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The Link between the Compliance with Environmental Legislation on Separate Collection and the Municipal Solid Waste Costs

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Abstract: Promoting Agenda 2030 through Circular Economy transition requires improving waste system management and increasing separate collection. In Italy, municipal solid waste management is entrusted to the municipalities, most of which have not yet reached the minimum threshold of 65% for the separate collection imposed by the Environmental Code in 2012. This research aims to investigate the effect of compliance with environmental legislation by Italian municipalities on the total cost of municipal solid waste management, filling a shortage of literature studies on this issue. It also investigates the other significant factors affecting municipal solid waste costs, analysing a large dataset of 1914 municipalities. The study uses regression analysis on aggregate and regional samples and population-based subsamples to verify the existence of economies of scale or density. The results show that environmental compliance determines cost reduction in the northern regions, thanks to more efficient separate collection management and recycling activities in the downstream phases of the process. Instead, environmental compliance produces a cost increase in central regions due to the lack of waste recycling and composting infrastructure. Finally, in the conclusions, policy implications are drawn for the Italian case.

Keywords: waste management; municipal waste costs; environmental compliance; separate collection; regional analysis

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1. Introduction

The Circular Economy has great potential for achieving the Sustainable Development Goals (SDGs) of the 2030 Agenda, promoted by the United Nations with the aim of involving governments, businesses, and civil society towards the creation of a sustainable world through the achievement of sustainability objectives linked to the economic, social, and environmental spheres. Moreover, from the perspective of the literature, economic, environmental, and social sustainability has become one of the fastest-growing fields of research in recent years [1–3].

In particular, Circular Economy practices can improve urban waste management to accomplish SDG11 (Sustainable Cities and Communities) and SDG12 (Responsible Consumption and Production).

According to the UN 2019 Revision of World Population Prospects, four global demographic megatrends will impact both social-economic development and environmental sustainability: population growth, population ageing, migration, and urbanisation. The global population is expected to rise to around 8.5 billion people in 2030, 9.7 billion in 2050, and 10.9 billion in 2100. Urban areas are expected to be home to 68% of the world's population in 2050.

Urban rapid population growth holds a negative pressure on the environment. It implies a more significant erosion of natural habitats, and larger human communities

consume more natural resources and cause more contaminant begetting, such as large volumes of solid waste [4,5].

Therefore, Municipal Solid Waste (MSW) management is a crucial topic related to sustainability. Because of the inevitable urbanisation and migration processes, it is a substantial environmental problem even in countries facing a decrease in total population, such as Italy.

MSW management is a complex service whose efficacy, efficiency, and costs depend on three main categories of actors: the governments that define waste management policies, companies that operate in the MSW sector, and citizens whose behaviours must comply with government directives [6].

The European Union (EU) issued specific regulations on waste management, aiming to avoid negative environmental impacts and foster a resource-efficient economy. MSW management is part of the environmental policy in the Europe 2020 Strategy for smart, sustainable, and inclusive growth [7]. Together with other legislative proposals on waste, Directives 2006/12 and 2008/98 and the more recent EU Circular Economy Package (Directives 2018/849, 2018/250, 2018/251, 2018/252) aim to encourage the use of waste as secondary raw materials in industrial processes, promoting the conceptual shift to resources that can be efficiently reused [8]. In order to achieve this goal, EU policies foster member states to address the issue of reducing waste generation alongside the problem of increasing separate collection, as it is a prerequisite for waste reuse, recovery, and recycling.

A broad strand of the literature investigates the link between separate waste collection and related regulations and policies for environmental goals [9–13]. Vice versa, understanding whether and how the separate waste collection economically affects the practices of MSW management remains a little-explored topic, although it is very relevant for policymakers, companies operating in the sector, and citizens. This paper aims to fill this gap, considering Italy as the country under study. In Italy, many regions still do not reach the minimum threshold for separate collection set by the government. Indeed, the Legislative Decree 2006/152 (Code on the Environment) imposed the minimum separate waste collection rate equal to 65% by 2012. Still, the Italian waste management system remained highly fragmented, with significant differences between the northern regions and the others. In 2021, only the regions of the north achieved an annual separate collection rate above 65% (70.8%), whereas the central regions stopped at 59.2% and the southern ones at 53.6% [14].

