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ORIGINAL PAPER

# Gender politics, environmental behaviours, and local territories: evidence from Italian municipalities

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**Abstract**
We investigated the impact of female politicians on waste collection in Italian municipalities in different territories observed over the years 2010–2019. We used a staggered difference-in-differences design to obtain a causal interpretation of the estimated effects. We find that the majority of women in the municipal council positively influence pro-environmental individual behaviour. The impact of a female-majority council is heterogeneous by region and more pronounced in areas with lower social capital. Female politicians as catalysts for positive change fade after 5–6 years, likely due to persistent social norms locally, thus stressing the need for additional cultural actions with long-lasting effects.

**JEL Classification** D72 · R50 · C21 · D73 · H75

## 1 Introduction

Where do policies, public interventions, and the effects of human events on the environment stand? We believe they are also rooted in the cultural foundation of a territory, enabling them to evolve and produce positive outcomes if the conditions are conducive; for this reason, a territory might react to changes, possibly with high intensity, but this reaction may prove unproductive. Social norms, civil capital, environmentalism culture, and institutional setting represent crucial elements for the success (Guiso et al. 2006, 2011; Asquith et al. 2021; Baycan and Öner 2023).

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Therefore, to assess the impact of a cultural change on local territories, it could be helpful to interpret the territory as a set of social conventions rather than a simple administrative unit; this means no longer considering geographical areas as merely determined ex ante by normative criteria only.

Based on these arguments, we assess the effects of women in politics, as a culturally relevant change in recent years, on public place-based policies, such as waste disposal management, at the municipal level in Italy over the years 2010–2019. Specifically, we first estimate the impact of having a female mayor or a municipal council mainly composed of women on the waste recycling rate and then test if this impact is similar in different territories, i.e. spatial stationary.

In recent years, the study of the positive effect of female policymakers on environmental issues has increased. It may be influenced by multiple variables, such as women's roles, lifestyle, and the social norms to which they adhere (Wilde and Parry 2022; De Sario et al. 2023; Stef and Ben Jabeur 2023; Rios et al. 2023). However, further investigation is needed to understand whether these positive pro-environmental behaviours depend on gender or if they only reflect confounding variables. In addition, there may be a selection bias, as mayors who are less effective in waste management tend to govern municipalities where residents are less vigilant about environmental protection. To obtain unbiased estimates and a causal interpretation of the estimated effect, we use the staggered difference-in-differences design (CSDID) proposed by Callaway and Sant'Anna 2021. This empirical approach allows for a comparison among municipalities that have the same political, environmental, and gender preferences while taking into account that elections are held at different times.

We rely on Italian municipalities that serve as a laboratory example for different reasons. First, they provide a range of local public services, including waste management (recycling and disposal) and interventions that affect citizens' quality of life and well-being (Ferraresi et al. 2023; Ermini et al. 2023). As a recent example, local investments in territorial development, green transition, and environmental protection have increased over time and have been further stimulated by the Next Generation EU programme (Commission European 2023). Within this framework, the mayor and the municipal council manage their territory's specific functions and are responsible for the municipality's administration and policy. Second, gender politics and related institutional reforms have stimulated interest in investigating the impact of female politicians on public spending and other political outcomes, especially at the local level (Baltrunaite et al. 2019; Bucci et al. 2024; Baraldi et al. 2024).

Our results offer new insights into the existing literature. First, we provide causal evidence for the effect of female representation on citizen green behaviour (i.e. the rate of recycled waste).[1] This occurs not mainly when a female mayor is elected but when the majority of the local council comprises women. Put differently, a single person cannot trigger a substantial change in citizens' recycling behaviours that instead occurs when a critical mass is at work. Second, such a change is statistically significant but tends to fade in the medium term; this may be due to our

[1] It is worth noting that mechanisms driving the election of a female major, including voters' preferences on parties, topics, etc., go beyond the scope of the paper. We analyse the causality once the major has been elected and in office.

limited time frame, and it is more likely that more structural behaviours return in the medium term. Third, the effect of waste recycling rate change due to a female-majority council is not stationary in space, but it is stronger in regions with lower social capital.

Our evidence supports previous findings linking behaviour, civic sense, and social capital in a macro-perspective depending on the local territory (Putnam et al. 1993; Calcagnini and Perugini 2019). We highlight that every change is shown to lie in a specific territory. Therefore, it is necessary to focus on *where* and not only *how* such change takes place without relying on predetermined administrative boundaries, which could not effectively capture the cultural basis (Agovino et al. 2016). From a policy point of view, our results support the idea that gender roles shape attitudes and behaviour towards environmental and climate issues (EIGE 2023). As a corollary, alleviating the gender gap in politics and the power domain is also crucial to achieving the green transition goals, as the impact of climate and environmental change is not gender neutral (OECD 2021).

The remainder of the article is structured as follows. Section 2 briefly explains the research design and the mechanisms. Section 3 describes the institutional background of Italian municipalities concerning electoral rules and gender political reforms, then the regulations that ruled waste management and its separate collection. Sections 4 and 5 illustrate the empirical analysis, including the data description, the econometric framework, the main findings, and robustness checks. Section 6 concludes, providing some policy recommendations.

## 2 Research design and mechanisms

In the modern economy, it is common to measure the effects of a policy in a detached manner from the social rules in which it is supported and in a territory often not adequately known; the latter would serve only as a passive backdrop to empirical analyses. In our study, the issue of *where* should be understood for statistical sophistication but also as the core of the policy evaluation, originating its significance from the inner heterogeneity of individuals and their social habits.

In Italy, there is evidence of different civic culture, social capital, trust, and ethical attitudes related to unequal participation in public, civil, and political life when comparing, for example, the southern and northern regions (Putnam et al. 1993). The persistence of such profound differences has also had inevitable implications for economics and politics (Calcagnini and Perugini 2019; Asquith et al. 2021; Marè et al. 2024), making it difficult to depict these aspects with numerical data and imposing ex ante geographies.

More importantly, a change in behaviours or cultural/social customs will likely have a locally differentiated effect, not necessarily uniform across territories. Gender norms might affect women's and men's participation in the political arena (Dassonneville and Kostelka 2021), and the geographical context might also affect the impacts of gender, if any, on environmental concerns in our case. Generally speaking, the observed gender gap in political participation could reflect the lower interest of women in politics, possibly arising from cultural perceptions of traditional gender

roles and stereotypes, where politics is viewed as a male domain (OECD 2023). Ultimately, this circumstance could have different strengths between territories and policy domains.

In terms of mechanisms, there is evidence that women politicians implement policies more often than their male counterparts in areas traditionally seen as women's issues, such as childcare, environment, health, and social services (Funk and Gathmann 2015). So far, much of the literature on the relationship between gender and environmental issues has focused on the private sector using micro-data by investigating the impact of women in executive or leadership roles on ecological policies and performance and the adoption of eco-innovations or other green practices at the firm level (Liu 2018; Moreno-Ureba et al. 2022).

Gender disparities in attitudes about climate change and mitigation actions have recently been documented (Bush and Clayton 2023). Evidence suggests that women show, on average, a greater awareness of environmental issues than men, leading the former to adopt behaviours aimed at protecting and preserving the environment as a global public good (Barsky et al. 1997; Coelho et al. 2017; De Sario et al. 2023). For example, women are more likely to move towards more sustainable and "zero waste" household practices, in terms of energy consumption (cooking, cleaning) and recycling (Räty and Carlsson-Kanyama 2010; Wilde and Parry 2022), and participate in less visible environmental conservation efforts in the private sphere than men, who are more likely to adopt more visible green behaviours (Thaller et al. 2020). Furthermore, recent research in the European context highlights that girls and young women have emerged prominently as activists and leaders in climate movements (Noth and Tonzer 2022), calling for immediate action by those in decision-making positions as recognised in the EU Gender Equality Strategy 2020–2025.

Regarding Italy, recent evidence from the EIGE (2023) shows that women are more inclined than men to choose environmentally friendly options, including feeling responsible for reducing climate change and avoiding plastic and/or single-use products. On the other hand, it should be noted that the ongoing green transition is expected to increase the demand for STEM topics and skills, where women are still underrepresented, making them not necessarily more sensitive to environmental issues.[2]

Given this framework, we shed new light on the relationship between gender in politics and citizens' environmental behaviours in heterogeneous geographic areas. In particular, we aim to assess whether women's more significant concern for environmental challenges translates into more political engagement and green actions from citizens, which can increase waste recycling in Italian municipalities in different territories. We also contribute to previous literature highlighting the impact of cultural values and social factors on pro-environmental attitudes (Crociata et al. 2015; Knickmeyer 2020), in line with the "civic environmentalism" approach (Agyeman and Angus 2003).

[2] Where the acronym STEM stands for *Science, Technology, Engineering, and Mathematics.*

## 3 The institutional background

In this section, we describe the institutional background of Italian municipalities regarding major and council elections and provide some information on separate waste collection at the municipal level.

### 3.1 Electoral rules and gender politics in Italian municipalities

The municipal government is composed of the mayor and the executive committee (*Giunta comunale*), appointed by the mayor and whose number of members depends on the municipality's population size.[3] The mayor and the executive body carry out the electoral platform and implement the general guidelines of the municipal council (*Consiglio comunale*), which exercises political and administrative control of municipal activities. Like the executive committee, the municipal council is composed of a different number of elected councillors based on population size (Ermini et al. 2023).[4]

A direct election scheme for mayors in municipalities was introduced in Italy in 1993. Before 1993, they were appointed by the municipal council; since 1993, they were directly elected under majoritarian rules by voters,[5] The mayor remains in office for no more than two mandates of five years each, as stated by Law 120/1999, but the number of mandates has increased to three for municipalities with a population of up to 3000 since 2014 (Law 56/2014).

Recent empirical evidence from Cipullo (2023) shows that introducing such a direct election scheme substantially increased the proportion of municipalities where a woman was selected as the new mayor (see Fig. 1, also). In addition, the reform increased the proportion of female elected officials, mainly in localities with a large pool of female potential candidates from which parties and voters could select.

The 1993 reform also introduced gender quotas in all municipalities having less than 15,000 inhabitants, meaning that each party was required to have at least one-third of women candidates on its list of candidates for the municipal council. However, the Italian Constitutional Court abolished this part of the reform in 1995, so gender quotas were in place exclusively for three subsequent years since 1993.

