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# Clearing the Air: Women in Politics and Air Pollution

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## Abstract

Differing attitudes towards environmental issues between men and women as policy-makers may affect policies and actions. Accordingly, this research analyses the issue of the causal relationship between women politicians and the level of air pollution. The analysis tests for this in Italy, exploiting a gender quota measure (Law 215/2012) as an exogenous shock to the percentage of female municipal councilors. Difference-in-differences instrumental variable approach finds that an increase in the percentage of female councilors decreases the maximum number of days in which at least one type of monitoring stations (among all the stations installed in the provincial capital municipality) has detected an excess of PM10 with respect to its daily limit. This research provides evidence of the most likely mechanism driving the results by proving that an increase in female officeholders has a positive impact on a number of environmental friendly policies and measures (as the bicycle lanes, the urban green, the bike- and car-sharing services, district heating and traffic blockage) aimed at reducing the harmful air particles.

JEL CLASSIFICATION: C26, D72, J16, K38, Q53

KEYWORDS: Air pollution, Gender quotas, Municipal elections, Female politicians.

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# 1 Introduction

Air pollution is acknowledged as a prominent challenge for public health globally and is identified as a significant environmental concern, prompting increasing attention from the scientific community (Brunekreef and Holgate, 2002, Landrigan, 2017). The presence of pollutants in the atmosphere, including particulate matter (PM), ground-level ozone (O<sub>3</sub>), carbon monoxide (CO), sulfur dioxide (SO<sub>2</sub>), and nitrogen dioxide (NO<sub>2</sub>), constitutes the primary focus of research. Air pollution increases the number of premature deaths due to strokes, ischemic heart diseases, lung cancer, infections of the lower respiratory tract, diabetes, and chronic obstructive pulmonary disease (McDuffie et al., 2021). It has causal adverse effects on infant and adult mortality, hospitalization rates, health care expenditures, and mental health (Chay and Greenstone, 2003, Deryugina et al., 2019, Jans et al., 2018, Tanaka, 2015). Nonetheless, air pollution provides also economic damages, in terms of working hours, labor productivity, decisions in the labor market, academic performance, and income (Hanna and Oliva, 2015, Zivin and Neidell, 2012).

In this respect, governments have been extensively revising their environmental policies, implementing new and more effective actions to protect the environment. Although recent researches indicate that women tend to show more concern for the environment compared to men (McCright and Xiao, 2014), studies exploring the relationship between gender and environment at the political level remain inconclusive. Indeed, a growing body of the recent literature is arguing that female legislators exhibit greater attitudes and actions regarding environmental issues than their male counterpart (Ergas and York, 2012). Proofs in that direction are provided in context as Sweden (Sundström and McCright, 2014), USA (Fraune, 2016, Fredriksson and Wang, 2011) and Germany (Fraune, 2016). Conversely, when the legislator's political party is accounted for, the gender effect on environmental concerns becomes insignificant. Evidence of that kind has been offered for Canada (Tremblay, 1998), Australia (Fielding et al., 2012, McAllister and Studlar, 1992), Argentina (Jones, 1997) and Italy (Papavero et al., 2009).

While the literature offers support of effective policies and actions addressing environmental issues (such as CO<sub>2</sub> emissions and renewable energy production) following the female political empowerment (Bansal and D'Agosti, 2023, Ergas and York, 2012, Salamon, 2023), it lacks direct evidence regarding air pollution. Our objective is to enhance the existing body of literature by offering a causal analysis of how an increase in women's political representation influences the degree of air pollution through the formulation of local policies and initiatives designed to enhance air quality. Specifically, we show empirically that an increase in the percentage of women in Italian local governments leads to a reduction in the air pollution measured by the maximum number of days in which at least one type of monitoring stations (among all the stations installed in a given area — the provincial capital municipality) has detected an excess of PM<sub>10</sub> (particles suspended in outdoor air with an

aerodynamic diameter equal to or less than  $10 \mu$  (micrometers)) with respect to the daily limit of  $50\mu\text{g}/\text{m}^3$  (micro-grams per cubic meter).

While previous literature indicates the significance of female political representation across various policy domains, establishing a clear causal relationship between female politicians and policy outcomes remains challenging. To address potential endogeneity issues arising from omitted variable bias, we leverage the implementation of gender quotas mandated by Law 215/2012 as a random allocation of women in city councils. Under Law 215/2012, municipalities with a resident population exceeding 5,000 are permitted to cast one preference vote for a candidate of either gender, but dual preferences require selecting candidates of different genders. This legislative provision serves as an exogenous variation in the gender composition of municipal councils (Baltrunaite et al., 2019), unrelated to air pollution concerns.

Therefore, we employ a difference-in-differences instrumental variable approach in the time-span 2010-2019 to assess the influence of the proportion of female councilors on the annual occurrence of air pollution days, detected for the provincial capital municipalities where the monitoring stations are located. To instrument the percentage of female councilors, in the first stage of the 2SLS estimate this study uses a dummy for Law 215/2012 and takes as treatment group the provincial capital municipalities that are affected by it (those belonging to regions with ordinary statute voting under Law 215), and, as control group, provincial capital municipalities in the regions with special statute (unaffected by Law 215).

The primary contribution of this study lies in offering compelling evidence that our measure of air pollution is influenced by the proportion of women in local political institutions. Specifically, a 10-percentage points (p.p.) rise in the proportion of female councilors leads from 10.9 to a 11.4 number of days decrease in the maximum number of days in which at least one type of monitoring stations has detected an excess of PM10 with respect to the daily limit. A corroboration of the result is given by concentrating on female aldermen, which gains a non-marginal role within the city council and it is confirmed when other measures of air pollution (such as maximum annual average concentration of PM2.5, the maximum value of the annual average concentration of NO2 and the highest annual value of the annual average concentration of benzo(a)pyrene (all detected across all air monitoring stations) are considered.

Moreover the result is robust to the enlargement of the time-span going back to 2003; it is not driven by the gender of the mayor; it is unaffected by the inclusion (among controls) of the municipal expenditure as well as dummies for the political party affiliation of the majority within council.

The second contribution concerns the discussion of the most likely mechanism behind these findings, reflecting the literature documenting that women have stronger environmental concerns than men and are more likely to adopt environment-friendly actions and politics (Eurobarometer, 2008, Meyer, 2016, Subiza-Pérez et al., 2020). In this regard, we provide

empirical evidence that as the percentage of female councilors increases, the density of bicycle lanes, the urban green spaces, the bike- and car-sharing services, the district heating and the traffic blockage increase too. All those measures are implemented by the municipal council with the aim to reduce the air pollution.

This study adds to a significant body of literature demonstrating that an increased proportion of women in political positions influences the implementation of environmental policies aimed at fostering human health. Such initiatives represent crucial steps toward addressing the global climate crisis ([Atchison and Down, 2019](#)). Despite theories suggesting that policy choices tend to align with the preferences of the median voter ([Downs, 1957](#)), empirical research has demonstrated the importance of policymakers' gender. Women in policymaking roles influence both the nature of public spending ([Bagues and Campa, 2021](#), [Baltrunaite et al., 2019](#), [Bhalotra and Clots-Figueras, 2014](#), [Casarico et al., 2022](#), [Clots-Figueras, 2012](#), [Ferreira and Gyourko, 2014](#), [Funk and Gathmann, 2015](#), [Hessami and da Fonseca, 2020](#), [Lippmann, 2019](#), [Mavisakalyan, 2014](#)) and the formulation of public policies ([Bansal and D'Agosti, 2023](#), [Baraldi et al., 2024](#), [Berkman and O'connor, 1993](#), [Besley and Case, 2003](#), [Kittilson, 2005](#), [Ramstetter and Habersack, 2019](#), [Salamon, 2023](#), [Schwindt-Bayer, 2006](#), [Svaleryd, 2009](#), [Thomas, 1991](#)).

When dealing with air pollution, the paper by [Lv and Deng \(2019\)](#) is the only evidence showing that female empowerment has long-run effects on the CO2 emissions.

In contrast to the aforementioned literature (reporting cross-countries and parliamentary evidences), this study focuses on the lowest level of Italian governance, which is more responsive to local needs and capable of implementing tailored measures based on specific circumstances. Additionally, it represents the first attempt to link the presence of women in local institutions with the pressing issue of damage particles in the air (as PM10), highlighting credible mechanisms through which effective policies and initiatives — such as expanding bicycle lanes, increasing urban green spaces, promoting bike- and car-sharing programs, and implementing district heating systems and traffic blockage — led by female policymakers may mitigate harmful air particles. Thus, enhancing women's political representation through gender quotas has the potential to empower them as influential agents of change, fostering more environmentally responsible policies and behaviors.

The rest of the work is organized as follows. Section 2 describes the institutional framework. In Section 3 the work presents the variables of the analysis. Section 4 illustrates the strategy and Section 5 presents the empirical evidence on the effect of an increase in the number of women city councilors on the air pollution measures and sets out the discussion of the results shedding some light on the possible driving mechanism. Section 6 presents some robustness checks and 7 concludes.

## 2 Institutional framework

### 2.1 Local political institutions in Italy

The lowest level of government in Italy is represented by the municipalities. Our sample analysis refers to the “provincial capital” municipality, where the provincial administration is located and that generally gives the name to the related province.<sup>1</sup> Italy counts 112 provincial capitals; they constitute the focal point of the current analysis since they house the pollution monitoring stations. Such provincial capitals belong to the 15 ordinary-statute regions<sup>2</sup> and to the 5 special-statute (*Regioni a Statuto Speciale*) regions.<sup>3</sup>

Municipalities are overseen by a mayor, supported by both a legislative body, known as the municipal council (Consiglio Comunale), and an executive body, called the executive committee (Giunta Comunale), which consists of aldermen. The municipal council holds legislative authority at the local level and comprises the mayor along with a varying number of councilors based on the population of the municipality. Within our sample of provincial capitals (ranging from a population between 21,517 and 2,638,842), the number of councilors ranges from a minimum of 21 to a maximum of 60. The mayor receives support from the executive body, and the aldermen are selected by the mayor from the council members in municipalities with fewer than 15,000 residents. In larger municipalities, as the provincial capital, they may also be chosen from individuals outside the council. In our sample, the number of aldermen varies from a minimum of 1 to a maximum of 17.