Considering the critical issues that feature the sector in the diverse Italian regions, this paper is focused on studying how compliance with the environmental regulation on separate waste collection impacts MSW costs. The empirical analysis of this study considers the legal compliance on separate collection as the explanatory variable of the total MSW costs. To our best knowledge, no previous empirical research focused on legal compliance as an MSW cost driver. Furthermore, the present paper differs from previous studies since it sampled a much larger set of municipalities, i.e., 1914 municipalities (equal to 48.1% of the resident population in Italy), and provides significant comparative analysis of Italian regions' performance in MSW service.

This research is needed because an appropriate cost analysis is an important information source for the MSW system actors, who progressively can adopt or review their decisions and behaviour to maximise service efficiency, social well-being, and the achievement of environmental goals [15]. Furthermore, the cost analysis is also relevant from a regulatory point of view, as the waste tariff is cost reflexive and based on a method imposed by the Regulatory Authority for Energy, Networks and the Environment (ARERA) to ensure the full coverage of the cost of the service. More generally, understanding the impact of regulation in the energy sectors is useful from various perspectives [16,17]. Firstly, from the government's point of view, policies should ensure both environmental and financial sustainability objectives. From a company's point of view, service efficiency should be optimised considering costs resulting from legal compliance. From the citizens'

point of view, the balance between the impact on quality of life and the tariff paid should be positive.

2. Literature Review

The first "ideal" econometric model to analyse the determinants of MSW costs was proposed by Hirsch [18], who sampled 24 municipalities of St. Louis City County (USA). In his work, he determined five major groups of variables able to have an impact on the average cost per service: 1. Quantity of the service (number of basic service units); 2. Quality of the service (weekly collection frequency, pickup location, nature of pickup, disposal method, type of hauling equipment); 3. Service conditions affecting input requirements (pickup density, residential—non-residential land use mix, hauling distance, number of people per pickup unit, per capita income, nature of contractual arrangement, type of financing); 4. Factor price level; 5. The state of technology and productivity. Using a simplified working model, which included fewer variables than the ideal model (e.g., pickup location, weekly collection frequency, nature of contractual arrangement), Hirsch [18] found that pickup frequency and pickup location are statistically cost determinants. However, he did not find significant variances in service costs between private and municipal service management and neither economies of scale concerning the output of the service.

Several subsequent studies followed Hirsch's model (e.g., [19,20]), finding significantly lower costs for private delivery, but only towards the end of the 1970s did better quality data and more advanced statistical techniques allow substantial improvements in the analyses. In 1978, Stevens [21] proposed a study on the relationship between the total service cost (the explained variable) and several explanatory variables: the amount of waste generated, sectoral average wage, private or public nature of the service, market structure, frequency of waste collection, amount and density of population, and variability of climate conditions. By analysing 340 American cities, Stevens' [21] empirical findings pointed out positive economies of scale in municipalities with fewer than 50,000 inhabitants but no indication of economies of density. In addition, a positive influence on costs was found for the frequency of waste collection and the wage levels, whereas no effect on costs was found for climate conditions. According to Stevens' study, the public or private monopolistic approach to the service was significantly less expensive than private delivery with competition among firms. In municipalities with more than 50,000 inhabitants, public monopolies showed higher costs than private ones.

Following Stevens' [21] approach, Dubin and Navarro [22] proposed a model in which the explained variable was the average service cost, and the explanatory variables were: the amount of waste collected per household, the market organisation, the frequency of collection, the population density, the collection from homes or waste deposit points, and the variability in climate conditions (proxied by the average temperature). They sampled 261 American municipalities. The results confirmed the presence of positive economies of scale in municipalities with fewer than 20,000 inhabitants. The collection frequency positively impacted costs, although these were lower when the collection was from waste deposit points. Temperature variations had no significant influence on costs. The private form of provision resulted in the most expensive approach to the service, while the least costly forms were municipal provision and competitively tendered contracts. This latter result was confirmed by Dijkgraaf and Gradus [23] in their study on 120 municipalities in the Netherlands. In addition, Dubin and Navarro [22] did not find a structural variation in the cost equation concerning population size.

In their study on 88 municipalities in Ireland, Reeves and Barrow [24] pointed out high-cost savings associated with private delivery. According to Domberger et al. [25], cost savings are achieved through competitive tendering and are similar whether the contract is awarded to the in-house public unit or a private company.

