

# When Green Turns Costly: The Fiscal Fallout of EU Waste Management Funds in Italian Municipalities <sup>\*</sup>

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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 matched difference-in-differences approach on panel data from 2007 to 2023, we find that municipalities receiving EU cohesion funds experienced an increase in per-capita waste taxes, driven by rising service costs. A decomposition of these costs reveals that while separate waste collection expanded, the associated logistical and operational expenses increased sharply. Conversely, although the volume of unsorted waste declined, disposal costs rose, consistent with the interpretation that residual fractions are more complex and costly to process. To assess whether cost increases reflected inefficiency or technological progress, we estimate 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.

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

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# 1 Introduction

Municipal waste management represents a crucial sector for both environmental sustainability and local public finance. On the environmental side, the sector is central to the EU circular economy agenda, with binding recycling targets and directives reducing landfill use (European Commission, 2020). On the fiscal side, waste services are one of the largest items of local spending in Italy, with full cost recovery mandated by law and household charges equal to about 20% of municipal revenues (ISPRA, 2022, Messina et al., 2018). This dual relevance explains why scholars have long considered waste management a paradigmatic case for studying efficiency and distributional implications of local services (Abrate et al., 2014, Bel and Warner, 2008). Over the past two decades, EU Cohesion Policy has supported investments in waste management aimed at modernizing facilities, promoting recycling, and fostering the circular economy. In Italy, waste services are locally managed and financed by users, with costs fully reflected in municipal taxation under national rules. While EU-funded projects primarily aim to improve environmental and service outcomes, they can also have unintended fiscal effects. Whether these investments relieve or exacerbate household burdens—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 must set the waste tax to fully cover actual costs of collection, transport, treatment, and disposal, including overheads. The principle is that the waste tax is not a general revenue source but a fee for service, and cannot fund other municipal spending. This framework was established by Law No. 147/2013, Article 1, paragraphs 639–668, which introduced TARI within a broader local tax reform. Changes to the waste tax burden are permitted only when waste service costs vary.

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 citizens) by covering capital costs for infrastructure improvements—such as composting plants, sorting facilities, or smart collection systems—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 increase costs: many EU-funded projects expand service quality and scope, raising long-term operational expenditures (ISPRA, 2022); co-financing can strain local budgets in the absence of long-term planning; and meeting environmental targets may necessitate costly technological upgrades (Abrate

et al., 2014). Inefficiencies in implementation, delays, and mismatches between funded infrastructure and local capacity can further erode 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, compliance obligations, or fiscal stress—especially under limited administrative capacity—the net effect may be neutral or regressive. Understanding these trade-offs is essential to designing EU funding frameworks that promote both environmental sustainability and 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.

Italy represents a particularly appropriate setting to investigate the fiscal consequences of EU-funded waste management projects for two main reasons. First, it combines exceptional data availability with distinctive institutional features. The *OpenCoesione* database provides comprehensive project-level information on all EU Cohesion Policy interventions, while ISPRA reports detailed municipal-level data on waste management costs. In addition, Italian municipalities are legally required to set waste taxes to fully cover actual service costs, ensuring a direct and transparent link between expenditure dynamics and local taxation. Second, Italy is one of the largest beneficiaries of EU funds for environmental infrastructure, with marked regional heterogeneity in administrative capacity and institutional quality. This combination makes the country an informative case study to examine how external transfers affect local fiscal outcomes.

To assess the causal impact of EU funds on municipal waste taxation, we implement a matched Difference-in-Differences (DiD) strategy. Because municipalities receiving EU funding are disproportionately located in the Mezzogiorno and differ systematically from others, we first apply Propensity Score Matching (PSM) to construct a balanced sample of treated and untreated municipalities with comparable observable characteristics. Within this matched framework, we then estimate the average treatment effect of EU-funded projects using a staggered DiD design over 2007–2023.

The results consistently indicate that municipalities benefiting from EU-funded waste projects experienced a sizeable increase in per-capita waste taxes, in the order of 16–24% depending on the specification. Event-study estimates confirm the validity of the parallel trends assumption and reveal that the increase emerges from the second year after project initiation, reflecting implementation lags and co-financing obligations. Robustness checks using the HonestDiD sensitivity analysis and the Sun and Abraham (2021) estimator further validate the findings against concerns of pre-trends and negative weighting in

staggered adoption settings. Additional analyses corroborate these results. A continuous treatment specification shows a positive elasticity between funding intensity and tax levels, while heterogeneity tests highlight stronger effects in Northern municipalities, where administrative capacity and fiscal transparency are higher.

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 (+10.7%) and unsorted waste collection (+13.7%). 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 moderate productivity gains in the management of sorted waste, largely driven by technological advancement and accompanied by slight improvements in operational efficiency. In contrast, the performance of unsorted waste management remains broadly stable, with limited technological progress offset by 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). This literature has substantially advanced our understanding of environmental outcomes, service quality, and cost drivers. What remains largely unexplored, however, is the fiscal dimension: we know much less about how green investments affect the structure of local taxation. Our paper contributes to this gap by showing how EU-funded waste projects translate into higher municipal waste taxes, thereby linking environmental interventions to their local fiscal consequences.

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. The effect of earmarked EU environmental funds on user-charge-based services such as municipal waste remains largely unaddressed. By analyzing how Cohesion Policy resources in waste management affect the waste tax our paper extends this literature to a new and policy-relevant domain.

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). Yet, these works have predominantly focused on environmental performance and service design, while little is known about the unintended fiscal side-effects of green investments, particularly how they reshape local taxation structures and household burdens. Our paper contributes to this gap by documenting the fiscal fallout of EU-funded waste projects, identifying the transmission channel through increased service costs, and disentangling whether these increases reflect technological improvements or inefficiencies through a productivity analysis (using a Malmquist index, following Färe et al. (1994), Halkos and Aslanidis (2024), Io Storto (2021)).

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 estimation results and the robustness. Section 6 assesses the cost-transmission mechanism and 7 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 EU’s main tool for promoting sustainable development, reducing regional disparities, and improving quality of life. It operates through seven-year programming cycles with specific goals, instruments, and priorities, subject to the “n+2” rule to ensure timely fund absorption.

Our analysis covers 2007–2023, spanning three cycles (2007–2013, 2014–2020, 2021–2027). We start in 2007 because this marks the introduction of harmonized monitoring procedures and the effective intensification of environmental infrastructure funding. Investments during these periods were largely concentrated in less developed regions.<sup>1</sup>

Data on funded projects come from *OpenCoesione*.<sup>2</sup> The thematic area Waste includes landfill remediation and closure, expansion of separate collection systems, and upgrading of treatment and recycling facilities, in line with EU circular economy goals. The dataset

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<sup>1</sup>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).

<sup>2</sup>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.

spans all three programming periods and reports number of projects, spending, payments, geographic coverage, and intervention types.

Waste management projects are grouped into three categories: (1) separate collection, (2) remediation, and (3) infrastructure, further subdivided into public works, goods and services, grants, incentives, and equity participation. Most fall under public works or goods and services.

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 geographical pattern, with most funded municipalities located in the South and untreated ones concentrated in the North, underscores the need for a matching procedure to construct a suitable control group. Accordingly, our empirical strategy relies on propensity score matching to ensure comparability between treated and untreated municipalities before applying the treatment model.

## 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 such as 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 has been 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](#)).

Alongside the TARI, municipalities with appropriate measurement technologies can adopt the alternative pay-as-you-throw system (TARIP), introduced by Article 1, paragraph 668 of Law No. 147/2013. TARIP directly links the variable component of the tax to the actual quantity of unsorted waste produced by each user and has been increasingly adopted in Northern regions, particularly in Veneto ([Buccioli et al., 2025](#)). This system creates an additional source of heterogeneity in observed tax levels, as municipalities applying TARIP may follow different dynamics in response to changes in service costs. Moreover, TARIP often goes hand in hand with the diffusion of door-to-door collection schemes, which also affect both service costs and the resulting tariffs. While our empirical strategy mitigates confounding by matching municipalities on observable characteristics, it is important to acknowledge that part of the North–South divide in treatment exposure reflects differences in local tariff policies such as TARIP and in the organization of collection systems.

