.44)
Nouvelle-Aquitaine	-0.028 (-0.42)	0.484 (1.08)	0.052 (0.75)	5.440 *** (14.74)	0.024 * (1.71)
Occitanie	-0.026 (-0.58)	0.655 ** (2.22)	0.047 (0.92)	5.474 *** (21.48)	0.021 (1.37)
Auvergne-Rhône-Alpes	-0.021 (-0.46)	0.682 ** (2.34)	0.033 (0.65)	5.508 *** (21.83)	0.012 (0.89)
Provence-Alpes-Côte d'Azur	-0.031 (-0.43)	0.909 * (1.98)	0.040 (0.53)	5.255 *** (13.38)	0.009 (0.58)
Corse	-0.020 (-0.22)	1.618 ** (2.65)	0.004 (0.04)	4.747 *** (10.05)	-0.02 (-0.90)

Note: Control variables are not included in the ITSA regressions. Newey-West standard errors are robust to autocorrelation of first order for Corse, Hauts-de-France; La Réunion; third order for Occitanie; fourth order for Pays de la Loire; fifth order for Auvergne-Rhône-Alpes, Centre-Val de Loire, Ile-de-France, Grand Est, Guadeloupe, Normandie, Nouvelle-Aquitaine, Provence-Alpes-Côte d'Azur. Time period: 2 July-2 August 2021. Date of announcement: 12 July 2021.

Provence-Alpes-Côte d'Azur, or in those late with vaccinations, like Corse, Guadeloupe, Guyane, and La Réunion. As shown by [Table 5](#), the inclusion of controls in the interrupted time series regression analysis maintains the immediate impacts of the announcement on first-dose rates for Corse, Guadeloupe, Guyane, La Réunion, Auvergne-Rhône-Alpes and Provence-Alpes-Côte d'Azur significant. It also becomes statistically significant for the regions of Centre-Val de Loire and Hauts-de-France. Several French regions (Martinique, Mayotte, Bourgogne-

Table 4

Estimation results with controls for Italian regions.

	β_1	β_2	β_3	β_0	$\beta_1 + \beta_3$
	(1)	(2)	(3)	(4)	(5)
Liguria	-0.091 *** (-6.39)	1.231 *** (4.12)	-0.061 (-1.17)	6.837 *** (13.73)	-0.152 ** (-2.62)
Lombardia	-0.104 *** (-20.84)	0.049 (0.19)	0.159 *** (5.71)	8.581 *** (21.39)	0.055 * (1.99)
Piemonte	-0.061 ** (-2.96)	0.821 ** (3.29)	0.093 ** (3.46)	5.404 *** (15.26)	0.032 ** (2.57)
Valle D'Aosta	-0.007 (-0.74)	0.159 (1.12)	0.015 (0.84)	5.562 *** (38.84)	0.007 (0.52)
Friuli-Venezia Giulia	-0.026 (-1.33)	1.110 ** (3.54)	0.012 (0.36)	5.182 *** (21.76)	-0.014 (-0.53)
Trentino-Alto Adige	-0.003 (-0.14)	0.257 (1.06)	0.042 (0.93)	5.438 *** (12.51)	0.039 (1.03)
Veneto	-0.046 ** (-2.10)	1.108 *** (4.65)	0.064 ** (2.16)	5.644 *** (16.31)	0.018 (1.09)
Emilia-Romagna	-0.003 (-0.15)	1.292 *** (4.44)	-0.033 (-0.93)	3.906 *** (4.65)	-0.036 (-1.46)
Marche	-0.052 *** (-4.77)	0.430 * (1.78)	0.127 *** (3.90)	5.557 *** (19.55)	0.075 ** (2.43)
Toscana	-0.016 *** (-3.86)	-0.313 ** (-2.13)	0.119 *** (6.00)	5.468 *** (18.83)	0.103 *** (5.21)
Lazio	0.033 (0.62)	-0.416 (-0.54)	-0.124 (-1.28)	5.983 * (1.94)	-0.091 (-1.20)
Umbria	0.004 (0.04)	1.508 (1.69)	-0.055 (-0.42)	3.163 ** (3.00)	-0.051 (-0.71)
Molise	0.093 * (1.81)	0.346 (0.62)	-0.063 (-0.85)	3.405 *** (5.04)	0.030 (0.57)
Abruzzo	-0.031 *** (-7.56)	0.447 *** (4.42)	0.050 ** (2.57)	5.656 *** (39.02)	0.019 (0.99)
Basilicata	-0.021 ** (-2.90)	0.186 ** (2.43)	0.024 ** (3.10)	6.068 *** (71.35)	0.004 (1.35)
Calabria	-0.021 (-1.68)	0.543 (1.57)	0.003 (0.07)	5.048 *** (19.39)	-0.018 (-0.44)
Campania	-0.040 (-1.30)	0.584 * (1.90)	0.102 ** (3.35)	5.384 *** (4.50)	0.062 ** (2.29)
Puglia	-0.006 (-0.23)	0.238 (1.03)	0.014 (0.38)	5.195 *** (6.43)	0.009 (0.38)
Sardegna	-0.002 (-0.11)	0.240 (0.95)	0.088 (1.59)	5.744 *** (36.35)	0.087 (1.43)
Sicilia	0.016 (1.38)	0.493 ** (2.14)	-0.056 * (-2.00)	5.636 *** (10.14)	-0.040 (-1.61)

