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When Green Turns Costly: The Fiscal Fallout of EU Waste Management Funds in Italian Municipalities*

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Abstract

This paper investigates the fiscal consequences of EU-funded waste management projects on local taxation in Italian municipalities. Using a difference-in-differences approach on panel data from 2007 to 2023, we find that municipalities receiving EU cohesion funds experienced a significant increase in per-capita waste taxes, driven by rising service costs. A decomposition of these costs reveals that while separate waste collection expanded — in line with sustainability goals — the associated logistical and operational expenses increased sharply. Conversely, although the volume of unsorted waste declined, disposal costs rose, likely due to lower quality and more complex treatment requirements. To assess whether cost increases reflected inefficiency or technological progress, we estimate total factor productivity changes via a non-parametric Malmquist index. The results indicate substantial productivity gains in sorted waste management, mostly from technological advancement, but also suggest transitional inefficiencies. Our findings highlight the need for more integrated investment strategies to balance environmental goals with fiscal sustainability.

JEL Classification: H23, H72, Q58, R53

Keywords: EU Cohesion Policy, Waste Management, Local Public Finance, Environmental Taxation, Service Costs, Efficiency and Productivity

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1 Introduction

A crucial sector for ensuring environmental sustainability and the efficiency of public services is municipal waste management. Over the past two decades, European Union Cohesion Policy has played a key role in supporting investments in waste management system aimed at modernizing facilities, promoting recycling, and fostering the transition to a circular economy (European Commission, 2020). In Italy, the waste management services are locally managed and entirely financed by users, with costs fully reflected in municipal taxation under national rules. While the primary goal of EU-funded waste projects is to improve environmental and service outcomes, they can have unintended fiscal effects. Whether these investments relieve or exacerbate the fiscal burden on households — by reducing infrastructure costs or triggering higher operational expenses — remains ambiguous and underexplored.

This paper aims to fill this gap by investigating how EU co-financed waste management investments have affected municipal waste taxes across Italian municipalities. Using panel data from 2007 to 2023, the analysis examines the relationship between EU public funding and local taxation, contributing to the broader debate on the fiscal effects of EU environmental spending.

In Italy, municipalities are legally required to set the waste tax to fully cover the actual costs incurred for collection, transport, treatment, and disposal, including overhead and administrative expenses. The principle behind this rule is that the waste tax is not a general revenue tax but a fee for service, and it cannot be used to fund other areas of municipal spending. This regulatory framework is established by Law No. 147/2013, Article 1, paragraphs 639–668, which introduced the TARI as part of the broader reform of local taxation. Changes to the waste tax burden on citizens are only permitted following variations in the costs of waste collection and disposal services.

Theoretically, the effect of EU funds in waste management projects on local taxation can go in two opposite directions. On the one hand, EU-funded investments may ease the financial burden on municipalities (and, then, on citizens) by covering capital costs for infrastructure improvements - such as composting plants, sorting facilities, or smart collection systems - thereby reducing the need for local borrowing or co-financing and potentially stabilizing or lowering waste taxes (Bel and Warner, 2008, Dijkgraaf and Gradus, 2004, OECD, 2024). On the other hand, several factors may lead to increased costs: many EU-funded projects expand service quality and scope, raising long-term operational and maintenance expenditures (ISPRA, 2022); co-financing requirements can strain local budgets in the absence of long-term financial planning; and adherence to environmental performance targets may necessitate costly technological upgrades (Abrate et al., 2014). Furthermore, inefficiencies in project implementation, delays, and mismatches between funded infrastructure and local operational capacity can reduce or reverse potential cost savings, leading municipalities to raise tariffs to recover sunk costs or comply with post-project obligations (Bartolacci et al., 2019, Dijkgraaf and Gradus, 2004, Rodríguez-Pose and Garcilazo, 2018). These dynamics highlight that subsidies do not automatically translate into lower taxation: when they lead to higher operating costs, complex compliance obligations, or financial stress — especially in the presence of limited administrative capacity — the net effect may be neutral or even regressive. Understanding these trade-offs is essential to designing EU funding frameworks that promote both environmental sustainability and local fiscal equity.

Using detailed project-level data from the *OpenCoesione* database and municipal waste tax records, we provide new empirical evidence on how EU environmental investments shape local fiscal policy. Our identification strategy compares municipalities that received EU-funded waste management projects to municipalities that did not, leveraging variation in the timing of project start dates.

The empirical analysis estimates the average treatment effect (ATE) of the EU funds in waste management projects on the level of municipal waste taxes by adopting the Difference-in-differences (DiD) methodology. We exploit the staggered starting years of each project among Italian municipalities to identify a treatment group, i.e. municipalities that receive the funding, and a control group, i.e municipalities that did not receive funding, over the time-span 2007-2023. Results show that the per-capita waste tax increases by about 24% to 28% in municipalities in the treatment group with respect to the control group. The DiD framework is based on the validity of the parallel trend assumption that we verify by estimating an event-study model. It also allows to examine the dynamic over years of the effect of the EU cohesion policy on the citizens' waste tax between treatment and control group of municipalities. Under the validity of the parallel trend assumption, the dynamic pattern of the municipal per-capita waste tax shows an increasing trend, in the treatment group than in the control group, starting from the second year after the beginning of the project. Moreover, findings remain robust to possible negative weights due to the staggered adoption of the treatment (that we check by the recent methodology proposed by Sun and Abraham (2021)) and to strengthening of the DiD identification (by employing a matched DiD analysis).

The second part of the empirical analysis concentrates on the transmission mechanism behind the main result that passes through the variation in the costs of waste management service after EU financing. We empirically test this relationship by using data on costs of total, separate and unsorted waste collection provided by ISPRA from 2011 (the first available year) to 2023. The empirical evidence suggests that EU funds on waste management projects have increased the total costs of the waste management service in the treatment group more than in the control group of municipalities. This increase is driven by both the rise in costs for separate and unsorted waste collection. This evidence prompts a fundamental policy question: do higher costs reflect improved service quality and long-term efficiency gains, or are they the result of implementation inefficiencies and suboptimal resource allocation? To address this issue, we next examine changes in the composition and volume of collected waste, with the aim of identifying whether cost increases are associated with a shift towards more sustainable practices. The results reveal a substantial rise in separate waste collection and a concurrent decline in residual waste, suggesting behavioral and organizational adjustments in line with the policy objectives. However, these compositional changes alone do not fully explain the observed cost dynamics. The next stage therefore decomposes total waste management costs into collection and transportation costs and disposal and recycling costs, for both waste streams. This breakdown enables a more granular assessment of the intervention's effects along the waste management chain and helps identify whether cost increases are concentrated in upstream logistical improvements or downstream treatment inefficiencies. Finally, to assess whether EU-funded interventions translated into genuine improvements in operational efficiency, we estimate total factor productivity (TFP) changes using a non-parametric Malmquist index approach (Färe et al., 1994). By comparing pre- and post-intervention performance in municipalities that received EU cohesion funds, we are able to disentangle the contribution of technological progress from changes in relative efficiency. The results point to significant productivity gains in the management of sorted waste, largely driven by technological advancement, although accompanied by some temporary decline in operational efficiency. In contrast, the performance of unsorted waste management remains broadly stable, with limited gains in technology and modest reductions in relative efficiency. This final stage of the analysis provides a comprehensive view of how public investment affects not only service coverage and composition but also the capacity of local systems to use resources effectively.

This paper contributes to the growing literature at the intersection of environmental economics, local public finance, and the economics of the green transition. Within environmental economics, prior research has examined the design and effectiveness of interventions in waste management, energy efficiency, and climate mitigation (Cerqua et al., 2024, Cetrulo et al., 2018, de Coninck and Puig, 2015, Du et al., 2023, Gillingham et al., 2009, Shooshtarian et al., 2024, Tanaka, 2011). Recent studies have also explored the fiscal dimension of environmental policies: unit pricing for unsorted waste reduces waste volumes and municipal expenditures (Valente, 2023), and environmental taxes can foster both economic performance and innovation (Stameski et al., 2024, Wang et al., 2022). However, little is known about how green investments affect local taxation structures. Our findings show that while such investments support service modernization, they may also lead to higher short-term costs, increasing fiscal pressure on households.

From the perspective of fiscal federalism, our study adds to a well-established literature on how intergovernmental transfers shape local taxation and spending decisions (Baicker and Staiger, 2005, Cascio et al., 2013, Dahlberg et al., 2008, Gennari and

Messina, 2014, Gordon, 2004, Knight, 2002, Lundqvist, 2015). In particular, it relates to the flypaper effect (Gramlich, 1969, 1998, Hines Jr and Thaler, 1995), emphasizing that the impact of transfers depends critically on their design. We extend this reasoning to the underexplored area of environmental grants, documenting how EU-funded waste projects influence municipal fiscal choices.

Finally, in line with recent contributions on the green transition (Cerqua et al., 2024, OECD, 2024), we examine how environmental goals interact with local financial and operational constraints. While separate collection systems require substantial investments (Cerqua et al., 2024), evidence also points to the effectiveness of low-cost interventions such as awareness campaigns (Nepal et al., 2023) and voluntary local initiatives (Meleddu et al., 2024). Our analysis enriches this debate by providing novel empirical evidence on how EU-funded green investments affect not only the structure and scope of waste services, but also their cost dynamics and productivity, highlighting key trade-offs in the pursuit of sustainable local governance.

Overall, our evidence suggests that EU cohesion funds have contributed to a structural shift toward more sustainable waste management, primarily by expanding the scope and intensity of separate waste collection. However, the persistence of high disposal costs for residual waste highlights downstream inefficiencies — such as limited treatment capacity or suboptimal waste quality — that constrain the overall effectiveness of the intervention. From a policy perspective, this underscores the need for a more integrated funding strategy that complements investments in collection systems with support for processing infrastructure and quality control. Without such coordination, higher operational costs may be passed on to local taxpayers, potentially generating regressive effects, particularly in economically vulnerable areas.

The paper is organized as follows. In Section 2 we provide information on the EU policy funds and on the waste taxes in Italy. In Section 3 we describe the data and variables used in the empirical analysis. In Section 4 we explain the empirical strategy and in Section 5 we provide the results of estimation of the ATE and the dynamic of waste taxes between treated and untreated municipalities. In Section 6 we offer robustness checks on the estimation method. Section 7 assesses the cost-transmission mechanism and 8 concludes.

2 Italian institutional framework

This section outlines the institutional framework governing the relevant EU policy regulations, the waste taxation in Italy, and presents the data and variables used in the empirical analysis.