More recently, Law 215/2012 reformed the elections of Italian municipal councils by introducing a gender quota on candidates. In detail, the reform introduced

[3] The number ranges from 2 for municipalities with fewer than 3000 inhabitants to 12 for those with over 1 million inhabitants, according to Law 56/2014.

[4] It consists of 10 councillors in municipalities with a population of fewer than 3000 inhabitants, of 48 councillors in municipalities with more than 1 million inhabitants.

[5] Moreover, depending on the population size of the municipalities, the most voted candidate could be elected as mayor in the first round (i.e. in municipalities with less than 15,000 inhabitants), or the mayor could be elected in a runoff, taking place two weeks later if none of the candidates surpasses 50% of valid votes (i.e. in municipalities with more than 15,000 inhabitants).

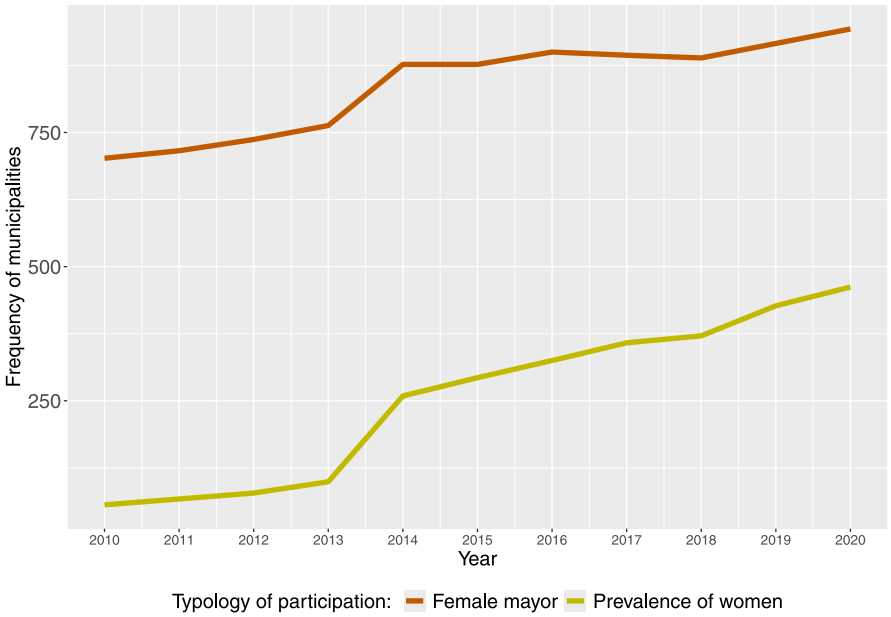



**Fig. 1** Total number of municipalities with female mayor and prevalence of women by year

both a candidate gender quota and the possibility of expressing a double preference when voting if the voters' preferences are for candidates of a different gender.[6]

Using the introduction of a gender quota by Law 215/2012 applied in 2013, Andreoli et al. (2022) find that the reform affected the gender composition of candidates in Italian municipal council elections, increasing the share of female councillors by about 13.9 percentage points. Furthermore, they show that a one percentage point increase in female participation in councils raises certain expenditures (e.g. public order and local security) rather than others (e.g. administrative costs). These effects are enhanced by the increase in the share of educated, employed, and relatively young women who are municipality board members.

Finally, in 2014, the parliament approved Law 56/2014, which requires that in municipalities with more than 3000 residents, each gender represents at least 40% of the members of the executive committee (*Giunta comunale*). Given this framework, Spaziani (2022) investigates the ability of the gender quota systems implemented in 1993, 2013, and 2014 to promote the election of female mayors. In general, she finds that the three policies increased the share of female politicians in less senior government positions beyond the minimum legal level. However, there is no evidence about the effects on the mayoral position, concluding that the "acceleration effects" (O'brien and Rickne 2016) produced by the quotas have been too weak to advance female political leadership in Italian municipal governments.

[6] These specific features of the law were enforced exclusively in municipalities of size larger than 5000 inhabitants.

Despite the importance of policies that foster gender equality at the institutional level, such as Law 215/2012, this article does not focus on the effect of a specific policy, as the above-mentioned cited articles do, but on the impact of electing a female mayor or a predominantly female council at the municipality level only. Figure 1 highlights an increase in the frequency of these municipalities but does not affect the estimated coefficient.

### 3.2 Waste management and separate collection at the municipal level in Italy

Waste management and its separate collection have become a fundamental aspect of Italian environmental policies, which are closely related to mitigate climate change, especially in reducing greenhouse gas emissions and lowering the use of raw materials in production. The generation of waste is strictly connected to a constant extraction of raw resources, which are necessary to produce new goods (D'Amato et al. 2013; Musella et al. 2019; Ferraresi et al. 2023) that will become new waste, so it is fundamental to design an efficient framework to dispose and manage it.

This scenario and the increased awareness of citizens and the scientific community about environmental degradation have fostered the promotion and adoption of more environmentally friendly disposal techniques at both European and United Nations levels.

Concerning Italy, although environmental and ecosystem protection was already promoted by the Constitution (Art. 117), waste disposal was effectively regulated in 1982 (Decree of the President of the Republic (DPR) n. 915) by implementing three directives of the European Economic Community (EEC): Directive n. 75/442, Directive n. 76/403, and Directive n. 78/319. Overall, such a normative framework states the fundamental principles of waste management, including waste disposal, classification of waste types, and allocation of responsibilities in a multilevel governance system.[7] Under this setting, the role of municipalities is crucial for waste management (Agovino et al. 2016; Cerqueti et al. 2021). Local governments have the right to implement and apply the regulations enacted at the upper government level, organise waste collection services and treatment facilities, and promote awareness campaigns.

A second important step towards reducing the environmental effects of waste was the 1997 "Ronchi decree", which reorganises the waste management legislation in Italy.[8] Two important principles on waste were introduced. First, the Ronchi Decree banned the abandonment of waste by anyone responsible for disposing of or recovering it and provided the related guidelines. Second, it reasserted that waste

[7] The central government gives general rules and coordinates sub-national levels; regions enact specific laws under national legislation and provide directions on separate waste collection according to local needs; provinces control the general activities, and municipalities are effectively in charge of the organisation and management of waste separate collection and its disposal, under the general regulatory framework.

[8] It had replaced the DPR n. 915 and had transposed new EEC Directives (n. 91/156 on waste, n. 91/689 on hazardous waste, and n. 94/62 on packaging and packaging and packaging waste).

management is an activity of public interest and ruled out the recovery, reuse, and recycling of waste.[9]

Finally, in 2006, the "Testo Unico Ambientale" (TUA) was introduced, representing Italy's main waste management legislation. The core of the document is the general principles (precaution, prevention, sustainability, accountability, and cooperation among those involved, according to the "polluter pays principle") and procedures of waste management (mainly the promotion, prevention, and reduction of waste production by reuse, recycling, and recovery of materials and energy from the waste itself). More important to our analysis, the TUA had explicitly established that the municipal government is devoted to drawing a waste management plan that fosters waste reduction, reuse, and recycling in order to reach the targets.

Furthermore, the crucial role of municipalities in implementing and facilitating the recycling has been reinforced by supranational directives (Chioatto and Sospiro 2023), in line with national policies to minimise the impact of climate change. In this framework, environmental education of citizens can be provided through information campaigns on proper waste separation and can contribute to creating a circular economy at the local level.

Ultimately, the mayor and the municipal council are responsible for defining clear targets for separate collection and recycling in the waste management plan following national and regional regulations. This implies that each municipality can decide how waste collection should be done. However, regions and metropolitan areas coordinate municipal activities by providing technical and financial support and defining guidelines and goals for separate waste collection (Agovino et al. 2019).

## 4 Methods and data

### 4.1 Methodological approach

The empirical approach to evaluating how gender politics influences the share of collected waste at the municipal level is presented in three distinct parts, employing cutting-edge techniques to gradually dive deeper into the causal assessment of a greater female presence in citizens' environmental behaviours and attitudes.

Within the field of causal inference and programme evaluation, the difference-in-differences (DID) approach allows researchers to estimate the causal impact of a treatment or intervention by comparing changes in outcomes over time between a treatment group and a control group.[10]

Despite its widespread use and effectiveness in many contexts, the traditional TWFE framework has some limitations, particularly when faced with staggered treatment timing or when treatment effects evolve gradually. Many authors,

[9] Accordingly, the quantity of waste to be reduced to disposal by explicitly calling it the "residual phase" of waste management to foster activities that envisaged a new implementation of products at the end of their life cycle (recycling, recovery to obtain raw materials from waste; waste to generate energy, etc.).

[10] This methodology is equivalent to two-way fixed effects regressions (TWFE) proposed by de Chaisemartin and D'Haultfœuille (2022).

including Callaway and Sant'Anna (2021) and Baker et al. (2022), propose specific staggered DID models that enable the grouping of municipalities into cohorts that start the treatment simultaneously.

The approach of Callaway and Sant'Anna (2021) offers several advantages to other staggered approaches to causal inference. First, treatment effects can vary smoothly over time, accommodating gradual and immediate changes in the impact of interventions. Furthermore, using local polynomial regression to estimate treatment effects provides more precise estimates. Finally, employing a control function approach effectively controls for time-varying confounders and unobserved heterogeneity.

Following the compact notation proposed by de Chaisemartin and D'Haultfœuille (2022), we denote $\overline{Y}_{c,t}$ as the average result in period $t$ between the groups belonging to the cohort $c$, and $\overline{Y}_{n,t}$ as the average result in period $t$ between the groups that remain untreated from period 1 to $T$ (the groups never treated) for all $c$ and $t$ and for all $l \in (0, \ldots, t)$.

Callaway and Sant'Anna (2021) define their parameters of interest as:

$$TE_{c,c+l} = E[\overline{Y}_{c,c+l}(\mathbf{0}_{c-1}, \mathbf{1}_{l+1}) - \overline{Y}_{c,c+l}(\mathbf{0}_{c+l})] \tag{1}$$

the average effect of having been treated for $l+1$ periods in the cohort that started receiving the treatment at period $c$, for every $c \in (2, ..., T)$ and $l \geq 0$ such that $l + c \leq T$.

To estimate $TE_{c,c}$, Callaway and Sant'Anna (2021) propose[11]:

$$\overline{\text{DID}}_{c,0} = \overline{Y}_{c,c} - \overline{Y}_{c,c-1} - (\overline{Y}_{n,c} - \overline{Y}_{n,c-1}) \tag{2}$$

a DID estimator comparing the period $c-1$ to $c$ outcome evolution in cohort $c$ and in the never-treated groups $n$.