Note: Control variables are included in the ITSA regressions. The variable ICU was dropped in the interrupted time-series regression for the Valle D'Aosta region since it was time invariant over the period examined. Newey-West standard errors are robust to autocorrelation of first order for Abruzzo, Calabria, Campania, Lazio, Liguria, Lombardia, Piemonte, Puglia, Sicilia, Toscana, and Veneto; second order autocorrelation for Basilicata and Umbria. Time period: 2 July-2 August 2021. Date of announcement: 22 July 2021.

Table 5
Estimation results with controls for French regions.

Region	β_1	β_2	β_3	β_0	$\beta_1 + \beta_3$
	(1)	(2)	(3)	(4)	(5)
Guadeloupe	0.0004 (0.01)	0.608 * * (2.55)	0.012 (0.20)	4.764 * * * (6.08)	0.012 (0.54)
Martinique	0.144 (0.95)	0.506 (0.48)	-0.202 (1.22)	4.024 * * * (4.82)	-0.059 (-1.48)
Guyane	-0.046 (-0.89)	0.954 * * (3.09)	0.022 (0.41)	5.650 * * * (4.95)	-0.024 (-1.38)
La Réunion	-0.022 (-0.32)	0.984 * (1.99)	0.009 (0.11)	4.452 * * (2.68)	-0.013 (-0.51)
Mayotte	-0.024 (-0.11)	0.665 (0.42)	0.025 (0.11)	4.222 * * (3.25)	0.001 (0.02)
Ile-de-France	0.024 (0.53)	0.447 (1.26)	-0.035 (-0.70)	7.815 * * (3.26)	-0.011 (-0.70)
Centre-Val de Loire	-0.096 (-1.33)	1.380 * * (2.62)	0.101 (1.45)	4.91 * (1.94)	0.005 (0.18)
Bourgogne-Franche-Comté	-0.050 (-0.50)	0.858 (1.21)	0.052 (0.52)	6.896 * * * (6.42)	0.002 (0.08)
Normandie	-0.044 (-0.73)	0.567 (1.29)	0.076 (1.16)	8.226 * * * (3.64)	0.031 * * (2.25)
Hauts-de-France	-0.025 (-0.67)	0.581 * (1.99)	0.004 (0.12)	8.061 * * * (7.50)	-0.021 (-0.98)
Grand Est	-0.023 (-0.24)	0.610 (0.94)	0.047 (0.45)	5.333 * * (3.06)	0.024 (0.86)
Pays de la Loire	-0.029 (-0.31)	0.622 (1.08)	0.043 (0.46)	5.129 * * * (3.68)	0.014 (0.58)
Bretagne	-0.050 (-0.80)	0.616 (1.37)	0.056 (0.68)	5.488 * * (2.40)	0.006 (0.18)
Nouvelle-Aquitaine	-0.017 (-0.37)	0.548 * (1.93)	0.025 (0.44)	5.472 * * * (4.03)	0.008 (0.29)
Occitanie	-0.020 (-0.52)	0.421 (1.42)	0.086 * (1.71)	6.737 * * * (9.64)	0.065 * * (2.42)
Auvergne-Rhône-Alpes	-0.011 (-0.21)	0.680 * (1.86)	0.023 (0.30)	6.248 * * (2.81)	0.012 (0.35)
Provence-Alpes-Côte d'Azur	-0.008 (-0.14)	0.907 * * (2.59)	0.036 (0.57)	9.208 * * * (3.66)	0.028 (1.36)
Corse	-0.035 (-0.39)	1.655 * * (2.47)	0.014 (0.15)	4.604 * * * (7.72)	-0.021 (-0.96)

