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ABSTRACT

The paper investigates the link between organized crime and municipal solid waste management costs. Using a panel dataset of 7069 Italian municipalities in the 2015–19 period, we find that organized crime operating in the environmental sector is associated with an increase in waste management costs. The effect of organized crime is stronger in macro-regions where organized crime is historically rooted. These results are established after controlling for municipality fixed effects as well as national and regional trends in the total cost of service delivery. This paper contributes to a deeper understanding of local service costs and provides implications for policymakers.

KEYWORDS

municipal waste management; organized crime; cost-efficiency; regional heterogeneity

INTRODUCTION

The infiltration of criminal organizations into the environmental sector worldwide is a phenomenon of worrying extension because it causes damage to the environment and public health, with consequent significant social costs. The investigations undertaken by the judicial authorities have always highlighted a strong connection between criminal organizations and environmental crimes, especially in the waste sector. In Italy, this problem is deeply felt, so much so that the neologism 'Ecomafia', which indicates organized criminal groups that cause damage to the environment, has been coined to refer to this phenomenon. The growth of illegal activities in the environmental sector is mainly due to the profitability of the related businesses. In an interception carried out during an investigation, a waste trafficker said: 'garbage has become a mine … it has become gold' (Direzione Investigativa Antimafia (DIA), 2019). In the 2015–19 period, environmental crimes in the waste cycle grew by 90%, involved 371 criminal clans and generated an estimated turnover of €19.9 billion in 2019 alone (Legambiente, 2020). Municipal solid waste (MSW) management is a particularly attractive business for the Ecomafia. In this sector, organized criminal associations no longer settle for the disposal service, but have also extended their activities to the other phases of the waste cycle, from collection to transport and treatment, also by influencing public procurement (Legambiente, 2020).

The criminal penetration in the waste management sector has been favoured by a lack of disposal capacities and deficiencies in differentiated and undifferentiated waste collection, driven primarily by policy failures (Mazzanti & Montini, 2014). The plant deficit and the poor management of the waste system have favoured the proliferation of criminal infiltrations throughout the cycle. Italy, for instance, does not have sufficient, adequate and homogeneously distributed disposal and treatment plants throughout the national territory (DIA, 2019). In this scenario, the supply of illegal services proliferates especially for the management of unsorted waste, because no special skills or high-tech plants and machinery are required for the transformation of waste materials. Finally, the infiltration of crime has been facilitated by the corruption of some public officials and politicians, who allowed the MSW service to be entrusted to companies linked to crime, or authorized the start-up or expansion of non-compliant plants. Often these are criminal organizations operating behind the front of legal companies, holding authorized disposal facilities and landfills and, more

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generally, all the requirements to participate in public tenders (DIA, 2019).

All these conditions hinder the development of competition: organized crime gets procurement contracts for the MSW collection and disposal through intimidation to the detriment of competitors, but also through agreements and relationships with representatives of local institutions and entrepreneurs. When, on the other hand, the criminal intervention takes place in the execution phase of the contractual relationship, the Ecomafia requires the companies awarded the contracts for the MSW collection and disposal to hire extra-labour by subcontracting to companies related to criminal organizations (DIA, 2019). Moreover, several police investigations have found the existence of fake documents that over-certified the quantities of waste disposed, in order to induce the municipality to pay undue amounts to the disposal company. Again, fake invoicing is facilitated by the corruption of subjects in charge of monitoring the authorization process along the waste cycle.

Therefore, the influence of criminal organizations on the MSW management entails inefficiencies that could lead to an increase in the total costs of delivering the service. Starting from this hypothesis, this paper verifies whether and to what extent the infiltration of organized crime in the MSW cycle affects the costs of the service, and if so, how heterogenous the impact of organized crime on waste management is across regions.

The study of MSW costs is important because they translate to service tariffs applied to citizens, and their distortion could therefore cause a loss of social welfare. This analysis is also useful from a regulatory perspective since in 2020 (through the 2018 Budget Law) the Italian government has delegated the Regulatory Authority for Energy, Networks and the Environment (ARERA) to carry out regulatory and supervisory activities in the waste sector. As a result, the ARERA issued Resolution No. 443/2019, which introduced a national tariff method that has standardized the economic terms for the MSW management service throughout Italy and made information to users reliable and transparent for the first time. The new method determined the waste management service tariff (TARI) to be applied to users for the first time in 2020–21 and is aimed at ensuring the full coverage of the service costs (see Appendix A in the supplemental data online for details). Since the new tariff will have to be cost-reflective, it is very important to understand how criminal organizations affect MSW management costs.

Cost-efficiency in the waste management sector is an extremely relevant issue for both public managers and citizens. In fact, while the former must achieve a balanced budget through efficient MSW service delivery, the latter bear the cost of service through the waste management service tariff. Despite the importance of this issue, to the best of our knowledge this is the first study to examine the link between waste service cost and organized crime. The scientific literature has focused more generally on the analysis of the cost drivers of the service, and empirical studies have been mainly carried out in the United States

and in Spain (Bel & Costas, 2006; Bel & Mur, 2009; Bel & Fageda, 2010; Callan & Thomas, 2001; Dubin & Navarro, 1988; Fernández-Aracil et al., 2018). Furthermore, the empirical literature has devoted much more attention to demand-side aspects than to supply-side issues such as the cost of MSW (Abrate et al., 2014; Callan & Thomas, 2001). Data limitations may have also hindered costs studies such as this (Bohm et al., 2010).