Policy decisions concerning expenditures and revenues entail collaboration among the mayor and executive committee, which propose budgetary policies, and the municipal council, which authorize them. This implies that the mayor can only enact desired policies if sufficient support by the councilors is garnered. Therefore, if women and men hold distinct policy priorities and women tend to prioritize certain issues (such as the environment) more than men, one might anticipate this gender discrepancy to manifest in particular types of policies and actions.

The standard interval for municipal elections is every five years, and the tenure of councilors aligns with that of the mayor. However, under certain circumstances (permanent obstruction, dismissal, expiration of tenure, or death hindering the mayor or a majority of the council from fulfilling their responsibilities; a breach of the Constitution or national legislation; and the inability to approve the budget), municipal administrations can schedule early elections.

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<sup>1</sup>The provinces are the second-highest level of Italian government.

<sup>2</sup>Abruzzo, Basilicata, Calabria, Campania, Emilia Romagna, Lazio, Liguria, Lombardy, Marche, Molise, Piedmont, Puglia, Tuscany, Umbria, and Veneto.

<sup>3</sup>Friuli-Venezia Giulia, Sicily, Sardinia, Trentino-Alto Adige, and Valle d’Aosta.

## 2.2 Law 215/2012

Law 215/2012 aims to promote gender balance within city councils by stipulating certain provisions. In municipalities with over 5,000 residents, neither gender can constitute more than two-thirds of the total number of candidates on party council slates. This necessitates political parties to reserve a minimum of one-third of the total positions for female candidates. Furthermore, in these municipalities, the law introduces double-preference voting, contingent on gender: voters can cast a vote for a list and indicate one preference for a candidate of either gender (or opt not to express any preference), but if they choose to express two preferences, they must select candidates of different genders. It's important to note that these provisions exclusively pertain to city councilors, excluding the mayor and aldermen.

Law 215/2012 does not apply to the municipalities in the five special-statute regions of Friuli-Venezia Giulia, Sicily, Trentino-Alto Adige, Valle d'Aosta, and Sardinia. These regions operate under their own legislative frameworks, employing distinct methods to promote gender equality.<sup>4</sup>

An important matter for our purpose is that the election rules differ for towns above and below the 15,000-inhabitant threshold. In smaller municipalities, the mayor is elected by a single-ballot system, while in larger ones there is a run-off system.

As said in the previous Subsection 2.1, in our sample of provincial capital municipalities, the elections of the city council are staggered over time. The first elections under Law 215 were held in May 2013. During 2013 the 13.88% of the sample of provincial capital municipalities voted under Law 215; in 2014 it was 27.04%, in 2015 it was 10.18%, in 2016 it was 16.66%, in 2017 and 2019 it was 17.59%. In 2019 all the provincial capital municipalities had already voted once under Law 215.

The enforcement of Law 215/2012, resulting in an exogenous increase in female councilors (as the paper by [Baltrunaite et al. \(2019\)](#) already proved and as we will show in the upcoming Subsection 4.1), enables to design a quasi-experimental setting. Here, provincial capital municipalities located in regions with ordinary statute (interested by Law 215) form the treatment group, while provincial capital municipalities located in regions with special statute (unaffected by Law 215) serve as the control group.

### 2.2.1 Control group

In this Section we deal with the provincial capital municipalities belonging to regions with special statute as a valid counterfactual. Article 116 of the Italian Constitution bestows autonomous governance upon the five special-statute regions (Friuli-Venezia Giulia, Sicily, Sardinia, Trentino-Alto Adige, and Valle d'Aosta), endowing them with legislative, administrative, and financial authority that varies according to their individual statutes. These

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<sup>4</sup>However, it's worth noting that Sardinia initiated voting under the double-preference system conditional on gender on June 16, 2019. This particular election has been excluded from the sample.

regions have the option to delegate their administrative powers directly to the municipalities. In contrast, ordinary-statute regions lack direct administrative competence, as the Constitution assigns such authority to the municipalities.

In the period of analysis (2010-2019), a particular fiscal rule constraint interested Italian municipalities: the Domestic Stability Pact (DSP). The DSP, in place from 1999 to 2015, comprised a series of fiscal measures aimed at managing spending among regions, provinces, and municipalities, in order to control national public expenditures. Looking at municipalities (the core of our analysis), the DSP stipulated that, for each year, the total municipal budget balance (with the exception for certain expenditure items) needed to be proportional to a (moving) average of balances achieved in previous years within the same municipality.<sup>5</sup> For the purpose of our analysis, all the municipalities above 5,000 (as our sample of provincial capital municipalities) were affected by the DSP constraints. Moreover, the discipline of the DSP was applied uniformly to ordinary-statute regions. Despite their special statute, Sicily and Sardinia also have limited autonomy in public finance and the three remaining special-status regions embraced a form of the DSP. In 2016, the DSP was repealed, and instead, a balanced budget requirement was implemented for all municipalities in all regions.

In our quasi-experimental setup, where we designate provincial capital municipalities unaffected by Law 2015/2012 as the control group, a potential issue may arise concerning public finance constraints due to their special autonomy. This autonomy extends to their authority to alter both the group of municipalities subject to the regulation and the specific numerical parameters of the fiscal rule (Grembi et al., 2016). Indeed, the potential variation in budget constraints between municipalities in regions with special statute and those in regions with ordinary statute (at least until 2016) could influence municipal spending and, then, policies, and measures, including those related to environmental sectors.<sup>6</sup> This could have repercussions on the level of air pollution as well. In the following, we will provide statistical evidence that municipal expenditure in provincial capital municipalities in regions with special statute is not a concern for the analysis and, consequently, that provincial capital municipalities in regions with special statute are a legitimate counterfactual.

We collect data on municipal expenditure in provincial capital municipalities in all the regions (hereafter *Expenditures*). We perform a t-test of the mean difference (over years) of the per-capita municipal expenditure (municipal expenditure/population) between provincial capital municipalities in the regions with ordinary statute (the treatment group) and provincial capital municipalities in the regions with special statute (the control group). The

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<sup>5</sup>In 2001, municipalities with populations fewer than 5,000 were excluded from this regulation. Subsequently, in 2013, a further reform reduced the population threshold to 1,000, thereby extending the rule's applicability to municipalities with populations ranging from 1,000 to 5,000 inhabitants.

<sup>6</sup>The greater fiscal autonomy characterizing the regions with special statute allows them to manage taxes and revenues, giving to them the possibility to transfer funds to municipalities to support services and investments. Those transfers may also increase the spending capacity of municipalities within regions with special statute with respect to municipalities within regions with ordinary statute.

p-value of the test is equal to 0.61, meaning no significant difference in the per-capita expenditure between the two groups. Moreover, we provide further evidence of no effectiveness of the possible different constraints imposed by the DSP between municipalities in both groups by estimating a diff-in-diff equation as the following:

$$Y_{i,t} = \alpha + \gamma Treat_i + \lambda Before_t + \beta(Treat * Before)_{i,t} + \delta_i + \delta_t + \varepsilon_{i,t} \quad (1)$$

where  $Y_{i,t}$  is the outcome of interest measuring the per-capital municipal expenditure in the provincial capital municipalities  $i$  in the year  $t$ ;<sup>7</sup>  $Treat$  is a dummy for provincial capital municipalities in the treatment group (in regions with ordinary status affected by the DSP) that allows us to control for the unobserved time-invariant characteristics that may differ across municipalities in the two groups;  $Before$  is a dummy variables taking the value of 1 from 2010 to 2015, when the DSP was in force (and 0 between 2016-2019) and captures the temporal trend common to both groups.  $Treat * Before$  is the interaction term between the two dummies and measures the treatment effect of our interest, that is, if there has been a significant difference in the municipal expenditure between treatment and control group when the DSP was in force. The coefficient of  $Treat * Before$  is positive but not significantly different from 0 (the p-value is 0.464)<sup>8</sup> meaning no difference in the municipal expenditure between treatment and control group, before and after the validity of the DSP.

Those evidences allow us to consider the provincial capital municipalities belonging to regions with special statute a suitable control group. However in the Robustness checks section, we add as control variable the per-capita municipal expenditures.

## 3 Data and variables

### 3.1 Dependent variable

Since 1987, the high risk to human health posed by PM10 has been recognized by the World Health Organization in the European Air Quality Guidelines. The term “PM10” identifies particles suspended in outdoor air with an aerodynamic diameter equal to or less than 10  $\mu m$  (micrometers). It may also contain other substances such as heavy metals, sulfates, nitrites, and poly-cyclic aromatic hydrocarbons (i.e., volatile organic compounds). Sources of particulate matter are both natural and anthropological.

Epidemiological studies, corroborated by clinical and toxicological analyses, have revealed the significant health impact of air pollution; the higher the concentration of fine PM in the air, the greater the effect on public health. Acute effects are linked to short-term exposure (one or two days) to high concentrations of PM containing metals. This condition can lead to inflammation of the respiratory tract, such as asthma attacks, or impair the functioning of

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<sup>7</sup>Tables A.3 and A.4 in Appendix A shows the descriptive statistics the per-capital municipal expenditure.

<sup>8</sup>The estimation results are available upon request.

the cardiovascular system. Chronic effects, on the other hand, result from prolonged exposure to high concentrations of PM and can cause respiratory symptoms such as coughing, phlegm, decreased lung capacity, and chronic bronchitis. For susceptible individuals, namely those already suffering from lung and heart diseases or asthma, there is reasonable concern about exacerbating existing conditions and triggering typical symptoms of the disorder. Studies in this field have also documented an increase in hospital admissions and mortality from respiratory and cardiac diseases directly attributable to particulate pollution.