Note: Control variables are included in the ITSA regressions. *ICU* and $\Delta death$ are dropped in Mayotte. Newey-West standard errors are robust to autocorrelation of fifth order for Bretagne. Time period: 2 July-2 August 2021. Date of announcement: 12 July 2021.

Franche-Comté, Normandie, Pays del La Loire, and Bretagne) did not react to the announcement (see [Tables 3 and 5](#)). Some of them (Normandie, Pays del La Loire, and Bretagne) had a high share of first-dose rates at the time of the announcement (see [Figure 3](#)), sterilizing its effect.

The long-term impact of the announcement on first-dose rates is not statistically significant in any French region. This may depend on the short period considered in the ITSA.

3.3. Sensitivity analysis

A sensitivity analysis was carried out to check whether the results in Tables 6 and 7 could depend on the ending date. Accordingly, the time period of the sample was extended until 2

Table 6
Estimation results with controls and extended ending date for Italian regions.

	β_1	β_2	β_3	β_0	$\beta_1 + \beta_3$
	(1)	(2)	(3)	(4)	(5)
Liguria	-0.074 *** (-3.44)	0.644 ** (2.35)	0.056 ** (2.57)	6.751 *** (13.12)	-0.019 ** (-2.81)
Lombardia	-0.104 *** (-17.85)	0.224 (1.30)	0.108 *** (12.60)	8.443 *** (14.96)	0.004 (0.48)
Piemonte	-0.070 *** (-3.39)	1.177 *** (3.71)	0.068 ** (3.21)	5.879 *** (16.68)	-0.003 (-0.52)
Valle D'Aosta	-0.011 (-0.81)	0.620 ** (3.22)	-0.038 ** (-2.43)	5.733 *** (26.98)	-0.049 *** (-5.33)
Friuli-Venezia Giulia	-0.028 (-1.50)	1.238 *** (4.86)	0.014 (0.69)	5.283 *** (20.80)	-0.014 * (-1.87)
Trentino-Alto Adige	0.009 (0.36)	0.666 *** (3.37)	-0.032 (-1.23)	5.101 *** (12.16)	-0.023 *** (-4.80)
Veneto	-0.026 (-1.58)	1.119 *** (5.37)	0.012 (0.72)	5.979 *** (27.44)	-0.015 *** (-4.40)
Emilia-Romagna	-0.008 (-0.56)	1.322 *** (7.03)	-0.026 (-1.30)	4.258 *** (7.86)	-0.034 *** (-4.17)
Marche	-0.058 *** (-3.81)	1.092 *** (4.94)	0.038 ** (2.20)	6.007 *** (24.84)	-0.02 ** (-2.27)
Toscana	-0.012 (-1.61)	-0.112 (-0.44)	0.011 (1.08)	6.765 *** (15.32)	-0.001 (-0.16)
Lazio	-0.002 (-0.04)	-0.183 (-0.28)	-0.004 (-0.07)	5.704 ** (2.10)	-0.006 (-0.56)
Umbria	0.039 (0.43)	1.465 * (1.82)	-0.052 (-0.57)	3.695 * (3.21)	-0.013 (-1.50)
Molise	0.084 (1.57)	0.885 * (1.85)	-0.128 ** (-2.32)	3.634 *** (4.89)	-0.044 *** (-4.23)
Abruzzo	-0.034 *** (-3.77)	0.559 ** (3.34)	0.011 (1.06)	6.055 *** (42.00)	-0.024 *** (-4.54)
Basilicata	-0.020 *** (-4.08)	0.235 *** (3.85)	0.009 (1.61)	6.057 *** (97.46)	-0.011 *** (-5.54)
Calabria	-0.025 * (-1.76)	0.590 ** (3.13)	0.005 (0.34)	5.316 *** (18.80)	-0.020 *** (-4.15)
Campania	-0.047 * (-1.78)	1.057 ** (3.09)	0.035 (1.35)	5.648 *** (7.33)	-0.011 * (-1.90)
Puglia	0.006 (0.23)	0.215 (0.69)	-0.027 (-0.97)	6.131 *** (11.64)	-0.021 ** (-3.09)
Sardegna	-0.028 ** (-2.20)	0.152 (0.62)	0.021 (1.48)	5.700 *** (36.26)	-0.008 (-1.16)
Sicilia	0.010 (0.74)	0.447 ** (2.06)	-0.029 ** (-2.20)	5.084 *** (10.05)	-0.020 *** (-3.52)