2.1 EU policy funds in waste management services

Cohesion policy is the European Union's primary instrument for fostering sustainable and inclusive economic development, reducing regional disparities, and enhancing citizens' quality of life. It channels targeted investments to support growth, employment, business competitiveness, and environmental sustainability. These policies are structured into multi-annual programming cycles, each spanning seven years, with financial allocations generally increasing over successive periods. Each cycle is defined by specific goals, funding instruments, and thematic priorities. According to the "n+2" rule, the allocated resources must be spent within two years following the end of the cycle to ensure timely and efficient fund absorption and to avoid delays that could hinder future programming.

Within the 2007–2023 time frame, three programming periods overlap: 2007–2013, 2014–2020, and 2021–2027 (now ongoing). Although the OpenCoesione database includes records for projects dating back to the 2000–2006 programming period, our empirical analysis begins in 2007. This choice reflects two main considerations. First, the 2007–2013 cycle marks the start of more systematic and harmonized monitoring procedures at the national level, ensuring greater data consistency and coverage — particularly for sector-specific interventions such as waste management. Second, the actual disbursement of EU cohesion funds, especially for environmental infrastructure, intensified only from 2007 onward, following the implementation of reformed governance rules and standardized reporting mechanisms. As such, starting the analysis from 2007 ensures both data reliability and alignment with the effective rollout of EU-funded projects in the sector. Investments during these periods were predominantly directed toward less developed regions, reflecting substantial territorial heterogeneity.[1]

The data on EU funded projects come from *OpenCoesione*.[2] In OpenCoesione, the thematic area *Waste* offers a comprehensive overview of projects co-financed by European and national funds that aim to improve urban waste management. These initiatives encompass landfill remediation and closure, the strengthening of separate waste collection systems, and the development or upgrading of waste treatment and recycling facilities. The efforts are in line with the European Union's goals for environmental sustainability and the shift toward a circular economy. The data, drawn from the National Monitoring System managed by IGRUE (State General Accounting Office), span the 2007–2013,

[1]Although all EU regions are eligible for cohesion support, the regulatory framework classifies them into three categories based on per-capita GDP, which determines the extent and type of financial assistance. Notably, Objective 1 (also known as the Convergence Objective) targets NUTS II regions with a per-capita GDP below 75% of the EU average, representing the cornerstone of regional policy. These less developed regions benefit most from the European Regional Development Fund (ERDF) and the European Social Fund (ESF), followed by transition regions, while the more developed regions receive comparatively limited support (Crucitti et al., 2024).

[2]Source: OpenCoesione. OpenCoesione is the national open government initiative on cohesion policies, coordinated by the Department for Cohesion Policies and for the South of the Presidency of the Council of Ministers. It provides data and information on projects funded with national and European resources, which are published on the portal.

2014–2020, and 2021–2027 programming periods. They include details on the number of projects, monitored public spending, disbursed payments, geographic distribution, and types of interventions.

In particulr, the data on EU funding for waste management projects are broken down into three main categories: (1) separate waste collection, (2) remediation, and (3) infrastructure. Each of these categories is further subdivided into specific types of interventions: (1) purchase of goods and services, (2) execution of public works, (3) provision of grants to other entities, (4) provision of incentives to production units, and (5) equity participation. The majority of projects fall into the first two subcategories.

Figure 1 shows the geographical (by regions) distribution of the municipalities receiving the EU funds for waste management projects (in green) and of municipalities not affected by EU policy intervention (in white) between 2007-2023. The map highlights two features. Firstly, the greatest part of the financed municipalities belong to the *Mezzogiorno* regions, namely Abruzzo, Apulia, Basilicata, Calabria, Campania, Molise, Sicily and Sardinia. Second, not all Italian regions had municipalities involved in EU-funded waste management projects. In particular, no municipalities in Emilia Romagna, Friuli Venezia Giulia and Valle d'Aosta received funding of this kind.

Figure 1: Geographical distribution of the EU funds for waste management projects

Note. The map illustrates the geographical (by regions) distribution of the municipalities receiving the EU funds for waste management projects (in green) and of municipalities not affected by EU policy intervention (in white). Period: 2007-2023.

This pattern supports the identification strategy adopted in the treatment model, as it allows for a clear distinction between treated municipalities (those receiving EU funds for waste management projects) and control municipalities (those not receiving any funds).

Finally, Figure B.1 (Appendix B) shows the yearly distribution of the EU funding in waste management projects per year of the beginning of the project. The greatest amount refers to 2008, 2014 and 2017 while the lowest between 2019 and 2023.

2.2 Waste taxes in Italy

In Italy, municipal waste services are managed locally and financed through specific waste taxes that have evolved over time. Initially introduced in 1993, the TARSU (Tax for the Disposal of Solid Urban Waste) was based on property size and use, but lacked alignment with actual waste generation. It was gradually replaced by the TIA in 1998, which introduced variables like household size and business type, aiming for a closer link to service costs. In 2013, the short-lived TARES combined waste and general public services in a single tax but proved administratively complex.

Since 2014, the national standard is the TARI, introduced by Law No. 147/2013. It is composed of a fixed and a variable component, calculated respectively on property size and occupancy characteristics, and is designed to fully cover the cost of the waste management service — including collection, treatment, overheads, and administration. Importantly, municipalities are legally required to adjust the TARI annually to reflect actual service costs. This results in a time-lagged pass-through: increases in costs in year t are reflected in tariffs in the following years.

TARI represents a significant share of local revenues (about 20%, see Messina et al. (2018)) and averaged €312 per household in 2021 (ISPRA, 2022). In municipalities with appropriate measurement technologies, the alternative TARIP system (Pay-As-You-Throw) can be adopted, linking the variable quota of the tax to the actual quantity of unsorted waste produced by each user (Article 1, paragraph 668 of Law No. 147/2013).

The evolution of per-capita waste taxes between 2007 and 2023, shown in Figure B.2 (Appendix B), reflects both institutional reforms and external shocks. After gradual increases between 2007 and 2011 (which may reflect a progressive adjustment of tariffs to service costs or a slow transition from the TARSU system to the TIA in some municipalities), a sharp rise occurred between 2012 and 2015 due to the TARES-to-TARI transition. A temporary reduction was observed during 2020–2021, when many municipalities applied emergency relief measures during the COVID-19 pandemic.

3 Data and variables

3.1 Dependent variable

AIDA ("Analisi Informatizzata Delle Aziende") PA ("Pubblica Amministrazione")[3] provides yearly data on the amount of resources collected through the waste taxes (as described above) in each Italian municipality from 2007 to 2023 . The dependent variable of the main analysis is this per-capita waste tax amount (i.e., the waste tax amount divided by the resident population) in real Euros. We express the variable in natural log to have the interpretation of the coefficients in terms of elasticity (*Waste tax*). Table A.1 shows the descriptive statistics of the waste tax variable.

3.2 Main regressor

The regressor of interest is constructed from the funding in waste management projects received by Italian municipalities. The study primarily utilizes the OpenCoesione database. As said above, OpenCoesione provides details on individual projects, including allocated

[3] AIDA PA is a database by Bureau van Dijk (a Moody's group company) that contains economic and financial information on Italian public administrations.

resources, implementation timelines, and progress status from 1997 to 2023. To obtain a coherent and relevant sample for our empirical analysis that span from 2007 to 2023, we cleaned municipalities receiving the EU funds on waste management projects in the years between 2000 and 2006.

We take into account payments received as EU transfers for financing EU-awarded projects, co-financing contributions from the central government as reimbursements for costs already incurred on EU-funded projects, and the amount of cohesion funds allocated to the region and province of each municipality involved.

As Figure 1 shows, we can identify a group of municipalities that received funding (the treatment group), and a group composed of municipalities that were not affected by waste management financing projects (the control group). Furthermore, since the funds were disbursed at different times between 2007 and 2023, we exploit the staggered rollout of the EU policy. This allows us to compare the outcome of interest over time between municipalities that have already received funding and those that have not yet received it in a given year, and those that never received it. Therefore the treatment status of a municipality begins in the starting year of the project. The years prior to this date are to be considered pre-treatment periods.

3.3 Control variables

In the empirical analysis, we control for time-variant variables related to municipal characteristics. We first control for the resident municipal population (*Pop*), in natural log, which captures a dimensional aspect. Then, we include the average household size residing in the municipality (*Family members*) calculated dividing the resident municipal population by the number of families in that municipality. This variable accounts for the fact that larger households tend to generate more waste, which affects the waste tax. Then, we control for the per-capita municipal income (in real Euros - *Per-capita income*), in natural log. Such data are taken from the Italian Ministry of Finance (MEF) that provides yearly information on the declared incomes of residents in each Italian municipality. We take the total municipal income that is composed by: 1) the amount of income from dependent work; 2) the amount of income from self-employment; 3) the amount of income attributable to the entrepreneur in ordinary accounting; 4) the amount of income attributable to the entrepreneur in simplified accounting; 5) the pension income. Income accounts for the fact that the calculation of the waste tax is also based on factors related to the surface area and use of properties, which are often correlated with income. We also control for the socio-demographic characteristics of municipal council members, such as the average level of education (*Councilors education*), the average age (*Councilors age*), the share of female councilors (*Female councilors*) and the gender of the mayor (*Mayor's gender*). Such characteristics of municipal council members can have a significant impact on local policies, including those related to the determination of the waste tax. Finally, in contexts with weak institutions (such as corruption, lack of transparency, and clientelism), funds can be misallocated, poorly managed, or used for inefficient projects (Cerqua and Pellegrini, 2018, Charron et al., 2014). Accordingly we control for *MAQI* (Municipal Administrative Quality Index), an index that measures the quality of local public administration at the municipal level in Italy (Cerqua et al., 2025). It was developed to comparably assess the efficiency, effectiveness, and transparency of local governments.[4]

Table A.1 (Appendix A) shows the descriptive statistics of the variables.

4 Empirical strategy

To examine whether — and through which mechanisms — the allocation of EU Cohesion Funds for waste management projects has affected municipal waste taxation in Italy, we apply a difference-in-differences (DiD) approach over the period 2007–2023. The analysis exploits the staggered timing of fund disbursements across municipalities as a source of temporal variation. We define the receipt of payments as the treatment. Given that payments are disbursed at different times, the DiD framework enables us to compare the per-capita waste tax levels over time between municipalities that have received funding (treatment group), those that have not yet received it at a given time, and those that never received any funding (control group). Municipalities are considered treated from the starting year of the funded project onwards.