In their model, Callan and Thomas [26] introduced the multiple-output nature of solid waste service, separating the general waste for disposal from the selective waste for recycling. Using a two-equation model, they analysed the service cost of disposal and

of recycling through explanatory variables such as the quantity of waste, the population density, the frequency of collection, the public monopolistic or contracting out forms of the service, the presence of a municipal dump, the presence of recycling facility, and public funding, among others. By sampling 110 municipalities in the USA, their study highlighted that greater collection quantities and greater collection frequency involved higher costs for both services. Furthermore, they observed economies of scope, as offering joint disposal and recycling services allowed cost savings. For recyclable waste, they detected economies of scale but no economies of density. On the contrary, they noticed economies of density for waste disposal but no economies of scale.

Bel and Costas [27] proposed an econometric study adding a novel variable beyond those in line with the variables used in the abovementioned studies. As well as other explanatory variables, they analysed the impact of the tourist factor on the total cost of solid waste service. Their empirical analysis of 186 municipalities in Catalonia confirmed economies of scale in less populated cities, with declining intensity as the population increased. They found a positive relationship between costs and the following factors: waste amount, percentage of waste separation, frequency of the service, employee wages, and degree of tourism. Instead, population density and market organisation did not significantly affect costs. In their study on 56 Aragon cities (Spain), Bel and Mur [28] confirmed a non-significant relationship between population density and costs. They observed a significant impact of the amount of population and employee wages on costs.

By sampling 65 municipalities in Galicia (Spain), Bel and Fageda [29] observed that the degree of tourism, the amount of population, and the private form of management of the service significantly impacted costs. Municipalities with less than 50,000 inhabitants did not show a significant positive association between the percentage of separated waste and costs.

Subsequently, by examining 85 small cities in Spain, Bel et al. [30] analysed the impact of municipalities' cooperation on costs. In the case of direct private contracts, the economies of scale allowed lower costs for municipalities.

A study on the Mediterranean area of Spain and Madrid by Fernández-Aracil et al. [31] highlighted the reduction in waste collection costs when population density increases. In contrast, higher wages, coastal vs. interior location, tourist zones, amount of population, and the separated collection had a positive association with costs. The indirect management of service was less expensive than direct public delivery.

Martins and Cró [32] evaluated the impact of tourism on solid waste generation in Madeira. For the period 1996–2018, from 41.9% to 46.6% of solid waste generation per resident depended on tourist activities.

Considering the geographical area covered by this study, Italy, the research on 30 firms belonging to the waste collection industry by Antonioli and Filippini [33] highlighted that most collection companies are not operating at optimal scale, and franchised monopoly was more efficient than the side-by-side competition. According to them, merging adjacent services could reduce costs.

In their study on 529 Italian municipalities, Abrate et al. [34] observed for cities of about 42,500 inhabitants moderate economies of scope between disposal and recycling services and constant return of scale. As far as the population increased, economies of scope grew, whereas diseconomies of scale appeared.

Greco et al. [35] analysed collection costs for different types of waste. By sampling 67 Italian municipalities, they noticed strong economies of scale for undifferentiated collection, and weak economies of scale, along with higher costs, for separate waste collection. They also observed different levels of efficiency among Italian regions. The northern regions were more efficient than the centre, south, and islands. In their study on 78 cities, Gastaldi et al. [36] found that the waste management systems of northern and central major towns were more efficient than southern and island ones.

Sampling Tuscan Region municipalities, Romano et al. [37] confirmed significant levels of inefficiency in waste management in Italy. The inefficiency increased with higher

mixed waste per capita produced, while it decreased with higher population density. They also found a positive relationship between good pro-environmental behaviours and better efficiency levels.

By using a deep learning approach for examining municipalities in the Apulia area, Fasano et al. [38] highlighted the influence of the characteristics of the residential buildings on MSW management costs and the effect of the combination of municipal collection centres and door-to-door service on separate MSW collection.

In a study on 68 Italian cities, Greco et al. [39] evaluated the impact of tourist activities on solid waste collection costs. According to their research, the effect differs depending on waste types. Di Pillo et al. [40] analyse the relationship between organised crime and the total cost of municipal solid waste services. Their results show how organised crime involves an increase in waste management costs, especially in the regions where crime organisations are historically rooted.