Air pollution measurement is carried out by the statistical offices of the municipalities, which collect information from the monitoring stations located within municipal boundaries. Since the 1990s, efforts have been made to establish a network of monitoring stations across the territories, a process that was consolidated in the early 2000s, particularly after the issuance of Ministerial Decree 60/2002. This decree, in conjunction with the document *Criteria for EuroAirnet*, provides guidelines for the identification of sampling points. Therefore, given the morphology of the Italian territory, it was decided to consider, as the main sampling points, urban centers of significant size, which mostly correspond to the provincial capital municipalities. Based on the source of pollution, we can distinguish between three different types of monitoring stations: traffic, industrial and background. While traffic and industrial stations are positioned where dominant sources exist, background stations are located in areas influenced by a comprehensive contribution from multiple sources.

We collect data on air pollution from the survey *Environmental Data in Cities* (ISTAT). Our dependent variable is the maximum number of days in which at least one type of monitoring stations (among all the stations installed in a given area — generally the provincial capital municipality) has detected an excess of PM10 with respect to the daily limit of  $50\mu\text{g}/\text{m}^3$  (micrograms per cubic meter) (hereafter *PM10*).<sup>9</sup> As an example, in the provincial capital of Rome, in 2019, there were 13 monitoring stations, including 9 background-type and 4 traffic-type. The traffic-type station located in Tiburtina reached the highest number of days exceeding the PM10 limit during 2019 (22 days) compared to the other stations. This value of 22 is taken as proxy for air pollution in Rome in 2019 and represents our dependent variable. Hence, it is necessary that at least one of the monitoring stations exceeds the limit to define that day outlawed: moreover, if, in a city and in a year, the maximum number of days exceeding the limit is greater than 35, that city is considered as at high risk to human health. Thus, the air pollution measure we use serves as a proxy for air quality as well as for assessing the risk to human health associated with PM10 exposure.

In Italy, two legislative decrees have represented a regulatory revolution in environmental policies addressing air pollution: Legislative Decrees (LD) 152/2006 and LD 155/2010. LD 152/2006, known as the Environmental Consolidated Text (TUA), aimed at consolidating environmental regulations. It addresses air pollution control and environmental damage and

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<sup>9</sup>The  $50\mu\text{g}/\text{m}^3$  represents the daily pollution limit for PM10 provided by the Ministerial Decree 60/2002 on the recommendation of the World Health Organization.

liability, providing detailed provisions for compensatory protection against environmental damage and imposing stricter sanctions on both public and private operators who cause or omit actions resulting in environmental damage. Directive 2008/50/EC, as incorporated into LD 155/2010, primarily addresses the evaluation and control of outdoor air quality. It establishes a comprehensive national framework for air quality management, delegating specific powers to regions and autonomous provinces. These responsibilities include adopting plans to achieve quality objectives and implementing further traffic restriction measures to mitigate pollution risks.

In order to take into account the two air pollution policies detailed above, we start the time-span for the baseline analysis at 2010, when both the policies went in force on the whole Italian territory.<sup>10</sup> Moreover, there are only 5 monitoring station points located in cities that are not provincial capital (they are located in the province of South-Sardinia in the city of Sanluri, Tempio Pausania, and Villacidro; and in the municipalities of Tortolì and Lanusei, both former capitals of the province of Ogliastra ); their resident population is below 15,000. Given the different electoral rule characterizing municipalities above and below 15,000 described just early, in the analysis we will work only on the 112 provincial capital municipalities. Moreover, only for 2 of these 5 monitoring station (that located in Tortolì and Villacidro) we are available data on air pollution. To sum up, the sample analysis is made of provincial capital municipalities detected from 2010 to 2019.

Figure B.1 in Appendix B shows the curve of the yearly mean (over the provincial capital municipalities) of the number of days when PM10 exceeds the daily limit of  $50\mu\text{g}/\text{m}^3$  (*PM10*), from 2010 to 2019. Such maximum number of days reaches the pick in 2011 (more than 50 days in a year) and its lower value in 2019 (more than 20 days). Table A.1 in Appendix A shows the descriptive statistics.

Graph B.2a within Figure B.2 in Appendix B illustrates the number of days exceeding the daily threshold for PM10 for various types of stations during the period from 2010 to 2019. Graph B.2b in the same figure, instead, shows the percentage of cities, by type of monitoring station, that recorded the maximum number of exceeding days for a specific type of pollutant during the same time period. These graphs indicate that traffic and background stations are the main contributors to urban pollution, showing consistently higher frequencies over the years. In summary, the main components of our air pollution proxies are mainly derived from these two sources. In contrast, despite a relatively high average number of pollution days over the years, industrial stations are the least frequent due to the limited presence of industrial plants near provincial capitals.

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<sup>10</sup>For robustness, we consider a longer time-span (2003-2019) adding as control variables the dummies controlling for the LD 152/2006 and LD155/2010.

## 3.2 Regressors

**Main regressor.** The regressor of interest in the empirical analysis is the percentage of female city councilors.

The data on the gender composition of Italian city councils are from the Ministry of the Interior. Figure B.3 in Appendix B shows the evolution of the (mean) percentage of women councilors in provincial capital municipalities between 2010 and 2019.

A first look at this figure clearly shows the sharp increase in the share of women in city councils starting in 2013, when Law 215/2012 went into force, confirming the results by Baltrunaite et al. (2019). In the empirical analysis, the main regressor is female councilors (hereafter *Female councilors*), because the double preference voting conditioned on gender refers only to the city council and not the mayoral election. As Table A.2 in Appendix A shows, on average the percentage of female councilors in the sample period is 21.1%.<sup>11</sup>

The graph presented in Figure B.4 in Appendix B illustrates the average annual percentage of female councilors in municipalities designated as provincial capitals, categorized into treatment and control groups. Both groups exhibit a notable upward trend in this percentage following the enactment of Law 215/2012.

**Control Variables.** In the empirical analysis we control for a number of variables. We include a control variable for population (designated as *Pop*) to accommodate the size-related impacts of municipalities, thereby mitigating the potential influence of population size on air pollution.

Since municipalities with more extensive public transport infrastructure tend to exhibit lower pollution levels, we control for the variable *Bus seats* (Adler and van Ommeren, 2016, Bauernschuster et al., 2017, Borck, 2019). This variable serves as a proxy for public transport supply and is defined as the number of bus seats per distance traveled per inhabitant (*Environmental Data in Cities*, ISTAT). Moreover, we consider public transport demand (hereafter *Transport demand*), defined as the ratio of total passengers carried for each type of public transport during the year over the population. Communities where residents prefer public transport for commuting may experience lower air pollution levels.

Additionally, to address for residents' travel behavior within the municipality, consisting on road congestion and urban mobility, which impact on air pollution levels, we include two variables (Büchs and Schnepf, 2013, Leroutier and Quirion, 2022). First, we consider vehicle density (hereafter *Vehicle density*), defined as the number of vehicles per square kilometer. Second, we include the motorization rate (hereafter *Motorization rate*), which is defined as the ratio of vehicles per 1000 inhabitants.

Ultimately, we control for election cycle because certain policies may be enacted or strengthened near elections to bolster the likelihood of reelection. This is achieved through

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<sup>11</sup>In the complementary analysis presented in subsection 5.3, the representation of female aldermen in the executive body is examined, which averages 33.2%.

a series of dummy variables representing election years and up to three years thereafter for all municipalities in the sample.<sup>12</sup> dummies are the following: *Electoral cycle\_1* taking the value of 1 in election year and 0 in other years; *Electoral cycle\_2* taking the value of 1 in the first year after the election year and 0 in other years; *Electoral cycle\_3* taking the value of 1 in the second year after the election year and 0 in other years; *Electoral cycle\_4* taking the value of 1 in the third year after the election year and 0 in other years.

Table A.2 in Appendix A gives the descriptive statistics of the full sample. Moreover, we provide in Tables A.3 and A.4 the descriptive statistics of the control variables for municipalities in the treatment and control group.

## 4 Empirical strategy

The empirical design is aimed at analyzing the impact of the percentage of female councilors in local political bodies of Italian provincial capitals on a measure of air pollution, i.e., the maximum number of days exceeding the limit for the protection of human health set for PM10 detected among all fixed stations for monitoring air quality (traffic, industrial, background, unclassified). We collect yearly observations from 2010 to 2019 of the level of air pollution and city council gender composition of the Italian provincial capital municipalities. As noted above, only councilors are considered, since the double preference conditional on gender applies only to city council elections. We stop the time-span to 2019, just before the COVID 19 pandemic crisis.

The relationship of interest is estimated by the following model where subscript  $i$  refers to provincial capitals and  $t$  to time:

$$Y_{i,t} = \beta_0 + \beta_1 W_{i,t} + \beta_2 X_{i,t} + \delta_i + \delta_t + \varepsilon_{i,t} \quad (2)$$

$Y_{i,t}$  is the level of pollution (*PM10*) in provincial capital municipality  $i$  in year  $t$  and  $W_{i,t}$  is the percentage of female councilors in local government  $i$  in year  $t$ .  $X_{i,t}$  is the set of controls (listed above) of provincial capital municipality  $i$  at time  $t$ ;  $\delta_i$  forms a vector of municipal fixed effects that address differences in the cross-sectional dimension and factor in unobserved time-invariant elements to prevent potential biases from omitted variables;  $\delta_t$  are year fixed effects that account for unobserved year-specific events that affect all municipalities.<sup>13</sup>  $\varepsilon_{i,t}$  is

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<sup>12</sup>Considering that the whole electoral cycle should normally last five years, four dummies are included to avoid the dummy variable trap.