The equation that estimates the Average Treatment Effect (ATE) of fund disbursement on citizens' taxation between treated and control groups is as follows:

$$Y_{it} = \beta_1 Treatment_{it-1} + \alpha_i + \delta_t + X_{it} + \epsilon_{it} \tag{1}$$

where Y_{it} represents the per-capita waste taxation at year t in municipality i. The dummy $Treatment_{it\text{-}1}$ takes the value of 1 from the year of the beginning of the project onward and 0 otherwise. We consider a one-year lagged effect of the treatment to take into account the fact that redefining waste taxes as a result of receiving EU funding requires time. α_i represents the set of municipality fixed effects that control for heterogeneity in the cross-sectional dimension, allowing us to account for unobservable time-invariant factors that could bias the estimates. δ_t represents the set of year fixed effects that control for unobservable events specific to each year, which may affect all municipalities in the same way. X_{it} is the vector of control variables listed above. ϵ_{it} is the error term. Under the

[4] MAQI is a composite index, built by aggregating 3 dimensions of administrative performance: Efficiency and Bureaucratic Capacity, Quality of Local Politicians, Economic and Fiscal Performance of Municipal Administrations.

parallel trend assumption, the coefficient β_1 measures the ATE of the disbursement of cohesion funds on the outcome.

The parallel trends assumption is fundamental to the validity of the DiD approach. It implies that, in the absence of treatment, the difference in outcomes between treated and control groups would have remained stable over time. To assess this assumption, we adopt a dynamic DiD specification by estimating an event-study model. This framework enables us to trace the trajectory of the outcome variable for both treated and control municipalities in each year before and after the fund disbursement (Mora and Reggio, 2019). This approach not only tests the parallel trends assumption, but also reveals the dynamic evolution of waste taxation in the years following the treatment.

The dynamic specification is the following:

$$Y_{it} = \sum_{t=-n}^{+n} \nu_t \cdot D_{it} + \alpha_i + \delta_t + X_{it} + \epsilon_{it} \tag{2}$$

where, as before, Y_{it} represent the per-capita taxation in municipality i at time t. D_t is the set of event-time dummies, which take the value of 1 for treated municipalities if the year t is the k period before/after the beginning of the project. Therefore, we identify as t_0 the year of the beginning of the project. Given that we consider a one-year lagged effect of EU funds on waste management projects on local waste tax, we consider as omitted category the year of the first payment, D_0; the remaining coefficients ν_t measure the difference in the citizens' waste taxation before and after the payments in the treatment group of municipalities with respect to the control group. n represent the number of estimated lags/leads. In all the specifications we control for municipality (α_i) and year (δ_t) fixed effects (FE); then, we include all the control variables listed above. ϵ_{it} is the error term.

5 Results

5.1 ATE

Table 1 presents the estimation results for the Average Treatment Effect (ATE) based on Equation 1. The dependent variable is the municipal per-capita waste tax (in real euros), and standard errors are clustered at the municipal level to account for intra-municipality correlation over time. The key regressor, *Treatment*, is a binary indicator equal to 1 for municipalities that received EU funding for waste management projects from the year of project initiation onward, and 0 otherwise. Across all specifications, the coefficient on *Treatment* is positive and statistically significant at the 1% level, suggesting that municipalities benefiting from EU-funded waste management projects experienced a systematic increase in local waste taxation compared to those not receiving such funding.

In the most parsimonious specification (Column 1), which includes only municipality and year fixed effects, the estimated impact is an increase of approximately 24.3% in the per-capita waste tax for treated municipalities relative to the control group. Given the mean value of the waste tax is approximately 101 euros (as shown in Table A.1), this implies an average increase of around 24.6 euros per person per year in treated municipalities. This magnitude is economically meaningful, suggesting that the fiscal impact of EU-funded waste projects on local taxpayers is not only statistically significant but also quantitatively relevant.

Introducing time-varying municipal characteristics in Column 2 — including the log of resident population, average household size, and log of per-capita income — slightly increases the estimated treatment effect to 27.8%. These variables capture demographic and socioeconomic conditions that may influence both the fiscal needs and service delivery costs of municipalities. Notably, larger municipalities (as captured by population) and those with bigger average households tend to levy higher waste taxes, while wealthier municipalities (higher per-capita income) are associated with significantly lower waste taxes, possibly due to greater efficiency or economies of scale in service provision.

Column 3 adds political variables, including the average education level and age of municipal council members, the share of women in the council, and the gender of the mayor. These controls aim to proxy for administrative capacity, gender diversity in local governance, and possible political economy dynamics. Interestingly, a higher share of female council members is associated with significantly higher waste taxes, while female mayors are linked with marginally lower taxes. Despite the additional controls, the treatment effect remains robust and consistent in magnitude (25.5%).

Table 1: Average Treatment Effect

	(1)	(2)	(3)	(4)
Dep. Var.:	Waste taxes	Waste taxes	Waste taxes	Waste taxes
Treatment(-1)	0.243***	0.278***	0.255***	0.252***
	(0.0801)	(0.0763)	(0.0766)	(0.0767)
Pop		1.130**	0.988**	0.931*
		(0.490)	(0.491)	(0.493)
Family members		332.9**	375.7***	425.8***
		(137.9)	(137.8)	(140.9)
Per-capita income		-1.614***	-1.573***	-1.627***
		(0.401)	(0.402)	(0.407)
Councilor's education			-0.0104	-0.0132
			(0.0185)	(0.0185)
Councilor's age			-0.00613	-0.00564
			(0.00528)	(0.00528)
Female councilors			0.530***	0.478***
			(0.178)	(0.181)
Mayor's gender			-0.110*	-0.113*
			(0.0645)	(0.0650)
MAQI				0.00721
				(0.00514)
Observations	111,363	103,100	102,489	101,203
No. Municipalities	7,792	7,762	7,609	7,452
Municipality FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Note. Estimation of the Average Treatment Effect (ATE) based on equation 1. The dependent variable is the municipal per-capita waste tax (in real Euros). The variable *Treatment* is a dummy that takes the value 1 starting from the year of the beginning of the financed waste management project onward, and 0 otherwise. The analysis period spans from 2007 to 2023. The control variables include: the resident population in thousands (in natural log), the average household size, the per-capita income (in real Euros) (in natural log), the average level of education and the average age and the share of female and the gender of the mayor of municipal council, the MAQI. All specifications include fixed effects for year and municipality, though the coefficients for these effects are not reported. Standard errors are clustered at the municipality level and are presented in parentheses. Coefficient significance levels are indicated by * (10% significance), ** (5% significance), and *** (1% significance).

In the final specification (Column 4), we further include the Municipal Administrative Quality Index (MAQI) (Cerqua et al., 2025), an index measuring institutional quality, transparency, and governance performance. Although the MAQI itself is not statistically significant, its inclusion helps rule out confounding effects due to variation in local institutional capacity. The treatment coefficient remains stable at 25.2%, very close to the estimate from the baseline model, reinforcing the robustness of the result.

The relative stability of the treatment effect across all model specifications is a strong indication of its robustness and supports the assumption that the treatment is exogenous with respect to unobserved factors that could otherwise bias the estimates. The inclusion of detailed control variables and fixed effects rules out several alternative explanations, such as omitted variable bias due to structural differences in local governance or socioeconomic context.

Taken together, the results suggest that EU funding for waste management projects, while intended to support service improvements, is associated with a significant increase in local waste taxation. This finding is consistent with the hypothesis that the operational and financial obligations linked to these projects — such as co-financing requirements, maintenance costs, and expanded service scope — may offset any short-run fiscal relief from the capital investment itself.

5.2 Dynamic specification - Event study

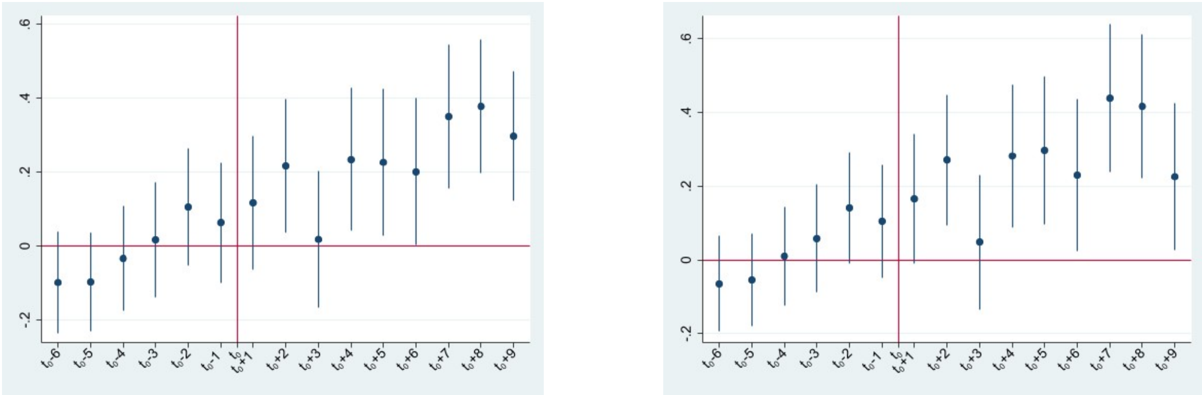
In this section we estimate an event-study model as in 2 in order to assess for 1) the validity of the parallel trend assumption and 2) the dynamic of the municipal per-capita waste tax during the post-treatment period. We estimate 6 pre-treatment coefficients and up to 9 post-treatment coefficients. Figure 2 shows the estimation results of eq. 2. In all Graphs we control for year and municipality FE; Graphs 2b adds all the control variables specified above, such as *Pop*, *Family members*, *Per-capita income*, *Councilor's education*, *Councilor's age*, *Female councilors*, *Mayor's gender*, *MAQI*.

First, both graphs indicate that the parallel trend assumption is likely satisfied, as the confidence intervals from $t_0 - 6$ to $t_0 - 1$ are centered around zero. To formally assess this, we conduct an F-test to determine whether all pre-treatment coefficients are jointly equal to zero. The results support the null hypothesis at conventional significance levels, with p-values of 0.093 and 0.107 for the estimations shown in Graph 2a and Graph 2b, respectively. These findings suggest that, prior to the disbursement of EU funds for waste management projects, there were no statistically significant differences in the trend of municipal per-capita income growth between the two groups of municipalities.

The analysis of the post-treatment dynamic presents an increasing trend of the waste tax in treatment group than in the control group starting from the second year after the beginning of the waste management project ($t_0 + 2$).

Figure 2: Event-study

(a) Without control variables (b) With control variables



Note. The graphs show the coefficients and confidence intervals estimated based on equation 2. The dependent variable is the municipal per-capita waste tax (in real Euros). Estimation in Graph 2a controls only for time and municipality FE. Estimation in Grapf 2b includes also for the resident population in thousands (in natural log), the average household size, the per-capita income (in real Euros and in natural log), the average level of education and the average age and the share of female and the gender of the mayor of municipal council, the MAQI. Standard errors are clustered at the municipal level. The points represent the estimated coefficients; the confidence intervals are at 95%. The p-value of the F-test that all pre-treatment coefficients are jointly equal to 0 is 0.093 and 0.107 for the estimates in Graph 2a and 2b, respectively. Time period: 2007-2023.