As for the literature on environmental compliance, to our best knowledge, previous research has not evaluated the impact on compliance costs with legal thresholds for separate waste collection. In Italy, the threshold is 65%. This work fills this gap and considers a large sample of municipalities, i.e., 1914 Italian cities in all Italian regions. The sample allows examining disparities in north, centre, south, and islands areas, which show significant differences in economic and productive development.

3. Materials and Methods

According to the empirical studies addressed in the main literature [21,26,27,31], we formulated an estimation equation, mapping a relationship between the total municipal cost and the explanatory variable of the delay in applying the legislation on separate collection by municipalities. In addition to the variable mirroring the environmental compliance, we considered the main other predictors chosen based on the literature review. This leads to the following regression model:

$$TC_i = \beta_0 + \beta_1 EC_i + \beta_2 OUTPUT_i + \beta_3 DENS_i + \beta_4 PLANT_i + \beta_5 PUBL_i + \beta_7 COOP_i + u_i \quad (1)$$

The total cost of the service paid by the municipality is the model's dependent variable, as in most works in the literature [21,23,26]. This includes the collection, transportation, and disposal or treatment of undifferentiated and differentiated waste. In particular, the latter include the costs of collection of separate waste, the treatment and recycling cost net of income from the sale of recovered materials and energy, and grants given by the CONAI (National Packaging Consortium). The packaging producer/user is obliged to pay the CONAI Environmental Contribution (CAC), which varies depending on the type of packaging put onto the market. CONAI retains a minimum amount to carry out its work, while a part is given to the Material Consortia, which, in turn, pays compensation to the municipalities for the differentiated waste delivered.

We used the method of ordinary least squares (OLS) to evaluate the impact on MSW costs of the following predictors:

1. Environmental compliance (*EC*): the key variable of our study. We introduced this new variable to evaluate the compliance with environmental regulations on separate collections by each municipality. The Italian Code on the Environment established that the minimum percentage for municipal waste separate collection to be met within each municipality is 65% by 2012 [41]. However, the average rate of separate waste collection in Italy is 54.1%, and 46.1%, considering only the southern regions. We measured the environmental compliance through a dummy variable that takes the value 1 if the mandatory threshold on separate collection is reached by the municipality and the value 0 otherwise. We had no expectations regarding the impact of this variable because, having been considered for the first time, we could not rely on the results of previous studies;
2. Output: the quantity of waste collected in the municipality, measured as the logarithm of waste generated in the municipality (in kilos). We expected that costs would

increase with the volume of waste collected. However, it is interesting to understand if the coefficient is greater or less than 1 to evaluate whether the total costs increase more or less than proportionally with quantity and consequently understand the existence of economies of scale. Some published empirical studies show the existence of economies of scale in less-populated municipalities [21–23];

3. Population density (*DENS*): this variable is measured as the logarithm of inhabitants per square kilometre, and its expected effect is ambiguous. Indeed, population density growth could increase the quantity of waste per bin, creating economies of density. At the same time, the increase in population density could entail traffic growth and a consequent time increase for the collection service. Even the literature disagrees on this issue. Abrate et al. [34] demonstrated diseconomies of density, Domberger et al. [25] showed economies of density, some authors found mixed results [22,26]; and others showed no significant relationship with costs [27,28];
4. Plant (*PLANT*): we considered, in this variable, the number of landfills, incineration, and composting plants, unlike the previous empirical literature, which considered only landfills [27,29]. We considered the plants located in the province (NUTS 3). As the disposal plants in a province increase, transport costs (which significantly affect the collection activity) should decrease. The expected effect of this variable on costs is negative;
5. Public (*PUBL*): we measured the mode of production through a dummy variable that takes the value 1 if a public firm produces the service and the value 0 if the service was contracted out to a private firm. The literature on the expected effect is ambiguous. According to Stevens [21], the management of the service by a private company involves a cost reduction. Other authors show that private production causes an increase in MSW costs [22,29]. Finally, according to other studies, the service production mode is insignificant compared to the MSW cost [27,28,39];
6. Cooperation (*COOP*): this variable considers the municipal solid waste service supply in associated form, through conventions or inter-municipal consortia. This dummy variable takes the value 1 if the MSW service is provided in the associated form. We expected the effect of this variable on costs to be negative since it should allow for an improvement in economies of scale, as demonstrated by Bel and Costas [27] and Bel et al. [30].