<sup>13</sup>We are dealing with: 1) Regulations to promote public transport. As an example, the National Fund for Local Public Transportation, established in 2013 and restructured by DL 50/2017, introduced the "Vehicle Fund." This initiative focuses on enhancing energy efficiency, electrification, and leasing of vehicles for local and regional transportation. The 2018 Budget Law augmented this fund, enabling it to allocate funds of up to 100 million euros for experimental projects aimed at fostering sustainable mobility. 2) Directives for clean transport. Specifically, Regulation No. 715/2007 sets out the regulations governing the type approval of motor vehicles falling under the Euro 5 and Euro 6 categories. Starting from 2009, vehicles failing to meet Euro 5 standards are ineligible for type approval, and since 2014, those failing to meet Euro 6 standards are

the idiosyncratic error term.  $\beta_1$  in eq. 2 is the parameter of interest, measuring the impact of a variation in the percentage of female councilors on air pollution.

However, the regression model represented in eq. 2 fails to address endogeneity concerns arising from unobservable characteristics of provincial capitals municipalities that may be correlated both with the gender of councilors and with air pollution levels. This endogeneity issue can be mitigated by randomly assigning women to political positions that should not be correlated with the outcomes of interest, which is essentially the approach taken by the 2012 gender election quota reform (Baltrunaite et al., 2019).

Thus, the quasi-experimental design leveraging Law 215 allows for the identification of treatment (provincial capitals municipalities within regions with ordinary statute affected by the gender quota reform) and control groups (provincial capitals municipalities within regions with special statute unaffected by the reform).

To empirically address the endogeneity of the percentage of women in municipal councils, a difference-in-differences instrumental variable approach for panel data is employed (Hudson et al., 2017). In this approach, eq. 2 serves as the second stage equation, while the first stage equation incorporates the potential endogenous variable as a function of all assumed exogenous explanatory variables and the instrument. The first stage equation is as follows:

$$W_{i,t} = \alpha_0 + \alpha_1 Law215_{i,t} + \alpha_2 X_{i,t} + \delta_i + \delta_t + u_{i,t} \quad (3)$$

where the variable *Law215* is a dummy variable that takes the value of 1 for all local governments elected after 2012 in provincial capitals within regions with an ordinary statute, and 0 otherwise.<sup>14</sup> Specifically, it takes the value of 0 for all local governments elected prior to the first election under Law 215 in provincial capitals within regions with an ordinary statute, as well as for all governments in provincial capitals within regions with a special statute for the entire period spanning from 2010 to 2019.

#### 4.1 First stage estimates: validity of the diff-in-diff design

As just explained in the previous section, the 2SLS estimation prescribes that the first stage regression is a diff-in diff where the treatment variable is *Law215* in eq. 3. The coefficient of interest,  $\alpha_i$ , shows the mean difference in the percentage of female in city council of the provincial capitals between the treatment and control group after the enforcement of Law 215/2012. Being the election of municipal council staggered over time, we provide evidence of the validity of “parallel trend” assumption (required in the diff-in-diff procedure) by an event-study model that estimates the effect of the application of Law 215 year-by-year (Mora and Reggio, 2019). This approach allows also the assessment of the dynamic effect of the Law 215.

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similarly excluded from type approval.

<sup>14</sup>The same empirical strategy has been employed by Acconcia and Ronza (2023) and Baraldi et al. (2024).

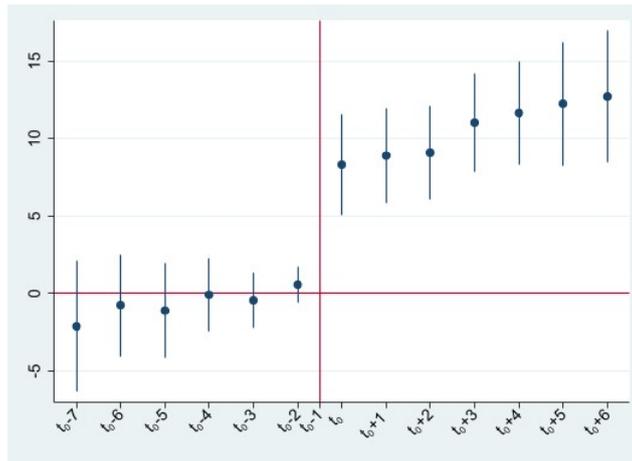
The event-study regression equation (subscript  $i$  is for municipalities,  $t$  for years) is:

$$Y_{it} = \sum_{t=-7}^{+6} \nu_t \cdot D_t + \delta_i + \delta_t + \gamma X_{it} + \epsilon_{it} \quad (4)$$

where  $Y_{it}$  is the percentage of females in the provincial capital city council at year  $t$  in municipality  $i$  and  $D_t$  is the set of event-time indicators assign a value of 1 exclusively to municipalities under treatment if the election at time  $t$  occurs  $k$  periods before/after the initial election governed by Law 215. Following convention in this field, we designate the year preceding the first Law 215 election as the reference category, denoted as  $D_{t_0-1}$ . The remaining coefficients  $\nu_t$  capture the difference between treatment and control groups among provincial capitals in terms of female councilors pre- and post-implementation of Law 215 at time  $t_0$ .

We estimate from 7 years before the election (that allows for the assessment of the “parallel trend” assumption) to 6 years after (the post-election effect of the gender measure).<sup>15</sup> We include municipality and year FE and control variables. The event-study graph is depicted in Figure 1. It clearly shows the validity of the “parallel trend” (all the confidence intervals of the pre-treatment coefficients are around 0), corroborated by the F-test that all the pre-treatment coefficients are jointly equal to 0 (the p-value of the F-test is equal to 0.31). Moreover, the dynamic of the percentage of female councilors in the post-treatment period confirms the findings of [Baltrunaite et al. \(2019\)](#) also for provincial capitals with population above 15,000.

Figure 1: Event study — First stage estimates



*Notes.* The graph reports coefficients and confidence intervals estimated according to eq. 3. The dependent variable is the percentage of female councilors. Standard errors are clustered at provincial capital municipality level. Dots refer to point estimates, spikes to 95% confidence intervals. Event-time dummy variables for 7 years before and 6 years after the election under Law 215/2012 are included. Regression includes municipality FEs, year FEs and as controls the resident population and dummies of electoral cycle. Period: 2010-2019

<sup>15</sup>7 lags and 6 leads are the maximum number of lags and leads that we are able to estimate.

## 5 Results

### 5.1 Panel FE estimates

We present the estimation results in two steps. The first shows the findings of the estimation of eq. 2 where the percentage of female in provincial capital city council is considered as exogenous. The dependent variable is the level of air pollution, measured as the maximum number of days exceeding the limit for the protection of human health set for PM10 detected among all fixed stations for monitoring air quality, between 2010-2019 (*PM10*). All the provincial capitals under consideration have resident population above 15,000 inhabitants that allows to control for the municipality electoral rule (municipalities above 15,000 population vote under the run-off system).

Table 1 reports the panel FE estimates where the standard errors are clustered at the municipal level and robust to heteroscedasticity.<sup>16</sup>

Table 1: Panel FE estimates

Dep. Var.: Air pollution	(1)	(2)	(3)
Female councilors	-0.694*** (0.0900)	-0.396*** (0.0905)	-0.401*** (0.110)
Pop			-9.69e-05 (0.000148)
Transport demand			-0.0552 (0.0376)
Motorization rate			0.0106 (0.00822)
Vehicle density			-0.00936 (0.00677)
Bus seats			0.00408* (0.00244)
Electoral cycle_1			2.068 (1.374)
Electoral cycle_2			2.168 (1.524)
Electoral cycle_3			0.297 (1.372)
Electoral cycle_4			0.581 (1.359)
Observations	1,020	1,020	1,010
No. municipalities	109	109	108
Municipality FE	Yes	No	No
Year FE	No	Yes	Yes
Controls	No	No	Yes

*Note.* Panel fixed effect estimates. The dependent variable is *PM10*. All regressions include municipality FEs; coefficients are not reported. Robust standard errors, clustered at municipal level, are in brackets. Period: 2010-2019. Significant coefficients are indicated by \* (10% level), \*\* (5% level) and \*\*\* (1% level).

<sup>16</sup>The number of observations in Table 1 is reduced to 109 because for the provincial capital of Cesena, Fermo and Trani the data on our measure of air pollution are not available.

From a first look at the coefficient of interest (*Female councilors*), it emerges that it is always negative and highly significant (at 1% level). From the poorest specification in Column 1, a 10 p.p. increase in the percentage of female councilors decreases the maximum number of days exceeding the PM10 limit of almost 7 in a year; while in the richest specification as in Column 3, the decrease amounts to 4 days in a year. No control variables seem to be significantly different from zero.

## 5.2 2SLS estimates

The second step of the analysis deals with the endogeneity issue of the percentage of female councilors with respect to air pollution outcome. In this respect we estimate a difference-in-differences instrumental variable model to assess for the causal link between the presence of women as in provincial capital councils and the level of air pollution. Table 2 reports the results of 2SLS estimates. The upper part of the table displays results of the first stage estimation as in eq. 3, while the lower part presents evidence of the second stage estimates as in eq. 2.

Firstly, the bottom rows of the upper section of Table 2 present a series of tests assessing the instrument’s validity across all specifications. The F-test for weak identification demonstrates that the instrument is highly robust. Additionally, the Kleibergen–Paap test refutes the null hypothesis of under-identification. In essence, there is no indication of a weak instrument issue. Furthermore, the endogeneity test dismisses the null hypothesis suggesting that the specified endogenous regressor, *Female councilors*, can be treated as exogenous. This implies that the 2SLS method addresses potential endogeneity bias effectively. As in Baltrunaite et al. (2019), across all estimates in the first stage, the coefficient associated with *Law215* consistently exhibits a positive and statistically significant effect, indicating that Law 215 indeed led to an increased proportion of female city councilors.