This work intends to fill this gap by delving into whether and how the presence of the Ecomafia influences the costs of the waste management service. Furthermore, it takes into consideration a much larger sample of municipalities than those present in the previous literature. The empirical analysis is carried out by using a sample of 7069 Italian municipalities, accounting for 93% of the national population. We perform our analyses at both the national and regional levels. This latter focus is necessary because of the profound differences in socio-economic development between Northern and Southern Italian regions. Our panel data fixed effects estimates support our claim that organized environmental crime makes the costs of delivering the MSW service significantly higher. Though this effect is statistically significant when using the full national sample, it is more pronounced in the South and on the Islands, where Italian criminal organizations are traditionally rooted. We establish these results after controlling for national and regional trends in the total costs. The results are also robust to the use of alternative measures of environmental crimes and the use of the random effects estimator.

The rest of the paper is organized as follows. We next provide a literature review of MSW costs analysis. We then describe the sample and present the methodological approach. We report descriptive statistics and the empirical results for both the full sample and the regional subsamples. Finally, we offer conclusions and policy implications.

LITERATURE REVIEW

The first studies to have analysed the MSW costs are those by Hirsch (1965), Stevens (1978) and Dubin and Navarro (1988). They consider several factors influencing MSW costs in the United States, such as wage, frequency and quantity of waste collection, market structure, population density, and climatic conditions. The results showed that service frequency and wage levels significantly influence costs, while climatic conditions are not significant. These studies also showed the presence of economies of scale in the municipal waste industry and indirectly suggested competition for the market as the best solution for maximizing the benefits of such economies of scale. Reeves and Barrow (2000) drew the same conclusion by analysing the MSW costs for a sample of 88 municipalities in Ireland.

The models specified in these studies were characterized by a low level of sophistication with important limitations due to the lack of data. However, in the early 2000s, the second generation of studies developed more accurate

analyses, thanks to higher quality data and more sophisticated econometric techniques. Callan and Thomas (2001) developed a multiple-output cost structure to model the relationship between recycling and disposal activities. Using a sample of 110 US municipalities, the authors studied the total MSW management costs as a function of quantities disposed and recycled, population density, frequency of collection, mode of production (private/public), availability of landfills, recycling facility and public funding. The empirical findings showed that the quantities and the collection frequency significantly affect total costs, for both general waste and recycling. The authors also found that public officials could obtain cost savings by offering joint disposal and recycling services, thanks to the existence of economies of scope.

Dijkgraaf and Gradus (2003) used a sample of 120 municipalities in the Netherlands. Their findings revealed that contracting out is associated with lower costs. The determinants of waste collection costs are also studied by Bel and Costas (2006), who used a sample of 186 municipalities of Catalonia observed in 2000. The results showed that waste quantities, percentage of waste separation, frequency of service, wage levels and an index of tourism activity all have positive and statistically significant relationships with costs, while population density and market organization do not show significant relations to costs. A further study by Bel and Mur (2009), conducted on 56 municipalities in the Aragon region, did not find a significant relationship between population density and service costs, while total population and salaries affect costs positively. Subsequently, Bel and Fageda (2010) used a sample of 65 municipalities in Galicia. This study revealed that private management, the level of tourist activity and the municipal population size have positive effects on costs, but found no significant relationship between costs and the percentage of separated waste, at least for municipalities with fewer than 50,000 inhabitants. Bel et al. (2014) have also examined 85 small Spanish municipalities to determine whether they can reduce the costs of the MSW service through cooperation. The results suggested that cooperating municipalities can achieve economies of scale and thus incur lower costs than they would by opting for direct private contracting. Fernández-Aracil et al. (2018), again referring to the Spanish context, found positive relations between waste collection costs and a set of factors such as separated collection, wages, coastal versus interior location, location in tourist versus non-tourist areas, and the population size of the municipality. In contrast, costs are found to decline with higher population density and the choice of indirect providing.

Moving to the Italian context, Antonioli and Filippini (2002) conducted a study on a sample of 30 waste collection and disposal companies. The results showed that the most efficient structure for managing waste collection services is generally the franchised monopoly, rather than side-by-side competition. Besides, they found that most waste collection companies do not operate at the optimal production scale: accordingly, the authors suggest that

cost savings could be achieved through joint operations of small municipalities.

Abrate et al. (2014) considered a sample of 529 Italian municipalities providing services for waste disposal and recycling. They showed that both disposal and recycling activities exhibit constant returns to scale and economies of scope. However, as the size of the municipality increases, economies of scope increase but diseconomies of scale start arising.

By using a sample of 67 Italian municipalities, Greco et al. (2015) provided evidence of economies of scale but did not find systematic evidence that the private collection service is associated with lower costs. In a more recent study, the same authors have focused on tourism's impact on solid waste collection costs by analysing a sample of 68 Italian municipalities (Greco et al., 2018).