This empirical study relied on a cross-sectional analysis of a sample of 1914 Italian municipalities, equal to 46.1% of the resident population. The sample was divided according to the population of the geographical macro-areas as follows: 49.4% represents the northern regions (the percentage compared to the whole of Italy is 46.4%), 23.1% the central regions (19.9% compared to the whole of Italy) and 27.4% the southern regions and islands (33.7% compared to the whole of Italy). The distribution of the sample by population size and geographical area is shown in Table 1.

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

Population Size	North	Center	South and Islands	Total
>100,000	17	6	10	33
50,000–100,000	10	5	19	34
25,000–50,000	57	14	31	102
5000–25,000	388	99	151	638
1000–5000	523	136	188	847
<1000	177	22	61	260
Total	1172	282	460	1914

Data on costs, quantity, mode of production, and plants were obtained from the Italian Institute for Environmental Protection and Research (ISPRA) database (National Waste Register). Data on population density were gathered from the Italian National Institute of Statistics (ISTAT).

Table 2 describes the summary statistics for each variable. In our sample, the mean value of total costs is 13.209, which means that the average total cost of delivering the MSW service is EUR 545,250 per year. The log transformation mitigates the high skewness of the total costs, ranging between approximately EUR 721 million and EUR 7982. The explanatory variable Environmental compliance has a mean of 0.515, which in terms of the percentage of separate waste collection is equal to 60.4%, still below the threshold of 65% for compliance with the Italian Environmental Code.

Table 2. Descriptive statistics.

	Mean	Sd	Min	Max
Total costs	13.209	1.412	8.985	20.397
Environmental Compliance	0.515	0.500	0.000	1.000
Output	14.404	1.433	10.061	21.247
Population density	5.191	1.432	0.891	9.010
Plant	5.227	3.121	0.000	14.000
Public	0.392	0.488	0.000	1.000
Cooperation	0.336	0.473	0.000	1.000

The mean value of the variable output is 14.404, which corresponds to 1800 tons of waste yearly processed, with a variation range between 23.4 and 1688 million tons.

The variable density shows a mean value of 5.191, corresponding to an average of 180 inhabitants per square kilometre. The range of variation of this variable is extensive: the municipality with the minimum value has 2.4 inhabitants per square kilometre, while the most densely populated municipality has a value of 8185 inhabitants per square kilometre.

The average number of the plant variable is equal to 5.227. Almost all the municipalities are in a province with at least one disposal plant. Despite this, there are many municipalities with few facilities (7% of the sample municipalities have only one plant located in the province), and the range of variation varies greatly, from a minimum of zero to a maximum of 14 plants.

Regarding the production mode, the management by a public company involves 39% of the sample, while 34% of the municipalities carry out the service in an associated form.

Table 3 shows the correlation matrix of the independent variables. As expected, output and population density are positively correlated. This evidence derives from the greater urbanisation of populous cities in Italy [42]. Therefore, as the population increases (and consequently the output), the urban density increases. In addition, public and cooperation are positively and highly correlated due to the composition of the inter-municipal consortia, constituted by the municipalities themselves. However, 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 2.66, well below the standard threshold of 6 [43].

Table 3. Correlation matrix.

		(1)	(2)	(3)	(4)	(5)	(6)
(1)	Environmental compliance	1.000					
(2)	Output	0.005	1.000				
(3)	Population density	0.321	0.633	1.000			
(4)	Plant	0.184	0.086	0.184	1.000		
(5)	Public	0.090	−0.173	0.026	0.109	1.000	
(6)	Coop	0.138	−0.201	0.059	0.139	0.885	1.000

4. Results

The analysis of the cost drivers of the MSW service was carried out considering the whole sample and the macro-regions of Italy: north, centre, south, and islands. The regression model for estimating the drivers that influence MSW costs was analysed using the Stata software package.

Table 4 reports the results of the OLS regression of the whole sample and macro-regions of Italy. For all samples, the explanatory power of the OLS method is very high since the R-square ranges between 94.7% and 96.6%.

Table 4. Estimation results of the regional analysis.