Note: Control variables are included in the ITSA regressions. Newey-West standard Errors are robust to autocorrelation of first order for Basilicata, Lombardia, Sardegna, Sicilia; second order for Lazio, Toscana, Umbria; third order autocorrelation for Campania, Piemonte. Time period: 2 July-2 September 2021. Date of announcement: 22 July 2021.

Table 7

Estimation results with controls and extended ending date for French regions.

	β_1	β_2	β_3	β_0	$\beta_1 + \beta_3$
Guadeloupe	-0.00002 (-0.00)	0.660 * * (3.23)	0.004 (0.13)	4.749 * * * (14.47)	0.004 (1.016)
Martinique	0.093 (0.67)	0.525 (0.53)	-0.084 (-0.60)	3.624 * * * (4.65)	0.009 (0.92)
Guyane	-0.045 (-1.12)	0.903 * * * (3.46)	0.032 (0.79)	5.071 * * * (5.59)	-0.014 * * * (-5.78)
La Réunion	-0.024 (-0.54)	1.076 * * * (3.92)	0.008 (0.17)	4.560 * * * (8.44)	-0.016 (-2.95)
Mayotte	-0.024 (-0.110)	0.800 (0.56)	0.031 (0.14)	4.190 * * * (3.38)	0.007 (0.45)
Ile-de-France	0.018 (0.43)	0.557 * (1.77)	-0.038 (-0.84)	7.734 * * * (5.77)	-0.02 * (-1.85)
Centre-Val de Loire	-0.111 * (-1.76)	1.821 * * * (4.46)	0.083 (1.28)	6.178 * * * (7.08)	-0.028 * * (-2.67)
Bourgogne-Franche-Comté	-0.045 (-0.48)	1.373 * * (2.20)	0.012 (0.12)	5.922 * * * (11.11)	-0.034 * * * (-3.77)
Normandie+	0.007 (0.12)	0.900 * * (2.16)	-0.040 (-0.57)	4.938 * * * (4.12)	-0.033 * * (-2.03)
Hauts-de-France	-0.015 (-0.44)	0.557 * * (2.13)	0.010 (0.30)	7.035 * * * (18.60)	-0.004 (-0.73)
Grand Est	-0.030 (-0.37)	1.456 * * (2.61)	-0.013 (-0.15)	4.777 * * * (4.72)	-0.043 * * (-2.19)
Pays de la Loire	-0.040 (-0.53)	1.103 * * (2.32)	0.025 (0.32)	6.198 * * * (8.22)	-0.015 * (-1.97)
Bretagne	-0.084 (-1.36)	0.758 (1.60)	0.090 (1.35)	7.815 * * * (8.21)	0.005 (0.41)
Nouvelle-Aquitaine	-0.025 (-0.45)	1.242 * * * (3.32)	-0.031 (-0.52)	4.84 * * * (8.08)	-0.055 * * (-3.26)
Occitanie	-0.002 (-0.80)	0.951 * * * (4.28)	-0.043 (-1.31)	5.070 * * * (17.38)	-0.046 * * * (-4.91)
Auvergne-Rhône-Alpes	-0.037 (-0.66)	1.083 * * * (3.19)	0.028 (0.35)	7.282 * * * (4.36)	-0.009 (-0.29)
Provence-Alpes-Côte d'Azur	-0.022 (-0.340)	1.503 * * (3.30)	-0.016 (-0.24)	5.613 * * * (4.33)	-0.039 * * (-2.44)
Corse	-0.034 (-0.39)	1.792 * * (2.90)	0.003 (0.04)	4.674 * * * (10.15)	-0.030 * * * (-3.79)

Note: Control variables are included in the ITSA regressions. ICU is dropped in Mayotte. Newey-West standard errors are robust to autocorrelation of first order for Normandie, Bretagne, Nouvelle-Aquitaine, Occitanie, Auvergne-Rhône-Alpes; second order for La Réunion, Pays de la Loire; sixth order for Guyane. Time period: 2 July-2 September 2021. Date of announcement: 12 July 2021.