Up to this point, we have assumed that the outcome comparisons within cohorts and between groups are stationary in geographical space; but, in real-world scenarios, this assumption may not be fully satisfactory because the relationship between variables can vary between different geographical locations. Ignoring spatial non-stationarity can lead to biased estimates and incorrect inferences since different regions or locations may exhibit unique characteristics that affect the outcome of interest. By assuming spatial stationarity, the DID framework may fail to capture these spatial differences, potentially masking important variations in treatment effects and leading to model misspecification.

Incorporating rationale under Geographic Weighted Regression (GWR, Brunsdon et al. 1998) or local spatial econometric models can help address these limitations by allowing for spatially varying treatment effects and capturing spatial heterogeneity more accurately. Such models repeatedly estimate the baseline specification by varying an estimation window in which points in space are weighted according to their distance from the centre of the window. More specifically—at each step defined by unit $i$—spatial weights $w_{ij}$ can be defined based on distance, such as using a linear

[11] The estimators are computed by the `csdid STATA` command (Rios-Avila et al. 2021).

decay function, a Gaussian kernel, or an adaptive kernel, to give more weight to nearby observations and less weight to distant ones.

This choice is clearly not always related to application-specific characteristics. For this reason, in Sect. 5.2 the local weights will be calculated on the basis of a restricted linear spatial decay function (see Eq. 3), while in Sect. 5.3, to empirically verify the robustness of the results obtained, the local weights will be calculated on the basis of a non-restricted Gaussian function (see Fig. 9).

$$w_{ij} = \begin{cases} 1 - (d_{ij}/d_{max}), \text{ if this ratio is } > 0.5 \\ 0, \text{ otherwise} \end{cases} \tag{3}$$

where $d_{ij}$ is the Euclidean distance between the municipality $i$ and $j$ and $d_{max}$ the maximum distance between all municipalities $i$ and $j$ considered.

The staggered DID model referenced in Callaway and Sant'Anna (2021) enables the calculation of ATTs for each subsequent period following the start of staggered treatments. When integrated with the previously mentioned local method, this facilitates the analysis of trends following treatment for every distinct municipality. We can then estimate clusters of curves, i.e. similar trends between municipalities to check not only whether there is spatial stationarity on average, but also in terms of trends, i.e. evolution over time. Functional data analysis (FDA), as defined by Ramsay and Silverman (2005), is an advanced extension of traditional multivariate methodologies, specifically designed to incorporate data conceptualised as functions or curves. Within the purview of this methodology, it is postulated that observations inhabit an infinite-dimensional continuum. However, in real-world applications, we are constrained to dealing with sampled trajectories that are accessible only at discrete temporal instances. Typically, discrete observations $X_{ij}$ of each sampled path $X_i(t)$ are obtained at a finite set of nodes $t_{ij} : j = 1, ..., m_i$ (for example, in this application the ATT coefficients by periods after treatment; see Table 2). Subsequently, the preliminary phase of the FDA requires the reconstitution of the data functional characteristics from these discrete observations, employing nonparametric smoothing techniques. In the context of the study described in this paper, the funFEM algorithm (Bouveyron and Jacques 2015) has been used to cluster different trends of the ATT post-treatment coefficient, treating them as curves within a shared and distinctive functional subspace (see, for example, Fig. 6).

### 4.2 Data sources, main variables, and descriptive statistics

The empirical analysis is based on annual 2010–2019 data from many sources. It relies on information related to waste services, focussing on the sorted waste collected at the municipal level, which represents the dependent variable of our analysis. Specifically, data were collected from the Italian Institute of Environmental Protection and Research (ISPRA) and include the composition of municipal waste (i.e. sorted and unsorted) and the main cost elements for waste management functions (i.e. related to the processing of the sorted fraction). The quantity of waste collected was calculated as the share of the total urban waste collected (sum of sorted and unsorted waste).

**Table 1** Summary statistics

| Statistic | *N* | Mean | St. Dev. | Min | Max |
|---|---|---|---|---|---|
| Sorted waste collection perc | 62,129 | 0.522 | 0.230 | 0.000 | 1.000 |
| Population density | 68,608 | 276.871 | 547.262 | 0.910 | 11,494.890 |
| Resident population | 68,629 | 6,493.189 | 29,857.900 | 29 | 1,406,242 |
| Area in square kilometres | 68,620 | 34.804 | 44.229 | 0.000 | 653.822 |
| Average n. of household members | 68,629 | 2.295 | 0.259 | 1.100 | 3.870 |
| Mountain municipality (Y/N) | 68,629 | 0.075 | 0.264 | 0 | 1 |
| Number of tourist beds | 60,887 | 582.334 | 2,914.223 | 0 | 75,864 |
| Income per inhabitant | 68,629 | 12,344.220 | 3,052.764 | 2,688.924 | 35,452.290 |
| Collection/transport costs of sorted waste (euro/inhab.) | 59,756 | 35.618 | 26.312 | 1.000 | 604.200 |
| Treatment/recycling costs of sorted waste (euro/inhab.) | 53,523 | 13.269 | 10.743 | 1.000 | 185.450 |

Concerning gender in politics, which represents the main independent variable of interest, we refer to data on municipal elections in Italy provided by the Department of Internal and Territorial Affairs of the Ministry of the Interior which annually reports information on local administrators in service at the 31$^{st}$ of December of each year.[12] The above-mentioned data set allows us to identify the gender. Two different identifier variables (`treatment group (cohort)`) have been constructed for each municipality and year as a dichotomous variable: the presence of a female mayor and a female majority in the municipal council.

The data set also includes geographic and socioeconomic characteristics of municipalities to account for other factors that may mediate or affect the impact of gender on the share of collected waste. In detail, as highlighted by the existing literature on municipal solid urban waste management, we consider, on the one hand, geographic variables of the municipality, such as resident population (number of inhabitants), municipality area in square kilometres, population density (ratio between population and municipality area), if the municipality is a mountain municipality or not, the average number of households members and the number of tourist beds (Struk and Bod'a 2022; Soukiazis and Proença 2020). However, the estimation has taken into account the socioeconomic characteristics of the municipality as controls. Specifically, we use the treatment and recycling costs of sorted municipal waste and the collection and transport costs of sorted municipal waste (Di Foggia and Beccarello 2020). Both variables are expressed as euros per inhabitant spent in a specific year. Finally, we have implemented the per capita average taxable incomes declared by residents of the municipality to be subject to the general income tax for individuals (IRPEF), henceforth income per inhabitant (Fiorillo 2013; Romano et al. 2022).

[12] It is the "Register of Local and Regional Administrators" (*Anagrafe degli Amministratori Locali*), compiled yearly since 1986, which represents the individual–level register of the universe of politicians holding any office at the municipality level; https://dait.interno.gov.it/elezioni/open-data.

In summary, Table 1 reports the descriptive statistics.

## 5 The empirical analysis

We start by describing the baseline model on a global scale. This helps us to determine whether having a female mayor or a majority of female municipal councillors would affect citizens' waste collection behaviour within a staggered counterfactual framework, on average, over the whole territory. Then, we investigate whether these findings are robust for different geographic areas or if omitted local factors regularly produce changing outcomes. As a final step, we check whether the effect of a majority of female municipal councillors is also stationary with respect to trends in single territories.[13]

### 5.1 Identification strategy and average baseline results

As discussed in Sect. 2, the main objective is to pinpoint the direct influence of electing a female mayor or having a majority of women in the municipal council on improving the civic participation of citizens in environmental issues, specifically increasing the share of sorted waste collection, in line with the "civic environmentalism" approach (Agyeman and Angus 2003).

As a baseline specification, the `percentage of sorted waste on total urban waste generated` controlling for geographic and socioeconomic variables (as described in Sect. 4.2) is considered for all Italian municipalities by taking into account the staggered treatment group $TG_{it}$ and following the approach described in Eq. (2):

$$\text{Perc}_{it}^{\text{sorted}} = f(X_{it}^{\text{eco}}, X_{it}^{\text{demo}}, TG_{it}) \tag{4}$$

The standard matching or balance step has not been implemented for two main reasons: the first reason is that when using Callaway and Sant'Anna (2021)'s DID estimator for multiple periods and staggered adoption, combined with doubly robust weighting based on stabilised inverse probability, as in our case, there is no strict need for propensity score matching beforehand. In fact, this estimator is specifically designed to account for selection in treatment by conditioning on covariates, which already helps to adjust for selection bias. The second reason is related to our proposed spatial approach. Since many latent local factors (such as social conventions, beliefs, and prejudices) may invalidate direct comparisons and are difficult to measure or incorporate into the analysis, we argue that a spatial approach is more appropriate. This method allows us to assign greater weights to units that are geographically closer, making comparisons more reliable in the presence of unobservable local heterogeneities.

[13] Findings regarding the impact of having a female mayor—being positive but less significant—are available from the authors on request.