## 3 Data and variables

### 3.1 Dependent variable

AIDA (“Analisi Informatizzata Delle Aziende”) PA (“Pubblica Amministrazione”)<sup>3</sup> 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*). Importantly, in our analysis, we do not use AIDA PA data at the waste-management company level, but rather a municipality-level dataset that directly reports waste tax revenues for each municipality and year. Thus, our outcome, that reflects the actual tax revenues of each municipality, is not affected by aggregation issues arising when multiple municipalities are served by the same company.

### 3.2 Main regressor

The regressor of interest is based on EU funding for waste management projects received by Italian municipalities, as reported in the OpenCoesione database (1997–2023). For consistency, we restrict the sample to 2007–2023, excluding municipalities that received funds in 2000–2006. The measure includes EU transfers, national co-financing reimbursements, and regional or provincial allocations of cohesion funds.

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-varying municipal characteristics. First, population size (*Pop*) and average household size (*Family members*, computed as residents divided by families), which account for waste generation. We also include per-capita

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<sup>3</sup>AIDA PA is a database by Bureau van Dijk (a Moody’s group company) that contains economic and financial information on Italian public administrations.

municipal income (log, real € – *Per-capita income*).<sup>4</sup> Since the waste tax partly depends on property size and use, income is an important determinant. We further control for council composition: average education and age (*Councilors education*, *Councilors age*), share of female councilors (*Female councilors*), and mayor’s gender (*Mayor’s gender*).<sup>5</sup> These features can affect local tax policy. Finally, we include the Municipal Administrative Quality Index (*MAQI*) (Cerqua et al., 2025), which captures efficiency, transparency, and fiscal performance of local governments, and is particularly relevant in contexts of weak institutions (Cerqua and Pellegrini, 2018, Charron et al., 2014).<sup>6</sup>

## 4 Research design

In this section, we discuss the matched DiD design we use to examine the effects of the EU funds in waste management services on municipal waste taxation.

### 4.1 Matched DiD

In this study, we employ a matched DiD analysis (Borusyak and Jaravel, 2017, Goodman-Bacon, 2021) to 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. Indeed, 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 with a logit model predicting the likelihood of a municipality receiving EU funds for waste management projects (treatment) in the 2007–2023 period. Treated municipalities are then matched to controls with similar

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<sup>4</sup>Source: Italian Ministry of Finance (MEF), yearly declared income by municipality, including dependent and self-employment income, entrepreneurial income (ordinary and simplified accounting), and pensions.

<sup>5</sup>Source: Italian Ministry of Interior.

<sup>6</sup>*MAQI* is a composite index of three dimensions: bureaucratic capacity, quality of politicians, and economic/fiscal performance.

scores, ensuring comparable pre-treatment trends.<sup>7</sup>

The logit model includes covariates capturing regional/provincial, demographic, political, and economic characteristics: regional and provincial dummies; resident population and female population (log); share of residents with a university degree (log); average household size; per-capita municipal waste; standardized municipal income; average age of residents (log); average education of councilors; and share of female councilors.

To assess matching quality, we conduct two-sample t-tests on covariate means between treated and matched controls. Results (Table A.1, Appendix A) show no significant mean differences, indicating good balance. Overall diagnostics also support this: pseudo  $R^2 = 0.003$ , LR  $\chi^2$  test  $p = 0.590$ , Rubin's  $B = 12.0$ , and Rubin's  $R = 0.85$ .

Figure B.1 illustrates propensity score distributions before and after matching. In particular, Graph B.1b shows strong overlap between treated and controls, confirming improved comparability.

## 4.2 Statistics

After the PSM procedure, the final sample consists of 3,891 municipalities (2,581 controls and 1,310 treated). By matching treated municipalities with observationally similar untreated ones, the procedure avoids comparisons merely reflecting the North–South divide in Figure 1, and instead balances demographic, economic, and institutional characteristics. This mitigates concerns that estimated effects capture pre-existing regional disparities rather than EU-funded interventions.

Table A.2 (Appendix A) reports descriptive statistics for the matched sample. Figure B.2 (Appendix B) shows the yearly distribution of EU funding by project start date, with peaks in 2008, 2014, and 2017, and lows between 2019–2023.

Table A.3 (Appendix A) highlights heterogeneity in treatment. On average, treated municipalities received €24 million (2007–2023), but amounts range from < 100,000 to > 2.4 billion. The number of projects per municipality varies between 0 (i.e., municipalities received funds but none in the five macro-typologies: public works, services, goods/equipment, grants, incentives) and 25, with an average of 1.6. This indicates strong variation in both intensity and composition of interventions. Typology data are qualitative (presence of at least one project per type) but, combined with funding aggregates, help contextualize results: some municipalities host large infrastructure projects, others only small-scale interventions.

The same table shows project distribution by typology. Most are public works (0.32 projects per municipality on average, max 16). Services (0.08 on average, max 21) and goods/equipment (0.13, max 6) are less common, while grants and incentives are rare, and equity participation is absent. This aligns with the policy focus on infrastructure

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<sup>7</sup>Matching implemented via Stata command *psmatch2* (Leuven and Sianesi, 2003).

and operational investments in waste management.

Figure B.3 (Appendix B) plots per-capita waste taxes (2007–2023). Taxes increased gradually until 2011, then rose sharply during the TARES–TARI transition (2012–2015), and temporarily declined in 2020–2021 due to COVID-19 relief. Before causal analysis, it is crucial to check baseline comparability: a two-sample t-test shows no significant difference between North (€96,406) and South (€94,811), with a mean gap of €1,594 ( $p = 0.22$ ). Thus, despite the concentration of EU funds in the South, treated and untreated municipalities in the matched sample do not differ systematically in waste taxes at baseline, supporting the validity of the matched DiD strategy.

Finally, Table A.4 (Appendix A) presents the mean covariates for treatment and control municipalities (2007–2023).

### 4.3 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 matched 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 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), all in the matched sample. Municipalities are considered treated from the starting year of the funded project onward.

The equation that estimates the treatment effect of fund disbursement on citizens’ taxation between treated and control groups is as follows:

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

where  $Y_{it}$  represents the per-capita waste taxation (expressed in log) at year  $t$  in municipality  $i$ . The dummy  $Treatment_{it-1}$  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.  $\alpha_i$  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.  $\delta_t$  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.  $\epsilon_{it}$  is the error term. Under the parallel trend assumption, the coefficient  $\beta_1$  measures the average effect 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 matched 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:

$$Y_{it} = \sum_{k=-n}^{+n} \nu_k \cdot D_{it-k} + \alpha_i + \delta_t + X_{it} + \epsilon_{it} \quad (2)$$

where, as before,  $Y_{it}$  represent the (log o) per-capita taxation in municipality  $i$  at time  $t$ .  $D_{t-k}$  is the set of event-time dummies, which take the value of 1 for treated municipalities if the year  $t$  is the  $k$  period (from  $-n$  to  $+n$ ) 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,  $D_{t_0}$ ; the remaining coefficients  $\nu_t$  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 ( $\alpha_i$ ) and year ( $\delta_t$ ) fixed effects (FE); then, we include all the control variables listed above.  $\epsilon_{it}$  is the error term.

## 5 Results and Robustness

### 5.1 Matched DiD

Table 1 presents the estimation results based on equation 1. The dependent variable is the (Log of) municipal per-capita waste tax (in real €), 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 conventional 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 15.5% in the per-capita waste tax for treated

municipalities relative to the control group. Given the mean value of the waste tax is approximately 95€ (as shown in Table A.2), this implies an average increase of around 15€ 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 resident population, average household size, and log of per-capita income — slightly increases the estimated treatment effect to 17.5%. These variables capture demographic and socio-economic 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 not associated with waste taxes.

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. Despite the additional controls, the treatment effect remains robust and consistent in magnitude (16.4%).

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 15.9%, 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.