The fact that a significant increase in the waste tax emerges starting from year $t_0 + 2$ may reflect the typical time lag between the approval of EU-funded projects and their full implementation. Construction of facilities, procurement processes, and administrative procedures often delay the onset of operational and financial effects. Hence, the increase in tariffs may coincide with the moment when new infrastructure becomes operational, rather than the funding year itself. An increase in waste tax following the receipt of EU funding for waste management projects at $t_0 + 2$, namely, in the very short run, may also reflect the fact that local governments are often required to co-finance EU-funded projects or cover non-eligible expenses, which can lead to temporary tax increases. This circumstance can explain also the insignificant coefficient at $t_0 + 3$, where waste tax in the treatment group align that in the control group, due to the end of such short-run expenditure. This can be interpreted as a “transition year” that may reflect administrative adjustments, temporary efficiency gains, or delays in the full activation of newly built facilities, leading to a momentary attenuation of cost — and thus tax — pressures.

From $t_0 + 4$ onward, the increase in citizens tax burden may reflect a number of circumstances. The implementation of new infrastructure and services financed by EU funds — such as advanced recycling systems or treatment plants — can raise operational and maintenance costs. While these investments aim to improve efficiency and sustainability, their financial burden may be reflected in higher tariffs, especially once EU funding ends.

Additionally, tax increases may result from the internalization of environmental costs or the transition toward more comprehensive and equitable waste management systems. These dynamics highlight that higher waste taxes may represent a phase of transition. Another possible interpretation is that the effectiveness of EU-funded investments depends on the scale of implementation and the presence of complementary investments (e.g., downstream treatment facilities). In municipalities where the infrastructure scale is suboptimal or where upstream investments are not matched with downstream capacity (e.g., disposal, recycling markets), the operational costs may rise disproportionately relative to service efficiency, resulting in tax increases. It is also plausible that, in some municipalities, the availability of external funding encouraged local governments to expand services or infrastructure beyond what would have been feasible under budget constraints. While this may enhance service provision, it can also generate budgetary rigidities and lock-ins that require higher tariffs to sustain, especially due to the legal obligation (under Law 147/2013) to fully cover costs via the TARI. The tax increase may be due to inefficiencies in the management of projects and resources. We will deal with these circumstances in Section 7.

6 Robustness checks

6.1 Estimations robust to negative weights

In our analysis, the treatment — namely, the EU intervention in waste management projects — is implemented in a staggered fashion over time, meaning that different units receive the treatment at different points. Recent contributions in the literature (De Chaisemartin and d'Haultfoeuille, 2020, Goodman-Bacon, 2021) have shown that the conventional DiD estimator may be inadequate in such settings and can yield misleading results. Specifically, the estimated treatment effect under the traditional DiD framework is a weighted average of group-time-specific treatment effects. Critically, some of these weights can be negative, even when the true treatment effects are positive, which can distort the overall estimate. As a result, the average treatment effect may appear negative despite the intervention having a genuinely positive impact. This issue arises when treatment effects are heterogeneous across groups and over time, leading to situations where already-treated units are incorrectly used as controls for newly treated ones. Such contamination in the comparison group due to timing differences can introduce bias into the final estimate of the treatment effect.

To address the problem of negative weights in the staggered treatment setting, we apply the estimator proposed by Sun and Abraham (2021), which is designed for linear models and remains robust in the presence of heterogeneous treatment effects. The results are presented in Figure B.3, with the estimated average treatment effect (ATE) reported in Table A.2. Graph B.3a shows estimation including municipality and year FE and the municipal resident population while estimation in Graph B.3b include also control variables as the municipal per-capita income and the average household size. Consistent with the baseline event-study design, we estimate event-time coefficients ranging from -6 to $+9$. At first glance, the dynamic pattern of the treatment effects — after accounting for treatment effect heterogeneity — closely mirrors the results of the main analysis shown in Figure 2. Notably, the confidence intervals for all pre-treatment coefficients include zero, lending support to the parallel trends assumption. This is further confirmed by F-tests on the joint significance of the pre-treatment coefficients: the p-value is 0.24 in Graph B.3a and 0.46 in Graph B.3b, both indicating failure to reject the null hypothesis that the pre-treatment effects are jointly equal to zero.

This analysis supports the validity of the DiD in the baseline analysis and shows that, although the treatment is staggered over time across treated municipalities, negative weights do not bias the baseline estimates.

6.2 Propensity score matching

In this section, we employ a matched DiD analysis (Borusyak and Jaravel, 2017, Goodman-Bacon, 2021) to further support the identification of the empirical research design. In evaluating the impact of EU funds allocated to waste management projects in Italian municipalities, Propensity Score Matching (PSM) offers a robust method to address potential selection bias inherent in observational data. Municipalities that receive EU funding for waste management initiatives often differ from those that do not, in terms of demographic, economic, and infrastructural characteristics. Moreover, they are mostly located in the Mezzogiorno of Italy, which has historically had very different characteristics compared to the rest of the country. These differences can confound the estimation of the treatment effect, making it challenging to attribute observed outcomes solely to the intervention.

PSM, introduced by Rosenbaum and Rubin (1983), estimates the probability (propensity score) of a municipality receiving treatment based on observed covariates. By matching treated municipalities with untreated ones that have similar propensity scores, PSM creates a counterfactual group that approximates a randomized control group, thereby isolating the effect of the intervention.

The propensity score is estimated through a logit model that predicts the likelihood of a municipality receiving the EU funds for waste management projects (i.e., receiving the treatment) within the full sample of Italian municipalities observed from 2007 to 2023. Based on these estimated probabilities, a control group is constructed by matching treated municipalities to those with similar propensity scores, thereby identifying municipalities that are highly likely to follow comparable pre-treatment trends.[5]

[5]The matching procedure is implemented using the Stata command *psmatch2*, developed by Leuven

The logit model includes the following covariates that account for regional and provincial, demografic, political and economic characteristics of municipalities: regional and provincial dummies, the resident population and resident female population size (log-transformed), population holding a university-level qualification (log-transformed), the average household size residing in the municipality, the per-capita municipal total waste, the standardized municipal income, the municipal average age of resident population (log-transformed), the average education level and the share of female councilors among city council members.

To evaluate the quality of the matching procedure, we perform two-sample t-tests for differences in covariate means between the treated and matched control municipalities. The results, shown in Table A.3 in Appendix A, indicate that the matching procedure produced good covariate balance between treated and control municipalities. Indeed, none of the mean differences are statistically significant, suggesting no systematic imbalance after matching. Moreover, the overall diagnostics—such as a low pseudo R^2 (0.003), non-significant LR chi^2 test ($p = 0.590$), and acceptable Rubin's B (12.0) and R (0.85)—confirm that the matching was effective.

The graphs in Figure B.4 display the distribution of propensity scores for both the treatment and comparison groups, before and after matching. Notably, Graph B.4b shows a good overlap in the propensity score distributions between the treated and control municipalities following the matching process, indicating improved comparability.

Table A.4 in the Appendix reports the matched DiD estimates of the average treatment effect of the EU intervention on the per-capita waste tax. These results are consistent with those previously shown in Table 1 with lower magnitude.

Finally, Figure B.5 in Appendix B displays the dynamic trends in per-capita waste tax before and after the receipt of EU funds for waste management projects, comparing treated and control municipalities. Consistent with the baseline findings, no anticipatory effects are observed, and an increase in waste tax occurs following the allocation of the EU funds.

7 The Cost Transmission Mechanism: from Public Funding to Waste Taxation

Our analysis shows that EU funds allocated to waste management projects lead to an increase in per-capita waste taxes in treated municipalities relative to untreated ones. This finding aligns with existing studies indicating that EU-funded investments in waste infrastructure often raise short-term service costs and, consequently, local taxation — particularly when projects involve advanced separate collection systems with high upfront

and Sianesi (2003).

and operational costs (Bel and Warner, 2008, Dijkgraaf and Gradus, 2004). However, other contributions point to potential cost reductions over the medium to long run, driven by economies of scale and improved efficiency (Bartolacci et al., 2019, Bel and Fageda, 2010). These contrasting outcomes highlight the role of local implementation capacity, service design, and complementary infrastructure in shaping the net fiscal effect.

The increase in local waste tax can be explained by a set of interrelated mechanisms, all revolving around the way in which EU-funded interventions affect the operational and financial structure of local waste services. A central transmission channel is the rise in operational and maintenance costs following waste structure upgrades — such as the construction of recycling facilities, the deployment of smart collection systems, or the expansion of separate waste streams — which, while improving service quality, often imply ongoing financial commitments not covered by the one-off EU grants (Dijkgraaf and Vollebergh, 2004, Ichinose, 2024, ISPRA, 2022). These burdens are especially significant for small or fiscally constrained municipalities, where EU funds relieve initial investment pressure but leave ongoing costs to local budgets (Dijkgraaf and Vollebergh, 2004). In Italy, this dynamic is reinforced by Article 1, paragraph 654, of Law No. 147/2013, which mandates full cost recovery through the TARI. Thus, any increase in service costs — whether due to maintenance, specialized personnel, or enhanced compliance obligations — must be passed on to taxpayers (Carattini et al., 2018). Moreover, co-financing and pre-financing requirements can amplify fiscal strain. Inefficient implementation or weak alignment with local needs may also result in overinvestment or underutilized assets. Overall, these mechanisms confirm that the fiscal impact of EU funds is mediated by administrative capacity and institutional quality (Cerqua and Pellegrini, 2018, Rodríguez-Pose and Garcilazo, 2018), and that insufficient lifecycle planning may ultimately raise the burden on local taxpayers. We now turn to an empirical test of the relationship between EU funding, waste management costs, and local taxation.

7.1 Empirical evidence

We use municipal-level data on urban hygiene expenditures from ISPRA, available for the period 2011–2023 (with 2011 being the first year such data are reported). The dataset includes both aggregate figures and a breakdown of per-capita spending (in euros) for differentiated and unsorted municipal waste.

Table A.5 in Appendix A reports descriptive statistics. The *Total waste cost* includes various components: collection and transportation (for both sorted and unsorted waste), treatment and recycling, street cleaning, general overhead (e.g., administration, utilities, insurance), capital-related outlays (e.g., equipment and infrastructure), and miscellaneous items such as awareness campaigns and educational activities.

Separate and unsorted waste streams account for the majority of these expenditures.