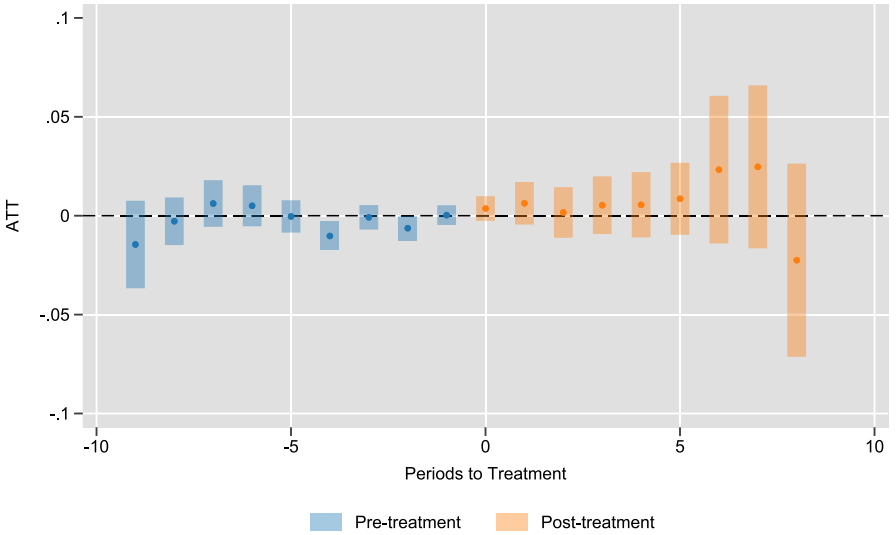



**Fig. 2** ATT by periods before and after treatment, event study: dynamic effects, woman mayor—CSDID model

**Table 2** ATT by periods before and after treatment, event study: dynamic effects, woman mayor—CSDID model

| | Coefficient | Std. err. | $z$ | $P > z$ | [95% conf. | Interval] |
|---|---|---|---|---|---|---|
| Pre_avg | −0.00228 | 0.001618 | −1.41 | 0.159 | −0.00545 | 0.000894 |
| Post_avg | 0.003923 | 0.008222 | 0.48 | 0.633 | −0.01219 | 0.020038 |
| Tm9 | −0.01231 | 0.010221 | −1.2 | 0.229 | −0.03234 | 0.007726 |
| Tm8 | −0.00154 | 0.005541 | −0.28 | 0.781 | −0.0124 | 0.009322 |
| Tm7 | 0.002058 | 0.005473 | 0.38 | 0.707 | −0.00867 | 0.012784 |
| Tm6 | 0.005988 | 0.004823 | 1.24 | 0.214 | −0.00346 | 0.01544 |
| Tm5 | 0.001273 | 0.003989 | 0.32 | 0.750 | −0.00655 | 0.009092 |
| Tm4 | −0.01235 | 0.003135 | −3.94 | 0.000 | −0.01849 | −0.0062 |
| Tm3 | 0.00053 | 0.002917 | 0.18 | 0.856 | −0.00519 | 0.006247 |
| Tm2 | −0.00523 | 0.002981 | −1.75 | 0.080 | −0.01107 | 0.000617 |
| Tm1 | 0.001078 | 0.002303 | 0.47 | 0.640 | −0.00344 | 0.005592 |
| Tp0 | 0.001847 | 0.002871 | 0.64 | 0.520 | −0.00378 | 0.007473 |
| Tp1 | 0.003414 | 0.005087 | 0.67 | 0.502 | −0.00656 | 0.013384 |
| Tp2 | −0.00247 | 0.006115 | −0.4 | 0.686 | −0.01446 | 0.009512 |
| Tp3 | 0.001258 | 0.007017 | 0.18 | 0.858 | −0.0125 | 0.01501 |
| Tp4 | 0.003119 | 0.00805 | 0.39 | 0.698 | −0.01266 | 0.018897 |
| Tp5 | −0.00042 | 0.008901 | −0.05 | 0.962 | −0.01787 | 0.017022 |
| Tp6 | 0.020741 | 0.018081 | 1.15 | 0.251 | −0.0147 | 0.056179 |
| Tp7 | 0.024561 | 0.020136 | 1.22 | 0.223 | −0.0149 | 0.064026 |
| Tp8 | −0.01674 | 0.024717 | −0.68 | 0.498 | −0.06518 | 0.031707 |

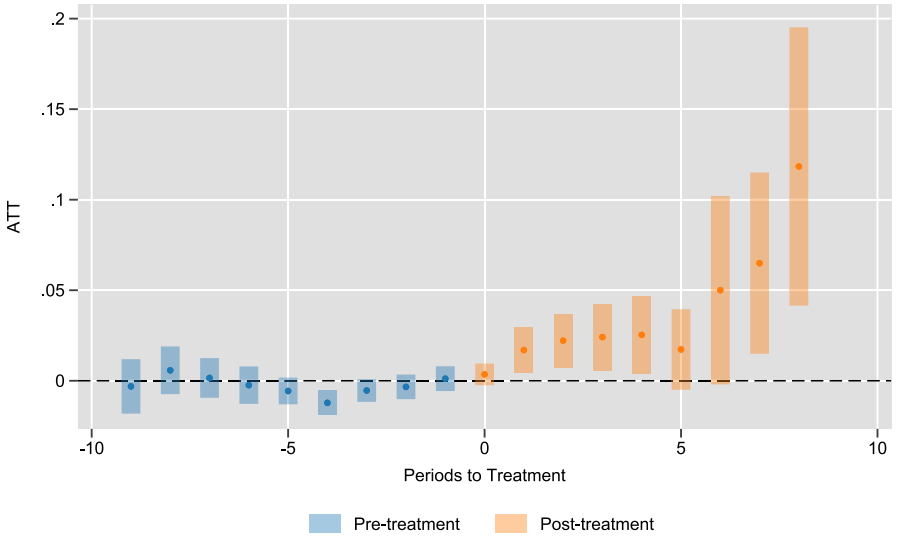



**Fig. 3** ATT by periods before and after treatment, event study: dynamic effects, majority of female councillors CSDID model

The effect of electing a female mayor on changing the waste recycling behaviour of citizens has been verified first. Figure 2 shows a modest positive impact, particularly in the medium term, although this impact is not statistically significant.

Table 2 also shows a positive average post-treatment coefficient (`Post_avg`), but not significant as for post-treatment coefficients per year (`Tp0-Tp8`). The election of a female major is not sufficient to change the recycling behaviours of the municipality's citizens, even after a different year from the election.

Shifting focus from the election of a woman mayor to a more evident change, like the election of a predominantly female council, the argument appears to be much more persuasive. In contrast to a very flat pretrend, Fig. 3 demonstrates a distinct positive and statistically significant impact over nearly all years on the share of sorted waste collection; this effect becomes more pronounced over time.[14]

Table 3 shows a statistically significant average effect of around 3%, which is also corroborated by the average post-treatment coefficients, which are positive and almost all statistically significant.

Analysing an econometric model from the particular to the general ensures a precise understanding of each variable before exploring their broader interactions and impacts.

[14] We investigate the potential reverse causality between pro-environmental attitudes and the preference for electing female politicians (majority of female councillors), also. To the best of our knowledge, no existing empirical framework integrates the instrumental variables (IV) approach within a staggered difference-in-differences model. Therefore, we conduct a Granger causality test, which reveals a unidirectional causal relationship: a council predominantly composed of women influences the share of recycled waste (Granger causality test, lag 1, $p$ value = 0.000701), whereas the reverse effect is not observed (Granger causality test, lag 1, $p$ value = 0.3379).

**Table 3** ATT by periods before and after treatment, event study: dynamic effects, majority of female councillors CSDID model

| | Coefficient | Std. err. | $z$ | $P > z$ | [95% conf. | Interval] |
|---|---|---|---|---|---|---|
| Pre_avg | −0.00262 | 0.001555 | −1.69 | 0.092 | −0.00567 | 0.000424 |
| Post_avg | 0.038078 | 0.009995 | 3.81 | 0.000 | 0.018489 | 0.057668 |
| Tm9 | −0.00312 | 0.007667 | −0.41 | 0.684 | −0.01814 | 0.011909 |
| Tm8 | 0.005773 | 0.006723 | 0.86 | 0.391 | −0.0074 | 0.018949 |
| Tm7 | 0.001562 | 0.005591 | 0.28 | 0.780 | −0.0094 | 0.012521 |
| Tm6 | −0.00242 | 0.005265 | −0.46 | 0.645 | −0.01274 | 0.007895 |
| Tm5 | −0.00564 | 0.003758 | −1.5 | 0.134 | −0.013 | 0.001727 |
| Tm4 | −0.01219 | 0.003449 | −3.53 | 0.000 | −0.01895 | −0.00543 |
| Tm3 | −0.00536 | 0.003213 | −1.67 | 0.095 | −0.01165 | 0.00094 |
| Tm2 | −0.00338 | 0.003471 | −0.97 | 0.331 | −0.01018 | 0.003427 |
| Tm1 | 0.001163 | 0.003489 | 0.33 | 0.739 | −0.00568 | 0.008 |
| Tp0 | 0.003533 | 0.00305 | 1.16 | 0.247 | −0.00244 | 0.00951 |
| Tp1 | 0.016952 | 0.006371 | 2.66 | 0.008 | 0.004464 | 0.029439 |
| Tp2 | 0.022156 | 0.007557 | 2.93 | 0.003 | 0.007344 | 0.036967 |
| Tp3 | 0.024123 | 0.009401 | 2.57 | 0.010 | 0.005698 | 0.042548 |
| Tp4 | 0.02533 | 0.010912 | 2.32 | 0.020 | 0.003944 | 0.046716 |
| Tp5 | 0.017294 | 0.01134 | 1.52 | 0.127 | −0.00493 | 0.03952 |
| Tp6 | 0.050024 | 0.026545 | 1.88 | 0.059 | −0.002 | 0.10205 |
| Tp7 | 0.064944 | 0.025542 | 2.54 | 0.011 | 0.014883 | 0.115005 |
| Tp8 | 0.118349 | 0.039199 | 3.02 | 0.003 | 0.041519 | 0.195178 |

For this reason, different model specifications have been estimated, which are described in Table 4 of Appendix B. Figures 10 and 11 graphically report the results obtained.

Furthermore, falsification tests or pseudo-treatments (Imbens and Rubin 2015; Eggers et al. 2024) have been conducted on the complete model to ensure that our findings are not driven by spurious correlations, verifying that the estimated effects do not arise from unobserved confounders or misspecification of the model. To meet this need, we have both randomised the assignment to treatment (respecting the same percentage as the original data, i.e. assigning treatment equal to 1 to approximately 5% of the population) showing that there is no effect in the post-treatment (see Fig. 12) and repeated this random assignment 100 times studying the significance of the ATT (see Fig. 13 where the lower bound and upper bound of the confidence interval of the estimated ATT are given for each sample); in all cases no statistically significant results are obtained. Finally, the unconfoundedness assumption has been tested by estimating the average effect on pseudo-outcome[15] (Fig. 14).

Moreover, to assess the parallel trends assumption, we have examined pre-treatment trends in environmental behaviours for both treated and untreated

[15] A normal random distribution with the same mean and standard deviation as the original data has been used.

municipalities conducting tests across different time windows to assess the robustness of our results; the estimates conducted on different time windows (−3.3), (−2.2), and (−1.1) (respectively, $p$ value equal to 0.1897, 0.3276 and 0.7864) lead us not to reject the null hypothesis that all pre-treatment ATTs are equal to zero, meaning there is no significant divergence in trends before the intervention.