As for the impact of organized crime on MSW service costs, to the best of our knowledge, no studies have been conducted in the past. However, assuming that organized crime in the MSW sector operates through the corruption of public officials, we can consider several studies that have dealt with the effects of corruption on the efficiency of public services in general. There is a vast literature exploring the relationship between corruption and welfare, measured by a whole range of indicators, such as gross domestic product (GDP), total factor productivity growth, investment rates and self-rated subjective well-being (Del Monte & Papagni, 2007; Fiorino et al., 2012; Lisciandra & Millemaci, 2017; Welsch, 2008). Most of the literature agrees that corruption could constitute an impediment to public performance and decrease efficiency (Abrate et al., 2015; Choi & Thum, 2004; Hanousek & Kochanova, 2016). Indeed, corruption implies price distortion due to rent-seeking, increases transaction costs and causes misallocation of production factors, which results in inefficient investment (Giordano & Lopez-Garcia, 2018; O'Toole & Tarp, 2014). Some authors show how corrupt bureaucrats may also preserve monopolies by hindering firm entry, supporting inefficient firms, discouraging innovation and allocating the resources away from their most productive uses (Campos et al., 2010; Murphy et al., 1993). Some studies based on production theory explain how corruption deflects managerial efforts, resulting in weak incentives and low levels of efficiency (Dal Bó & Rossi, 2007; Yan & Oum, 2014). These theories fit the Italian municipal waste sector (where judicial evidence has brought to light numerous episodes of corruption) and suggest that also in this sector, corruption leads to a decrease in efficiency and an increase in service management costs.

Other studies have analysed some aspects of crime in the waste cycle, such as the criminal enforcement in the waste context (Almer & Goeschl, 2015; D'Amato et al., 2018), the environmental consequences of illegal landfills (Vaverková et al., 2019), the determinants of waste crime (Dell'Anno et al., 2019) and the impact of organized crime on the waste disposed (D'Amato et al., 2015). However, none of these studies analysed the relationship between crime and service costs.

METHOD

Sample

The sample of this study consists of 7069 Italian municipalities, which cumulatively account for 93% of the Italian population, observed in the 2015–19 period. The distribution of the sample by population size and geographical area is reported in Table 1.

Model

The general model of the total cost function for the MSW service delivery proposed by extant empirical studies (Bel & Costas, 2006; Callan & Thomas, 2001; Fernández-Aracil et al., 2018) can be represented as:

$$Total\_cost = f(Output, P, X) \tag{1}$$

where P is the vector of input prices; and X is a vector of characteristics affecting the MSW service delivery. Starting from this basic function, we develop the following panel data model in which the total costs of the MSW management service ($Total\_cost$) is regressed against our explanatory variable measuring the organized environmental crime in the province (Env_crime) and controls that take into account some characteristics affecting the MSW service delivery (see the next subsection for details on the operationalization of the variables):

$$
\begin{aligned}
Total\_cost_{it} = {} & \beta_0 + \beta_1 Env\_crime_{it} + \beta_2 Output_{it} \\
& + \beta_3 Density_{it} + \beta_4 Waste\_sorted_{it} \\
& + \beta_5 Plant_{it} + \beta_6 Coop_{it} + \beta_7 Tourism_{it} \\
& + \gamma_{it} + \theta_i + \delta_t + u_{it}
\end{aligned}
\tag{2}
$$

where γ_{it} are a set of regional (NUTS-2) trends (obtained by interacting year and regional dummies); θ_i are municipality fixed effects (FE); δ_t are year FE; and u_{it} is the error term. As in Stevens (1978) and Domberger et al. (1986), we use a double logarithmic form. We estimate a FE model to reduce unobservable time-invariant heterogeneity at the municipality level. In addition, we include also regional trends and year FE in order to absorb time-varying factors that are unobserved but common to all municipalities at the regional and national level, respectively. Among these factors, the dynamics of input prices, that is, labour and capital costs, deserves a particular

mention. Since our unit of observation is the municipality, we cannot estimate labour and capital costs by using accounting information as it is commonly done when dealing with firm level data. However, since time variations in labour and capital costs occur mainly at the national and/or regional level, national and regional trends should absorb them and circumvent the omitted variable bias.

Our claim that organized crime in the environmental sector is conducive to higher total costs of MSW service delivery is supported if β_1 is positive and statistically significant.

Variables

The dependent variable is $Total\_cost$, measured as the logarithm of the yearly total cost of collection, transportation and disposal (or treatment) of the MSW at the municipality level (Callan & Thomas, 2001; Dijkgraaf & Gradus, 2003). The variable is sourced from the National Waste Register maintained by the Italian Institute for Environmental Protection and Research (ISPRA).

The explanatory variable is Env_crime, that is, the logarithm of people yearly arrested (per 100,000 inhabitants plus 1) for crimes against the environment committed by organized criminal associations at the province (NUTS-3) level. The indicator is sourced from the 'National Observatory Environment and Legality' maintained by Legambiente, the most important Italian environmentalist association. We are well aware that, as for the entire literature on crime, measuring organized crime in the environmental sector by using an enforcement indicator makes it hard to ascertain whether the empirical results come from differences in the propensity to commit the crime or from differences in the probability of detection. However, we believe that our measure is still a good proxy for the pervasiveness of organized crime in the environmental sector as it singles out the occurrence of the most serious environmental crimes (those resulting in subjects belonging to criminal associations being arrested), which are, at the same time, more clearly related to the all-pervasive activity of organized crime and the most likely to be detected (thus lowering the difference between crimes committed and detected).

The control variables have been selected following previous empirical studies (Callan & Thomas, 2001;

Table 1. Sampled municipalities by population size and geographical area.

Population size	North-West	North-East	Centre	South	Islands	Total
> 500,000	3	0	1	1	1	6
100,000–500,000	4	16	7	7	3	37
50,000–100,000	17	7	21	36	12	93
15,000–50,000	142	114	108	138	53	555
5000–15,000	472	421	210	285	128	1516
1000–5000	1,219	638	378	639	294	3168
< 1000	939	219	120	293	123	1694
Total	2796	1415	845	1399	614	7069

Dijkgraaf & Gradus, 2003). They are summarized in Table 2 along with the dependent and the explanatory variables.