Table 1: Matched DiD

Dep. Var.:	(1)	(2)	(3)	(4)
	(Log)Waste taxes	(Log)Waste taxes	(Log)Waste taxes	(Log)Waste taxes
Treatment(-1)	0.155*	0.175**	0.164**	0.159**
	(0.0842)	(0.0796)	(0.0799)	(0.0801)
Pop		2.96e-06***	2.91e-06***	2.90e-06***
		(5.34e-07)	(5.33e-07)	(5.28e-07)
Family members		798.2***	818.5***	838.1***
		(202.1)	(201.8)	(206.2)
(Log) Per-capita income		-0.727	-0.652	-0.593
		(0.600)	(0.601)	(0.610)
Councilor's education			-0.0266	-0.0282
			(0.0264)	(0.0264)
Councilor's age			-0.0105	-0.0102
			(0.00735)	(0.00737)
Female councilors			0.346	0.269
			(0.237)	(0.242)
Mayor's gender			0.0363	0.0351
			(0.0911)	(0.0921)
MAQI				0.00918
				(0.00666)
Observations	57,441	53,528	53,528	53,095
No. Municipalities	3,891	3,891	3,891	3,841
Municipality FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

*Note.* Matched DiD estimates based on equation 1. The dependent variable is the (Log of) municipal per-capita waste tax (in real €). 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, the average household size, the per-capita income (in real €) (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).

## 5.2 Dynamic specification - Event study

In this section we estimate an event-study model as in eq. 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.

This choice reflects a balance between the need to test the parallel trends assumption and to capture the long-run dynamics of EU-funded waste investments. A 6-year pre-treatment window provides a sufficiently long horizon to verify the absence of differential trends before the intervention without fragmenting the sample and reducing statistical power. At the same time, extending the horizon up to 9 years after the treatment allows us to trace the medium- and long-run consequences of EU funding. This is particularly relevant in the context of waste management projects, whose fiscal effects often materialize with a delay due to construction times, procurement processes, and the gradual rise of operating and maintenance costs once new facilities become fully operational. Moreover, limiting the window to 9 years prevents estimates at the tails from being driven by few observations, ensuring more reliable inference. Overall, this specification provides both

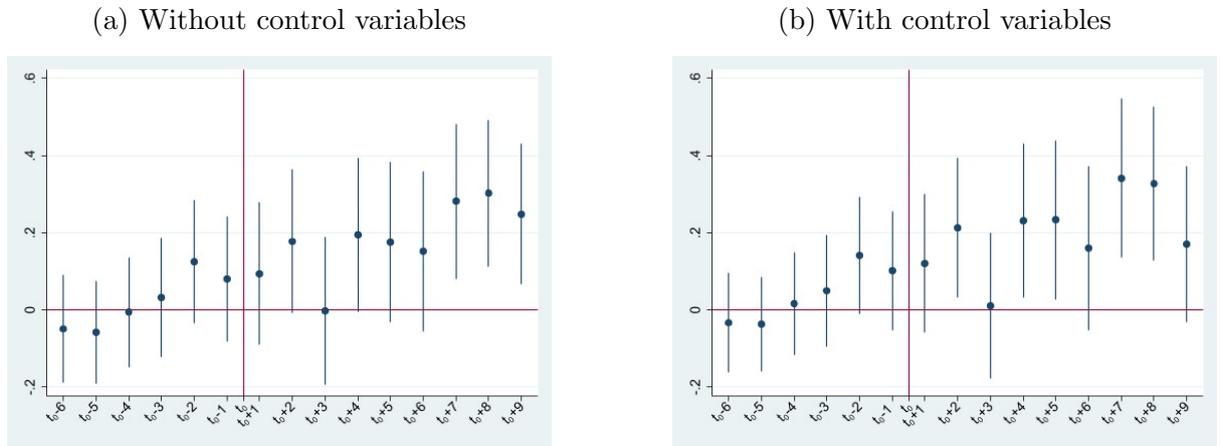
credibility to the identification strategy and a meaningful characterization of the temporal dynamics of investments in local waste services.

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*, *(Log) 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 0.27 for both the estimations shown in Graph 2a and Graph 2b. 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



*Note.* The graphs show the coefficients and confidence intervals estimated based on equation 2. The dependent variable is the (Log of) municipal per-capita waste tax (in real €). Estimation in Graph 2a controls only for time and municipality FE. Estimation in Graph 2b includes also for the resident population in thousands, the average household size, the per-capita income (in real € 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 0.27 and 0.27 for the estimates in Graph 2a and 2b, respectively. Time period: 2007-2023.

The significant increase in waste tax from  $t_0 + 2$  likely reflects the time lag between project approval and implementation: construction, procurement, and administrative procedures often delay operational and financial effects. Thus, higher tariffs coincide

with infrastructure becoming operational rather than with the funding year. Short-run increases may also stem from co-financing requirements or non-eligible expenses borne by municipalities, which explains the temporary rise at  $t_0 + 2$  and the insignificant effect at  $t_0 + 3$ , when such expenditures end. Year  $t_0 + 3$  can therefore be seen as a “transition year,” marked by administrative adjustments, temporary efficiency gains, or delays in activating new facilities.

From  $t_0 + 4$  onward, higher tax burdens may result from several factors. New infrastructure and services (e.g., recycling systems, treatment plants) increase operating and maintenance costs, which become visible once EU funding ends. Tariffs may also rise due to the internalization of environmental costs or broader waste-management reforms. Effectiveness depends on scale and complementarity: if upstream investments are not matched by downstream capacity (e.g., disposal or recycling markets), costs may grow faster than efficiency. Moreover, EU funding may have encouraged municipalities to expand services beyond what was fiscally feasible, creating rigidities and lock-ins that require higher tariffs, reinforced by the legal obligation (Law 147/2013) to fully cover costs via TARI. Finally, inefficiencies in project and resource management may also play a role, an issue further discussed in Section 6.

### 5.3 Sensitivity analysis to the possible violation of the parallel trend assumption

Although the joint F-test on the pre-treatment coefficients does not reject the null of parallel trends at conventional significance levels, the visual inspection of the event-study graphs suggests a mild upward trend in waste taxation even before the treatment. To address this concern and strengthen the credibility of our identification, we complement the baseline event-study estimates with the sensitivity analysis proposed by [Rambachan and Roth \(2023\)](#). 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.<sup>8</sup> By relaxing the identifying assumption in a transparent and parametric way, this methodology provides bounds on the treatment effect that remain valid even when pre-treatment dynamics indicate small but non-negligible differences between treated and control units. Hence, the

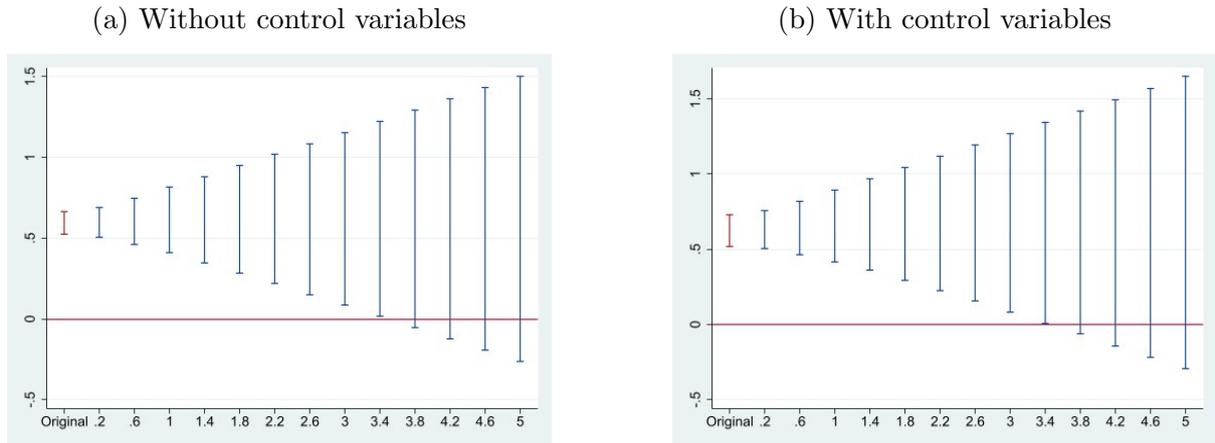
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<sup>8</sup>The `mvec()` specification in the *Honestdid* package defines a range of values for the sensitivity parameter  $M$ , which represents the degree to which the parallel trends assumption is allowed to be violated in the sensitivity analysis. 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](#)).