	Whole Sample	North	Center	South and Islands
Constant	−0.555 *** (0.086)	−0.707 *** (0.110)	−0.644 ** (0.204)	−0.099 (0.250)
EC	−0.153 *** (0.019)	−0.137 *** (0.018)	0.220 *** (0.039)	0.030 (0.037)
OUTPUT	0.977 *** (0.009)	0.966 *** (0.009)	0.991 *** (0.017)	0.919 *** (0.024)
DENS	−0.029 *** (0.010)	−0.016 * (0.008)	−0.069 *** (0.020)	0.072 ** (0.025)
PLANT	−0.017 *** (0.003)	0.003 (0.002)	−0.008 * (0.008)	−0.003 (0.007)
PUBL	0.135 *** (0.034)	−0.018 (0.067)	0.076 (0.057)	−0.031 (0.446)
COOP	−0.127 *** (0.037)	0.019 (0.067)	−0.280 *** (0.072)	0.617 (0.050)
R^2	0.947	0.964	0.966	0.956
F-test	5621.42 ***	3581.82 ***	1044.36 ***	2294.19 ***
n	1914	1172	282	460

Notes: Significantly different from zero at the 99% (***), 95% (**), and 90% (*) confidence level. In parentheses, standard errors robust to heteroscedasticity.

By considering the whole sample, environmental compliance negatively correlates with total costs. Therefore, reaching the separate waste collection threshold imposed by the Italian Environmental Code implies reducing costs. This result shows that the respect for environmental legislation reflects a virtuous behaviour of municipalities, which manage the service more efficiently. Concerning the macro-regions, environmental compliance negatively impacts costs in the northern regions. The northern regions started separate waste collection some years earlier than the rest of Italy. Now they carry out separate collections effectively and efficiently, which translates into a reduction in total costs. This reduction is also due to the possibility of waste valorisation through the recycling activities in the process downstream phases. This aspect is considered in our definition of the total cost, including treatment and recycling costs net of sales revenues of materials, recovered energy, and CONAI contributions.

In the centre's macro-region, the coefficient of environmental compliance is significant and positive, while it is not significant in the south and islands. The increase in costs caused by environmental compliance in the central regions is due to the lack of composting plants. As the separate collection increases, the organic fraction of municipal solid waste increases, but the local composting plants are insufficient to treat the organic waste produced. Consequently, the municipalities of the centre are forced to enter contracts with private companies managing composting plants for the treatment of their organic waste at a very high gate fee. Furthermore, since these treatment plants are mainly located in the northern regions, transportation costs also increase.

Regarding the other variables, the driver referring to the amount of waste collected (Output) is clearly significant for the whole sample and the regional analysis. However, the most relevant information that we can draw from this variable is the existence of economies of scale, which must be assessed by observing the β coefficient. Economies of scale exist if the β coefficient is less than 1: total costs increase less than proportionally with generated waste quantity.

The population density shows a negative and significant relationship with total costs, proving the existence of economies of density and are consistent with some previous findings [26,31]. This result is confirmed in the macro areas of the centre and north, while in the region of the south and islands, population density has a positive impact. These

diseconomies of density could be due to the morphological and urban characteristics of the territory from which congestion phenomena can derive: in southern Italy, there are many cities with narrow or very busy roads. The refuse collection is a sector based on local transport, therefore strongly conditioned by the characteristics of the territory and by traffic congestion phenomena. Therefore, a positive coefficient could indicate, as suggested by Bohm et al. [44], that high-density regions may incur high costs to transport waste to landfills for disposal [34].

The presence in the provincial territory of disposal, incineration, and composting plants decreases the service cost. This is due to a reduction in transport costs reflected in a decrease in total costs. At the regional level, this result is significant for central Italy.

Public management implies an increase in costs, confirming that externalisation (outsourcing or out-contracting) is the most efficient form of production, and this is consistent with some previous findings [22,23,31]. Regarding the regional analysis, this result is not significant.

The inter-municipal cooperation is significant and has a negative impact. The management of service in associated form allows for exploiting the economies of scale, as underlined by Bel and Costas [27] and Bel et al. [30]. In regional analyses, we observe that the sign of this coefficient is significant and negative in the central regions, where the forms of associated management are efficient, allowing better exploitation of economies of scale.

Table 5 shows the results of OLS regression of the whole sample and for sub-samples based on the population of the municipalities. We consider micro-municipalities with less than 5000 inhabitants, small municipalities with a population between 5000 and 25,000 inhabitants, and medium and large municipalities with more than 25,000 inhabitants [45,46]. Compliance with the environmental law implies the greatest reduction in costs in the most populous municipalities and the least in the micro municipalities. Therefore, there is a scale effect: as the population increases, separate waste management is more efficient. Indeed, the economies of scale are derived from the upstream phase of the process (collection), which has labour-intensive characteristics, and from the downstream phase (composting and recycling plants), which is capital intensive.