- *Output* is the logarithm of the quantity of waste (kg) yearly collected in the municipality. The variable is sourced from the National Waste Register maintained by ISPRA. One would expect the coefficient associated with this variable to be positive as the volume of waste collected should be one of the factors that have the greatest impact on the MSW service costs incurred by municipalities. It is also interesting to understand if the coefficient is greater than, equal to or less than 1 in order to evaluate whether the MSW collection, transportation and disposal (or treatment) services cumulatively exhibit economies (or diseconomies) of scale. The extant literature finds economies of scale in less-populated municipalities (Dijkgraaf & Gradus, 2003).
- *Density* is measured as the logarithm of the inhabitants per km^2 by relying on data provided by the Italian National Institute of Statistics (ISTAT). The expected effect of *Density* on MSW service costs is ambiguous. On the one hand, a greater population density could allow the collection of a greater quantity of waste per dustbin; on the other hand, it could cause an increase in congestion and a consequent rise in the time spent collecting MSW. This ambiguity is also supported by the conflicting results obtained by the literature: diseconomies of density (Abrate et al., 2014; Bohm et al., 2010), economies of density (Domberger et al., 1986), mixed results (Callan & Thomas, 2001) and no significant relationship with costs (Bel & Costas, 2006; Bel & Mur, 2009).

- *Waste_sorted* is the percentage of the MSW that is sorted each year at the municipality level. The Italian Environmental Code establishes that by 2012 in each municipality at least 65% of the MSW must be sorted (Italian government, 2006). However, currently, the average percentage of waste sorting in Italy is 54.1% (46.1% if only the Southern regions of the country are considered). The variable is sourced from the National Waste Register maintained by ISPRA. Although, to the best of our knowledge, no studies in the literature have investigated the relationship between waste sorting and costs, we posit that an increase in waste sorting should have a positive effect on costs. This claim lies with three considerations. First, door-to-door collection involves a greater number of vehicles and workers than road collection. Second, treatment and recycling plants, being technologically much more advanced than a landfill, are more expensive to run. Third, especially in some regions of Central and Southern Italy, the treatment and recycling plants are insufficient and sorted waste must be sent to plants in other regions with a consequent increase in cost.
- *Plant* is a dummy variable set equal to 1 if landfills and/or incineration plants are located in the province (NUTS-3), and 0 otherwise (Bel & Costas, 2006; Bel & Fageda, 2010). Since the lack of disposal plants in the province would require the MSW to be disposed in other provinces, thus making transport costs (which significantly affect the MSW service) increase, we expected the effect of this variable on total costs to be negative. The variable is sourced from the National Waste Register maintained by ISPRA.
- *Coop* is a dummy variable set equal to 1 if the MSW service is delivered in associated forms through conventions or inter-municipal consortia, and 0 otherwise.

Table 2. Description of the variables.

Variable	Description	Expected effect
Dependent		
Total_cost	Log of the total cost of waste collection, transportation, disposal and treatment at the municipality level	
Explanatory		
Env_crime	Log of people yearly arrested (per 100,000 inhabitants plus 1) for crimes against the environment committed by organized criminal associations at the province level	+
Controls		
Output	Log of waste generated in the municipality (kg)	+
Density	Log of inhabitants per km^2 at the municipality level	+/–
Waste_sorted	Percentage of waste sorted at the municipality level	+
Plant	Dummy variable that takes the value of 1 if landfills and/or incineration plants are located in the province, and 0 otherwise	–
Coop	Dummy variable that takes the value of 1 if the municipal solid waste (MSW) service is provided in the associated form	–
Tourism	Beds per inhabitant in accommodation facilities at the municipality level	+

The variable is sourced from the National Waste Register maintained by ISPRA. We expect the effect of this variable on MSW service costs to be negative since inter-municipal cooperation should allow the exploitation of potential economies of scale (Bel et al., 2014).

- *Tourism* is measured by using the ratio between the number of bed places (hotels and all other accommodation facilities) and population size at the municipal level. This indicator was computed using information provided by the ISTAT database. We expect a positive impact of this variable on MSW service costs (Bel & Costas, 2006; Greco et al., 2018).

ESTIMATION RESULTS

Summary statistics

Table 3A shows the summary statistics for each variable, overall, between- and within-municipality. In our sample, the mean of *Total_cost* is 12.802, which means that the average total cost of delivering the MSW service is €363,000 per year. The log-transformation mitigates the high skewness of the total costs, which range between approximately €730 million and €4155.

The variable measuring organized crime in the environmental sector, that is, *Env_crime*, has a mean of 0.620, which corresponds to 0.86 arrests per 100,000 inhabitants. It ranges from 2.018, that is, 6.52 arrests per 100,000 inhabitants and no arrests at all. Interestingly, between- and within-municipality variations are comparable, thus suggesting that the local dynamics of environmental crime is as significant as its geographical heterogeneity.

The distribution of the variable *Output* mirrors that of *Total_cost*. Its mean is 13.981, which corresponds to 1180 tons of waste yearly processed, whereas the variation ranges from 16.3 to 1.728 million tons. Not surprisingly, like the case of *Total_cost*, most of the variation in *Output* is a between-municipality variation. The same pattern can be observed for the variable *Density*.