September 2021. This is not without concerns because a longer time span involves further announcement and effective entry effects due to green pass reforms. 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 Italian and French regions. In [Table 4](#), it now becomes statistically significant for Valle D’Aosta, Molise, Trentino-Alto Adige, and Umbria. A negative long-term effect of the announcement is now statistically significant for Valle D’Aosta, Liguria, Molise and Sicilia. In the specific case of Lombardia, 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 Toscana region. In [Table 5](#), we find that, apart from Martinique, Mayotte, and Bretagne, the rest of the French regions reacted immediately and significantly to the announcement by increasing first doses of COVID-19 vaccine. Despite the extension of the ending date, the long-term effects of the announcement remained not statistically significant for the French regions.

3.4. 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 & Arbor, 2015](#); [Linden, 2020](#)) and there is a significant change in the outcome variable immediately after the policy intervention, which persists over time ([Baicker & 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](#)) was used to verify if there are structural breaks due to changes in the coefficients of the regressions during the pre-intervention period ([Linden & Arbor, 2015](#); [Linden, 2020](#)). The null hypothesis of the test was 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.

[Tables 8 and 9](#) display the results of the CUSUM test for Italian and France regions, respectively, with and without control variables in the ITSA. The CUSUM test statistic accepted the null hypothesis of parameters stability for the regions of Valle D’Aosta, Friuli-Venezia Giulia, Lazio, Liguria, Molise, Sardegna, Sicilia, Trentino-Alto Adige since its value was lower than the 10% critical level of 0.850. In the regions of Emilia-Romagna, Calabria, Puglia and Veneto, the test statistic rejected the null hypothesis only when the control variables are included in the ITSA. For the remaining regions, the null hypothesis of a constant mean was accepted. In [Table 9](#), the results of the CUSUM test suggest parameter stability before the announcement for all French regions.

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.¹⁰

[Tables 8 and 9](#) display the Wald test results for all Italian and French regions, respectively. We find that the announcement date represented a structural break for the Italian regions of Campania, Emilia-Romagna, Friuli-Venezia Giulia, Molise, Piemonte, and Sicilia, Umbria, and

¹⁰ The test was performed by using the Stata command “estat sbknown”.

Table 8
Results of structural break test for Italian regions.

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

Note: C(=Controls): *ICU*, $\Delta death$, *weekend*. *ICU* is dropped in Valle D'Aosta. *ICU* and $\Delta death$ are dropped in the CUSUM test for

Molise and Friuli-Venezia Giulia, respectively. Time period considered for the CUSUM test is July 2-July 21, 2021. Structural break date for the Wald test is Jul 22, 2021. The CUSUM test critical values are: 1.143 (1%), 0.948 (5%), 0.850 (10%).

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 Sardegna. Wald test results for French regions indicate that the announcement date was a structural break for all regions except Bourgogne-Franche-Comté, Bretagne, Mayotte and Pays de la Loire, where the test rejected the null hypothesis depending on the model specifications.

Table 9
Results of structural break test for French regions.