Finally, robustness checks are also implemented by varying the estimation method using the estimator proposed by Wooldridge (2021, 2023). Figure 15 beyond the pre-treatment phase shows a significant post-intervention trend that practically overlaps with the estimates used with the estimator proposed by Callaway and Sant'Anna (2021).

So far, we have supported recent studies that emphasise the critical role of women as "green" policymakers (Mavisakalyan and Tarverdi 2019; Hessami and da Fonseca 2020; Casarico et al. 2022). However, in our case, the election of a woman as a major is not sufficient to change the recycling behaviours of citizens, while the election of a predominantly female council shows a distinct positive and statistically significant impact over nearly all years on the share of sorted waste collection.

By focusing on only female municipal councils, we will examine the effect of social and cultural geography on these general results in the following section. As already discussed, we do not perform second-stage analyses on specific variables because numerous latent local factors—such as social conventions, beliefs, historical and institutional aspects, and quality of institutions—could undermine the validity of comparisons. These factors are inherently difficult to quantify and incorporate into the analysis, as they are intertwined with other local hidden confounders. Furthermore, the direction of causality between these variables is unclear. For this reason, we have adopted an original methodological approach that estimates our model locally, leveraging the assumption that, in the neighbourhood of each municipality, such institutional factors can be considered common (stationary). This allows us to mitigate concerns related to omitted variable bias and better capture the local dynamics at play.

### 5.2 Spatial non-stationarity

Standard counterfactual approaches assume that local factors are captured by variables specified in the model or by individual spatial dummies, thereby assuming that unexplained heterogeneity is saturated.

The proposed approach acknowledges that hidden local factors might influence policy outcomes, while also recognising the inherent difficulty of identifying and measuring specific factors in economic and social contexts. Rather than imposing predefined geographical boundaries or relying on proxies for territorial control variables, we adopt a dynamic approach by continuously shifting the estimation window across the territory.

We estimate the corresponding ATT for each municipality, leveraging the assumption that social and institutional factors can be considered common within its immediate neighbourhood. This allows us to assess whether the estimated coefficients remain stable across all spatial windows. It suggests that the policy

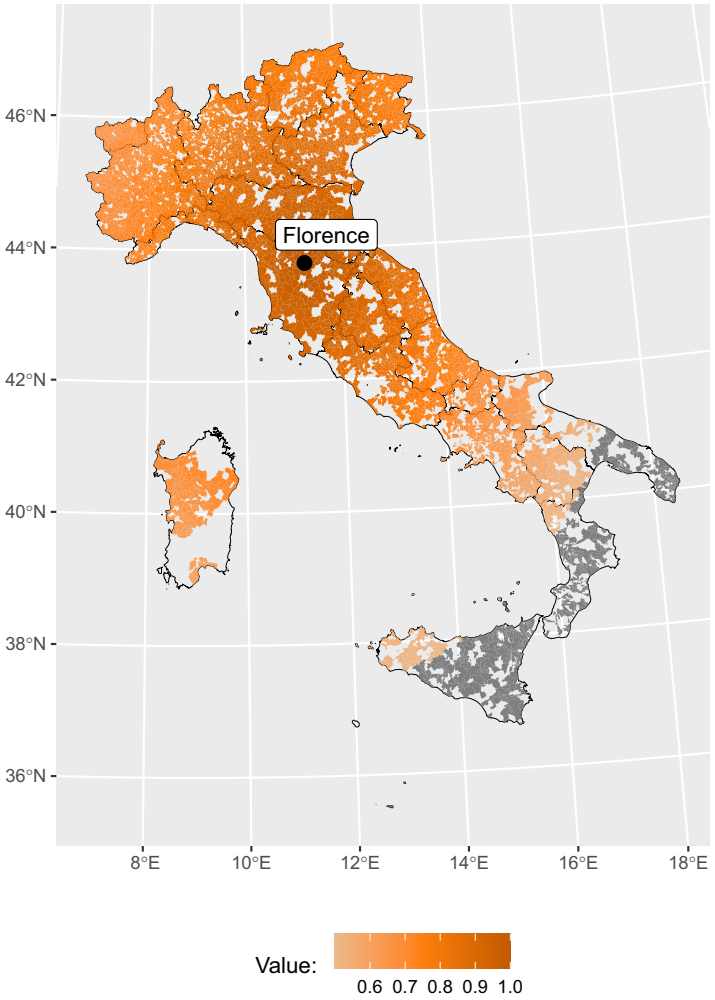



**Fig. 4** Local linear weights, municipality = Florence

has a locally differentiated effect driven by specific spatial factors if they do not. This approach mitigates the need to verify a fundamental hypothesis in counterfactual models, precisely the "*no hidden confounders*" assumption, requiring all significant confounding variables to be identified and incorporated into the analysis.

Given these premises, the GWR-like linear weights have been calculated for each municipality *i* compared to the other 6239 municipalities *j* at each step *i*. Figure 4 shows, for example, the weights centred in Florence; in this case, the weight is equal to 1 for Florence and decreases as the distance of each municipality *j* from Florence increases.

By positioning the spatial window in the centre of each municipality and applying the corresponding weights at each stage, we no longer calculated a single average post-treatment coefficient but 6239 average post-treatment coefficients to assess the spatial stationarity of the global model (see Table 3 and Fig. 3).

Referring to Fig. 5, the effect under examination exhibits notable spatial heterogeneity across the territory. The baseline effect indicates a higher representation of women in local councils, which is associated with increased attention to sustainability-related issues. This effect translates into about a 3% increase, closely aligning with the results obtained from the global model (see Table 3). Notably, this effect appears to be relatively homogeneous across municipalities in the Centre-North. Conversely, a significantly stronger impact is observed in

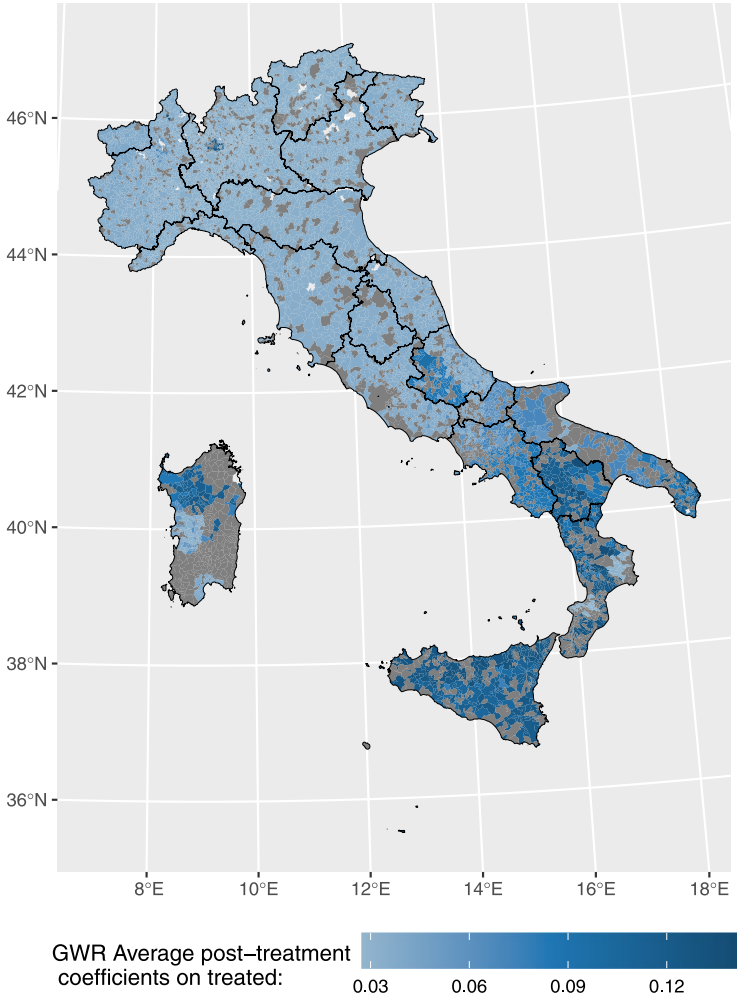



**Fig. 5** Map of the GWR ATT post-treatment coefficients, majority of female councillors

the South of Italy, including the islands, where a female-majority council demonstrates a more pronounced and geographically localised influence. The intensity of this effect varies across municipalities, highlighting the region-specific nature of the relationship between female representation and sustainability engagement.

To verify whether these highly heterogeneous impacts are substantial or simply due to anomalous and transient factors, it becomes essential to investigate the presence of clear spatial differences in trends. Using the clustering procedure for individual trends, here considered as individual functional curves, proposed by Bouveyron and Jacques (2015) and described in Sect. 4.1, we can identify three distinct clusters of curves depicting the heterogeneous effect of the increased presence of women in municipal councils on the sorted waste collection percentage of municipality citizens over years.

Figure 6 shows the smoothed trend basis (a curve for each municipality) on the left and the estimated functional clusters of the trends of the effect of ATT post-treatment on the right. Three patterns emerge. First, Cluster 1 (referred to Fig. 7), mainly involving northern municipalities, is identified as the most uniform, with a minor but notable influence on the prevalence of women in the municipal council. Cluster 2, encompassing the Centre, Campania, and Apulia, is the least uniform, exhibiting a moderate effect, though not markedly trend divergent from Cluster 1. Finally, Cluster 3, which mainly comprises Calabria and Sicily, shows a more pronounced effect.