Waste_sorted has a mean of 0.616, slightly below the threshold of 0.65 for compliance with the Italian Environmental Code. However, the mean does not reveal an extremely heterogeneous situation. Some municipalities in our sample exhibit an extremely high level of waste sorting. The maximum of the variable is 0.991. Others seem not to sort waste at all, as the minimum of the variable is very close to zero. The structural differences between Italian municipalities in waste management practices are proved by the predominance of the between- over the within-municipality variation in *Waste_sorted*.

Most of the sampled municipalities (approximately 81.5%) are located in a province where landfills and/or incineration plants are operating. The within-municipality variation of *Plant* suggests that some plants have come into operation during the 2015–19 period, thus allowing provinces that lacked disposal and treatment facilities to start saving on waste transportation costs.

Approximately 28% of the municipalities in our sample (see the overall mean of *Coop* being 0.278) has the MSW service delivered in associated forms going from conventions to inter-municipal consortia.

The Italian tourist vocation is evident by looking at the distribution of the variable *Tourism*. On average, sampled municipalities have 0.155 beds per inhabitant in accommodation facilities. Of course, the high between-municipality variation of the variable reflects differences in the tourist attractiveness of the different areas of the country.

Table 3B shows the correlation matrix of our independent variables. As expected, *Output* and *Density* are positively (and highly) correlated. This evidence suggests that municipalities generating higher quantities of MSW (more populated municipalities) are also those exhibiting higher population density. All in all, the regressors have fairly low correlation coefficients and do not suffer from multicollinearity because the single variance inflation factors (VIF) are never higher than 10 – the widely accepted threshold to detect collinearity – while the mean VIF is 1.54, well below the standard threshold of 6 (Hair et al., 2010).

RESULTS

We estimate the average effect of organized crime in the environmental sector (*Env_crime*) on the total costs of delivering the MSW service (*Total_cost*). The first column of Table 4 shows the results of ordinary least squares (OLS) estimations. We compute robust standard errors to mitigate heteroscedasticity. Columns (2–5) report the estimates of four FE panel data models where FE absorb municipality-specific factors affecting the total costs of MSW delivery. In the specification reported in column (2), we only control for *Output*. In specification (3), we add the remaining controls. In specification (4), we include also time FE. Finally, in specification (5), we additionally include regional trends.

Regardless of the specification, the results in Table 4 provide evidence that, on average, organized crime in the environmental sector has a positive effect on the total cost of MSW service delivery. The magnitude of the coefficients of *Env_crime* ranges from 0.167 in specification (1) to 0.027 in specification (4), always statistically significant at the 1% level. The large difference in the magnitude of the coefficients when comparing OLS and FE estimates lies with the fact that the OLS estimator does not control for non-observable time-invariant factors that may influence total costs being, at the same time, correlated with organized crime. Thus, results obtained through FE estimations are way more reliable than those obtained by OLS. A back-of-the-envelope calculation indicates that when the organized crime in the environmental sector is measured as the number of arrests at the province level, at the mean of our measure, an additional arrest would translate into a 3.3% increase in the total costs of delivering the MSW service. These results (and the robustness checks that will be presented in the following subsection)

Table 3. Descriptive statistics and correlation matrix.

(A) Descriptive statistics

		Mean	SD	Minimum	Maximum	Observations
Total_costs	Overall	12.802	1.451	8.332	20.407	29,119
	Between		1.435	8.508	20.400	N = 7069
	Within		0.098	11.446	14.217	T = 4.119
Env_crime	Overall	0.620	0.203	0.000	2.018	29,119
	Between		0.152	0.000	2.018	N = 7069
	Within		0.154	−1.008	1.492	T = 4.119
Output	Overall	13.981	1.458	9.701	21.270	29,119
	Between		1.446	9.785	21.251	N = 7069
	Within		0.084	12.660	16.259	T = 4.119
Density	Overall	4.837	1.429	0.003	9.393	28,693
	Between		1.404	0.025	9.379	N = 6922
	Within		0.021	3.821	5.847	T = 4.119
Waste_sorted	Overall	0.616	0.195	0.001	0.991	29,104
	Between		0.187	0.003	0.975	N = 7065
	Within		0.076	0.119	1.175	T = 4.119
Plant	Overall	0.815	0.388	0.000	1.000	29,119
	Between		0.360	0.000	1.000	N = 7069
	Within		0.150	0.015	1.615	T = 4.119
Coop	Overall	0.278	0.448	0.000	1.000	29,114
	Between		0.441	0.000	1.000	N = 7067
	Within		0.051	−0.522	1.078	T = 4.120
Tourism	Overall	0.155	0.492	0.000	10.019	28,788
	Between		0.475	0.000	9.721	N = 6972
	Within		0.085	−1.495	6.731	T = 4.129

(B) Correlation matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Env_crime	1.000						
(2) Output	0.033	1.000					
(3) Density	0.022	0.706	1.000				
(4) Waste_sorted	−0.087	0.131	0.275	1.000			
(5) Plant	−0.056	0.067	0.083	−0.009	1.000		
(6) Coop	−0.119	−0.284	−0.250	0.095	−0.027	1.000	
(7) Tourism	−0.035	−0.042	−0.255	−0.093	−0.001	0.085	1.000

Note: *N* is the number of municipalities for which each variable is observed, whereas *T* is the average number of years each variable is observed in the data. Between-municipality minimums and maximums delimit the variation range of municipality-level averages. Within-municipality minimums and maximums refer to the deviation from municipality-level averages (adjusted by adding/subtracting back in the global mean), and naturally, some of those deviations may be negative.

support our claim that criminal organizations operating along the waste chain exert a significant impact on the cost of managing the MSW.