In our sample, on average, about 36% of the total cost refers to the management of sorted waste, and roughly 38% to unsorted waste. The remaining share reflects shared or ancillary services.

We define *Total costs for separate waste* as the combined expenditure for collecting, transporting, and processing sorted waste. Similarly, *Total costs for unsorted waste* refer to the entire set of expenses associated with residual waste, including logistical operations and downstream treatment.

Figure B.6 in Appendix B displays the annual trends in average per-capita waste management spending. Panel B.6a shows the evolution of overall expenditures, while Panel B.6b disaggregates the data for sorted and unsorted waste streams.

To analyze the cost pass-through mechanism of EU funds on municipal waste taxes, we estimate eq. 1 by regressing the treatment on the total costs of urban waste management (in real euros and in log). In this estimation, we control for the resident population and the per-capita municipal income (both in log), the total amount of waste collected per-capita in the municipality, the average household size. We also include year and municipality fixed effects; the latter account for key factors that influence waste management costs, such as the presence (or absence) of disposal and/or recycling facilities in the municipality, or its distance from such facilities. Result is in column 1 of Table 2 which shows that the EU funds in waste management projects increases of 2.4% the per-inhabitant total cost of waste service in the treatment group compared to the control group.

To fully understand the effect of European funding for waste management projects, it is essential to distinguish between the two most important components of the total costs, namely the costs of separate and unsorted waste collection. European funds often support interventions that promote more sustainable practices — such as the expansion of door-to-door collection, the introduction of digital tracking systems, or the purchase of new vehicles and containers for recyclable materials — which can increase the operational costs of separate collection in the short term, while improving service quality and potentially leading to long-term efficiency gains. At the same time, these funds can also finance investments in mechanical-biological treatment plants or local composting systems which, if well designed and integrated, help reduce the volume of residual waste and thus lower its associated collection and disposal costs. However, there are cases where funding may paradoxically increase the costs of residual collection — for instance, when it supports underutilized or poorly integrated infrastructure, resulting in inefficiencies. Similarly, poorly targeted or oversized projects may inflate the costs of separate collection without delivering proportional environmental or economic benefits (Kinnaman et al., 2014). For these reasons, a disaggregated analysis of cost components is crucial to accurately capture the mechanisms triggered by EU funding on the level of waste taxes.

Accordingly, we estimate eq. 1 by regressing the treatment variable on the (log of) total cost for separate and unsorted waste collection, whose results are respectively in columns 2 and 3 of Table 2. Here, the estimated treatment coefficient shows a positive and highly significant sign, meaning that the EU waste funds increased of 11.3% and 15.8% the costs for separate and unsorted collection, respectively, in the treatment group of municipalities than in the control group.

Table 2: ATE — Costs of waste management service

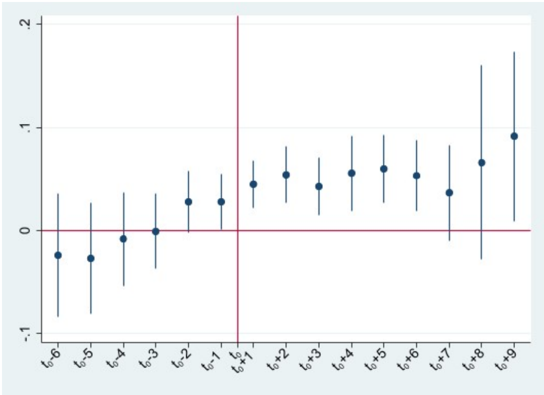
	(1)	(2)	(3)
Dep. Var.:	Total waste cost	Total cost for separate waste	Total cost for unsorted waste
Treatment(-1)	0.0240**	0.113**	0.158***
	(0.0118)	(0.0471)	(0.0324)
Observations	34,493	34,337	34,453
No. Municipalities	2,798	2,798	2,798
Municipality FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes

Note. Estimation of the ATE based on equation 1. The dependent variable is 1) the municipal per-inhabitant total cost of waste management service in column 1; 2) the municipal per-inhabitant total cost of separate waste collection in column 2; 3) the municipal per-inhabitant total cost of unsorted waste collection in column 3. The variable *Treatment* is a dummy that takes the value 1 starting from the year of the beginning of the financed waste management project onward, and 0 otherwise. The analysis period spans from 2011 to 2023. All specifications include fixed effects for year and municipality, though the coefficients for these effects are not reported. The control variables include, in all the specifications: the (log of) resident population, the average household members and the (log of) per-capita municipal income. Moreover, in regression in column 1 we also control for the municipal per-capita tonnes in total waste collection; in column 2 we also control for the municipal per-capita tonnes in separate waste collection; in column 3 we also control for the municipal per-capita tonnes in unsorted waste collection. Coefficient significance levels are indicated by * (10% significance), ** (5% significance), and *** (1% significance).

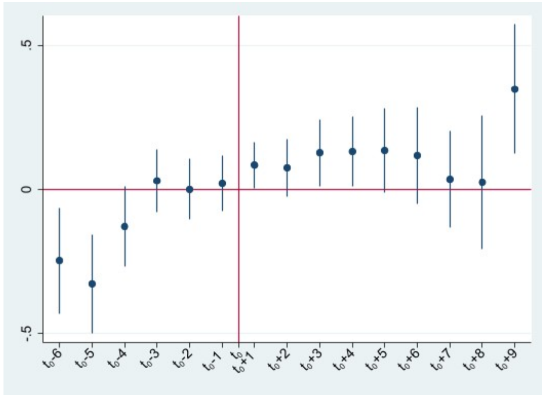
To assess for the validity of the DiD methodology for this analysis, in Figure 3 we provide evidence of the dynamic model estimation as in eq. 2. First of all, while the parallel trend assumption is satisfied in Graphs 3a and 3c (the validity of the parallel trend assumption is also confirmed by the acceptance of the null that all pre-treatment coefficients in the event-study model are jointly equal to 0 — the p-value of the F-test is equal to 0.21 and 0.36, respectively), it falls for estimation in Graph 3b (here the p-value of the F-test that all pre-treatment coefficients in the event-study model are jointly equal to 0 is equal to 0.00).

Figure 3: Event study - Costs

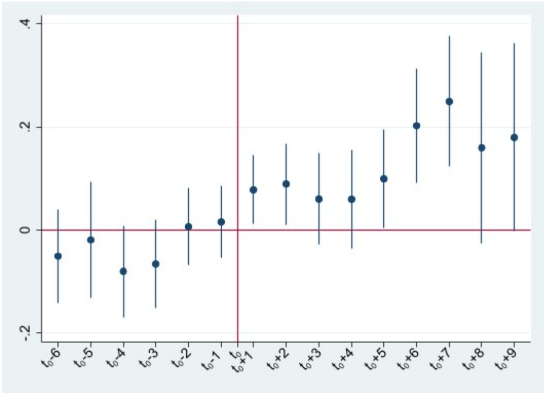
(a) Total costs



(b) Total costs for separate waste collection



(c) Total costs for unsorted waste collection



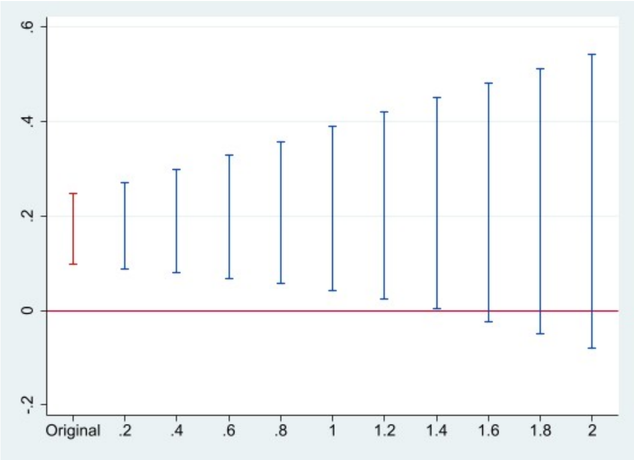
Note. The Graphs show the coefficients and confidence intervals estimated based on equation 2. The dependent variable is: the municipal total cost of waste collection (in real Euros) per inhabitant in Graph 3a, the municipal total cost of separate waste collection (in real Euros) per inhabitant in Graph 3b, the municipal total cost of unsorted waste collection (in real Euros) per inhabitant in Graph 3c. Estimations include the municipal resident population and the per-capita municipal income (both in log), the total amount of waste collected/the total amount of separate waste collected/the total amount of unsorted waste collected per-capita in the municipality, the average household size. Standard errors are clustered at the municipal level. The points represent the estimated coefficients; the confidence intervals are at 95%. The p-value of the F-test that all pre-treatment coefficients are jointly equal to 0 is 0.21, 0.00 and 0.36 for the estimates in Graph 3a, 3b and 3c, respectively. Time period: 2011-2023.

The violation of the parallel trend assumption in estimation as in Graph 3b raises concerns about the causal interpretation of the treatment effect. To address this, we implement the sensitivity analysis proposed by Rambachan and Roth (2023), which relaxes the strict identifying assumptions and quantifies the extent to which the estimated effects remain valid under plausible deviations. Using the *Honestdid* package in Stata (Bravo et al., 2024), we simulate how the estimated average treatment effect changes as we allow for increasing degrees of deviation from the parallel trends assumption, using the mvec() specification.[6] The result of the sensitivity analysis of separate waste collection costs is

[6]The mvec() specification in the *Honestdid* package defines a range of values for the sensitivity parameter M, which represents the degree to which the parallel trends assumption is allowed to be violated

in Figure 4.

Figure 4: Honestdid



Note. The Graph shows the result of the sensitivity analysis to violation of the parallel trend assumption for estimation of total cost of separate waste collection by using the *Honestdid* Stata command (Bravo et al., 2024). Period: 2011-2023.

When no deviation is permitted (M = 0), the estimated treatment effect is statistically significant, with a 95% confidence interval of [0.098, 0.248]. As M increases—representing growing violations of the assumption—the confidence intervals become wider. Importantly, the estimate remains robust and statistically distinguishable from zero up to M = 1.4. However, for $M \geq 1.6$, the confidence intervals include zero, suggesting that the effect may no longer be statistically credible under stronger deviations from identification. This analysis supports the conclusion that while the classical DiD approach is invalidated by empirical pre-trend violations, the estimated treatment effect remains reasonably robust to moderate misspecification, thereby providing (partial) reassurance regarding its credibility.