Honestdid framework offers a more credible assessment of the causal interpretation of our results.

The baseline estimate, in Figure 3, lies between 0.52 and 0.73. Importantly, the estimated effect remains positive and statistically different from zero under a wide range of relaxations of the identifying assumption. Even when allowing the pre-treatment trend to deviate substantially from strict parallelism (e.g.  $M = 2.6$  or  $M = 3.0$ ), the lower bound of the confidence interval remains positive (0.155 and 0.084, respectively). Only for very large deviations ( $M > 3.4$ ) do the bounds include zero, and only beyond  $M = 3.8$  does the lower bound become negative. This robustness is particularly relevant given that our outcome is in logs: an effect of 0.52–0.73 corresponds to an increase of roughly 68–107% in waste taxation, and even the most conservative credible estimates (e.g. 0.15 at  $M = 2.6$ ) still imply a double-digit percentage increase. Thus, the sensitivity analysis confirms that our main conclusion—EU-funded waste investments lead to higher local waste taxes—holds under a broad and realistic set of deviations from the parallel trend assumption, indicating that the causal interpretation of the estimated effects is robust.

Figure 3: Honestdid



*Note.* The Graph shows the result of the sensitivity analysis to violation of the parallel trend assumption for estimation of the (Log of) municipal per-capita waste tax (in real €) by using the *Honestdid* Stata command (Bravo et al., 2024). Panel 3a reports the results of the HonestDiD sensitivity analysis based on the event-study specification with only year and municipality fixed effects. Panel 3b extends the specification by including the full set of control variables (population, household size, (Log of) per-capita income, councilors’ characteristics, mayor’s gender, and MAQI). Time period: 2007-2023.

## 5.4 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 \(2021\)](#), on the matched sample of municipalities, which is designed for linear models and remains robust in the presence of heterogeneous treatment effects. The results are presented in [Figure 4](#), with the estimated average effect reported in [Table 2](#).

Table 2: Estimates robust to heterogeneity treatment effects

	(1)	(2)
Dep. Var.:	(Log)Waste taxes	(Log)Waste taxes
Treatment	0.222*** (0.071)	0.204*** (0.071)
Observations	61,131	56,686
Municipality FE	Yes	Yes
Year FE	Yes	Yes
Controls	No	Yes
P-value F-test	0.39	0.40

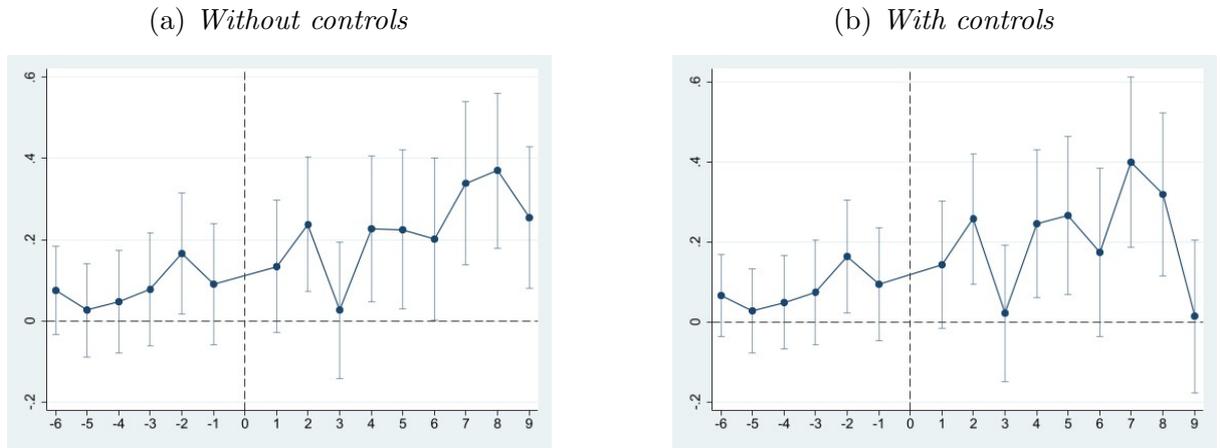
*Note.* The table reports the estimates according to the [Sun and Abraham \(2021\)](#)'s procedure. The dependent variable is the (Log of) municipal per-capita waste tax (in real €). The variable *Treatment* is the average of all the post-treatment coefficients in the event study model estimated according 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, the average household size, the per-capita income (in real €) (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).

[Graph 4a](#) shows estimation including municipality and year FE while estimation in [Graph 4b](#) 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 treat-

ment 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 0.39 in Graph 4a and 0.40 in Graph 4b, 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 matched 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.

Figure 4: Sun & Abraham estimates



*Note.* The graphs report coefficients and confidence intervals estimated according to the [Sun and Abraham \(2021\)](#)’s procedure. The dependent variable is the (Log of) municipal per-capita waste tax (in real €). Estimation in Graph 4a controls only for time and municipality FE. Estimation in Graph 4b includes also for the resident population in thousands, the average household size, the per-capita income (in real € 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 0.39 and 0.40 for the estimates in Graph 4a and 4b, respectively. Time period: 2007-2023.

## 5.5 Continuous treatment and dose–response effects

While the baseline analysis considered treatment as a binary condition, municipalities differ substantially in the intensity of EU funding they receive. To capture this heterogeneity, we re-estimate the model using a continuous treatment variable defined as the (Log of) EU funds received for waste management investments, which is set to zero until the first year of disbursement (hereafter *Treatment intensity*). This specification enables us to assess whether the relationship between EU funding and waste taxation scales with the amount of resources transferred. Results are in Table 3.

The estimates indicate a positive and significant elasticity of 0.015 (Column 1). In practical terms, a 10% increase in funding intensity leads, on average, to a 0.15% increase

in per-capita waste taxes in the following year.

These results highlight a dose–response relationship: municipalities receiving larger transfers exhibit stronger increases in local waste taxation, whereas smaller projects are associated with more modest changes. The elasticity is quantitatively limited, implying that even substantial variations in funding translate into relatively contained adjustments in taxation. This pattern suggests that local tariff dynamics reflect not only the inflow of external resources but also structural and institutional factors—such as pre-existing infrastructure, cost recovery mechanisms, and administrative capacity—that mediate the extent to which EU funding affects municipal tax levels.

Table 3: Matched Continuous DiD

	(1)	(2)
Dep. Var.:	(Log)Waste taxes	(Log)Waste taxes
(Log) Treatment intensity(-1)	0.0153** (0.00647)	0.0148** (0.00618)
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 Estimates based on equation 1. The dependent variable is the (Log of) municipal per-capita waste tax (in real €). The variable *Treatment intensity* is the (Log of) EU funds received for waste management investments, and 0 otherwise. The analysis period spans from 2007 to 2023. The control variables include: the resident population in thousands, the average household size, the per-capita income (in real €) (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 MAQL. 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).

## 5.6 Regional heterogeneity of treatment effects

A possible concern is that the relationship between Cohesion Policy funds and local waste taxation may not be homogeneous across Italian regions. In particular, previous literature has highlighted persistent problems of waste misreporting and illegal dumping in Southern Italy (e.g., [Savona et al. \(2018\)](#)), which may lead to biased cost calculations and weaker links between actual service costs and local taxation. If such mechanisms are indeed present, the way in which EU funds translate into per-capita tax levels may vary between Northern and Southern regions.

To test this hypothesis, we extend our baseline specification by allowing the effect of EU funds to differ between Northern and Southern municipalities. Concretely, we interact the treatment variable with a dummy for Southern regions (the regions of Mezzogiorno, namely Abruzzo, Molise, Campania, Apulia, Basilicata, Calabria, Sicily, and Sardinia),

so that the estimated coefficient for the treatment captures the impact in the North and Center, while the sum of the treatment and interaction coefficients represents the corresponding effect in the South. In this way, we can directly assess whether the relationship between EU funds and local waste taxation is homogeneous across the country or whether it differs between macro-areas.