Moving to our control variables, their estimated coefficients are rather in line with expectations. *Output* is clearly positively related to *Total_cost*. FE estimations produce lower *Output* coefficients as they consider within-municipality variations. In any case, the estimated coefficients are always statistically significant at the 1% level. Interestingly, OLS estimates seem to suggest that the MSW service

exhibits economies of scale as the coefficient in specification (1) is statistically lower than 1.

The coefficient of *Density* is also positive and statistically significant (at the 1% level) when the most thorough FE model (column 5) is considered. This means that municipalities characterized by a higher population density experience higher costs of MSW service delivery.

The percentage of waste sorted, that is, *Waste_sorted*, also exerts a positive effect on total costs. Our estimates indicate that increasing the percentage of waste sorting

Table 4. Main estimates.

	OLS (1)	FE (2)	FE (3)	FE (4)	FE (5)
Env_crime	0.167***	0.036***	0.035***	0.027***	0.028***
	(0.012)	(0.004)	(0.004)	(0.004)	(0.005)
Output	0.963***	0.068***	0.078***	0.038***	0.044***
	(0.005)	(0.008)	(0.008)	(0.008)	(0.008)
Density	−0.007		0.280***	0.466***	0.454***
	(0.005)		(0.033)	(0.034)	(0.035)
Waste_sorted	0.162***		0.118***	0.024**	0.023**
	(0.020)		(0.009)	(0.010)	(0.011)
Plant	−0.106***		0.007	0.010**	0.001
	(0.010)		(0.004)	(0.004)	(0.005)
Coop	−0.070***		−0.160***	−0.158***	−0.159***
	(0.010)		(0.013)	(0.013)	(0.013)
Tourism	−0.111***		0.000	0.006	0.007
	(0.017)		(0.008)	(0.008)	(0.008)
Regional fixed effects*Year fixed effects	No	No	No	No	Yes
Municipality fixed effects	No	Yes	Yes	Yes	Yes
Year fixed effects	No	No	No	Yes	Yes
Prob > F	0.000	0.000	0.000	0.000	0.000
Adjusted R^2	0.937	–	–	–	–
Municipalities	6877	7069	6877	6877	6877
Observations	28,476	29,119	28,476	28,476	28,476

Note: Robust standard errors are shown in parentheses. **$p < 0.05$, ***$p < 0.01$.

by 10% leads to a corresponding 0.23% increase in the total costs of MSW service delivery. The effect is statistically significant at the 5% level (see column 5).

Delivering the MSW service by relying on different forms of inter-municipal cooperation reduces costs. The coefficients of the variable *Coop* are always negative and statistically significant. In particular, if again the last model (column 5) is considered, we can conclude that inter-municipal cooperation reduces the total cost of delivery by 15.9%, a somewhat substantial effect.

The presence of landfills and/or incineration plants in the province and the tourist vocation of the municipality seem not to play any effect on the total costs of MSW service delivery (see column 5).

Robustness checks

In this subsection we perform some robustness checks aimed at strengthening the results shown in Table 4. The results of these robustness checks are reported in Table 5.

In column (1) of Table 5 we check whether our results are robust to the change of the variable used to measure organized crime in the environmental sector. To this end, we re-estimate our model by measuring *Env_crime* as the logarithm of seizures yearly decreed by the judicial system (per 100,000 inhabitants plus 1) for crimes against the environment committed by organized criminal associations at the province level. Like the indicator used so far, this one is sourced from the National Observatory Environment and Legality maintained by Legambiente.

The effect of organized crime in the environmental sector on the total cost of delivering the MSW service remains positive and statistically significant (at the 5% level).

In column (2), we establish the effect of organized crime in the environmental sector on waste management costs after controlling for differences in past cost-efficiency across municipalities by augmenting the specification with *Total_cost* lagged by one year. It is well recognized that FE estimates are inconsistent when lags of the dependent variable are included as explanatory variables because of the correlation between lags and residuals. We, therefore, rely on the dynamic generalized method of moments (dynamic-GMM) developed by Arellano and Bond (1991). This method first differentiates the model (to eliminate FE) and then performs an instrumental variables regression of the resulting model using lags of the explanatory variables as instruments. As reported in column (2) of Table 5, the variable *Env_crime* keeps being positive and statistically significant at the 1% level.

In column (3), we show that even for a specification based on random effects, municipalities located in provinces that are more plagued by organized crime in the environmental sector experience an increase in total costs of delivering the MSW service. The effect is again statistically significant at the 1% level.

Regional heterogeneity

In this subsection we carry out the analysis of the link between organized crime in the environmental sector

Table 5. Robustness checks.