The second-stage estimations are presented in the lower section of Table 2. Similar to the exogenous scenario, the presence of female councilors has a negative impact on the maximum number of days with air pollution. Specifically, a 10 p.p. increase in the percentage of female councilors decreases the maximum number of days exceeding the PM10 threshold to nearly 11 (as shown in Column 1a). With the inclusion of control variables (as in Column 3a), this figure slightly increases to 11.5. Accounting for endogeneity amplifies the effect of female policymakers, indicating a stronger impact compared to the exogenous model, revealing an upward bias when compared with estimations in Table 1. Taking the result in Column 3a, the reduction of 11.5 days of *PM10* (given to a 10 p.p. increase in the percentage of female councilors, which corresponds to almost its standard deviation of 11.12) aligns with less than 1/3 of its standard deviation (equals to 32.21, as shown in Table A.2 in Appendix A).

Table 2: 2SLS estimates

Dep. Var.: Female councilors	First stage		
	(1)	(2)	(3)
Law215	14.03*** (0.92)	11.32*** (1.08)	9.60*** (1.20)
No.Observations	1,018	1,018	1,008
No. Municipalities	109	109	108
Municipality FE	Yes	No	No
Year FE	No	Yes	Yes
Controls	No	No	Yes
F-test	229.85	108.43	63.99
Chi <sup>2</sup> Kleibergen-Paap test	60.76	49.16	36.77
Endogeneity test (p-value)	0.00	0.00	0.00
Dep. Var.: Air pollution	Second stage		
	(1a)	(2a)	(3a)
Female councilors	-1.090*** (0.114)	-0.885*** (0.180)	-1.141*** (0.249)
Pop			9.25e-05 (0.000150)
Transport demand			-0.0256 (0.0402)
Motorization rate			0.0245 (0.0157)
Vehicle density			-0.0165* (0.00899)
Bus seats			-0.000625 (0.00256)
Electoral cycle_1			6.700*** (1.904)
Electoral cycle_2			5.020*** (1.734)
Electoral cycle_3			2.886* (1.496)
Electoral cycle_4			1.777 (1.327)
Observations	1,018	1,018	1,008
No. municipalities	109	109	108
Municipality FE	Yes	Yes	Yes
Year FE	No	Yes	Yes
Controls	No	No	Yes

*Note.* 2SLS estimates. The dependent variable is *PM10*. All regressions include municipality FEs; coefficients are not reported. Robust standard errors, clustered at municipal level, are in brackets. Period: 2010-2019. Significant coefficients are indicated by \* (10% level), \*\* (5% level) and \*\*\* (1% level).

### 5.3 Women as aldermen

A strand of the literature highlights that women's involvement within institutions, particularly in political settings, is frequently marginalized (Barnes, 2016, Bjarnegård, 2013, Michelle Heath et al., 2005), suggesting a general absence of connections to established political networks (Escobar-Lemmon and Taylor-Robinson, 2009, Sundström and Wängnerud,

2016). Consequently, women are often less likely to be incorporated into the networks essential for political decision-making (Barr, 2009, Morgan, 2011). Our findings’ effectiveness remains robust if gender quota measures not only increase women’s representation in political bodies but also strengthen their role as effective catalysts for environmental policies and actions.

To address this issue, we focus our analysis on the subset of female aldermen. Aldermen are responsible for overseeing particular sectors of administration, specific projects, or services, guiding the activities of municipal offices based on guidelines set by the municipality’s governing bodies, and ensuring proper administration and management. In essence, being appointed as an alderman likely confers a significant role within the political body to the appointee.

As said above, Law 215 applies only to the election of councilors. However, given that mayor can appoint aldermen among the elected councilors and (sometimes) outside (in municipalities with population above 15,000, as our sample), we can imagine that Law 215 has been effective in enhancing also the presence of female aldermen in the treatment group with respect to the control group. In Table 3 we present 2SLS estimate where the regressor of interest is the percentage of female aldermen. The first stage estimates (in the upper part of the table) confirm the prediction that the enforcement of law 215 has been effective in enhancing also the percentage of female aldermen in treatment group of provincial capital municipalities compared to the control group. The first stage tests on the instrument validity requirements are met.<sup>17</sup> The lower part of Table 3 presents the second stage estimates of the percentage of female aldermen (*Female aldermen*) on *PM10*. The coefficient of *Female aldermen* is highly significant for all the specifications. Taking the most complete specification in Column 3a, it is interpreted as a decrease of almost 8 days exceeding the level of air pollution following a 10 p.p. increase in the percentage of female aldermen.

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<sup>17</sup>Figure B.5 in Appendix B shows the validity of the “parallel trend” assumption when dealing with female aldermen. At 5% confidence level we accept the null that all the pre-treatment coefficient are jointly equal to zero.

Table 3: 2SLS estimates - female aldermen

Dep. Var.: Female aldermen	First stage		
	(1)	(2)	(3)
Law215	18.31*** (1.51)	16.75*** (1.60)	13.88*** (1.87)
No.Observations	1,018	1,018	1,008
No. Municipalities	109	109	108
Municipality FE	Yes	No	No
Year FE	No	Yes	Yes
Controls	No	No	Yes
F-test	147.49	108.90	55.02
Chi <sup>2</sup> Kleibergen-Paap test	52.57	52.35	35.46
Endogeneity test (p-value)	0.00	0.00	0.00
Dep. Var.: Air pollution	Second stage		
	(1a)	(2a)	(3a)
Female aldermen	-0.835*** (0.109)	-0.598*** (0.125)	-0.789*** (0.184)
Observations	1,018	1,018	1,008
No. municipalities	109	109	108
Municipality FE	Yes	Yes	Yes
Year FE	No	Yes	Yes
Controls	No	No	Yes

*Note.* 2SLS estimates. The dependent variable is *PM10*. All regressions include municipality FEs; coefficients are not reported. Control variables are: *Pop*, *Transport demand*, *Motorization rate*, *Vehicle density*, *Bus seats* and dummies for the electoral cycle. Robust standard errors, clustered at municipal level, are in brackets. Period: 2010-2019. Significant coefficients are indicated by \* (10% level), \*\* (5% level) and \*\*\* (1% level).

## 5.4 Discussion on the mechanism

This study highlights the role of gender in municipal environmental policies and actions. Opinion polling emphasizes a gender gap, being the environmentally conscious attitudes of women greater than that of men. Additionally, the risk perception regarding environmental degradation is greater for women (Honda et al., 2014, Norgaard and York, 2005), as well as their engagement in pro-environmental actions (Luchs and Mooradian, 2012, Stolle et al., 2005).

Research validates the persistence of the gender gap observed among individual citizens at the political level. Studies indicate that the gender of legislators influences policy outcomes in society, with women often prioritizing issues related to their gender (Besley and Case, 2003, Chattopadhyay and Duflo, 2004, Clots-Figueras, 2011). The research conducted by McEvoy (2016) and Dittmar et al. (2018) suggest that female representatives advocate for women's interests and consider women's concerns in their decision-making processes. Additionally, studies affirm that congresswomen are more inclined to support women's issues (Ramstetter and Habersack, 2019, Schwindt-Bayer, 2006, Thomas, 1991), such as gender equality, education, abortion, family assistance and childcare compared to their male coun-

terparts (Berkman and O’connor, 1993, Besley and Case, 2003, Jenkins, 2012, Kittilson, 2005, Svaleryd, 2009, Swers, 1998, Vega and Firestone, 1995).

Female representatives also exhibit a higher propensity to endorse environmental legislation. Typically, empirical evidence suggests that increased women’s representation is associated with a greater budget allocation towards spending in the welfare sector (Bolzendahl and Coffé, 2009, Bratton and Ray, 2002, Clayton and Zetterberg, 2018, Svaleryd, 2009, Wittenberg-Cox, 2010). Furthermore, female legislators are more inclined to support environmental policies and provide public goods (Beaman et al., 2006, Duflo et al., 2004, Fredriksson and Wang, 2011, Mavisakalyan and Tarverdi, 2019, Norgaard and York, 2005, Pearl-Martinez, 2014), invest more in education (Clots-Figueras, 2012) and public health infrastructure (Bhalotra and Clots-Figueras, 2014, Mavisakalyan, 2014). In this respect, studies have shown that decisions related to public service provision can differ depending on the gender of the municipal leader (Fox and Schuhmann, 1999, Hamidullah et al., 2015). For instance, Funk and Philips (2019) observed significant disparities in government expenditure allocation between male and female mayors. For Italy, Casarico et al. (2022) observe that female mayors allocate a larger portion of spending to the environment when there is a higher representation of women in the municipal council.

When assessing the implementation of effective measures and policies addressing environmental concerns, Ergas and York (2012) assert that countries with a higher political representation of women tend to exhibit lower per-capita CO2 emissions. Additionally, Bansal and D’Agosti (2023) and Salamon (2023) discover that an increased proportion of women in legislative bodies correlates with higher levels of renewable energy production and consumption. Fredriksson and Wang (2011) observe a preference among female legislators in the U.S. House of Representatives for stricter environmental policies compared to their male counterparts. Similarly, Fraune (2016) concludes that gender disparities exist in energy policy-making among male and female legislators in both the U.S. and Germany. Ramstetter and Habersack (2019), in their analysis of the European Parliament, discover that women are significantly more inclined to support environmental legislation compared to men. Finally, Baraldi et al. (2024) proved that an increase in female councilors due to the enforcement of Law 215/2012 has improved the municipal selective waste collection.

Therefore, female politicians, motivated by their heightened awareness of human health and, more generally, climate change, have the potential to inspire more impactful environmental policies and initiatives.

## 5.5 Empirical evidence

We aim at giving evidence of environmental policies and actions directed to reduce air pollution by collecting data, for the provincial capital municipalities from 2010 to 2019, on various measures air pollution friendly. They are: 1) Bicycle lane density (kilometers per

100 square kilometers) (hereafter *Bicycle lane*); 2) Urban greenery surface (values in square meters) (hereafter *Urban green*); 3) Number of bicycles for bike-sharing services (values per 10 thousand inhabitants) (hereafter *Bike-sharing*); 4) Number of cars for car-sharing services (values per 10 thousand inhabitants) (hereafter *Car-sharing*); 5) Volume served by district heating (m<sup>3</sup> per inhabitant) (hereafter *District heating*); 6) Number of hours of scheduled traffic blockage per EURO 3 vehicle (hereafter *Traffic blockage*).