7.2 Discussion of results

Preliminary findings indicate that Italian municipalities receiving EU cohesion funds for waste management projects experienced an increase in per-capita expenditures on municipal solid waste services. This is consistent with findings in the literature that investments in advanced waste management technologies, such as waste-to-energy facilities, are typically associated with higher unit operating costs compared to traditional options (Di-

in the sensitivity analysis. Each value of M corresponds to a bound on the maximum deviation of untreated potential outcomes from the parallel trend path. Lower values of M reflect strict adherence to the parallel trends assumption, while higher values allow for increasing departures from it. By specifying a vector of values through mvec(), we can trace how the estimated treatment effect and its confidence interval evolve as identification becomes progressively weaker. This approach allows for a transparent assessment of robustness to deviations from the key identifying assumptions in DiD designs (Rambachan and Roth, 2023).

jkgraaf and Vollebergh, 2004). This rise in costs pertains to both the sorted (recyclable) and unsorted (residual) waste collection components.

However, cost increases alone do not provide a sufficient basis for assessing the actual impact of the intervention.[7] Such increases may stem from two fundamentally different scenarios: on one hand, they may reflect investments in system improvements and the adoption of more advanced infrastructure and services — such as smart bins, door-to-door collection, and public awareness campaigns; on the other hand, they may result from inefficient or poorly targeted spending.

7.2.1 Waste management system improvement or inefficiences?

To assess whether the observed increase in costs corresponds to genuine improvements in service quality or rather signals inefficiency, it is crucial to examine whether the intervention led to meaningful changes in the volume and composition of waste collected — particularly an increase in per-capita sorted waste and a reduction in unsorted waste. This analysis is key to distinguishing between a virtuous transition towards more sustainable waste practices and a scenario of resource misallocation.

Therefore, we investigate the impact of the intervention on per-capita sorted and unsorted waste collection. If higher costs are accompanied by a significant rise in differentiated waste and a simultaneous decline in undifferentiated waste, the cost increase may be interpreted as indicative of a shift towards a more sustainable, though initially more expensive, waste management system (Dijkgraaf and Gradus, 2003). In this case, public intervention appears to have successfully influenced both user behavior and service design in a more environmentally sound direction, thus at least partially justifying the higher expenditures.

Table 3: ATE — Separate/unsorted waste collection and types of waste costs

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.:	Per-capita sorted waste	Per-capita unsorted waste	C/T costs of sorted waste	C/T costs of unsorted waste	D/R costs of sorted waste	D/R costs of unsorted waste
Treatment(-1)	0.285***	-0.159***	0.0955**	-0.0990**	-0.0872	0.194***
	(0.0334)	(0.0193)	(0.0481)	(0.0390)	(0.0620)	(0.0423)
Observations	68,370	68,374	33,743	33,919	29,437	32,083
No. Municipalities	7,197	7,197	2,801	2,801	2,773	2,800
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Note. Estimation of the ATE based on equation 1. The dependent variable is: in columns 1 and 2, the (log of) municipal per-capita tonnes of separate and unsorted waste collection, respectively; in columns 3 and 4, the (log of) municipal per-capita collection and transportation costs for separate and unsorted waste collection, respectively; in column 5 and 6 the (log of) per-capita disposal and recycling costs for separate and unsorted waste collection, respectively. The variable *Treatment* is a dummy that takes the value 1 starting from the year of the beginning of the financed waste management project onward, and 0 otherwise. The analysis period spans from 2011 to 2023. All specifications include fixed effects for year and municipality, though the coefficients for these effects are not reported. We control for the resident population.

[7] Moreover, research indicates that increased waste tariffs may be more readily accepted by citizens if clearly linked to improved environmental outcomes and transparent pricing schemes (Carattini et al., 2018).

The estimation results are presented in Columns 1 and 2 of Table 3, where we regress the treatment variable on the (log of) per-capita separate and unsorted waste collection in Italian municipalities (hereafter *Per-capita sorted waste* and *Per-capita unsorted waste*, respectively). They indicate a significant increase in per-capita separate waste (about 28%) and a reduction in unsorted waste (about 16%) in the treated municipalities compared to the control group. The increase in separate waste, combined with the rise in its associated collection costs, can be interpreted as consistent with the policy goal of the EU cohesion funds: promoting recycling and separate waste collection may lead to higher costs, reflecting investment in a more sustainable — but also more expensive — waste management system. This result is in line with the findings by Bel and Warner (2008), which show that more advanced waste management systems often lead to higher per-unit costs due to service quality upgrades. Moreover, recent experimental evidence suggests that households respond not only to economic incentives but also to behavioral interventions: Bonan et al. (2025) find that norm-based feedback can significantly reduce unsorted waste, while making tariff structures more salient may paradoxically weaken intrinsic environmental motivations. These findings support the interpretation that the observed increase in sorted waste collection in treated municipalities may reflect both infrastructural upgrades and behavioral adaptation, even when marginal pricing signals remain weak. In contrast, the empirical findings related to unsorted waste are less intuitive. While a reduction in unsorted waste is observed, it is accompanied by an increase in the costs associated with its collection. This suggests that the intervention may have heterogeneous effects across different stages of the waste management cycle. Consequently, a more detailed analysis is required to identify where and how these additional costs are being generated. Indeed, changes in waste volumes — positive for sorted and negative for unsorted — are not sufficient on their own to fully account for the observed increase in the costs on waste services. This calls for further investigation into the mechanisms driving cost dynamics within the treated municipalities.

7.2.2 Disentangling cost dynamics across operational phases of waste management

In this perspective, we assess the impact of the intervention on the breakdown of total waste management costs — specifically for both separate and unsorted waste — across the two main operational phases of the waste management cycle: 1) Collection and transportation costs, which are primarily driven by logistics (e.g., frequency of collection rounds, territorial coverage, equipment, labor); 2) Disposal and recycling costs, which depend on the type of final treatment, the facilities involved, and the quality of waste separation. This distinction is critical, as each phase is governed by distinct cost structures and operational logic. Collection and transport costs are largely influenced by urban logistics factors, such as door-to-door collection schemes, population density, scheduling frequency, and the characteristics of the collection fleet and workforce. By contrast, disposal and recycling costs are more sensitive to the availability and type of treatment infrastructure, pricing schemes, and the compositional quality of the collected waste. In treated municipalities, the observed increase in per capita costs for separate waste, for instance, may be attributed to a shift toward more intensive collection systems — such as door-to-door collection, RFID tracking technologies, or increased collection frequency — which raise logistical costs but can yield environmental benefits. Conversely, even if the volume of unsorted waste declines, associated collection costs may not decrease proportionally. These costs could remain high due to structural rigidities or operational inefficiencies, or they could decrease when lower volumes reduce service demand. Similarly, trends in disposal and recycling costs can be ambivalent. An increase in the cost of disposing of residual waste might result from the use of more advanced but expensive treatment facilities, or from a deterioration in the quality of residual waste, which requires more complex processing (Ichinose, 2024). On the other hand, improvements in separate waste collection could potentially lower recycling costs — but only if the collected fraction is of sufficiently high quality to be processed efficiently and valorized in downstream markets.

In order to check how the receipt of Eu funds in waste management projects affects the costs of the two main operational phases of the waste management cycle, we regress the treatment variable on the (log of) per-capita collection and transportation costs for separate and unsorted waste collection (*C/T costs of sorted waste* and *C/T costs of unsorted waste*, respectively) and on the (log of) per-capita disposal and recycling costs for separate and unsorted waste collection (*D/R costs of sorted waste* and *D/R costs of unsorted waste*, respectively). Results are presented in Columns 3-6 Table 3. They reveal a nuanced pattern. In treated municipalities, the intervention leads to an increase in collection and transportation costs for sorted waste (about 9.5%), coupled with a decrease in the corresponding costs for unsorted waste (−9.9%). The first finding aligns with the initial hypothesis that the adoption of more intensive and service-rich systems — such as door-to-door collection or increased collection frequency — may drive up logistical expenditures for differentiated waste, reflecting a shift toward more sustainable, albeit costlier, practices. On the other hand, the reduction in collection and transport costs for unsorted waste is consistent with the observed decline in its volume: with fewer residuals to collect, the service becomes more efficient or less resource-intensive. However, this apparent efficiency gain is partially offset by an increase in disposal and recycling costs for unsorted waste (about 19.4%). This result may indicate that, although the overall quantity is lower, the residual waste that remains is of poorer quality — less easily processed and more expensive to treat (Guerrero et al., 2013). This aligns with the hypothesis that lower-quality unsorted fractions may require more complex or technologically advanced treatment solutions. Interestingly, the disposal and recycling costs for separate waste do not differ significantly between treated and control municipalities. This could suggest that, while collection systems for recyclable materials have become more sophisticated and costly, the downstream treatment infrastructure has not changed in ways that significantly affect costs. Alternatively, it may reflect that the quality of the separately collected materials, while sufficient to meet system thresholds, has not improved enough to generate substantial processing efficiencies or market value.

7.2.3 Assessing efficiency and technological change through productivity analysis

While the econometric evidence discussed above offers a detailed picture of how the intervention influenced waste volumes and associated costs, it does not allow us to disentangle whether the observed cost increases stem from genuine improvements in service technology or from inefficiencies in implementation. In other words, higher expenditures may result from productivity-enhancing innovations — such as better sorting, improved logistics, or upgraded equipment — or alternatively from operational rigidities, mismanagement, or poor coordination among service providers. To address this ambiguity, we estimate a non-parametric productivity frontier using the Malmquist index framework (a non-parametric tool used to measure changes in total factor productivity (TFP) over time) (Färe et al., 1994, Halkos and Aslanidis, 2024), comparing municipalities before and after the implementation of EU-funded waste management projects (lo Storto, 2021).[8] We estimate two separate efficiency frontiers: one for sorted (differentiated) waste and one for unsorted (residual) waste. In each case, we treat the per-inhabitant total cost of the service as the output and the corresponding per-capita volume of waste collected as the input. Since unsorted waste represents an undesirable input from an environmental perspective, we apply a monotonic transformation to reframe it as a desirable input, in accordance with the methodological requirements of the Malmquist index. This approach enables the estimation of efficiency changes over time while accounting for the joint treatment of desirable and undesirable inputs.

The analysis compares the relative efficiency of municipalities before and after the receipt of EU cohesion funds for waste management projects. The Malmquist index captures changes in productivity by comparing the distance of each observation to a best-practice frontier estimated for each period. Specifically, it measures how much the ratio of inputs to outputs has improved (or deteriorated) over time, decomposing the total factor productivity (TFPCH) into two components: technological change (shifts in the frontier itself - TECH) and efficiency change relative to the frontier (best-practice catch-up - BPC). This allows us to assess whether public investment has been associated

[8] We use the *malmq2* Stata routine.

with gains in technical efficiency, technological progress, or both.