Table 4: Matched DiD - Nord vs South

	(1)	(2)
Dep. Var.:	(Log)Waste taxes	(Log)Waste taxes
Treatment(-1)	1.007*** (0.255)	0.812*** (0.253)
South*Treatment(-1)	-0.877*** (0.264)	-0.674*** (0.261)
Observations	57,441	53,095
No. Municipalities	3,891	3,841
Municipality FE	Yes	Yes
Year FE	Yes	Yes
Controls	Yes	Yes

*Note.* Matched DiD Estimates based on equation 1. The dependent variable is the (Log of) municipal per-capita waste tax (in real €). 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 variable *South\*Treatment* is the interaction term between the dummy variable *South* that takes the value of 1 in the regions of Mezzogiorno, namely Abruzzo, Molise, Campania, Apulia, Basilicata, Calabria, Sicily, Sardinia and 0 otherwise, and the *Treatment* variable. In the estimated equation we also add the dummy *South* that is dropped because of collinearity. The analysis period spans from 2007 to 2023. The control variables include: the resident population in thousands, the average household size, the per-capita income (in real €) (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 4 reports the results. The coefficient on  $Treatment_{it-1}$  is positive and significant, indicating that in Northern municipalities EU funds are associated with a sizable increase in per-capita waste tax, consistent with our baseline findings. By contrast, the interaction term is negative and significant, implying that the effect in Southern municipalities is reduced to roughly 0.138 ( $=0.812 - 0.674$ ).

This result has two important implications. First, the results indicate that the relationship between EU funds and per-capita taxation is not the same across Italian regions: the impact of EU funds on waste taxation differs sharply between North and South. Second, the weaker effect in the South suggests that EU funding does not translate into higher local taxation with the same intensity as in the North. One plausible interpretation is that, in the presence of widespread underreporting of waste flows and reliance on illegal disposal channels, additional resources may not be fully reflected in service costs, and hence in municipal tariffs. In other words, while in the North EU funds are more

transparently incorporated into the cost structure of waste management (and ultimately passed on to households through taxation), in the South institutional weaknesses and data inconsistencies tend to attenuate this transmission channel.

Taken together, these findings reinforce our main result by showing that the effect of EU funds on local taxation is not only positive on average, but also heterogeneous across space: it is stronger in the more institutionally capable regions of the North, and weaker where misreporting and inefficiencies are more prevalent. This pattern is consistent with the broader literature on the role of administrative capacity and institutional quality in shaping the local impact of Cohesion Policy (Becker et al., 2013, Crescenzi and Giua, 2020).

## 6 The Cost Transmission Mechanism: from Public Funding to Waste Taxation

Our analysis shows that EU-funded waste projects raise per-capita waste taxes in treated municipalities, consistent with evidence that such investments often increase short-term service costs, especially when they expand separate collection systems with high fixed and operating expenses (Bel and Warner, 2008, Dijkgraaf and Gradus, 2004). Other studies, however, highlight possible medium- to long-run savings from economies of scale and efficiency gains (Bartolacci et al., 2019, Bel and Fageda, 2010). These mixed outcomes stress the role of implementation capacity, service design, and complementary infrastructure.

The main transmission channel is higher operating and maintenance costs from system upgrades—new recycling facilities, smart collection, or expanded waste streams—which, while improving service quality, entail recurring expenses not covered by one-off EU grants (Dijkgraaf and Vollebergh, 2004, Ichinose, 2024, ISPRA, 2022). This burden is heavier for small or fiscally constrained municipalities (Dijkgraaf and Vollebergh, 2004). In Italy, Article 1, paragraph 654, of Law No. 147/2013 requires full cost recovery through the TARI, so any cost increase—maintenance, staff, or compliance—is passed on to taxpayers (Carattini et al., 2018). Co-financing and pre-financing add further pressure, while inefficiencies or poor alignment with local needs may produce overinvestment or underused assets.

Overall, these mechanisms suggest that the fiscal impact of EU funds depends on administrative capacity and institutional quality (Cerqua and Pellegrini, 2018, Rodríguez-Pose and Garcilazo, 2018), and that weak lifecycle planning can increase the burden on local taxpayers.

## 6.1 Empirical evidence

We use municipal-level data on urban hygiene expenditures from ISPRA, available for 2011–2023 (the first year of reporting). The dataset provides aggregate figures and a breakdown of per-capita spending (real €) on differentiated and unsorted waste.

Table A.5 (Appendix A) reports descriptive statistics. The *Total waste cost* covers collection and transportation (sorted and unsorted), treatment and recycling, street cleaning, overhead (administration, utilities, insurance), capital outlays (equipment, infrastructure), and ancillary services (e.g., awareness campaigns). Sorted and unsorted waste account for most expenditures: on average, 35% for sorted waste and 37% for unsorted, with the rest reflecting shared or ancillary services. We define *Total costs for separate waste* as the expenditure for collection, transport, and processing of sorted waste, and *Total costs for unsorted waste* as all expenses linked to residual waste, including logistics and downstream treatment.

Figure B.4 (Appendix B) shows annual trends in per-capita spending: Panel B.4a reports overall expenditures, while Panel B.4b disaggregates sorted and unsorted waste.

To analyze cost pass-through, we estimate eq. 1, regressing treatment on the log of total municipal waste costs (real €), using the matched sample. Controls include resident population, per-capita income (log), total per-capita waste, and household size, plus municipality and year fixed effects. The latter capture structural cost drivers such as the presence or distance of disposal/recycling facilities. Results (Column 1, Table 5) show that EU-funded projects raise per-capita total waste costs in treated municipalities by 2.7% relative to controls.

Table 5: Matched DiD — Costs of waste management service

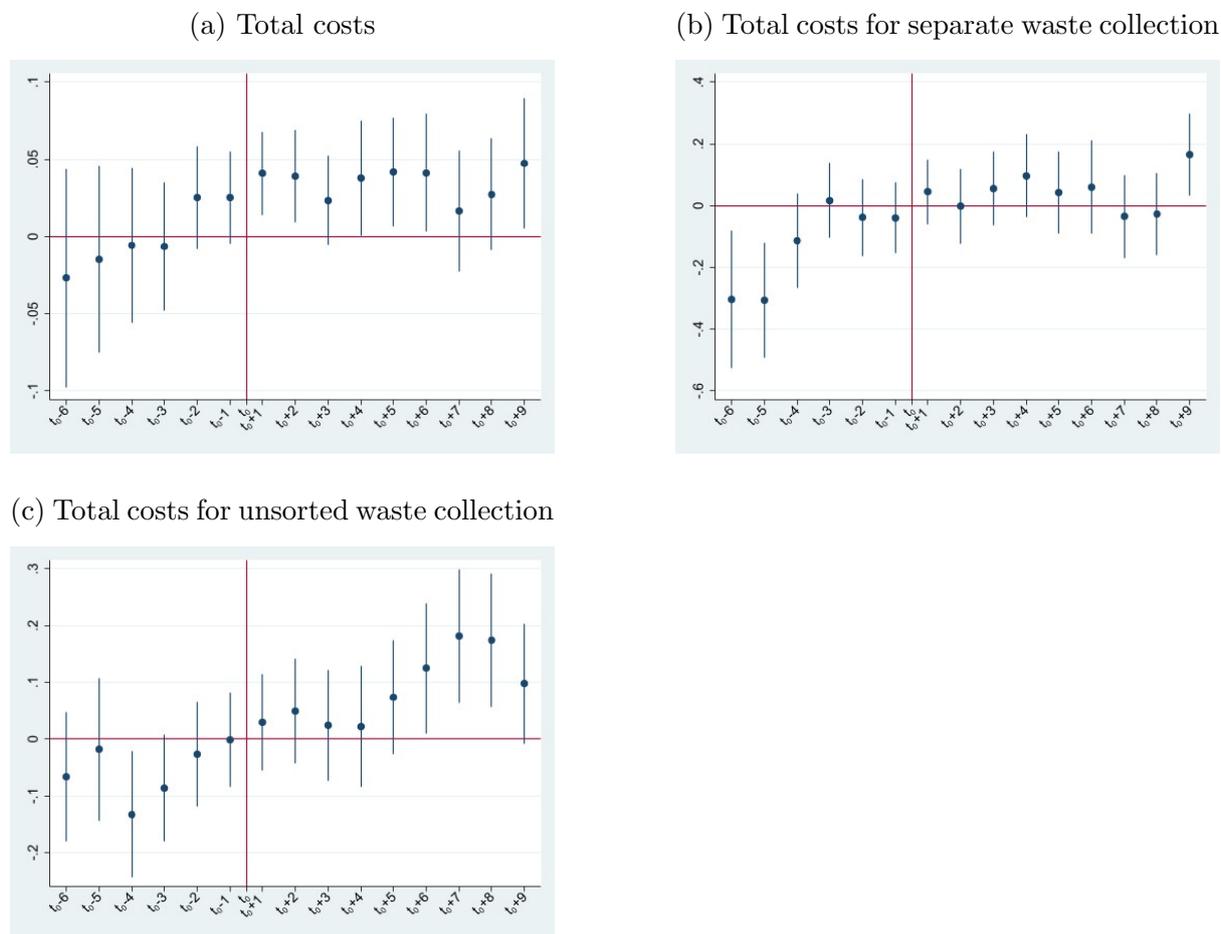
	(1)	(2)	(3)
Dep. Var.:	(Log)Total waste cost	(Log)Total cost for separate waste	(Log)Total cost for unsorted waste
Treatment(-1)	0.0276** (0.0129)	0.107** (0.0514)	0.137*** (0.0370)
Observations	14,855	14,763	14,822
No. Municipalities	1,210	1,210	1,210
Municipality FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes

*Note.* Estimation of the ATE based on equation 1. The dependent variable is 1) the (Log of) municipal per-inhabitant total cost of waste management service (in real €) in Column 1; 2) the (Log of) municipal per-inhabitant total cost of separate waste collection (in real €) in Column 2; 3) the (Log of) municipal per-inhabitant total cost of unsorted waste collection (in real €) 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 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).

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 5. Here, the estimated treatment coefficient shows a positive and highly

significant sign, meaning that the EU waste funds increased of 10.7% and 13.7% the costs for separate and unsorted collection, respectively, in the treatment group of municipalities than in the control group.<sup>9</sup>

Figure 5: Event study - Costs



*Note.* The Graphs show the coefficients and confidence intervals estimated based on equation 2. The dependent variable is: the (Log of) municipal total cost of waste collection (in real €) per inhabitant in Graph 5a, the (Log of) municipal total cost of separate waste collection (in real €) per inhabitant in Graph 5b, the (Log of) municipal total cost of unsorted waste collection (in real €) per inhabitant in Graph 5c. Estimations include the municipal resident population and the per-capita municipal income (in log), the total amount of waste collected (Panel 5a)/the total amount of separate waste collected (Panel 5b)/the total amount of unsorted waste collected (Panel 5c) 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 0.55, 0.02 and 0.11 for the estimates in Graph 5a, 5b and 5c, respectively. Time period: 2011-2023.

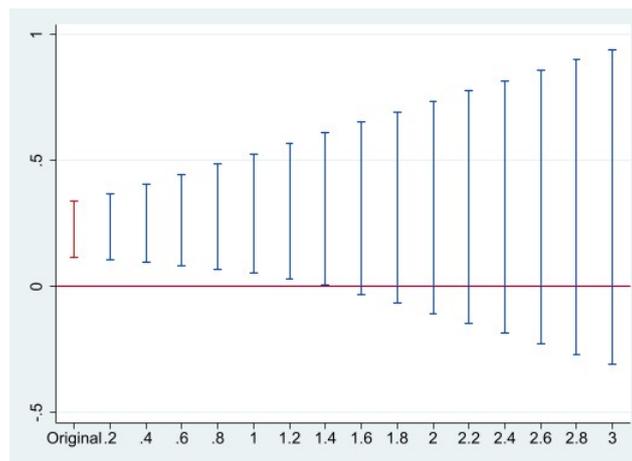
<sup>9</sup>A noteworthy aspect of the cost analysis is that the estimated impact on total expenditure (+2.7%) is smaller than for separate and unsorted waste (+10.7% and +13.7%). This discrepancy reflects measurement and compositional factors rather than inconsistency. First, total waste costs include items beyond the two streams—about 28% of spending relates to street cleaning, overheads, capital outlays, or awareness campaigns—that are largely unaffected by EU funds and thus dilute the aggregate effect. Second, total, separate, and unsorted costs come from distinct regressions with different controls (e.g., per-capita tonnes of total vs. stream-specific waste), so coefficients are not directly additive. Finally, cost components within each stream may move in opposite directions—for example, unsorted collection and transport costs fall while disposal costs rise—muting the net effect at the aggregate level..

To assess for the validity of the matched DiD methodology for this analysis, in Figure 5 we provide evidence of the dynamic model estimation as in eq. 2. First of all, while the parallel trend assumption is satisfied in Graphs 5a and 5c (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 0.55 and 0.11, respectively), it falls for estimation in Graph 5b (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 0.02).

The violation of the parallel trend assumption in estimation as in Graph 5b raises concerns about the causal interpretation of the treatment effect. To address this, as before, 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.

The result of the sensitivity analysis of separate waste collection costs is in Figure 6.

Figure 6: Honestdid



*Note.* The Graph shows the result of the sensitivity analysis to violation of the parallel trend assumption for estimation of (Log of) total cost of separate waste collection (in real €) by using the *Honestdid* Stata command (Bravo et al., 2024). The results of the HonestDiD sensitivity analysis based on the event-study specification as in Panel 5b with year and municipality fixed effects and the municipal resident population and the per-capita municipal income (in log), the total amount of separate waste collected in the municipality, the average household size. Period: 2011-2023.

When no deviation from parallel trends is allowed ( $M = 0$ ), the estimated treatment effect is statistically significant, with a 95% CI of [0.115; 0.340].<sup>10</sup> As  $M$  increases—permitting greater deviations from strict parallelism—confidence intervals widen. For moderate relaxations ( $M = 0.6$  or  $M = 1.0$ ), effects remain positive and significant, with lower bounds of 0.084 and 0.054, respectively. Even at  $M = 1.4$ , the interval includes only

<sup>10</sup>The sensitivity analysis relies on an event-study with six pre-treatment and nine post-treatment coefficients, consistent with the dynamic specification.

small but positive values (lower bound 0.004).

At  $M = 1.6$ , however, the lower bound falls below zero ( $-0.030$ ), implying that under stronger violations the effect may be null or negative. In sum, the HonestDiD results show that the estimated increase in (Log) per-capita differentiated collection costs is robust to moderate deviations from parallel trends but loses credibility under severe ones ( $M \geq 1.6$ ). This suggests that causal interpretation is reliable as long as pre-treatment dynamics between treated and controls were not too divergent, while very large divergences—less plausible given the data—would undermine inference.

## 6.2 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 (Dijkgraaf 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.<sup>11</sup> 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.

### 6.2.1 Waste management system improvement or inefficiencies?

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

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<sup>11</sup>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).

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 6: Matched DiD — Separate/unsorted waste collection

	(1)	(2)
Dep. Var.:	(Log)Per-capita sorted waste	(Log)Per-capita unsorted waste
Treatment(-1)	0.237*** (0.0366)	-0.117*** (0.0214)
Observations	30,531	30,534
No. Municipalities	3,361	3,361
Municipality FE	Yes	Yes
Year FE	Yes	Yes
Controls	Yes	Yes

*Note.* Matched DiD Estimates 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. 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. All specifications include fixed effects for year and municipality, though the coefficients for these effects are not reported. We control for the resident population. The analysis period spans from 2011 to 2023.

Table 6 shows that EU funding increases per-capita sorted waste by about 24% and reduces unsorted waste by 12% in treated municipalities. The rise in sorted waste, together with higher collection costs, aligns with the policy goal of promoting recycling: investments foster more sustainable but also more expensive systems, consistent with Bel and Warner (2008). Behavioral responses may also matter: Bonan et al. (2025) show that norm-based feedback reduces unsorted waste, while tariff salience can weaken intrinsic motivations.

By contrast, the decline in unsorted waste is coupled with higher collection costs, suggesting heterogeneous effects across stages of the waste cycle. Volume changes alone cannot explain the observed cost dynamics, calling for further analysis of the mechanisms driving these increases.