	Alternative measure of crime (1)	Lagged dependent variable (2)	Random effects (3)
Total_costs $(t-1)$		−0.536**	
		(0.213)	
Env_crime	0.004**	0.016***	0.035***
	(0.002)	(0.005)	(0.005)
Output	0.038***	0.000	0.745***
	(0.008)	(0.013)	(0.004)
Density	0.471***	0.253	0.168***
	(0.034)	(0.166)	(0.005)
Waste_sorted	0.022**	0.058**	0.214***
	(0.010)	(0.026)	(0.011)
Plant	0.010**	0.007	−0.002
	(0.004)	(0.006)	(0.005)
Coop	−0.159***	−0.063	−0.129***
	(0.013)	(0.054)	(0.010)
Tourism	0.007	0.020***	0.010
	(0.008)	(0.006)	(0.007)
Regional fixed effects	–	–	Yes
Municipality fixed effects	Yes	Yes	No
Year fixed effects	Yes	Yes	Yes
Prob > F	0.000	0.000	0.000
Municipalities	6877	5659	6877
Observations	28,476	14,455	28,476

Note: Robust standard errors are shown in parentheses. **$p < 0.05$, ***$p < 0.01$.

and the total costs of delivering the MSW service also by considering the Italian macro-regions (North-West, North-East, Centre, South and Islands) one at a time in order to delve into the regional heterogeneity in the effect of the organized crime on the waste management. Table 6 reports the results of these additional analyses. We re-estimate the same model whose results are shown in column (5) of Table 4 by using the five regional subsamples. As before, we control for both national and regional trends.

By looking at Table 6 we can conclude that when significant, the signs of the control variables' coefficients are the same as those obtained with the aggregate sample. The coefficient of *Output* is positive and statistically significant at the conventional levels in the Centre, in the South and on the Islands, whereas it is not statistically significant in the North. Since FE estimates indicate the within-municipality output elasticity of total costs, these results seem to suggest the presence of slack capacity in Northern municipalities, where the amount of municipal waste generated and processed at the municipality level has been decreasing during the 2015–19 period. The effect of *Density* also changes with the macro-region considered, possibly due to morphological and urban characteristics of the territory from which, in turn, congestion phenomena can derive (Abrate et al., 2014; Bohm et al., 2010). The regional heterogeneity in the effect of *Waste_sorted* may reflect the geographic prevalence of different waste sorting strategies as well as the availability/lack of plants devoted

to the treatment of sorted waste in the area.[1] The coefficient of *Coop* keeps being negative and statistically significant in each of the five estimates (at the 5% level in the Centre and at the 1% level in the remaining macro-regions). *Plant*, which was not statistically significant in the full sample, exhibits a mixed impact depending on the macro-region considered. Finally, *Tourism* basically remains not statistically significant irrespective of the macro-region considered (except for the Centre, where it is negative and statistically significant at the 10% level).

After having gone through the control variables, we can now focus on our main explanatory variable. *Env_crime* is positive and statistically significant only in the South and on the Islands (at the 5% statistical level in the South and at the 1% statistical level on the Islands), where organized crime is historically rooted (Camorra, Cosa Nostra and 'Ndrangheta). The effect in the two macro-regions is naturally stronger than that obtained by considering the full sample. In particular, the two sub-sample estimates indicate that an additional arrest would translate into a 3.5% and a 7.3% increase in the total costs of delivering the MSW service in the South and on the Islands, respectively. On the other hand, organized crime in the environmental sector seems not to have any statistically significant effect in the remaining three macro-regions (North-West, North-East and Centre). This regional heterogeneity in the impact of organized crime on municipal waste management may reflect

Table 6. Regional heterogeneity.

	North-West (1)	North-East (2)	Centre (3)	South (4)	Islands (5)
Env_crime	0.005	−0.049	0.017	0.030**	0.063***
	(0.007)	(0.097)	(0.014)	(0.013)	(0.012)
Output	0.001	−0.017	0.152***	0.095***	0.112**
	(0.011)	(0.017)	(0.024)	(0.023)	(0.039)
Density	0.771***	0.126***	0.115	0.584***	−0.167
	(0.047)	(0.047)	(0.157)	(0.135)	(0.260)
Waste_sorted	−0.019	0.140***	0.080***	0.053**	−0.064
	(0.019)	(0.030)	(0.027)	(0.024)	(0.043)
Plant	−0.019***	0.040***	0.016	−0.017	0.042**
	(0.007)	(0.010)	(0.014)	(0.011)	(0.019)
Coop	−0.152***	−0.087***	−0.133**	−0.203***	−0.197***
	(0.023)	(0.020)	(0.053)	(0.030)	(0.043)
Tourism	0.009	0.012	−0.044*	0.024	0.089
	(0.009)	(0.014)	(0.024)	(0.062)	(0.101)
Regional fixed effects*Year fixed effects	Yes	Yes	Yes	Yes	Yes
Municipality fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Prob > F	0.000	0.000	0.000	0.000	0.000
Municipalities	2720	1340	827	1393	597
Observations	12,228	5910	3130	5073	2135

Note: Robust standard errors are shown in parentheses. $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.

differences in the permeability of local governments to organized crime in the five macro-regions. The South and the Islands traditionally exhibit higher levels of infiltrations of criminal organizations in the local administration and the local service delivery. This circumstance may help interpret the result.

DISCUSSION AND CONCLUSIONS

The municipal waste management is an essential public service and its rational and efficient organization assumes considerable importance for the well-being of citizens and environmental sustainability. Despite the importance of this service, the empirical literature on the MSW costs is rather limited. In many institutional contexts, the infiltration of organized crime in the waste cycle makes the management of the service even more problematic. The impact of organized crime in the environmental sector on MSW costs has never been considered in previous literature and this study aims to fill this gap.

In this work, an empirical analysis has been performed considering a very large sample consisting of 7069 Italian municipalities observed in the 2015–19 period. The analysis was carried out both at the national and regional level, taking into account the five macro-regions of North-West, North-East, Centre, South and Islands thus making it possible to consider economic and political characteristics operating at lower levels of the spatial aggregation. At the national level, the results of the panel analysis show that organized environmental crime increases the costs of the MSW service.