Results from the Malmquist decomposition are presented in Table 4 for the two main collection types — differentiated (recyclable) and undifferentiated (residual) waste:

Table 4: Productivity analysis

Types of waste	TFPCH	TECH	BPC
Selected	1.144932	1.286237	0.892345
Unsorted	0.984849	1.036716	0.950187

Note. Estimation of non-parametric productivity frontier using the Malmquist index framework (Färe et al., 1994). We estimate two separate frontiers, one for selective waste collection (first row) and one for unsorted waste collection (second row). We use the (log) of the per-inhabitant cost and the per-capita volume of sorted waste respectively as output and input of the estimation of the frontier for selective waste collection. We use the (log) of the per-inhabitant cost and the (monotonic transformation of the) per-capita volume of unsorted waste respectively as output and input of the estimation of the frontier for unsorted waste collection. TFPCH refers to the total factor productivity; TECH refers to technological change; BPC refers to best-practice catch-up. Period 2011-2023.

The estimated TFPCH for differentiated waste exceeds 1.14, indicating a 14.5% increase in total productivity after the receipt of EU cohesion funds. This improvement is largely driven by substantial technological progress (TECH = 1.286), suggesting that the funded municipalities adopted significantly more advanced methods and infrastructure for recyclable waste collection. However, the BPC index is below 1 (0.892), meaning that — despite improvements in technology — municipalities moved away from the efficiency frontier on average. This may reflect transitional inefficiencies such as learning costs, delays in organizational adaptation, or suboptimal implementation following the receipt of funds. By contrast, the results for undifferentiated waste reveal a different dynamic. The overall productivity change (TFPCH = 0.985) is slightly negative, indicating no appreciable productivity gain in the period following the intervention. While there is still evidence of modest technological advancement (TECH = 1.037), the decline in best-practice catch-up (BPC = 0.950) suggests a small deterioration in relative efficiency.

These findings shed light on the cost dynamics observed in earlier analyses. The increase in collection costs for recyclable waste appears consistent with both the adoption of new technologies and a temporary decline in efficiency, possibly due to the complexity of operational change. In the case of residual waste, the combination of stable or declining volumes, limited technological improvement, and minor efficiency losses suggests that post-intervention cost increases are likely tied to the growing complexity and poorer composition of the remaining residual fraction, rather than to improvements in efficiency or service quality.

8 Conclusions

This paper provides novel empirical evidence on the fiscal effects of EU-funded waste management investments on local taxation in Italy. Overall, the results indicate that municipalities receiving cohesion funds experienced a significant increase in per-capita waste taxes compared to untreated ones. This effect emerges gradually in the years following the intervention and appears robust across specifications. It suggests that while European funding aims to modernize infrastructure and promote sustainability, it may also entail financial burdens for local governments and households, particularly when operational costs rise or when co-financing obligations are substantial (Bel and Fageda, 2010).

To unpack these dynamics, we analyzed the evolution of waste volumes and service costs. Our findings reveal that the intervention led to a notable expansion of separate waste collection and a simultaneous reduction in residual waste, consistent with the environmental objectives of EU policy. However, this transition was also accompanied by higher costs — both for differentiated and residual streams. A more detailed decomposition of costs along the waste management chain shows that while collection and transport costs increased for recyclable waste, they decreased for residual waste. At the same time, disposal costs for residual waste rose significantly, possibly due to lower quality of the residual fraction and structural inefficiencies in treatment (Dijkgraaf and Vollebergh, 2004).

In the final stage of the analysis, we estimated changes in total factor productivity (TFP) to assess whether cost increases reflected genuine efficiency gains or implementation frictions. Results from the Malmquist decomposition indicate significant technological progress in the management of recyclable waste, but also a temporary decline in relative efficiency. In the case of residual waste, modest technological gains were offset by efficiency losses, resulting in stable or slightly declining productivity. These findings suggest that while EU funding contributed to modernization and service innovation, its effectiveness in improving cost efficiency remains uneven — especially downstream.

Beyond its empirical findings, this paper offers new insights into how environmentally motivated public investments shape local fiscal outcomes. By linking EU-funded improvements in waste management to changes in cost structures, tax levels, and service productivity, it highlights the complex interplay between environmental ambitions and local budgetary constraints. In doing so, it sheds light on an often-overlooked dimension of the green transition — its implications for municipal finance and governance

— complementing recent work on the fiscal effects of environmental taxation and policy interventions (Meleddu et al., 2024, Stameski et al., 2024, Valente, 2023) and extending the debate on how intergovernmental transfers affect local decision-making (Baicker and Staiger, 2005, Gramlich, 1998).

From a policy perspective, this underlines the need to complement infrastructure funding with targeted support for institutional capacity and lifecycle cost planning, in order to maximize the return on investment and minimize regressive fiscal effects. Indeed, strategic infrastructure planning becomes crucial in scenarios where traditional disposal options, such as landfills, become scarce or unsustainable, thus raising the financial burden of alternative waste management solutions (Ichinose, 2024). At the same time, recent evidence suggests that pairing infrastructure investments with behavioral interventions — such as norm-based feedback or clearer communication of tariff structures — may enhance the effectiveness of environmental spending while mitigating public resistance to tax increases (Bonan et al., 2025). These softer tools may be especially valuable in economically vulnerable municipalities, where tariff hikes risk generating regressive effects and undermining support for the green transition.

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Appendix

A *Tables*

Table A.1: Descriptive statistics

	Obs	Mean	Std.Dev.	Min	Max
Waste tax	118384	101.121	138.112	0	34568.191
Pop	132376	7357.219	41715.091	0	2820219
Family members	122751	2.316	0.242	0	4.969
Per-capita income	121380	49713.072	11349.752	13940.785	203664.59
Councilor's education	136947	13.359	1.688	5	21
Councilor's age	136947	44.878	4.457	19.011	76.926
Female councilors	136930	0.259	0.13	0	0.857
Mayor's gender	136947	0.129	0.335	0	1
MAQI	129132	102.427	3.731	81.719	117.703

Note. Descriptive statistics of the variables. *waste tax* is the municipal waste tax amount divided by the resident population. *Pop* is the municipal resident population. *Family members* is calculated dividing the resident municipal population by the number of families in that municipality. *Per-capita income* is the municipal income divided by the resident population. *Councilor's education* is the average councilors education. To construct this variable we converted the qualitative data on the degrees held by councilors and mayors into years of education. Where data are not available, we exploit information about politicians' previous occupations to infer, where possible, the level of education required for such occupations. Therefore, we tab the measure of the city councilor's education as the follow: no education = 0 years; primary education = 5 years; lower secondary = 8 years; upper secondary = 13 years; university = 18 year and higher level = 21 years. *Councilor's age* is the average age of city council members. *Female councilors* is the share of female councilors in city council. *Mayor's gender* is a dummy that takes the value of 1 if the mayor is female and 0 otherwise. *MAQI* is the MAQI index. Period: 2007-2023.

Table A.2: Estimates robust to heterogeneity treatment effects

Dep. Var.: Waste tax	(1)	(2)
Treatment	0.265	0.246
	(0.069)	(0.069)
Observations	118,383	108,019
Municipality FE	Yes	Yes
Year FE	Yes	Yes
Controls	No	Yes
P-value F-test	0.53	0.41

Note. The table reports the ATE estimated according to the Sun and Abraham (2021)'s procedure. The dependent variable is the municipal per-capita waste tax (in real Euros). The variable *Treatment* is the average of all the post-treatment coefficients in the event study model estimated according to the Sun and Abraham (2021)'s procedure. The analysis period spans from 2007 to 2023. The specification in column 1 include fixed effects for year and municipality, though the coefficients for these effects are not reported. The specification in column 2 includes control variables as: the resident population in thousands (in natural log), the average household size, the per-capita income (in real Euros) (in natural log), the average level of education and the average age and the share of female and the gender of the mayor of municipal council, the MAQI. Standard errors are clustered at the municipality level and are presented in parentheses. The last row of the table report the P-value of the F-test whose null hypothesis is that all the pre-treatment coefficients are jointly equal to zero. Coefficient significance levels are indicated by * (10% significance), ** (5% significance), and *** (1% significance).

Table A.3: Mean difference tests

	Mean		t-test	
Variable	Treated	Control	t	p>t
Region dummies	6.908	6.830	0.410	0.680
Province dummies	49.173	48.203	0.810	0.416
(log) Population	1.278	1.202	1.490	0.137
(log) Female population	7.520	7.442	1.510	0.131
(log) Population holding a university-level qualification	5.815	5.733	1.430	0.154
Average household size	0.002	0.002	-0.350	0.726
Per-capita municipal total waste	383.320	385.980	-0.490	0.626
Standardized municipal income	0.084	0.072	0.160	0.874
(log) Municipal average age of resident population	3.798	3.798	0.000	0.998
Average education council level	14.140	14.135	0.110	0.910
Share of female councilors	0.217	0.214	1.090	0.274

Note. The Table shows the value of the t and the p-value of the covariates used for the logit estimation of the treatment status. The variables are: regional and provincial dummies, the resident population and resident female population size (log-transformed), population holding a university-level qualification (log-transformed), the average household size residing in the municipality, the per-capita municipal total waste, the standardized municipal income, the municipal average age of resident population (log-transformed), the average education level and the share of female councilors among city council members. We use the Stata command *pstest*.

Table A.4: ATE - Matched DiD

Dep. Var.: Waste taxes	(1)	(2)
Treatment(-1)	0.155*	0.176**
	(0.0842)	(0.0803)
Observations	57,441	53,095
No Municipalities	3,891	3,841
Municipality FE	Yes	Yes
Year FE	Yes	Yes
Controls	No	Yes

Note. Matched DiD estimation of the ATE based on equation 1. The dependent variable is the municipal per-capita waste tax (in real Euros). The variable *Treatment* is a dummy that takes the value 1 starting from the year of the beginning of the financed waste management project onward, and 0 otherwise. The analysis period spans from 2007 to 2023. The control variables include: the resident population in thousands (in natural log), the average household size, the per-capita income (in real Euros) (in natural log), the average level of education and the average age and the share of female and the gender of the mayor of municipal council, the MAQI. All specifications include fixed effects for year and municipality, though the coefficients for these effects are not reported. Standard errors are clustered at the municipality level and are presented in parentheses. Coefficient significance levels are indicated by * (10% significance), ** (5% significance), and *** (1% significance).