Bicycle lanes are dedicated infrastructure for bicycles, separated from vehicular traffic. Municipalities that invest in them reduce air pollution by promoting cycling over driving, which in turn decreases traffic congestion and emissions. In summary, bicycle lanes reduce vehicle numbers on the road, fostering cleaner environments.

Local administrations can adopt urban planning policies that prioritize the conservation and creation of green spaces, such as parks, public gardens, and protected natural areas. Additionally, they can initiate tree planting programs in urban areas. Introducing and maintaining urban greenery are effective strategies to improve air quality in urban areas, reducing exposure to PM<sub>10</sub> and other atmospheric pollutants. The presence of vegetation can influence the local micro climate, lowering temperature and increasing humidity, which can help reduce the formation and dispersion of fine particles. Additionally, tree leaves and other plants can capture and retain fine particles in the air, acting as natural filters.

Bike-sharing, or bike rental, is a system where bicycles are made available to the public for temporary use, usually for a fee. Bicycles are distributed across various stations throughout the city and can be borrowed from one station and returned to another. Therefore, bike-sharing programs can play a big role in cutting down air pollution. When cities invest in these programs, they usually upgrade cycling infrastructure like bike lanes and racks. This makes it easier and safer for people to ride bikes. By encouraging people to choose bikes over cars for short trips, public administration can ease traffic jams and lower emissions in cities.

Car-sharing system allows multiple people to share the use of a car instead of owning it individually. People can book a car for a specific period, use it, and then return it to a designated point. The municipality can designate parking spaces exclusively for shared cars, making it easier for users to find and pick up vehicles. Therefore, with car-sharing, fewer people need to own cars, leading to a reduction in the overall number of vehicles on the roads, reducing air pollutants. Further, many car-sharing services offer electric or hybrid vehicles, which emit fewer harmful gases compared to traditional internal combustion engine vehicles.

District heating is a centralized heating system in which thermal energy is produced in a plant and distributed through a network of insulated pipes to residential, commercial and industrial buildings in a given area. Instead of having your own heating system, heat is generated from a single central source and then transported to buildings through underground pipes. This eliminates the need for individual stoves and boilers. By reducing the number

of individual heating systems, district heating also reduces PM10 emissions from these local heating sources. Wood stoves and older boilers in particular can be significant sources of particulate matter, which is mainly measured by background monitoring stations. Therefore, providing the municipality with a district heating network that covers a large part of the existing buildings is an effective strategy to reduce PM10 emissions from civilian plants,

Scheduled blocks are regulations that enforce time constraints on the usage of vehicles with specific emission levels within designated areas, aiming to mitigate airborne particulate emissions. For instance, municipalities may implement access limitations during peak traffic periods or at times of elevated air pollutant concentrations, targeting the least efficient vehicles (in terms of harmful emission), such as those compliant only with Euro 3 standards.<sup>18</sup>

We perform a 2SLS estimation where the dependent variables are those listed just above (proxies for municipal environmental policies and actions) and the endogenous variable is the percentage of female councilors that we instrument with the dummy for Law 2015/2012 (as in eq. 3). Table 4 proposes the second stage estimation.<sup>19</sup>

Table 4: 2SLS estimates

Dep. Var.:	Bicycle lane	Urban green	Bike-sharing	Car-sharing	District heating	Traffic blockage
	(1)	(2)	(3)	(4)	(5)	(6)
Female councilors	0.592*** (0.138)	9,269*** (3,595)	0.161*** (0.0478)	0.0364 (0.0232)	0.131*** (0.0422)	0.177** (0.0698)
Observations	1,108	997	1,108	775	997	762
R-squared	-0.014	0.035	0.059	0.168	0.001	-0.051
Number of id_comune	111	111	111	111	111	110
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes

*Note.* 2SLS Estimates. All regressions include municipality FEs and year FEs. Controls are: *Pop* and dummies of election cycle. Robust standard errors, clustered at municipal level, are in brackets. Period: 2010-2019. The available data on *Urban green*, *Bike-sharing* and *District heating* start in 2011; the available data on *Car-sharing* and *Traffic blockage* start in 2013. Significant coefficients are indicated by \* (10% level), \*\* (5% level) and \*\*\* (1% level).

As the Table 4 clearly shows, all the coefficients of *Female councilors* are positive and highly significant, meaning that the increasing female political presence in city council positively affects air pollution friendly policies. The Table reports that a 10 p.p. increase in the percentage of female councilors increases the bicycle lane density by almost 6 kilometers (per 100 square kilometers), the urban greenery surface by 9,270 square meters, the number of bicycles for bike-sharing services by 1.6 per 10 thousand inhabitant, the number of cars for car-sharing services by 0.3 per 10 thousand inhabitant, the volume served by district heating by 1.3 m<sup>3</sup> per inhabitant, the number of hours of scheduled traffic blockage per EURO 3 vehicle by 1.77. As a consequence, it is very likely that those policies are the drivers of our

<sup>18</sup>The authority for municipalities to impose traffic restrictions is outlined in Article 11, paragraph 3 of Decree 267/2000, which pertains to urban management. Scheduled blocks also serve as a significant tool in the development of regional emission reduction strategies, as stipulated in LD 155/2010.

<sup>19</sup>The first stage estimates as well as all the tests on the instrument are available on request; all the validity requirements are met.

main result: enlarging the body of women as policymakers has beneficial effect in terms of the air pollution reduction.

## 6 Robustness

In this section we provide robustness evidences of our main result. Firstly, we use other measures of air pollution and the relative estimation results are displayed in Table A.5 in Appendix A. Secondly, we enlarge the sample comprising observations starting in 2003; we check if results are driven by the gender of the mayor’s provincial capital municipalities; we control for provincial capital municipal public spending as well as dummies for the political party orientation of the majority in the city council. The Table A.6 of the findings is in Appendix A.

### 6.1 Other measures of air pollution

Our primary measure of air pollution is PM10. However, other substances can generate air pollution and be harmful to health. Therefore, we investigate in Table A.5 the effects of female political empowerment on other air quality measures.

PM2.5, or particulate matter with a diameter of 2.5 microns or less, is airborne particles that can deeply penetrate the lungs upon inhalation, posing health risks to humans. These particles originate from various sources including vehicle emissions, industrial activities, home heating, and agricultural practices. Chronic exposure to PM2.5 can result in respiratory issues such as bronchitis, asthma, emphysema, and lung infections, as they can cause inflammation and damage to lung tissues. Moreover, PM2.5 can enter the bloodstream through the lungs, leading to inflammation and damage to blood vessels, thereby increasing the risk of cardiovascular diseases including high blood pressure, heart attacks, and strokes.<sup>20</sup> Consequently, PM2.5 contributes significantly to the overall mass concentration of particulate matter in the atmosphere. We employ the maximum annual average concentration of PM2.5 detected across all air monitoring stations, categorized by station type (background, industrial, traffic, other), as the dependent variable (referred to as *PM2.5*). The estimation outcome is presented in Column 1 of Table A.5, revealing a negative and highly significant coefficient for *Female councilors*. The coefficient value indicates that a 10 p.p. increase in the proportion of female councilors results in a decrease of  $2.12\mu\text{g}/\text{m}^3$  in PM2.5 concentration.

Nitrogen dioxide (NO<sub>2</sub>) is a reddish-brown gas characterized by a pungent odor and potent toxicity. It primarily stems from high-temperature combustion processes, such as those found in vehicle engines and coal-fired power plants. As a significant air pollutant, NO<sub>2</sub> can catalyze the formation of other pollutants like ground-level ozone and particulate

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<sup>20</sup>Directive 2008/50/EC, enacted in Italy through Legislative Decree 155/2010, mandates Member States to formulate air quality management plans incorporating measures to mitigate PM2.5 exposure. Additionally, the directive sets an annual limit value of  $25\mu\text{g}/\text{m}^3$  for PM2.5 concentrations.

matter, thereby impacting air quality and environmental well-being. Exposure to NO<sub>2</sub> poses health risks to humans, manifesting in respiratory issues and irritation of the respiratory tract. Furthermore, its reaction with atmospheric moisture can lead to the acidification of soil and water, forming nitric acid.<sup>21</sup> We utilize the maximum value of the annual average concentration of NO<sub>2</sub> (measured in micrograms per cubic meter) detected across all air monitoring stations, categorized by station type, as the measure of air pollution (referred to as *NO2*). Result is in Column 2 of Table A.5 and significantly shows that a 10 p.p. increase in the percentage of female councilors decreases by 2.88 $\mu\text{g}/\text{m}^3$  highest annual value of NO<sub>2</sub>.

Benzo(a)pyrene (BaP), a polycyclic aromatic hydrocarbon (PAH), is a component of air pollution, particularly prevalent in areas with combustion sources such as vehicular traffic, industrial activities, and tobacco smoke. This compound is classified as carcinogenic and poses significant health risks when absorbed in substantial quantities, especially through prolonged exposure. The adverse effects of benzo(a)pyrene include DNA damage and an elevated risk of cancer. BaP can adhere to particulate matter, serving as an atmospheric contaminant. Upon inhalation of these particles, benzo(a)pyrene can be transported to the lungs and subsequently absorbed into the bloodstream. The presence of benzo(a)pyrene in particulate matter is of notable concern as it heightens the risk of severe health complications, notably lung cancer. Reducing exposure to this compound by mitigating air pollution and sources of combustion is imperative.<sup>22</sup> We utilize the highest annual value of the annual average concentration of benzo(a)pyrene, measured in *ng/m<sup>3</sup>*, detected among all air monitoring stations classified by station type (referred to as *Bap*), as a measure of BaP. The results, presented in Column 3 of Table A.5, corroborate the previous findings, indicating a significant reduction in the highest annual value of *Bap* attributable to an increase in female councilors.