### 6.2.2 Disentangling cost dynamics across operational phases of waste management

We next decompose total waste management costs into two phases: (1) collection and transportation, mainly driven by logistics (e.g., frequency, coverage, equipment, labor), and (2) disposal and recycling, which depend on treatment facilities, pricing, and waste quality.

In treated municipalities, higher per-capita costs for sorted waste likely reflect more intensive systems—door-to-door schemes, RFID tracking, or more frequent rounds—that improve sustainability but raise logistical expenses. For unsorted waste, costs may not fall in line with reduced volumes, due to structural rigidities or inefficiencies.

Disposal and recycling trends are also mixed. Residual waste becomes more expensive to process when advanced facilities are used or when its quality deteriorates, requiring

complex treatments (Ichinose, 2024). By contrast, better quality in separately collected waste could reduce recycling costs, but only if the fraction is sufficiently pure to be efficiently processed and valorized.

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 (in real €) 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 (in real €) 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 1-4 Table 7.

Table 7: Matched DiD — Types of waste costs

Dep. Var.:	(1) (Log)C/T costs of sorted waste	(2) (Log)C/T costs of unsorted waste	(3) (Log)D/R costs of sorted waste	(4) (Log)D/R costs of unsorted waste
Treatment(-1)	0.137*** (0.0524)	-0.0969** (0.0437)	-0.0671 (0.0693)	0.181*** (0.0475)
Observations	14,434	14,448	12,099	13,710
No. Municipalities	1,211	1,211	1,195	1,211
Municipality FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes

*Note.* Matched DiD Estimates based on equation 1. The dependent variable is: in Columns 1 and 2, the (Log of) municipal per-capita collection and transportation costs for separate and unsorted waste collection (in real €), respectively; in Columns 3 and 4 the (Log of) per-capita disposal and recycling costs for separate and unsorted waste collection (in real €), 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. All specifications include fixed effects for year and municipality, though the coefficients for these effects are not reported. We control for the resident population. The analysis period spans from 2011 to 2023.

The results reveal a nuanced pattern. In treated municipalities, collection and transport costs for sorted waste rise by about 13.7%, consistent with the adoption of more service-intensive systems (e.g., door-to-door schemes, higher frequency), which promote sustainability but increase logistics costs. Conversely, unsorted collection and transport costs fall by −9.7%, reflecting lower residual volumes and greater efficiency.

However, this efficiency gain is offset by a sharp increase in disposal and recycling costs for unsorted waste (+18.1%). This suggests that although residual quantities decline, the remaining waste is of poorer quality and more expensive to process (Guerrero et al., 2013). Two complementary mechanisms likely explain this: (i) EU-funded projects accelerate the shift toward higher separate collection rates, so residuals quickly reach a composition dominated by harder-to-treat fractions, raising processing costs; (ii) investments create rigidities in treatment capacity and long-term contracts, so shrinking residual volumes increase unit costs by spreading fixed costs over fewer tons. Since the dataset lacks direct indicators of waste quality, this interpretation should be seen as a plausible mechanism, consistent with the evidence and literature (Guerrero et al., 2013, Ichinose, 2024), rather than as a causal estimate.

Interestingly, disposal and recycling costs for sorted waste show no significant differences between treated and control municipalities. This may indicate that, while collection systems for recyclables have become more sophisticated and costly, downstream treatment

infrastructure has not changed in ways that significantly affect costs. Alternatively, the quality of separately collected materials may have improved only modestly, insufficient to yield substantial processing efficiencies or market value.

### 6.2.3 Assessing efficiency and technological change through productivity analysis

While the econometric evidence above details how the intervention influenced waste volumes and costs, it does not clarify whether higher expenditures reflect genuine technological improvements or inefficiencies in implementation. In other words, rising costs may stem from productivity-enhancing innovations — such as better sorting, improved logistics, or upgraded equipment — or from rigidities, mismanagement, or poor coordination. To address this ambiguity, we estimate a non-parametric productivity frontier using the Malmquist index framework (a tool to measure changes in total factor productivity, TFP, over time) (Färe et al., 1994, Halkos and Aslanidis, 2024), comparing municipalities before and after EU-funded waste management projects (Io Storto, 2021).<sup>12</sup>

Methodologically, the Malmquist productivity index is appropriate for several reasons. First, it requires only input and output quantities rather than detailed price data, typically unavailable in municipal waste management. Second, unlike static DEA measures, it traces productivity changes over time and decomposes them into efficiency change (catch-up to the frontier) and technological progress (frontier shifts). This decomposition directly addresses our research question by distinguishing transitional inefficiencies from genuine technological improvements. Third, compared to parametric approaches such as stochastic frontier analysis, the Malmquist index avoids strong assumptions on functional form and error distributions, which are difficult to validate given the heterogeneity of Italian municipalities. For these reasons, the Malmquist approach represents a robust tool to assess the impact of EU-funded waste projects on service efficiency.

We estimate two separate efficiency frontiers: one for sorted (differentiated) waste and one for unsorted (residual) waste. In each case, the per-inhabitant total cost of the service is treated as the output, and the corresponding per-capita waste volume as the input. Since unsorted waste represents an undesirable input environmentally, we apply a monotonic transformation to reframe it as desirable, consistent with Malmquist requirements. This enables efficiency measurement over time while accounting for both desirable and undesirable inputs.

The analysis compares municipal efficiency before and after receipt of EU cohesion funds. The Malmquist index captures productivity changes by measuring the distance of each observation from a best-practice frontier estimated for each period. Specifically, total factor productivity change (TFPCH) is decomposed into technological change

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<sup>12</sup>We use the *malmq2* Stata routine.

(TECH, frontier shifts) and efficiency change (BPC, best-practice catch-up). This allows us to assess whether public investment is associated with gains in efficiency, technological progress, or both.

Results are reported in Table 8 for differentiated (recyclable) and undifferentiated (residual) waste. For differentiated waste, the estimated TFPCH is 1.079, indicating a 7.9% productivity increase after EU funding. This improvement is mainly driven by technological progress (TECH = 1.077), while the BPC index is slightly above unity (1.004), suggesting that municipalities not only adopted more advanced methods and infrastructure but also marginally improved their relative efficiency.

By contrast, results for undifferentiated waste show essentially no productivity gain: TFPCH = 0.994, very close to unity. Although modest technological progress is observed (TECH = 1.015), the decline in relative efficiency (BPC = 0.987) points to a slight deterioration in best-practice catch-up.

Table 8: Productivity analysis

Types of waste	TFPCH	TECH	BPC
Selected	1.079151	1.076859	1.003547
Unsorted	0.99358	1.014699	0.986942

*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.

These findings help explain the cost dynamics observed earlier. The increase in collection costs for recyclable waste reflects both the adoption of new technologies and a temporary decline in efficiency linked to the complexity of operational change. For residual waste, stable or falling volumes combined with limited technological progress and minor efficiency losses suggest that post-intervention cost increases stem from the poorer composition and greater complexity of the residual fraction, rather than from genuine efficiency gains.

These findings help explain the cost dynamics observed earlier. The increase in collection costs for recyclable waste reflects the adoption of new technologies, accompanied by a slight efficiency gain, consistent with a gradual but genuine improvement in produc-

tivity. For residual waste, stable or falling volumes combined with limited technological progress and minor efficiency losses suggest that post-intervention cost increases stem from the poorer composition and greater complexity of the residual fraction, rather than from genuine efficiency gains.

Overall, these results clarify the apparent paradox from the cost analysis. Although declining residual volumes would suggest lower disposal costs, the opposite occurs: the remaining fraction is more expensive to process as it concentrates less recoverable materials requiring advanced treatment. In other words, quantity reductions are offset by quality deterioration. Consistent with the productivity analysis, recyclable waste shows moderate technological progress with slight efficiency gains, while residual waste registers no productivity improvements and a modest decline in best-practice catch-up. Thus, rising disposal costs do not signal inconsistency but reflect structural rigidities and transitional inefficiencies in residual waste treatment.

## 7 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 moderate technological progress in the management of recyclable waste, accompanied by slight efficiency gains.