Second, the impact across the three regions appears to be transient, i.e. more pronounced initially and decreasing after the fourth and fifth year after the elections. Third, a significant increase in the effect is observed towards the last years of the analysis (years 7 and 8), but this should be moderated considering the expanding

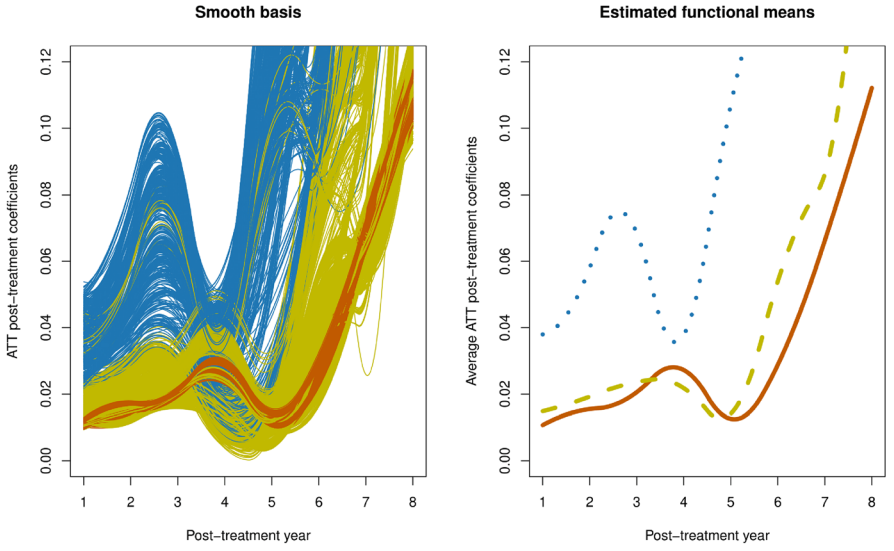
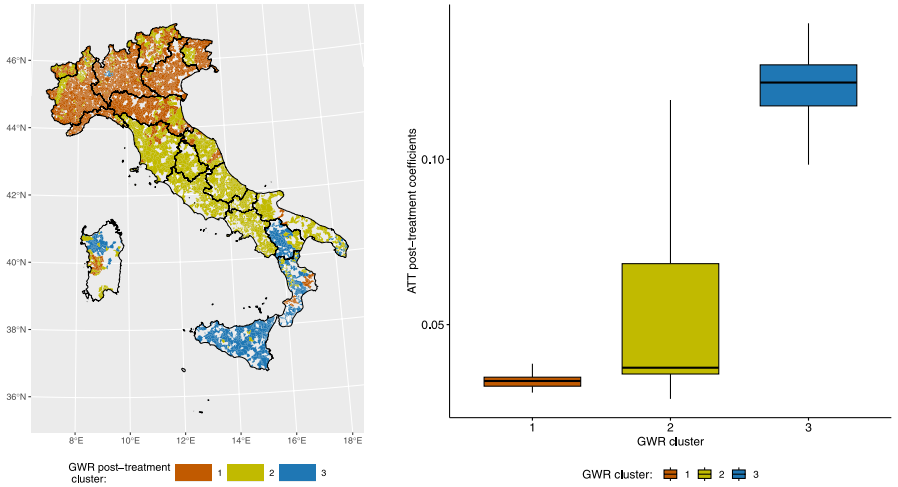



**Fig. 6** Smoothed trend basis and functional clusters of ATT post-treatment effects, majority of female councillors




(a) Map (b) Distribution

**Fig. 7** Map and distributions of the ATT post-treatment coefficients by functional cluster, majority of female councillors

confidence intervals during those years; additionally, in the early years of the panel, there were very few municipalities with a prevalence of women in the municipal council (see Fig. 1).

When estimating the impact of female mayors alone, the GWR results are weakly positive but not statistically significant in all areas of Italy (Fig. 8). Therefore, this stationary trend does not allow clear differences to emerge.[16]

### 5.3 Robustness analysis

Robustness checks are implemented by modifying the local weights through a Gaussian decaying nonlinear weight function as described in Eq. (5):

$$w_{ij} = \exp(-(d_{ij}/h)^2) \tag{5}$$

where the distance between the municipality $i$ and $j$ ($d_{ij}$) is standardised for the bandwidth $h$ calculated for a given geographically weighted regression by optimising the linear model introduced in Eq. (4).

This weighting approach, unrestricted and featuring broader tails (see Fig. 9b), incorporates more units at each stage than the earlier scheme. Consequently, we expect that the disparities between regions will be smoother.

In Fig. 16 in Appendix C, we observe a trend similar to the estimation using linear weights, where the prevalence of the effect in southern regions is highlighted. By construction, this evidence is not as pronounced as in Fig. 5. However, the correlation

[16] Results are not reported and available upon request from the authors.

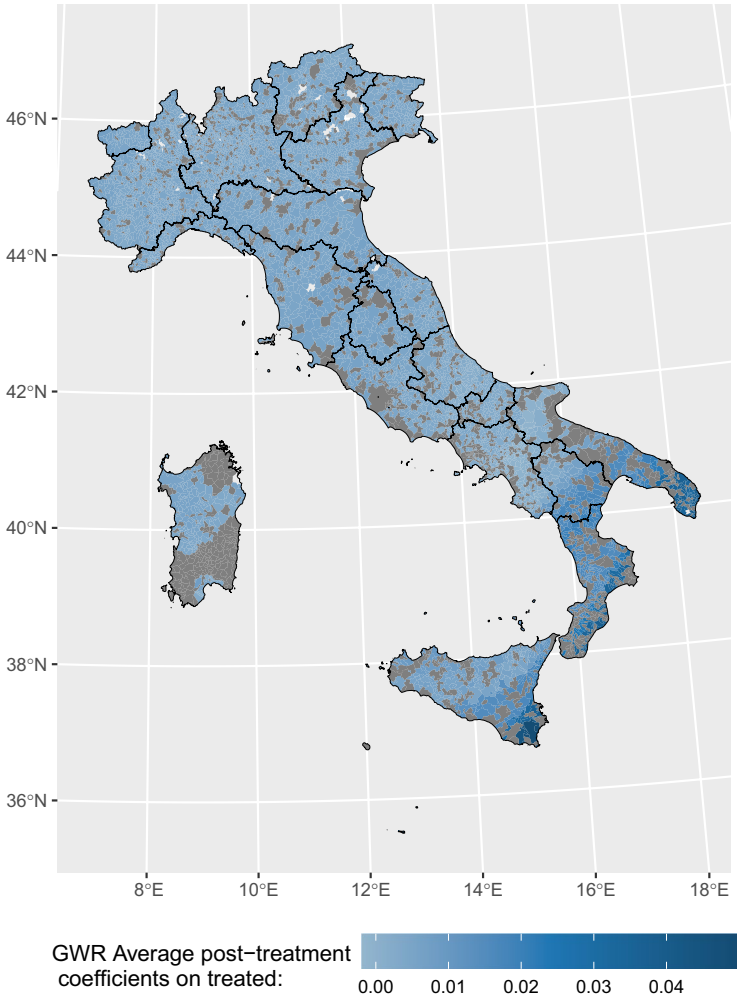



**Fig. 8** Map of the GWR ATT post-treatment coefficients, woman mayor

between the post-average coefficients computed across various municipalities in the constrained linear scenario and the unconstrained Gaussian scenario is impressively high at 0.711. This substantial correlation underlines the robustness of our estimates, indicating a reliable inference despite differing methodologies.

### 5.4 Implications of spatial non-stationarity

The non-stationarity of the estimated impacts highlights that societal behaviour and governance changes, including environmental ones, are dynamic and require enduring cultural efforts to achieve lasting transformation. Those changes are mainly

influenced by rooted social and cultural aspects (Massey 1994; Guiso et al. 2006, 2011) rather than administrative boundaries.

One of the sociocultural features in Italy is the decisive role of the family, fostering a unique form of mutual support and trust that are paramount and whose influence extends to various aspects of life, affecting social behaviours, economic decisions, and political attitudes (Marè et al. 2024). It is worth noting that this kind of trust in people known personally, such as in a family, represents a "particularised trust" (Uslaner 2002) according to which an individual only trusts close friends and relatives but is distrustful of people outside her social network (Lombardo and Ricotta 2022).

Even though this type of trust might not be the most useful for territories, women play a crucial role within the Italian families and territories (Caldwell 1991; Willson 2009). Initially, they were the ones who performed the so-called traditional tasks (e.g. care of children and home). More recently, since the post-war period, women have started to be involved in more complex tasks or activities carried out by men until that moment (e.g. working). Changes in the social role of women have been heterogeneous across regions, reflecting diverse cultural and economic contexts.

All this given, the role of women in family and society represents a case of non-stationarity in sociocultural geography. Accordingly, the impact of changes on environmental issues is not uniform but varies in strength and duration. The transition has been smooth in some regions and has been integrated into the existing social background. In others, where traditional views on gender roles are more rooted, changes have been more disruptive.

Our research highlights two main findings on the changing roles of women in municipal governance in Italy. Municipalities have responded positively to the changing roles of women by diversifying their compositions. This is more pronounced in areas where traditional gender roles were previously more rigid. The disruptive nature of these changes in these areas catalyses a more visible transformation in local governance structures.

Despite the initial positive response, the impact of the change tends to fade in the medium term (after 5–6 years). This suggests that while initial shifts in governance and social attitudes occur, following regulatory measures (De Paola et al. 2014), it is useless if continuous cultural efforts do not support them. In other words, long-term values, beliefs, and traditions play a significant role in this process. They might counterbalance in the medium-long term, indicating the need for cultural actions to maintain and build upon these positive changes.

## 6 Concluding remarks

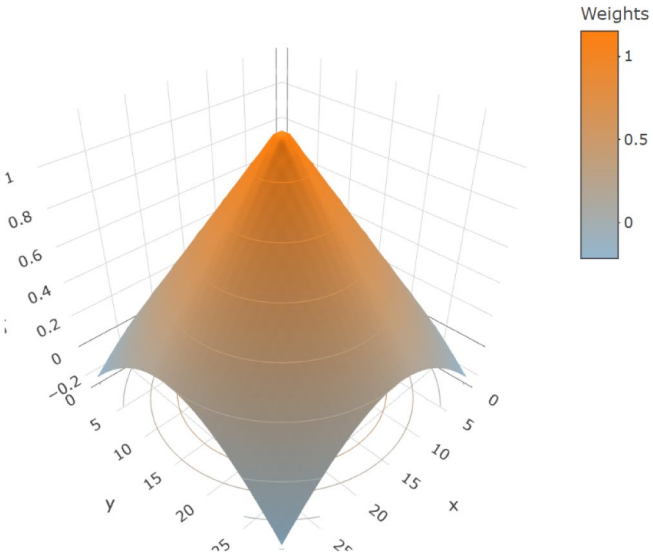
In the last decades, the role of women in society, the growing environmental focus, and their interaction have received increasing attention. Changes related to these aspects are strictly connected to local territories and their institutions, being able to affect culture and citizens' habits through public policies.

From a policy perspective, our results underscore the critical role of gender in shaping citizens' environmental attitudes and behaviours. Bridging the gender gap in political representation can significantly contribute to achieving the green transition goals. In addition, understanding the geographical nuances of these impacts is crucial for designing effective and context-sensitive policies. Our study highlights the intersection of gender politics and environmental sustainability, advocating for greater female representation in political spheres as a catalyst for positive environmental change.