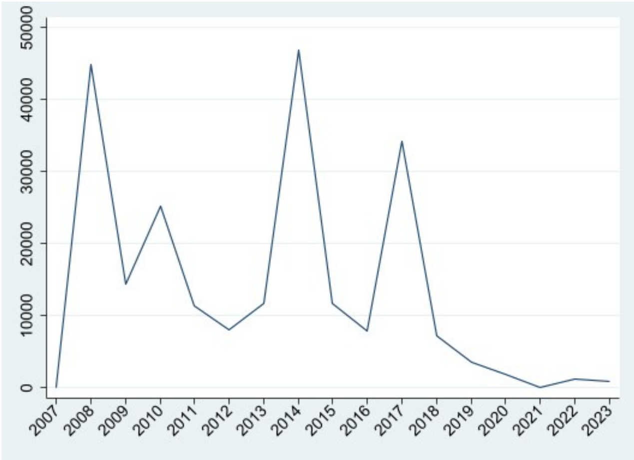
Table A.5: Descriptive statistics of costs

	Obs	Mean	Std.Dev.	Min	Max
Total waste cost	34596	141.242	74.634	17.77	1581.856
Total cost for separate waste	34467	49.518	30.73	0	590.116
Total cost for unsorted waste	34564	48.169	39.235	0	645.017

Note. Descriptive statistics of the waste cost variables. Period: 2011-2023.

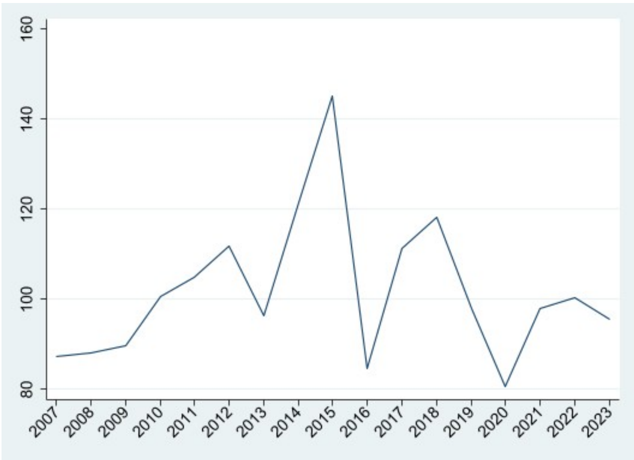
B *Figures*

Figure B.1: EU funding in waste management project per year of the beginning of the project



Note. The Graph shows the yearly distribution of the EU funding in waste management projects per year of the beginning of the project. Period: 2007-2023.

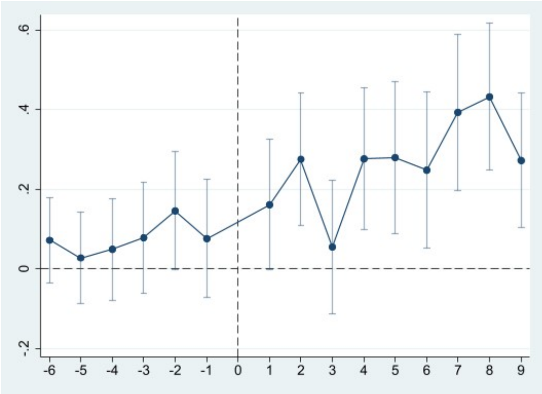
Figure B.2: Waste tax over years



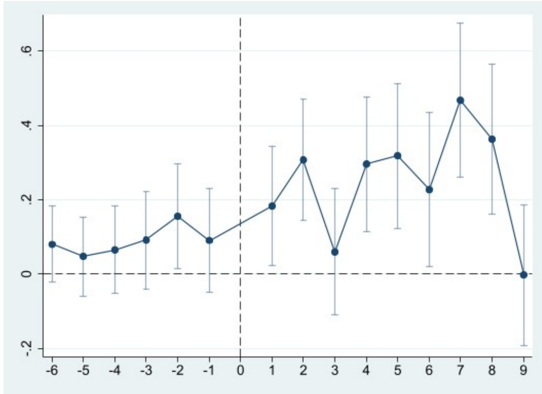
Note. The Graph shows the mean, over years, of the municipal per-capita waste tax. Time period: 2007-2023.

Figure B.3: Sun & Abraham estimates

(a) *Without controls*



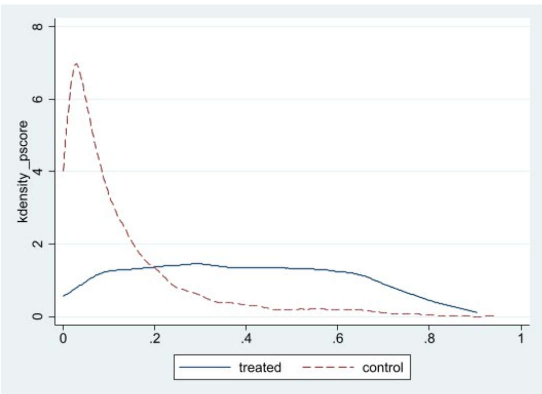
(b) *With controls*



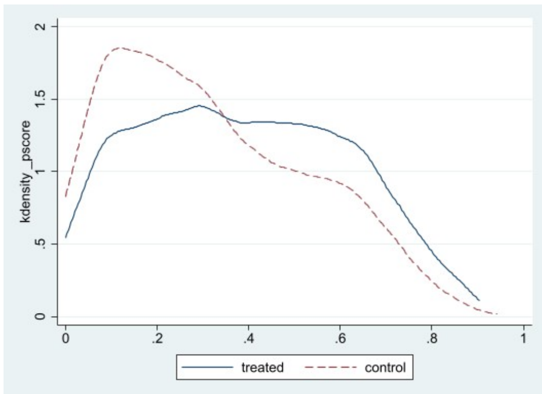
Note. The graphs report coefficients and confidence intervals estimated according to the Sun and Abraham (2021)'s procedure. The dependent variable is the municipal per-capita waste tax (in real Euros). Estimation in Graph B.3a controls only for time and municipality FE. Estimation in Grapf B.3b includes also for the resident population in thousands (in natural log), the average household size, the per-capita income (in real Euros) (in natural log), the average level of education and the average age and the share of female and the gender of the mayor of municipal council, the MAQI. Standard errors are clustered at the municipal level. The points represent the estimated coefficients; the confidence intervals are at 95%. The p-value of the F-test that all pre-treatment coefficients are jointly equal to 0 is 0.53 and 0.41 for the estimates in Graph B.3a and B.3b, respectively. Time period: 2007-2023.

Figure B.4: Propensity score graphs

(a) Propensity score *before* matching



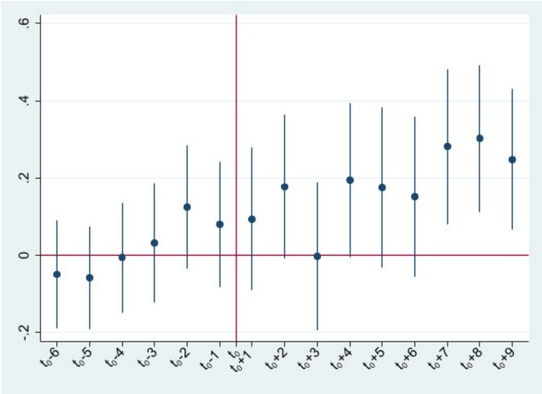
(b) Propensity score *after* matching



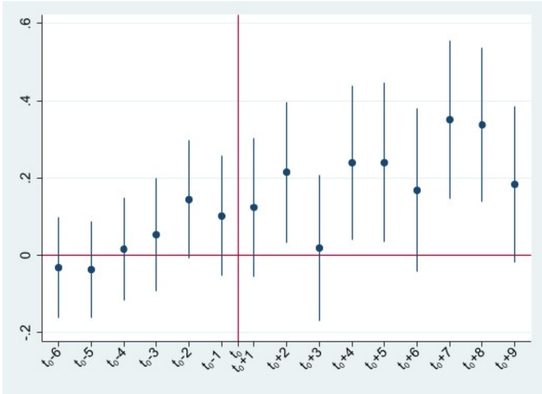
Note. Overlap in propensity scores in treated and matched samples of municipalities before and after the propensity score matching.

Figure B.5: Event study - Matched DiD

(a) Without control variables



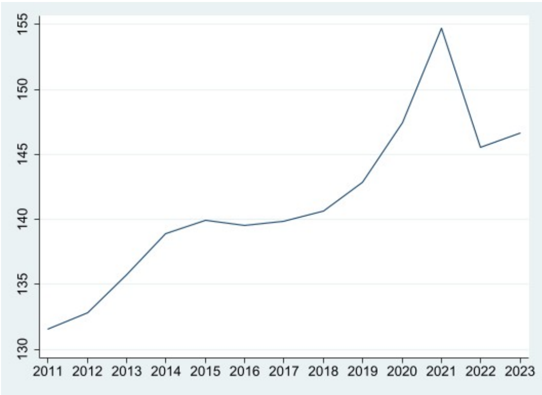
(b) With control variables



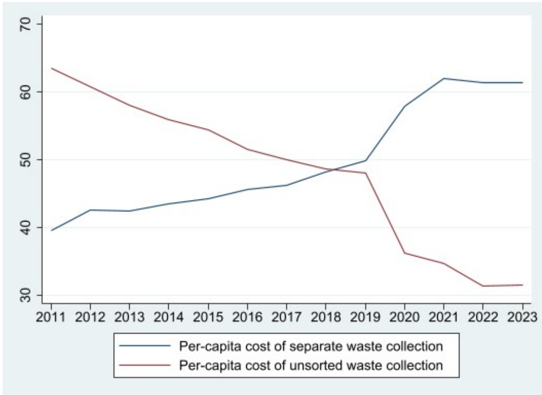
Note. The graphs show the coefficients and confidence intervals estimated based on equation 2. The dependent variable is the municipal per-capita waste tax (in real Euros). Estimation in Graph B.5a controls only for time and municipality FE. Estimation in Grapf B.5b includes also for the resident population in thousands (in natural log), the average household size, the per-capita income (in real Euros) (in natural log), the average level of education and the average age and the share of female and the gender of the mayor of municipal council, the MAQI. Standard errors are clustered at the municipal level. The points represent the estimated coefficients; the confidence intervals are at 95%. The p-value of the F-test that all pre-treatment coefficients are jointly equal to 0 is 0.27 and 0.25 for the estimates in Graph B.5a and B.5b, respectively. Time period: 2007-2023.

Figure B.6: Per-capita total costs of waste collection

(a) Per-capita total costs of waste collection



(b) Per-capita total costs of separate/unsorted waste collection



Note. The Graph B.6a shows the mean, over years, of the per-capita total cost of the municipal waste collection. It comprises the costs for separate and unsorted waste collection and other costs as street sweeping and washing costs and common costs. The Graph B.6b shows the mean, over years, of the per-capita total costs of separate and unsorted waste collection. Period: 2011-2023.