Region	CUSUMstatistic	Wald test p-value	C	Ext. date	Region	CUSUM statistic	Wald Test p-value	C	Ext. date
Guadeloupe	0.610	0.000	no	no	Hauts-de-France	0.462	0.000	no	no
	0.426	0.000	yes	no		0.543	0.067	yes	no
Martinique	0.465	0.016	no	no	Grand Est	0.493	0.001	no	no
	0.656	0.012	yes	no		0.169	0.000	yes	no
Guyane	0.646	0.003	yes	yes	Pays de la Loire	0.563	0.000	yes	yes
	0.291	0.017	no	no		0.362	0.019	no	no
La Réunion	0.467	0.003	yes	no	Bretagne	0.489	0.103	yes	no
	0.412	0.028	yes	yes		0.590	0.056	yes	yes
Mayotte	0.424	0.000	no	no	Nouvelle-Aquitaine	0.539	0.022	yes	yes
	0.282	0.511	no	no		0.617	0.023	no	no
Ile-de-France	0.532	0.699	yes	no	Occitanie	0.542	0.001	yes	no
	0.318	0.056	yes	yes		0.283	0.000	yes	yes
Centre-Val de Loire	0.482	0.000	no	no	Auvergne-Rhône-Alpes	0.513	0.000	no	no
	0.357	0.000	yes	no		0.316	0.000	yes	no
Bourgogne-Franche-Comté	0.506	0.000	yes	yes	Provence-Alpes-Côte d'Azur	0.529	0.000	yes	yes
	0.142	0.024	no	no		0.405	0.003	no	no
Normandie	0.541	0.140	yes	no	Corse	0.325	0.000	yes	no
	0.483	0.008	yes	yes		0.241	0.000	no	no
		0.001	yes	no			0.000	yes	no
		0.000	yes	yes			0.000	yes	yes

Note: C(=Controls): *ICU*, $\Delta death$, *weekend*, *Bastille day* (July 14), *Assumption of Mary day* (August 15). *ICU* and $\Delta death$ are dropped in the regressions to perform CUSUM and Wald structural break test for Mayotte. *ICU* is dropped in the regression with extended ending date to perform the Wald structural break test for Mayotte. $\Delta death$ and *Bastille day* are dropped in the CUSUM test for Martinique and Corse. Time period considered for the CUSUM test is July 2–July 11, 2021. Structural break date for the Wald test is Jul 12, 2021. The CUSUM test critical values are: 1.143 (1%), 0.948 (5%), 0.850 (10%).

4. Conclusions and policy implications

This study has analysed the effect of the green certificate extension announcement on the first-dose rates of the COVID-19 vaccine at the French and Italian regional levels. It has demonstrated that the announcement was a successful political strategy with which to increase the first-dose rates almost immediately after it, but not in the long run, strengthening the effect obtained from the entry into force of the green certificate. The announcement alleviated regional

disparities by increasing the first-dose rates, especially in regions lagging in vaccinations. On the other hand, it was less effective in those regions that already had high levels of vaccination coverage. This finding is interesting because it demonstrates that the policy strategy of the announcement did not have uniform effects throughout the country but was mainly limited to increasing the first-dose rates in regions late with the vaccination campaign because of a lack of confidence in the efficacy of the vaccine, a high share of natural immunity, and/or a poor perception of the severity of the COVID-19 disease, among other plausible reasons.

These findings have important policy implications. Firstly, the announcement of the extension of the green certificate had the effect desired by national governments, i.e. the increase in the first-dose rates of the vaccine. However, this situation did not necessarily imply that national governments gained greater public confidence in the vaccine. Many doubts may remain or even increase in the vaccinated after their first doses of vaccine (Ward et al., 2022). This may give rise to less responsiveness of the population to upcoming announcements of further restrictions via the green certificate. Secondly, the fact that even more restrictive measures, such as the introduction of the ‘super green pass’ and the vaccination obligation, were added over time in both of the countries examined, suggests that the impact in terms of increased first-dose rates due to the basic version of the green certificate was perhaps more modest than what national governments expected to achieve. Thirdly, coercive policies to counter the pandemic may have the opposite effect to what the policymaker hoped for. Accordingly, the use of the green certificate has raised many doubts about its usefulness in limiting the spread of infections since it has been observed that it may induce people to deliberately become infected with SARS-CoV-2 in order to obtain the certificate (Drury et al., 2021) and/or to be less conscientious in respecting the basic rules of pandemic containment (e.g., social distancing, use of face masks and personal hygiene) after the first-dose administration (Waitzberg et al., 2021), potentially increasing the number of infected people. Finally, a national government that imposes an indirect vaccination mandate, such as the green certificate, in times of pandemic could emit a signal of institutional weakness to its citizens by pointing out a lack of trust between them and the public institutions. The lack of public trust has contributed significantly to vaccine hesitancy during the pandemic (Antonini et al., 2022).