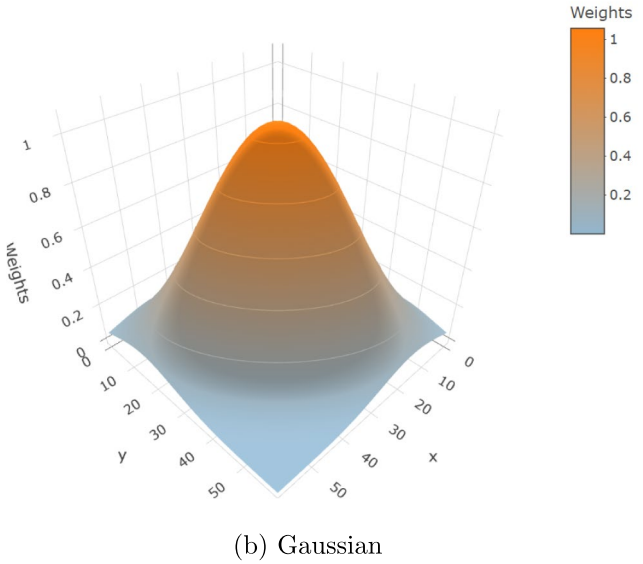
Following this direction, local authorities could foster, on the one hand, diversity and inclusion initiatives. On the other hand, citizens and municipalities are the key levers of change; local governments are the most responsible entities for making local areas more dynamic and institutions more gender-equal, inclusive, and democratic rather than more environmentally sustainable. Put differently, considering gender issues is crucial for the success and efficiency of climate change and environmental policies. Ignoring these aspects can make climate actions less effective, as they may only engage a portion of the population or potentially harm specific social groups.

Given the supportive results of women's political roles in higher ecological sustainability, how female politicians can manage and address ongoing global issues remains to be investigated. Future research should continue to explore the long-term effects of such representations and consider other factors that may influence these dynamics.

## Appendix A. Spatial decay functions




(a) Linear




(b) Gaussian

**Fig. 9** Linear and Gaussian weights

## Appendix B. From baseline to complex model

In the appendix, the average treatment effects (ATTs) for periods before and after treatment are separately documented for scenarios with a woman mayor and where there are a majority of female councillors (different *TG*), under different specifications.

**Table 4** From baseline to complex counterfactual model

| Model | Specification<br>$Perc^{sorted} = f(TG$ and covariates) |
|---|---|
| Baseline | No covariates |
| Baseline and Socio-Demographic Controls 1 | Density + Mountain + Tourist beds |
| Baseline and Socio-Demographic Controls 2 | Density + Area + Number of household members + Mountain + Tourist beds |
| Baseline and Socio-Demographic Controls 3 | Density + Population + Area + Number of household members + Mountain + Tourist beds |
| Baseline and Economic Controls 1 | Collection/transport cost per hab. + Treatment/recycling costs per hab |
| Baseline and Economic Controls 2 | Collection/transport cost per kg + Treatment/recycling costs per kg |
| Baseline and Economic Controls 3 | Income per capita |
| Baseline and Economic Controls 4 | Income per capita + Collection/transport waste per hab. + Treatment/recycling costs per hab |
| Baseline and Economic Controls 5 | Income per capita + Collection/transport waste cost per kg + Treatment/recycling costs per kg |
| Complete | Density + Population + Area + Number of household members + Mountain + Tourist beds + Income per capita + Collection/transport cost per hab. + Treatment/recycling costs per hab |

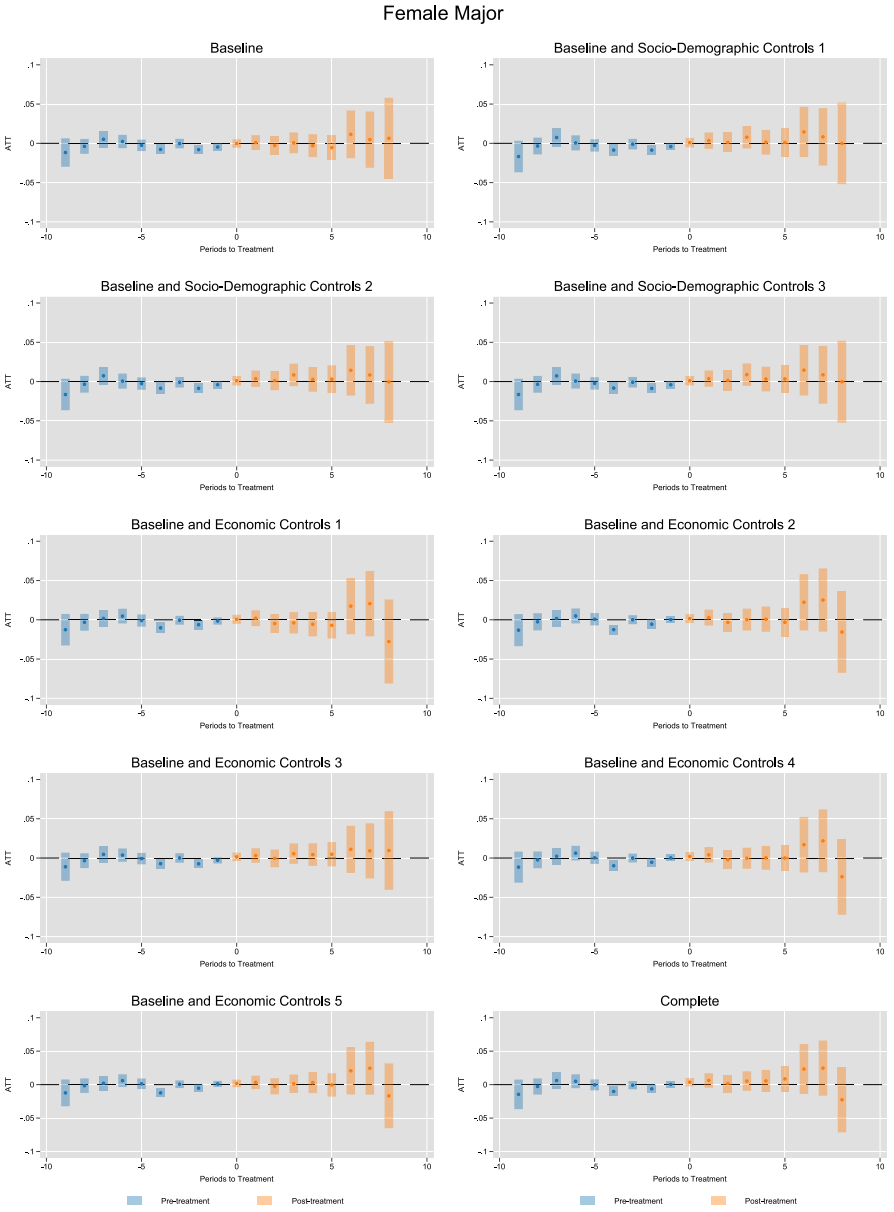



**Fig. 10** ATT by periods before and after treatment, event study: dynamic effects, woman mayor—CSDID model, by specification

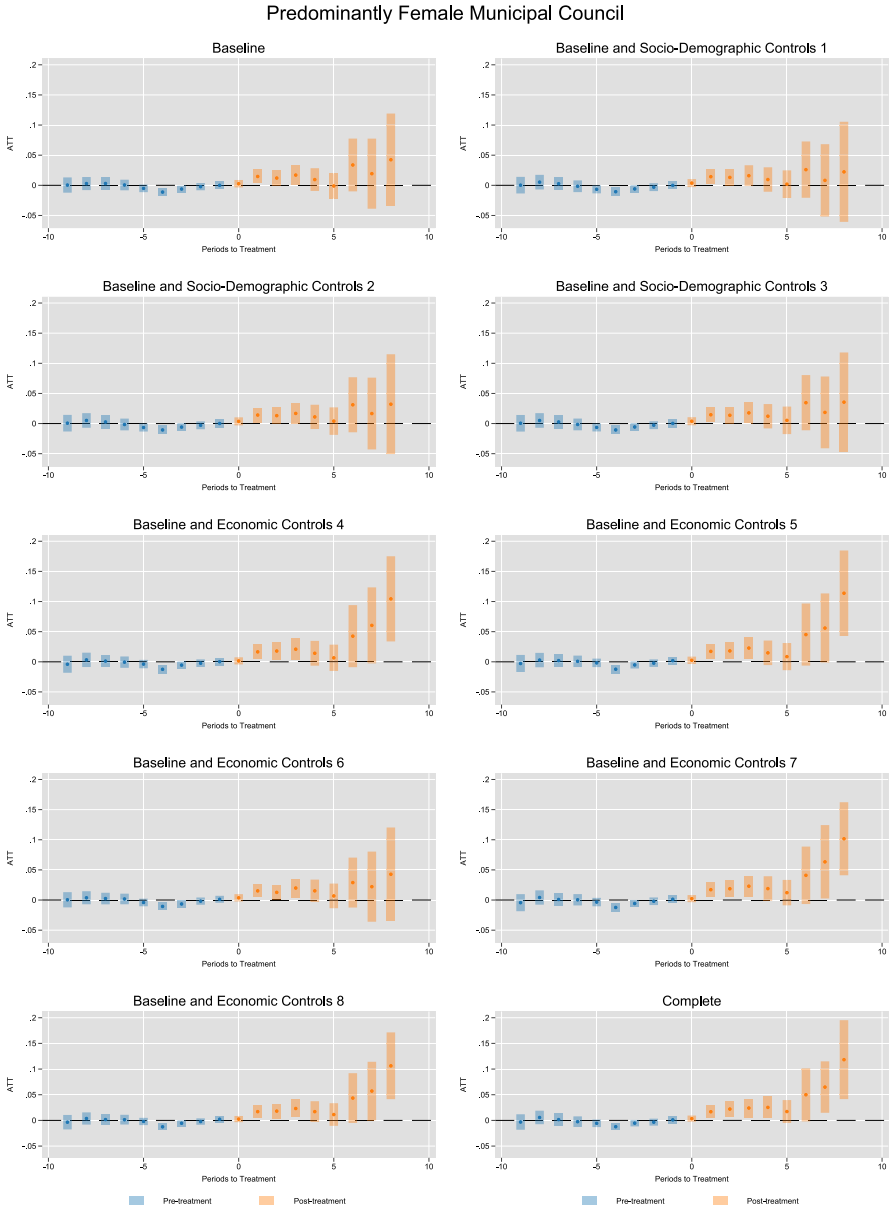



**Fig. 11** ATT by periods before and after treatment, event study: dynamic effects, majority of female councillors CSDID model, by specification