## 6.2 Time-span 2003-2019

In the baseline analysis we start the time-span at 2010 in order to take into account the effects of the LD 152/2006 and LD 155/2010 on the air pollution, as explained in Subsection 3.1. Here, for robustness, we enlarge the time-span starting from 2003 (the first year of available data on our measure of air pollution *PM10*) and we control for the two legislative intervention through two binary variables: 1) *LD 152/2006* which is equal to 1 from 2006 onward and 0 between 2003-2005; 2) *LD 155/2010* which is equal to 1 from 2010 onward and 0 between 2003-2009.

Results are in Column 1 of Table A.6, which shows only the second stage of the 2SLS

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<sup>21</sup>Current legislation, including DM 60/2002, stipulates an annual limit value of 40 $\mu\text{g}/\text{m}^3$  to safeguard human health against NO<sub>2</sub> exposure. Additionally, an hourly limit value of 200 $\mu\text{g}/\text{m}^3$  is set, with the hourly average not to exceed this threshold more than 18 times per year.

<sup>22</sup>Current regulations (e.g., LD 155/2010) mandate that the concentration of benzo(a)pyrene present in the PM<sub>10</sub> fraction of particulate matter, calculated as an annual average, must not exceed 1 nanogram per cubic meter (*ng/m<sup>3</sup>*).

estimation, as in eq. 2.<sup>23</sup> The coefficient of female councilors is negative and significant at conventional level and slightly lower than the corresponding in Column 3a of Table 2. As expected the two legislative interventions negatively impacted the air pollution.

### 6.3 Gender of the mayor

As discussed in Subsection 2.1, expenditures and relative policies and measures are proposed by the mayor, under the consensus of, at least, the majority of the council. Hence, considering women’s generally stronger inclination towards environmental issues, it could be anticipated that the gender of the mayor, rather than that of councilors, would influence the extent of air pollution through the implementation of targeted local policies. To explore this hypothesis, we concentrate on mayors and examine whether the gender of the mayor plays a role in shaping the outcome. Initially, Baltrunaite et al. (2019) presented inconclusive findings regarding the effectiveness of Law 215/2012 in improving the likelihood of women being elected to the highest executive position in municipalities affected by the law. Then, we include, as the main regressor, a dummy for the gender of the mayor (equal to 1 for female mayor and 0 otherwise) (hereafter *Gender mayor*). Result, in Column 2 of Table A.6 reveals no significant impact on the air pollution measure.

### 6.4 Controlling for municipal expenditure

As anticipated in Subsection 2.2.1, to address potential variations in public budget constraints among provincial capital municipalities in the treatment and control groups, we include per-capita municipal expenditure as a control variable. The results, presented in Column 3 of table A.6, remain unchanged. Specifically, the coefficient of interest remains negative and highly significant, and the coefficient of *Expenditure* is not significant.

### 6.5 Controlling for municipal council political orientation

Recent literature exploring the connection between female policymakers and environmental awareness suggests that once the legislator’s political party is taken into account, the influence of gender becomes negligible. For instance, studies on Australian politicians by McAllister and Studlar (1992) and Fielding et al. (2012) demonstrate that political ideology and party affiliation play a significant role in shaping climate change concerns, overshadowing the impact of gender. Similarly, Jensen (2000) found that in the Norwegian Parliament, it is the politician’s party affiliation rather than gender that primarily influences perceptions of environmental risks. Likewise, Sundström and McCright (2014) conclude that differences

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<sup>23</sup>The first stage estimates as well as all the tests on the instrument are available on request; all the validity requirements are met.

in environmental awareness among Swedish Parliamentarians are largely attributed to their political orientation rather than gender.

As a results of such evidences, our main finding may be driven by the political orientation of the majority in city council, that coincides with the political orientation of the mayor. Here, this work controls for this aspect through dummies for the political orientation of the local government. In Italian municipalities, local elections involve national parties with a well-defined political orientation as well as civic lists, often with no clear political orientation. By gathering information regarding the political allegiance of mayors, we categorized local parties into three classifications: those aligned with the right and center-right ideologies (comprising parties and civic lists bearing names indicative of right-wing affiliations - referred to as *Center-right*), those aligned with the left and center-left ideologies (encompassing parties and civic lists with names suggestive of left-wing affiliations - termed *Center-left*), and parties and civic lists lacking a clear political orientation (*Civic lists*).

In the 2SLS estimations we control for the dummies *Center-right*, *Center-left* and *Civic list*. The findings, displayed in Column 4 of Table A.6, align with the baseline results, suggesting that the political orientation of the mayor does not impact the outcome variable. However, contrary to expectations that leftist political parties have greater connotations of green issues, the dummy variable for left-wings parties exhibits a positive association with the measure of air pollution.

## 7 Conclusions

As the prevalence of airborne pollutant particles continues to rise, the detrimental impact of air pollution on human health and the environment has become increasingly evident. Governments have responded by extensively reassessing their environmental policies and adopting new, more potent measures to mitigate the environmental repercussions of air pollution. In this context, one noteworthy aspect to explore is the heightened concern among women, compared to men, regarding environmental matters.

Exploring the temporal and geographical variation in the air pollution detected by the monitoring stations posed in Italian provincial capital municipalities during 2010-2019, this study empirically investigates whether and to what extend an upsurge in female political involvement influences the extent of air pollution, measured by the maximum number of days in which at least one type of monitoring stations has detected an excess of PM10 with respect to the daily limit.

To address the endogeneity problem, we use the enforcement of Law 215/2012, allowing voters to express double voting preferences on candidates of different gender at municipal election, as a source of random shock in the presence of female in city council. The 2SLS instrumental variables estimate finds strong and robust evidence that the maximum number of exceeding days of air pollution (with respect to the day limit) decreases due to an increase

in the percentage of women as councilors. The effect is not negligible because it corresponds to 1/3 of the standard deviation in the measure of air pollution (following an increase of 10 p.p. in the percentage of female councilors). Moreover, even though the Law 215 applies only to councilors, also female aldermen play a significant role in the reduction of air pollution. This negative causation remains robust to other measures of air pollution, as the maximum annual average concentration of PM<sub>2.5</sub>, the maximum value of the annual average concentration of NO<sub>2</sub> and the highest annual value of the annual average concentration of benzo(a)pyrene, detected across all air monitoring stations. Additional robustness checks reveal that the main result is unaffected by the expansion to the time-span, the gender of the mayor, the municipal public spending and the political orientation of the city council.

Further analysis of driving channels reveals that the increasing presence of women as policymakers positively affects a number of policies and actions directed at reducing air pollution, as bicycle lane density, urban greenery surface, the number of bicycles and cars for bike- and car-sharing services, the volume served by district heating and the number of hours of scheduled traffic blockage per EURO 3 vehicle.

This study contributes to the literature documenting that, as women manifest greater environmental attitude than men in daily life, also within political bodies this gender gap persists. While previous studies concentrated on the difference in types of public spending between women and men as policymakers (Casarico et al., 2022, Clayton and Zetterberg, 2018, Duflo et al., 2004, Funk and Philips, 2019), there is a lack of proofs documenting the impact of female leaders on air pollution measures. We advance in this respect by providing the first, at least in our knowledge, evidence of beneficial effects of female political empowerment in addressing air pollution concerns. This research also contributes to the literature examining the effect of gender quotas on policy decisions, in terms of child care provision (Baskaran and Hessami, 2019), child and health issues (Lippmann, 2019) and environment and social services (Funk and Gathmann, 2015, Hessami and da Fonseca, 2020).

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APPENDIX

**A** *Tables*

Table A.1: Descriptive statistics of dependent variables

	Obs	Mean	Std.Dev.	Min	Max
PM10	1020	35.94	32.218	0	158
PM2.5	813	17.963	7.193	0	50
NO2	702	32.86	13.915	0	80
BaP	398	0.522	0.423	0	2.3
Bicycle lane	1120	30.297	38.884	0	184.9
Urban green	1008	5009865.1	7557709.1	0	47754354
Bike-sharing	1120	3.739	6.122	0	43.6
Car-sharing	1120	0.477	2.166	0	24.5
District heating	1008	9.35	27.001	0	209.86
Traffic blockage	771	2.53	5.139	0	24

Descriptive statistics of all the dependent variables in the analysis. Sample of provincial capital municipalities. Period: 2010-2019.

Table A.2: Descriptive statistics of regressors

	Obs	Mean	Std.Dev.	Min	Max
Female councilors	1120	21.092	11.125	0	52.778
Female aldermen	1120	33.238	15.789	0	100
Pop	1110	160438.28	299610.36	21517	2638842
Transport demand	1104	80.722	108.309	1.5	844.1
Motorization rate	1107	651.74	170.612	408.7	2522.8
Vehicle density	1107	996.941	1102.626	66	6494
Bus seats	1102	460.671	1239.576	3.9	14144.5

Descriptive statistics of all the regressors in the analysis. Sample of provincial capital municipalities. Period: 2010-2019.

Table A.3: Descriptive statistics of control variables in treatment group

	Obs	Mean	Std.Dev.	Min	Max
Pop	890	169789.82	326764.61	21517	2638842
Transport demand	880	84.829	113.989	2.9	844.1
Motorization rate	883	628.71	65.383	408.7	809
Vehicle density	883	992.335	1088.179	124	6494
Bus seats	878	501.885	1371.165	5.5	14144.5
Expenditures	890	1768.646	985.939	632.444	12880.398

Descriptive statistics of all the control variables in the treatment group (provincial capital municipalities in regions with ordinary statute and population above 15,000. Period: 2010-2019.