Table 5. Estimation results of the dimensional analysis.

	Whole Sample	**Population ≤5000**	**Population (5000–25,000)**	**Population ≥25,000**
Constant	−0.555 *** (0.086)	0.506 ** (0.189)	−0.051 * (0.344)	−0.114 (1.450)
EC	−0.153 *** (0.019)	−0.097 *** (0.025)	−0.144 *** (0.030)	−0.181 * (0.100)
OUTPUT	0.977 *** (0.009)	0.899 *** (0.016)	0.945 *** (0.022)	0.925 *** (0.094)
DENS	−0.029 *** (0.010)	−0.035 ** (0.013)	−0.018 *** (0.004)	0.026 (0.035)
PLANT	−0.017 *** (0.003)	−0.018 (0.003)	−0.008 * (0.008)	−0.011 (0.008)
PUBL	0.135 *** (0.034)	0.157 *** (0.048)	0.073 (0.072)	0.041 (0.068)
COOP	−0.127 *** (0.037)	−0.136 ** (0.050)	−0.103 (0.076)	−0.111 (0.092)
R2	0.947	0.835	0.768	0.877
F-test	5621.42 ***	963.61 ***	410.44 ***	163.28 ***
n	1914	1107	638	169

Notes: Significantly different from zero at the 99% (***), 95% (**), and 90% (*) confidence level. In parentheses, standard errors robust to heteroscedasticity.

As for the other predictors, the signs of coefficients are the same as those obtained with the aggregate sample in all sub-samples, with some exceptions where they are not significant.

Among the most interesting results, it can be highlighted how the economies of density are significant only for cities with less than 25,000 inhabitants. This can be explained by the effect of congestion created in correspondence with territorial situations characterised by a larger population. It can be argued that, in the Italian context characterised by high urbanisation rates, the operational difficulties linked to congestion often prevail over the possible advantages traditionally related to the density of users in network services. In particular, the disadvantages begin to prevail when the density equals 1000 or more inhabitants per square kilometre [42]. In Italy, the density increases as the population

increases, and the sample of our study reflects this trend: the average density of the sub-sample with more than 25,000 inhabitants is equal to 1443 inhabitants per square kilometre compared to 355 of the sub-sample with less than 25,000 inhabitants.

Another result to be highlighted is that the coefficient associated with inter-municipal cooperation is negative and significant for sub-sample with less than 5000 inhabitants. This result underlines how, for micro-municipalities, management in associated form is essential to reduce costs by exploiting economies of scale. This theory is also the rationale of the Italian legislation introduced with the Legislative Decree n. 78 of 2010, converted by law No. 122 of 2010 [47]. The legislator's purpose was to oblige municipalities with up to 5000 inhabitants to join together to manage fundamental functions, including urban waste management. However, the considerable uncertainty about the methods and timing of implementation of the legislation has de facto limited the diffusion of forms of associated management. The percentage of municipalities implementing the legislation is still unsatisfactory [48]. Compared to our sample, 38% of the municipalities with less than 5000 inhabitants manage the service through inter-municipal cooperation.

5. Discussion

The results of the empirical analysis show that compliance with environmental legislation is significant and negative both in the aggregate sample and in the northern regions. Vice versa, in the central regions, this factor has a positive impact on costs, and in the southern regions and islands, it is not significant. The northern regions have a well-developed separate collection system, which has allowed them to manage the entire cycle more efficiently and consequently reduce costs. In addition, the efficiency of the collection model must be evaluated in relation to the possibilities of economic use of waste deriving from recycling activities. The northern regions are also more virtuous in the downstream segment thanks to the sales revenues of waste for recycling, ensuring overall management costs are lower than those relating to the undifferentiated fraction [49].

The increase in costs caused by compliance with environmental legislation in the central regions is due to the lack of composting plants that characterise this area. Therefore, as separate collection increases, the MSW costs increase since the municipalities of the centre are forced to send their organic waste to the plants of private companies, which impose a very high gate fee. Furthermore, since these treatment plants are mainly located in the northern regions, transportation costs also increase.