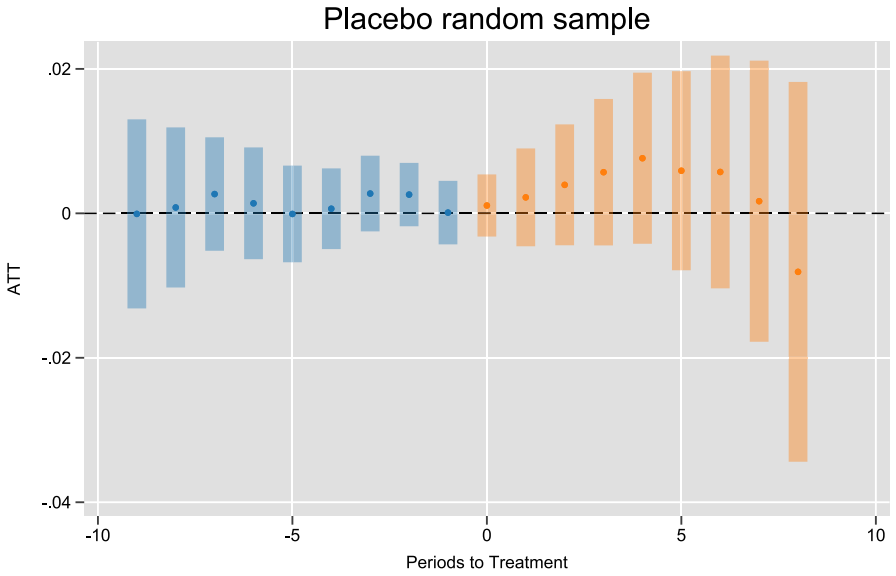



**Fig. 12** Falsification test assigning random treatment

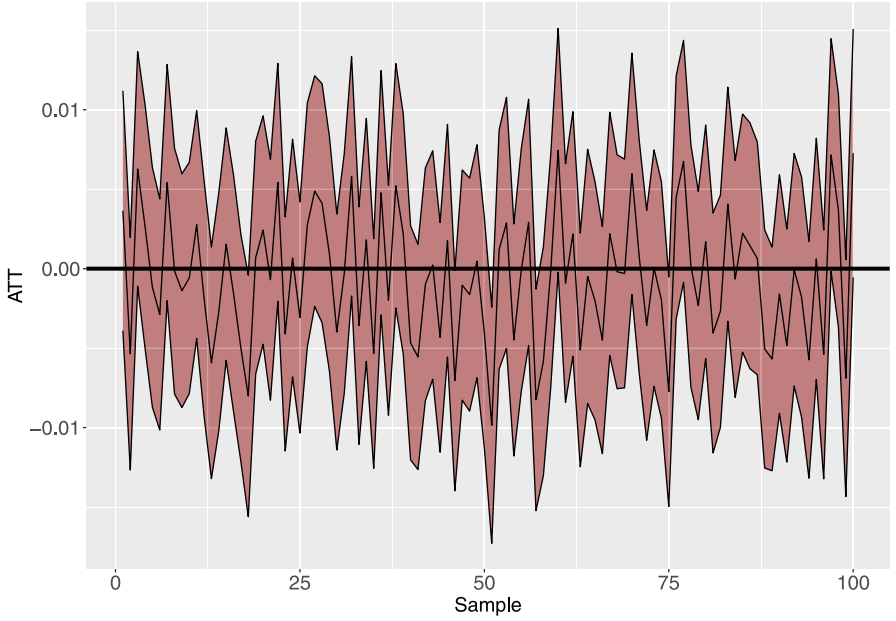



**Fig. 13** Falsification test varying random sample assignment, 100 samples—lower bound and upper bound of the confidence interval of the estimated ATT are given for each sample

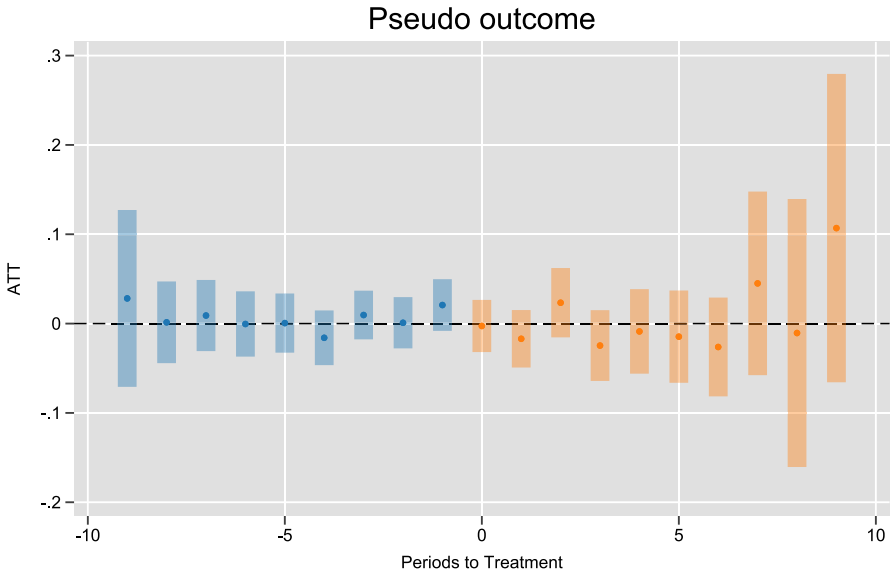



**Fig. 14** ATT by periods before and after treatment on pseudo-outcome

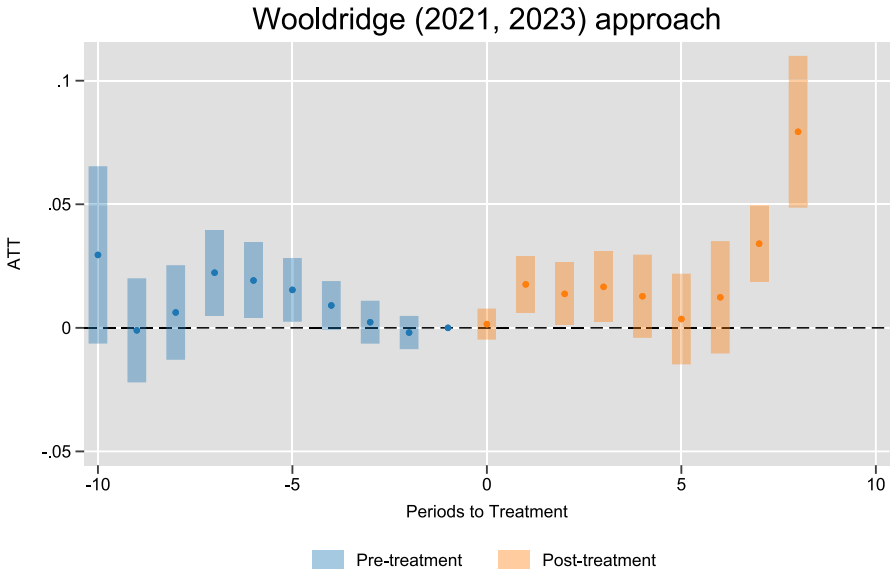



**Fig. 15** ATT by periods before and after treatment, Wooldridge (2021, 2023) approach

## Appendix C. Robustness

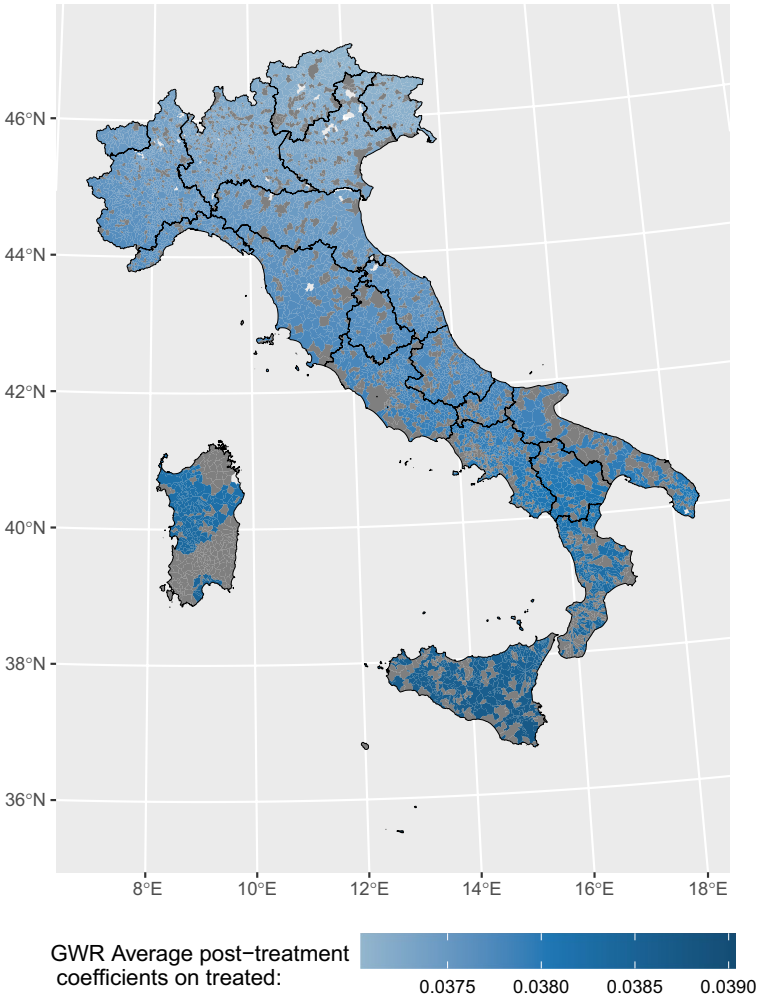



**Fig. 16** Map of the GWR ATT post-treatment coefficients, woman mayor, Gaussian weights

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**Author contributions** All authors contributed equally to the conception, design, data analysis, interpretation of results, drafting, and revision of the manuscript. All authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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**Data availability** No data sets were generated or analysed during the current study.

## Declarations

**Conflict of interest** The authors declare no competing interests.



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