Alternative policy strategies should be devised for the next outbreak in order to reconcile the health security of the community with the need to exercise civil rights. They should focus on increasing citizens’ trust in health authorities and thus increase vaccine uptake. This policy view should be based on crystal-clear information about the beneficial and adverse effects of the vaccine. They would persuade the unvaccinated by means of public debates and personal meetings with doctors (Montanari Vergallo et al., 2022). Policies addressed to strengthening the national health systems through the increase of healthcare workers and intensive care units per inhabitant should be the priority in the years to come for any country to ensure adequate health protection. A national health system capable of responding promptly to health emergencies is crucial for countering a pandemic and creating a climate of trust between citizens and health authorities. This would encourage voluntary adherence to the vaccine campaign and limit the intrusion of the state into citizens’ daily lives through measures, like the green certificate, that excessively harm personal freedoms in times of pandemic.

Declaration of Competing Interest

The author declares that has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

- Antonini, M., Eid, M. A., Falkenbach, M., Rosenbluth, S. T., Prieto, P. A., Brammli-Greenberg, S., McMeekin, P., & Paolucci, F. (2022). An Analysis of the COVID-19 Vaccination Campaigns in France, Israel, Italy and Spain and Their Impact on Health and Economic Outcomes. *Health Policy Technology*, 11, Article 100594.
- Baicker, K., & Svoronos, T. (2019). Testing the validity of the single interrupted time series design. *National Bureau of Economic Research Working Paper No. 26080*.
- Baum, C.F., and M.E. Schaffer (1990). ACTEST: Stata module to perform Cumby- Huizinga general test for autocorrelation in time series. Statistical Software Components S457668, Department of Economics, Boston College available at: <https://ideas.repec.org/c/boc/bocode/s457668.html>.
- Bernal, J. L., Cummins, S., & Gasparrini, A. (2017). Interrupted time series regression for the evaluation of public health interventions: A tutorial. *International Journal of Epidemiology*, 46(1), 348–355.
- Berardi, C., Antonini, M., Genie, M. G., Cotugno, G., Lanteri, A., Melia, A., & Paolucci, F. (2020). The COVID-19 pandemic in Italy: Policy and technology impact on health and non-health outcomes. *Health Policy and Technology*, 9(4), 454–487.
- Beccia, F., Di Pilla, A., Causio, F. A., Federico, B., Specchia, M. L., Favaretti, C., Boccia, S., & Damiani, G. (2022). Narrative Review of the COVID-19 Pandemic’s First Two Years in Italy. *International Journal of Environmental Research and Public Health*, 19, 15443.
- Bottomley, C., Scott, J. A. G., & Isham, V. (2019). Analysing interrupted time series with a control. *Epidemiologic Methods*, 8(1).
- Brown, R. L., Durbin, J., & Evans, J. M. (1975). Techniques for testing the constancy of regression relationships over time. *Journal of the Royal Statistical Society: Series B (Methodological)*, 37(2), 149–163.
- Chevreur, K., Durand-Zaleski, I., Bahrami, S., Hernández-Quevedo, C., & Mladovsky, P. (2010). *France: Health system review. Health Systems in Transition*, 12, 1–291.
- Chow, G. C. (1960). Tests of equality between sets of coefficients in two linear regressions. *Econometrica*, 28(3), 591–605.
- Cumby, R. E., & Huizinga, J. (1990). Testing the autocorrelation structure of disturbances in ordinary least squares and instrumental variables regressions. *National Bureau of Economic Research Technical Working Paper No. 92*.
- Cumby, R. E., & Huizinga, J. (1992). Testing the autocorrelation structure of disturbances in ordinary least squares and instrumental variables regressions. *Econometrica*, 60(1), 185–195.
- Desson, Z., Weller, E., McMeekin, P., & Ammi, M. (2020). An analysis of the policy responses to the COVID-19 pandemic in France, Belgium, and Canada. *Health Policy and Technology*, 9(4), 430–446.
- Drury, J., Mao, G., John, A., Kamal, A., Rubin, G. J., Stott, C., Vandrevale, T., & Marteau, T. M. (2021). Behavioural responses to Covid-19 health certification: A rapid review. *BMC Public Health*, 21(1), 1–16.
- Ferré, F., de Belvis, A. G., Valerio, L., Longhi, S., Lazzari, A., Fattore, G., Ricciardi, W., & Maresso, A. (2014). *Health Systems in Transition*, 16, Italy: Health System Review, 1–168.
- France, G., Taroni, F., & Donatini, A. (2005). The Italian health-care system. *Health Economics*, 14(S1), S187–S202.
- Hassenteufel, P. (2020). Handling the COVID-19 crisis in France: paradoxes of a centralized state-led health system. *European Policy Analysis*, 6(2), 170–179.
- Hudson, J., Fielding, S., & Ramsay, C. R. (2019). Methodology and reporting characteristics of studies using interrupted time series design in healthcare. *BMC Medical Research Methodology*, 19(1), 1–7.
- Karaivanov, A., Kim, D., Lu, S. E., & Shigeoka, H. (2021). COVID-19 vaccination mandates and vaccine uptake. *National Bureau of Economic Research Working Paper No. 29563*.
- Karaivanov, A., Kim, D., Lu, S. E., & Shigeoka, H. (2022). COVID-19 vaccination mandates and vaccine uptake. *Nature Human Behaviour*, 6, 1615–1624.
- Lang, I. G. (2021). EU COVID-19 certificates: A critical analysis. *European Journal of Risk Regulation*, 12(2), 298–307.
- Linden, A. (2020). Implementing ODA from Within Stata: Identifying structural breaks in single-group interrupted time series designs (invited). *Optimal Data Analysis*, 9, 51–56.