At the regional level, the same effect is found in Southern regions as well as on the Islands, that is, the areas with a traditionally stronger criminal presence, whereas it loses statistical significance in the Northern and Central regions.

The investigations carried out by the judicial authorities and the report of the Italian Anti-Mafia Investigation Directorate (DIA) entitled 'Mafia & Waste' (DIA, 2019) show that the reason why the Ecomafia leads to cost increases in the waste management service is twofold. First, criminal waste management is inefficient because criminal clans have no incentive to reduce costs. the Ecomafia holds a monopoly position in gaining contracts thanks to the corruption of public officials and the exclusion of competing companies through intimidation. The investigations carried out by the judicial authorities shed light on how criminal waste management presupposes an organized system operating in the whole waste cycle (Italian Parliament, 2012). Second, the practice of reporting inflated costs to facilitate money-laundering activities, also thanks to aiding and abetting public officials in charge of monitoring the service delivery contributes to the increase in the MSW management costs. In fact, criminal companies are often legal entities created exclusively to provide coverage for illegal profits obtained through fake documents and bribery of public officials. In both cases, actual or fictitious increases in costs are reflected in the waste tariff causing damage to citizens.

From a policy point of view, the findings of this study provide some useful insights relating to the main critical issues in the MSW sector.

First, policymakers should improve the transparency of public procedures in the waste sector. For example, until June 2020, Italian companies subject to anti-mafia interdict were able to participate in public tenders in the waste sector without an anti-mafia certificate, because of a regulatory vacuum of the Anti-corruption law (Law 190/12). This situation changed only in 2020 (Law 40/20), when the obligation of the anti-mafia certificate was introduced (Legambiente, 2020). However, this measure represents only a mild deterrent as the Ecomafia is capable of operating through legal companies registered by figureheads. Therefore, it is appropriate to expand and intensify the controls that should be not only formal but related to the business operations.

Second, to ensure the transparency of public procedures in the waste sector, policymakers should encourage the development of optimal territorial areas for the provision of integrated MSW services. Optimal territorial areas may allow for more transparent and fairer tender procedures because they take decision making power away from every single municipality, thus making competition for the MSW management less vulnerable to organized crime. In Italy, for example, some investigations have highlighted how the most widespread anomalies in the MSW management are related to the programming phase entrusted to the local authorities. The use of emergency ordinances, with repeated extensions and renewals through direct service awarding facilitates organized crime infiltrations. Anomalies may also concern the execution phase with service quality levels lower than the contractual provisions. In order to counter these phenomena, policymakers should accelerate the development of optimal territorial areas with transparent competitive tenders for the provision of integrated MSW services.

Third, the lack of waste treatment infrastructure (composting plants, anaerobic digesters, incinerators, etc.) is a critical issue in many countries around the world: for instance, in Eastern and Southern Europe disposal in landfills is still the main method of managing MSW. Organized crime has always been very attracted to managing landfills, due to the low investment required and high economic returns. Some appropriate policy levers to contain the use of landfills could be the increase in the landfill tax and an improvement in the regulation of gate fees (access to treatment plants tariffs). These interventions should allow to cover the costs of social as well as environmental externalities and to support investments for recycling and recovery plants. In particular, a well devised gate fee should incentivize infrastructure investments and encourage new entrants in a market characterized by an oligopolistic structure, as a consequence of high barriers to entry due to the geomorphological constraints that limit the building of new plants, high investment costs, and the stringent environmental regulation.

In Italy, while most of the Northern regions have plants that can guarantee the entire execution of the waste cycle management, regions in the Centre and Southern part of the country have an inadequate (or non-existent) capacity in terms of treatment plants.

According to the DIA, the main cause of the active role played by the Ecomafia in the waste cycle is the lack of treatment facilities (DIA, 2019). Therefore, policymakers should stimulate investments in waste treatment infrastructures not only for environmental reasons but also for the fostering of legality.

To conclude, our work is not immune from limitations. First, as already mentioned, we use an enforcement indicator to measure organized crime in the environmental sector, thus making it hard to ascertain whether estimated results come from differences in the propensity to commit crime or from differences in the probability of detection. We have already upheld our measure by arguing that it tracks the most serious environmental crimes, which are, at the same time, more clearly related to activities of organized crime in the environmental sector and the most likely to be detected, thus making the difference between crimes committed and detected less substantial. Second, we do not have information on the evolution in the MSW service delivery mode (in-house versus contracted out) at the municipality level over the period, which could be relevant in explaining the evolution of municipal waste management costs, being, at the same time, potentially related to the pervasiveness of the organized crime in the environmental sector. Third, we do not tackle endogeneity issues that may potentially plague our estimates. Having said that, we are quite confident that our panel data models, which aside from municipality FE include national as well as regional trends in the total cost of service delivery are able to absorb unobservable time-invariant heterogeneity at the municipality level as well as most of unobservable time varying heterogeneity at the regional level, thus mitigating endogeneity concerns.

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DATA AVAILABILITY

The data that support the findings of this study are available from the ISPRA-Catasto dei Rifiuti Nazionale (https://www.catasto-rifiuti.isprambiente.it/index.php?pg=ru) and ISTAT (http://dati.istat.it).

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

NOTE

1. For instance, as the separate collection increases, the organic fraction of MSW increases accordingly, and this requires composting plants to treat the organic waste

produced. When these facilities are lacking, municipalities are forced to sign contracts with private companies managing composting plants in return for high gate fees. Furthermore, since these treatment plants may be located far from the municipality, transportation costs may also increase.

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