THE SELECTIVE COLLECTION OF MUNICIPAL SOLID WASTE AND OTHER FACTORS DETERMINING COST EFFICIENCY. AN ANALYSIS OF SERVICE PROVISION BY SPANISH MUNICIPALITIES.

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Abstract

In recent years, concerns about the increasing generation of municipal solid waste, together with related health and environmental issues and regulatory changes, have motivated significant alterations in the provision of waste management services, such as the introduction of selective collection (by type of waste). However, these changes may impact on service costs and/or efficiency. The present study was undertaken to analyse the efficiency of the waste management service in Spain, using data from 283 municipalities for the period 2005-2015. The analysis consists of two phases: first, the application of panel data order-m frontiers, that allows to obtain a homogeneous estimation of efficiency based on the input-output relationship at the production process (Surroca et al., 2016), and second, the use of bootstrapped truncated regression, considering different municipal sizes. The results obtained show that cost efficiency is increased with selective collection and by certain political and socio-economic factors of the local governments, concretely with the government by a progressive party, coalition governments, a greater financial independence, a greater tourist and industrial activity and a greater proportion of women and of foreign-born residents in the municipality. We also show that municipal direct provision is the least efficient management form for this service. The main contribution made by this study is to examine the influence of different elements of service output (i.e., selection by type of waste vs. non-selection) on cost efficiency.

Keywords: *Cost efficiency, Types of waste, Waste management service, Environment.*

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1. Introduction

In recent years, public administrations have significantly revised their environmental policies, in response to a worrying increase in the generation of municipal solid waste (Guerrini et al., 2017). The growing amount of waste disposed in landfills is a great concern for public policy makers, and recycling is considered the way to solve this problem (Kinnaman, 2006). So, the control of municipal waste management services plays an important role in public health and environmental protection (Abarca-Guerrero et al., 2013; Romano and Molinos-Senante, 2020). In this context, New EU guidelines to encourage recycling have obliged municipalities to make changes (Ferreira et al., 2017), such as the selective collection of municipal solid waste (Callan and Thomas, 2001). Separating waste at the source is considered key by authors such as Lavee (2000) to increase recycling. However, this process is usually related to higher costs, due to the need of infrastructure adjustments, a greater number of workers or collecting vehicles, among others (Lavee and Nardiya, 2013; Carvalho and Marques, 2014).

So, the analysis of waste management costs and cost efficiency and its determinants is essential in this context and research studies have addressed this question (Bel and Fageda, 2010; Benito-López et al., 2011; Simões and Marques, 2012). Moreover, the type of management structure adopted can play a decisive role, and forms such as direct management and privatisation have received considerable research attention (Simões and Marques, 2012).

However, other aspects have received little attention. When recycling, the selective waste collection can be implemented in different ways (Expósito and Velasco, 2018), so this factor must be considered also as an explanatory variable of the cost efficiency of waste management service. Nevertheless, to our knowledge, previous studies in this field have only addressed it in terms of the new costs generated, setting aside the question of cost efficiency (Greco et al., 2015; Chifari et al., 2017; Fernández-Aracil et al., 2018).

Another factor that has barely been considered in this analysis is that men and women differ in their attitudes towards recycling (Ekere et al., 2009; Sidique et al., 2010). These differences might impact on the cost efficiency obtained by the service, affecting both the amount of selective waste collected and the approach taken to service management. The presence of women in municipal government may enhance councils' economic results (Hernández-Nicolás et al., 2018). This finding is also an interesting contribution to the debate on the importance of gender in public management.

In view of the above considerations, our paper investigates the cost efficiency obtained by waste management services, distinguishing by type of waste collected (non-selective, paper, glass, plastic, organic and batteries) and by municipal size. This approach expands the scope adopted in previous studies, in which cost efficiency was calculated by reference to a single output. In addition, we analyse the effects produced on cost efficiency by different forms of service management, by the selective approach to waste collection and by other political and socioeconomic variables (Zafra-Gómez et al., 2016; Halkos and Petrou, 2019; Romano and Molinos-Senante, 2020). Finally, we examine the influence of gender on the cost efficiency obtained. Morover, the study of the factors conditioning the cost efficiency of waste management services is made considering three types of municipalities according with their municipal size (number of inhabitants) with the aim of analysing whether there are differences in the conditioning factors for each type of municipality.

To address these study goals, cost efficiency was calculated using order-m frontiers with panel data, as developed by Garrido-Rodríguez et al. (2018). These efficiency scores were then analysed by bootstrapped truncated regression, following Simar and Wilson (2007), thus highlighting the most important factors in this regard. Specifically, a two-stage analysis was made of a sample of 283 Spanish municipalities, for the period 2005 to 2015.

Our findings suggested that municipalities that collect selectively are more cost efficient, providing this question with a new perspective to the study of this service. Also, the results obtained revealed how external factors -political, financial and sociodemographic- may influence the cost efficiency of the waste management service and that municipal direct provision is the least efficient management form for this service.