In the case of residual waste, modest technological improvements were offset by efficiency losses, resulting in essentially stable 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: Mean difference tests

Variable	Mean		t	t-test p>t
	Treated	Control		
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.2: Descriptive statistics

	Obs	Mean	Std.Dev.	Min	Max
Waste tax	61131	95.582	159.511	0	34568.196
Pop	66147	7584.872	51261.878	0.036	2873494
Family members	62037	.002	0	0.001	0.004
Per-capita income	61806	46427.39	11693.721	13940.785	147724.11
Councilor's education	66128	13.869	1.578	5	21
Councilor's age	66128	44.437	4.254	19.934	76.447
Female councilors	66128	0.237	0.132	0	0.727
Mayor's gender	66128	0.104	0.305	0	1
MAQI	65297	102.495	3.838	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.3: Variation in EU waste management funds across treated municipalities

	Obs	Mean	Std.Dev.	Min	Max
Total funding received (real €)	1,310	24,000,000	121,000,000	83,811	2,450,000,000
N. projects per municipality	1,310	1.59	1.37	0	25
N. projects in Public works	3,891	0.325	0.748	0	16
N. projects in Services	3,891	0.082	0.475	0	21
N. projects in Goods and equipment	3,891	0.128	0.381	0	6
N. projects in Grants	3,891	0.001	0.032	0	1
N. projects in Incentives	3,891	0.001	0.023	0	1
N. projects in Equity participation	3,891	0.000	0.000	0	0

Note. The table reports summary statistics for municipalities that received at least one EU-funded waste management project. Funding amounts (*Total funding received* (€)) are expressed in current € and aggregated over the period 2007–2023. *N. projects per municipality* counts the number of projects per municipality across all typologies (works, services, goods, grants, incentives, equity) over the period 2007–2023.

Table A.4: Mean of covariate in treatment and control group

Covariates	Treatment group	Control group
Pop	10214.508	6250.187
Family members	0.002	0.002
Per-capita income	38763.308	50333.846
Councilor's education	14.138	13.732
Councilor's age	43.704	44.809
Female councilors	0.217	0.247
Mayor's gender	0.075	0.118
MAQI	102.372	102.559

Note. The table shows the mean of the covariates in the treatment and control group of municipalities in the matched sample. *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.

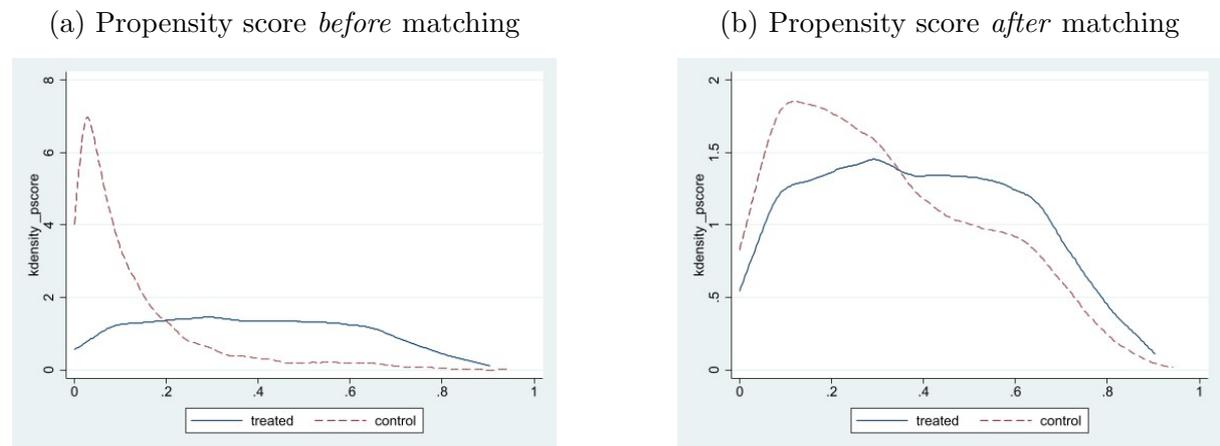
Table A.5: Descriptive statistics of costs

	Obs	Mean	Std.Dev.	Min	Max
Total waste cost	25616	148.647	72.993	14.555	1340.236
Total cost for separate waste	25409	50.802	34.324	0	609.224
Total cost for unsorted waste	25483	53.684	42.116	0	565.317

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

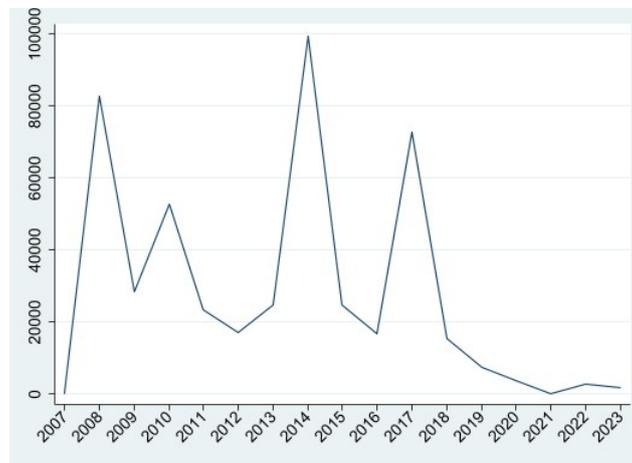
## B Figures

Figure B.1: Propensity score graphs



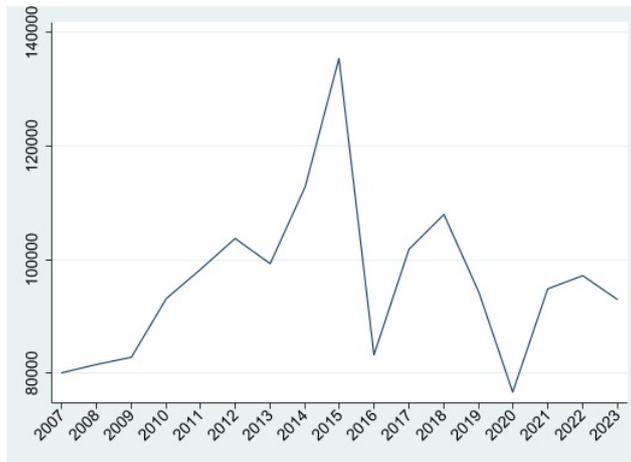
*Note.* Overlap in propensity scores in treated and matched samples of municipalities before and after the propensity score matching.

Figure B.2: 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.

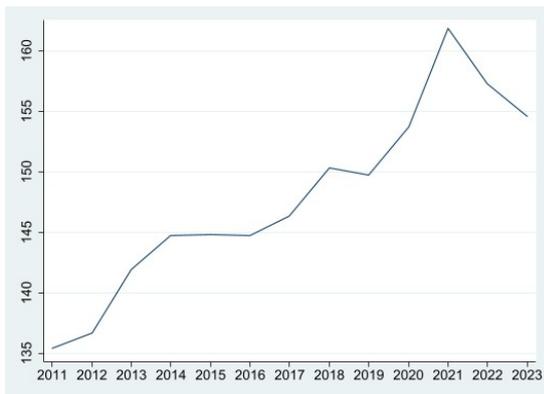
Figure B.3: Waste tax over years



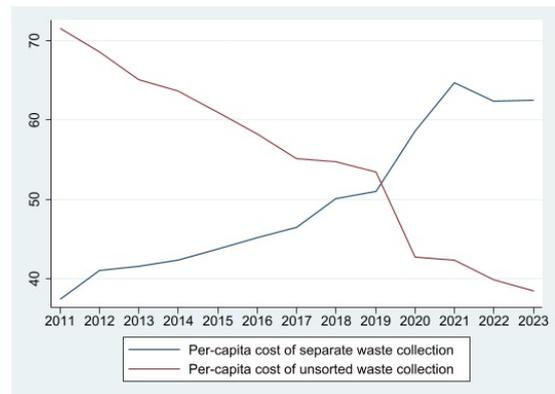
Note. The Graph shows the mean, over years, of the municipal per-capita waste tax. Time period: 2007-2023.

Figure B.4: 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.4a 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.4b shows the mean, over years, of the per-capita total costs of separate and unsorted waste collection. Period: 2011-2023.