In the southern regions and islands, separate waste collection is very far from the threshold of 65% imposed by environmental legislation. This could be the reason for the lack of significance of the EC coefficient.

Regarding the other predictors, the results of the empirical analysis demonstrate that the amount of waste collected has a positive and very significant impact on costs. There are economies of density for municipalities with up to 25,000 inhabitants. In the most populated cities, urban density increases, and this implies the criticality of traffic congestion associated with the collection phase. These diseconomies of density also result in southern regions and Islands likely due to the morphological and urbanistic characteristics of the territory: many southern cities have narrow and very busy roads. This leads to congestion phenomena that negatively affect refuse collection, increasing costs to transport waste to landfills for disposal [34,44]. The presence of disposal, incineration, and composting plants at the provincial level reduces the service cost since it influences transport costs. Public management is inefficient, especially in micro municipalities, and it should be replaced with outsourcing, i.e., the choice of a private company through public tender. The inter-municipal cooperation decreases MSW costs, also in this case, mainly in micro municipalities, where the management by the single municipality is inefficient and municipal consortia are necessary to exploit the economies of scale.

From a policy point of view, this study underlines the need to stimulate the separate collection because it could entail a reduction in total costs and a consequent decrease in

the waste tariff. Therefore, policymakers should encourage investments in treatment and composting plants.

A possible regulatory policy measure designed to increase investments in treatment and composting plants could be the regulation of gate fees by ARERA, which currently regulates only the waste tariff for citizens. This regulation is necessary because an oligopolistic structure characterises the downstream markets of the collection phase. The geo-morphological constraints that limit the building of new infrastructures, the high investment costs, and the stringent environmental regulation cause high barriers to entry. In addition, plant deficiency is due to the lack of actual will of the policymaker, often influenced by the protests of local committees for the defence of the territory, driven by the NIMBY (not in my backyard) syndrome.

More generally, at the level of government policies, the main measures to encourage separate collection could be manifold and have already been identified in the national strategy for sustainable development to be implemented by 2040 [50]. Firstly, it is necessary to create the conditions for the competitive market for secondary raw materials (End of Waste) to be more competitive in terms of performance, availability, and costs. Secondly, a review of the taxation system is needed to make recycling cheaper than landfill disposal by increasing the landfill tax. Finally, another valuable measure for the transition to circular models will be the development of tax incentive systems to support the use of materials deriving from the recycling chains.

The current study would benefit from further improvements in at least three major points, as any other study. Firstly, the model could be extended to incorporate additional predictors. Considering a smaller sample than the one used in this paper, more precise data can be extracted, such as those relating to the municipalities' geographical characteristics, e.g., altitude and location of coastal areas. Additionally, this future research could consider the number of bins, the frequency of collection, and even the kilometres travelled by trucks from waste containers to waste treatment plants (landfills, incineration, or recycling plants). Secondly, a new research direction could be an analysis of the costs of separate collection, considering different types of waste: organic waste, glass, plastic, metal, paper, and paperboard. This study will help understand which typology of waste has the highest costs and suggest the related policy implications. Finally, the study is only limited to Italy; it would be advisable to expand the research to carry out an international comparison of how environmental regulations impact waste management.

6. Conclusions

Italy's current municipal waste management system has numerous critical issues that hinder the path toward the circular economy. In 2020, the national share of landfill disposal is still high and, at the same time, the average percentage of the separate collection is below the 65% threshold set by the Environmental Code, with significant territorial variability: 70.8% in the north, 59.2% in the centre and 53.6% in the south and islands [14]. The separate collection management has relevance both in environmental and economic terms, being a matter of public finance with the governance entrusted to local authorities (municipalities). Despite this service's importance, studies on environmental regulation compliance's impact on waste management are somewhat limited in the literature. This study aims to fill this gap and understand how environmental compliance influences MSW costs.

The findings of this study show how the separate collection should be strongly encouraged not only for the obvious environmental reasons but also because it entails a reduction in total costs if carried out efficiently. Indeed, the virtuous municipalities of the northern regions show a negative relationship between the variable representing the achievement of 65% of separate collection and costs. Therefore, as separate waste collection increases, total costs decrease, which should be reflected in reducing the waste fee for citizens. There is an inverse relationship in the central regions, but this is due to the shortage of composting plants and increasing treatment and transport costs. Therefore, policymakers should stimulate investments in composting plants because this leads to total costs decrease.

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