The rest of this paper is structured as follows: in the following section, we review the literature in this field. The study method is detailed in Section 3, after which the study data and variables considered are presented. Finally, we discuss the results obtained and summarise the main conclusions drawn.

2. Literature review

The increasing generation of municipal solid waste, spurred by greater urbanisation and increased population density in the regions (Demirbas, 2011), together with growing environmental concerns, have brought about a new scenario for the management of urban solid waste (Karak et al., 2012; Das et al., 2019), in which the greater complexity involved in service provision has provoked significant cost increases (Huang et al., 2011; Caldas et al., 2019).

In Europe, the need to manage waste in a sustainable way was addressed in Directive 2008/98/EC (European Union, 2008). This priority was later incorporated into the European 2020 Horizon Strategy, which stipulated that levels of waste recycling should be significantly increased (Expósito and Velasco, 2018). However, this goal represents a major challenge for policymakers, as recycling is usually associated with higher service costs (Lavee and Khatib, 2010). The subsequent amending Directive (EU) 2018/851 (European Union, 2018) stipulated that waste management in the European Union should be improved, via sustainable management. Accordingly, the quest for greater cost efficiency has become an essential element in municipal planning considerations (Guerrini et al., 2017). In this respect, Lavee (2007) and Carvalho and Marques (2014) have reported that the introduction of recycling has actually improved efficiency in some Portuguese municipalities, by generating economies of size and density. However, some municipalities prefer continuing providing the service without recycling despite the better cost efficiency (Lavee and Reger, 2010), which poses a serious problem.

A fundamental pillar of sustainability via recycling is the selective collection of waste for this purpose (Agovino et al., 2016). To do so, differentiating between organic matter, paper/cardboard, glass, plastic, batteries, etc., specific measures must be taken, such as increasing the number of routes, vehicles, containers, workers and even fuel (Teixeira et al., 2014). These factors underlie the cost increases often observed with the selective collection of urban solid waste. Their influence in this respect has been studied by Chifari et al. (2017), by Fernández-Aracil et al. (2018), who evidenced the cost increases produced, and by Greco et al. (2015), who showed that the proportion of waste that is recycled is positively related to the costs of collecting paper, cardboard and organic matter, in particular. The latter finding highlights the importance of focusing research more specifically on the selective collection of certain types of waste.

D’Onza et al. (2016) also reported that waste collection service costs increased when selective methods were adopted. However, when the proportion of selective waste in the total waste collected increased, better use was made of collection resources. This improvement in collection capacity, in turn, could enhance cost efficiency by generating economies of scale for each type of waste. In another study of waste service costs, Callan and Thomas (2001) demonstrated the existence of product-specific economies of scale in the provision of recycling services in Massachusetts (USA), together with economies of scope. This finding suggests that such economies may also be obtained in municipal waste services, by differentiating the materials collected.

The selective collection of waste has been considered in various studies seeking to characterise the cost of municipal solid waste management services. However, to our knowledge, none have analysed the impact of selective collection on service costs and efficiency, or taken into account that these aspects might be improved by the consequent generation of economies of scale. For this reason, our study includes a variable that differentiates between municipalities that separate types of waste (the complete cycle of paper, glass and plastic) and those which do not.

Cost efficiency may also be influenced by how policymakers decide the service should be provided. Many local authorities have opted for privatisation (Jacobsen et al., 2013; Máñez et al., 2016), expecting this to enhance efficiency by incorporating the expertise and innovation assumed to be typical of the private sector (Carrozza, 2010). Moreover, costs might be reduced and efficiency enhanced if the service provider operates in more than one municipality, thereby generating economies of scale (Bel and Fageda, 2008; Pérez-López et al., 2016).

On the other hand, numerous empirical studies have failed to observe such cost and efficiency differences between the private and public provision of waste management services (Dijkgraaff and Gradus, 2003; Bel and Mur, 2009; Bel and Fageda, 2010; Campos-Alba et al., 2019). Indeed, some have reported that the introduction of private management actually increases service costs (Ohlsson, 2003; Zafra-Gómez et al., 2013). In contrast, other research findings suggest that privatisation does improve cost efficiency (Simões et al., 2012; Carvalho and Marques, 2014).

In addition to privatisation, other forms of service management are increasingly being adopted. One such is inter-municipal cooperation, which might enhance cost efficiency via the joint provision of services, taking advantage of latent economies of scale (Blaeschke and Haug, 2018). However, in order to improve efficiency by this means, the optimal size for this purpose must be identified and achieved, which may be more easily said than done (Abrate et al., 2012). In this respect, Carvalho et al. (2015) observed that a higher volume of waste collection does not necessarily mean that improvements will be obtained, despite possible economies of size and of output density. Another novel approach to the management of local public services is that of public-private collaboration, which is presumed to incorporate advantages traditionally assigned to the private sector, such as greater efficiency (Andrews and Entwistle, 2015), while maintaining the necessary degree of public control over service provision (Leviakangas et al., 2016).