- Linden, A., & Adams, J. L. (2011). Applying a propensity score-based weighting model to interrupted time series data: Improving causal inference in programme evaluation. *Journal of Evaluation in Clinical Practice*, 17(6), 1231–1238.
- Linden, A., & Arbor, A. (2015). Conducting interrupted time-series analysis for single- and multiple-group comparisons. *The Stata Journal*, 15(2), 480–500.
- Merkaj, E., & Santolini, R. (2022). Italian national policies in response to the COVID-19 pandemic: The case of the Friuli-Venezia-Giulia and Umbria Regions. *Health Policy*, 126(4), 287–293.
- Mills, M. C., & Rüttenauer, T. (2022). The effect of mandatory COVID-19 certificates on vaccine uptake: Synthetic-control modelling of six countries. *The Lancet Public Health*, 7(1), e15–e22.
- Montanari Vergallo, G., Del Rio, A., Negro, F., & Zaami, S. (2022). COVID-19 vaccine mandates: What are the current European public perspectives. *European Review for Medical and Pharmacological Sciences*, 26, 643–652.
- Newey, W., & West, K. (1987). A simple positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica*, 55(3), 703–770.
- Oliu-Barton, M., Pradelski, B. S., Woloszko, N., Guetta-Jeanrenaud, L., Aghion, P., Artus, P., Fontanet, A., Martin, P., & Wolff, G. B. (2022). The effect of COVID certificates on vaccine uptake, health outcomes, and the economy. *Working Paper No. 01/2022*, Bruegel.
- Roques, L., Klein, E. K., Papaix, J., Sar, A., & Soubeyrand, S. (2020). Impact of lockdown on the epidemic dynamics of COVID-19 in France. *Frontiers in Medicine*, 7, 274.
- Waitzberg, R., Triki, N., Alroy-Preis, S., Lotan, T., Shiran, L., & Ash, N. (2021). The Israeli experience with the “green pass” policy highlights issues to be considered by policymakers in other countries. *International Journal of Environmental Research and Public Health*, 18, 11212.
- Walkowiak, M. P., Walkowiak, J. B., & Walkowiak, D. (2021). COVID-19 passport as a factor determining the success of national vaccination campaigns: Does It Work? The Case of Lithuania vs. Poland. *Vaccines*, 9(12), 1498.
- Ward, J. K., Gauna, F., Gagneux-Brunon, A., Botelho-Nevers, E., Cracowski, J. L., Khouri, C., Launay, O., Verger, P., & Peretti-Watel, P. (2022). The French health pass holds lessons for mandatory COVID-19 vaccination. *Nature Medicine*, 28(2), 232–235.
- WHO (2020). WHO Director-General's opening remarks at the media briefing on COVID-19 - 11 March 2020, available at link: <https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19—11-march-2020>.
- Wise, J. (2021). Covid-19: France and Greece make vaccination mandatory for healthcare workers. *BMJ*, 374, n1797.