Table A.4: Descriptive statistics of control variables in control group

	Obs	Mean	Std.Dev.	Min	Max
Pop	220	122607.04	139062.95	27794	668518
Transport demand	224	64.586	80.485	1.5	347
Motorization rate	224	742.525	342.17	516	2522.8
Vehicle density	224	1015.099	1160.175	66	5407
Bus seats	224	299.124	399.33	3.9	1758.3
Expenditures	220	1804.088	631.892	839.518	4212.196

Descriptive statistics of all the control variables in the treatment group (provincial capital municipalities in regions with special statute and population above 15,000. Period: 2010-2019.

Table A.5: 2SLS estimates — Further dependent variables

Dep. Var.:	PM2.5 (1)	NO2 (2)	bapmg (3)
Female councilors	-0.212*** (0.0534)	-0.288** (0.117)	-0.00865** (0.00357)
Observations	795	693	377
Number of id_comune	94	106	69
Municipality FE	No	No	No
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes

*Note.* 2SLS Estimates. All regressions include municipality FEs and year FEs and controls as: *Pop*, *Transport demand*, *Motorization rate*, *Vehicle density*, *Bus seats* and dummies of election cycle. Robust standard errors, clustered at municipal level, are in brackets. Period: 2010-2019. Data for the *NO2* and *bapmg* start in 2013 Significant coefficients are indicated by \* (10% level), \*\* (5% level) and \*\*\* (1% level). The first stage estimates as well as all the tests on the instrument are available on request; all the validity requirements are met.

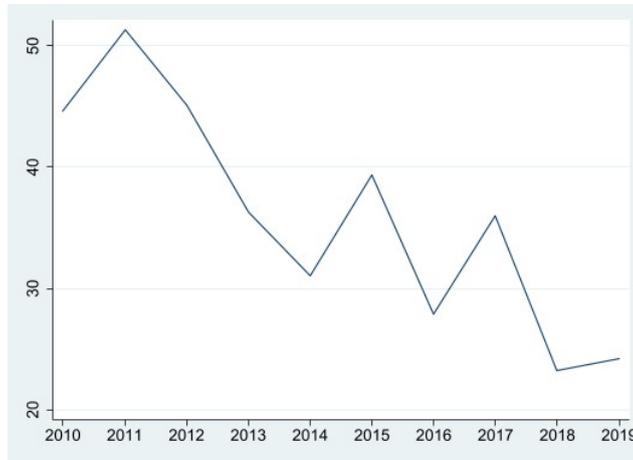
Table A.6: 2SLS estimates — Robustness

Dep. Var.: Air pollution	(1)	(2)	(3)	(4)
Female councilors	-0.978** (0.409)		-1.141*** (0.249)	-0.839** (0.330)
DL155/2010	-12.76** (4.992)			
DL152/2006	-16.87*** (3.611)			
Gender mayor		-231.2 (181.8)		
Expenditure			-0.000193 (0.00112)	
Center-right				8.720* (4.455)
Center-left				7.646*** (2.786)
Civic lists				6.008 (3.935)
Observations	1,634	1,008	1,008	1,008
No. Municipalities	108	108	108	108
Municipality FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes

*Note.* 2SLS Estimates. All regressions include municipality FEs and year FEs and controls as: *Pop*, *Transport demand*, *Motorization rate*, *Vehicle density*, *Bus seats* and dummies of election cycle. Robust standard errors, clustered at municipal level, are in brackets. Period: 2010-2019. Estimation in Column 1 includes years 2003-2019. Estimation in Column 2 has the gender of the mayor as the main regressor. Estimation in Column 3 includes the per-capita municipal expenditure among regressors. Estimation in Column 4 includes dummies for the political orientation of the mayor among regressors. Significant coefficients are indicated by \* (10% level), \*\* (5% level) and \*\*\* (1% level). The first stage estimates as well as all the tests on the instrument are available on request; all the validity requirements are met.

## B Figures

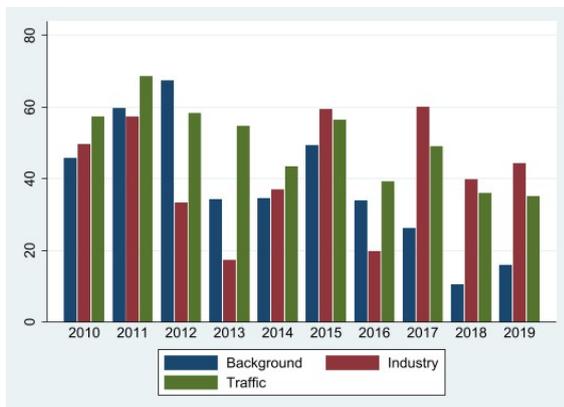
Figure B.1: *PM10* over years



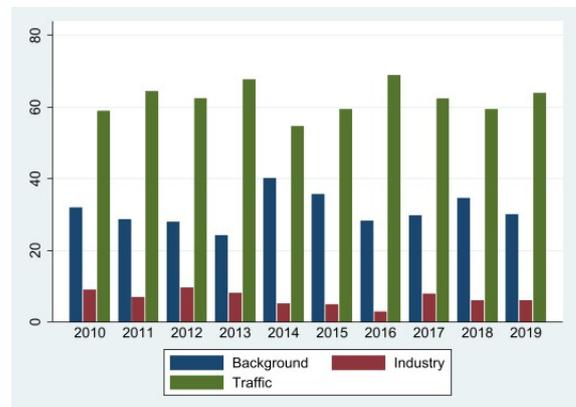
*Notes.* The graph reports the mean of the number of days when  $PM_{10}$  exceeds the daily limit of  $50\mu\text{g}/\text{m}^3$  ( $PM_{10}$ ) in the provincial capital municipalities. Period: 2010-2019.

Figure B.2: Average of exceeding days of  $PM_{10}$  limit and Relative frequency per type of monitoring stations over years.

(a) Average of exceeding days

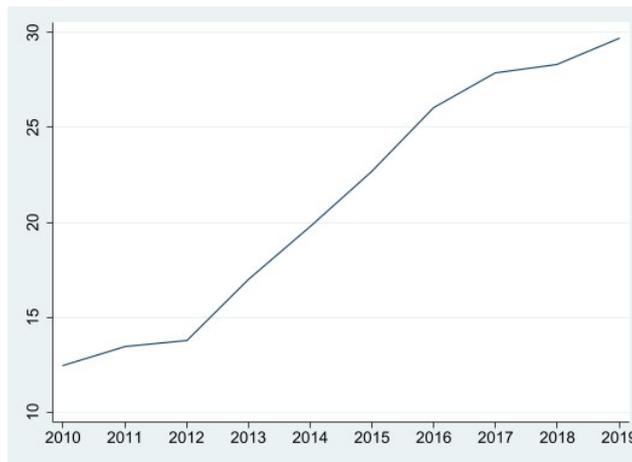


(b) Relative frequency



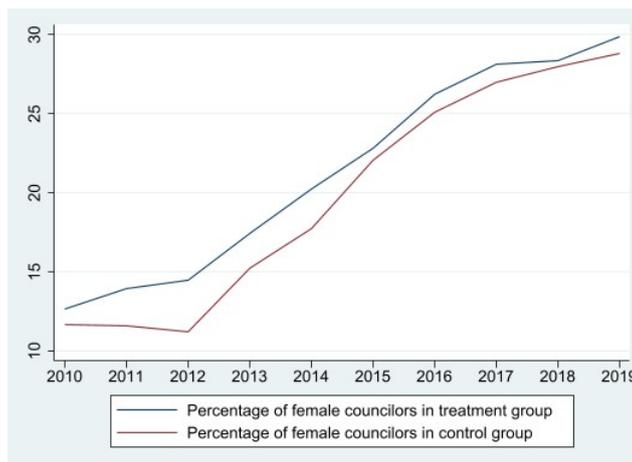
*Note.* The graph depicts the annual mean of the number of days when  $PM_{10}$  exceeds the daily limit of  $50\mu\text{g}/\text{m}^3$  per type of monitoring station (Graph B.2a) and the annual relative frequencies of cities that have reached the maximum number of exceedances for a specific type of monitoring station (Graph B.2b). The types of monitoring stations are background, industry, and traffic. Years 2010-2019.

Figure B.3: Females councilors. 2010-2019



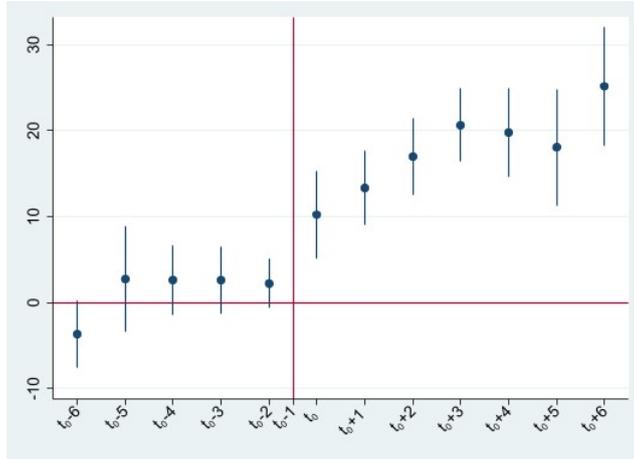
*Notes.* The Figure shows the percentage of women councilors for each year in provincial capital municipalities, 2010-2019.

Figure B.4: Percentage of female councilors in treatment and control groups



*Notes.* The graph reports the share of female city councilors in the treatment and control groups of provincial capital between 2010 and 2019. The treatment group is provincial capitals in regions with ordinary statute; the control group, those in regions with ordinary statute.

Figure B.5: Event study — First stage estimates- female aldermen



*Notes.* The graph reports coefficients and confidence intervals estimated according to eq. 3. The dependent variable is the percentage of female aldermen. Standard errors are clustered at provincial capital level. Dots refer to point estimates, spikes to 95% confidence intervals. Event-time dummy variables for 6 years before and 6 years after the election under Law 215/2012 are included. Regression includes municipality FEs, year FEs and as controls the resident population and dummies of election cycle. The p-value of the F-test that all the pre-treatment coefficients are jointly equal to 0 is 0.09. Period: 2010-2019.