The relationship between political variables and efficiency in public service management has been widely addressed in the literature, especially as regards variables related to political ideology (Hagen and Vabo, 2005; García-Sánchez, 2008; Benito-López et al. 2011, Benito et al., 2014) and political strength (Bel and Fageda, 2007). Although in the first case research findings have been mixed, studies conducted in Belgium and Spain have reported greater efficiency in public service management when a progressive party is a coalition partner in local government (De Borger and Kerstens, 1996; Benito et al., 2014).

Various studies have found that the decision taken regarding public service provision may vary according to the gender of the municipal leader (Fox and Schuhmann, 1999;

Hamidullah et al., 2015; De la Higuera-Molina et al., 2020). Therefore, it may be useful to examine whether and how the mayor's gender affects cost efficiency in the context addressed in this paper. In this respect, Funk and Philips (2019) recorded significant differences between male and female mayors in how government expenditure was allocated. Moreover, Hernández-Nicolás et al. (2018) argued that women tend to have more compassionate attitudes, while Wittenberg-Cox (2010) concluded that female leaders were more concerned than their male counterparts for people's welfare, and Little et al. (2001) reached similar conclusions with respect to the adoption of measures for environmental protection. Accordingly, we would expect the presence of a female leader of the municipal corporation to be associated with greater efficiency in the waste management service, as this area has a direct impact on citizens' quality of life.

Studies of efficiency in this field have also considered the status of municipal finances, via instruments such as the index of financial independence. Reduced external funding can lead public managers to adopt policies aimed at reducing costs (Plata-Díaz et al., 2014; López-Hernández et al., 2018). In this respect, Silkman and Young (1982), De Groot and Van der Sluis (1987) and De Borger and Kerstens (1996) have suggested there is an inverse relation between technical inefficiency and grant-sourced budget funding.

Finally, a municipality's socioeconomic and demographic characteristics may influence the cost efficiency of its waste management service (Bello and Szymanski, 1996, García-Sánchez, 2008; Rogge and De Jaeger, 2013). For example, municipalities dependent on income from tourism will seek to present a good image of the municipality, by policies such as keeping the streets clean and avoiding inefficiencies (Guerrini et al., 2017); for industrial waste collection, efficient use should be made of municipal infrastructure, taking into account that this waste is normally of higher density and mass than household refuse (García-Sánchez, 2008); higher local unemployment may reduce cost efficiency (the “cost effect”) or reduce the demand for high-quality service (the “preference effect”); the presence of a higher proportion of foreign-born population is associated with a lower cost efficiency (Nabrón-Perpiñá and De Witte, 2018) because this population group is, a priori, less interested in politics (Bruns & Himmler, 2011) or cannot vote (Bosch-Roca et al., 2012); the impact of a majority-female population may also affect cost efficiency, as women tend to be more concerned about the environment and are more willing to take action in this respect (Brough el al., 2016); moreover, men are reported to litter more than women (Kallgren et al., 2000) and to recycle less (Zelezny et al., 2000).

3. Study method

This study consists of a two-stage analysis of waste management service cost efficiency. In the first stage, we estimate the cost efficiency of the service. The term efficiency refers to the optimal relationship between production inputs and outputs of the transformation process (Andrews and Entwistle, 2013). To analyse it, the literature has traditionally employed two main methods: parametric or nonparametric techniques (Narbón-Perpiñá and De Witte, 2018a). The main difference between both approaches is that parametric techniques specify a function for the production frontier (Prior et al., 1993). The greater flexibility and the less restrictive assumptions of nonparametric methods, among other advantages, have provoked a higher use of it (Daouia and Simar, 2007; Narbón-Perpiñá et al., 2019). In view of this, the present analysis applies this nonparametric technique. Furthermore, an input orientation was selected, soefficiency will be achieved when the level of inputs is minimal for a given level of outputs (Karlaftis and Tsamboulas, 2012). This orientation has been chosen due to the level of outputs in public services are stablished externally (Balaguer-Coll and Prior, 2009).

Specifically, to estimate the cost efficiency we apply the procedure described by Garrido-Rodríguez et al. (2018), by which the estimation of partial order-m frontiers (Cazals et al., 2002) is extended to the calculation of panel data cost efficiency, as proposed by Surroca et al. (2016). There are several advantages of partial order-m frontiers: (1) it obtains results more robust to the presence of extreme values, and (2) it is not affected by problems of dimensionality (Simões et al., 2012; Balaguer-Coll, Prior, and Tortosa-Ausina, 2013). Additionally, the extension of the panel data order-m frontiers facilitates the control of possible outliers and/or random disturbances at certain moments (Campos-Alba et al., 2020). Thus, it obtains more robust results than is the case with traditional contemporaneous parametric techniques (Garrido-Rodríguez et al., 2018; Campos-Alba et al., 2020).

Specifically, panel data order-m frontier can be used to estimate the efficiency of each decision-making unit (in this case, the municipality), comparing it with a sub-sample of *m* units. A fixed positive integer m is taken to create a random subsample, for a given level of $\tilde{y}^0$, of size m with replacement between the y_{sm} that satisfy the condition $y_{sm} \geq \tilde{y}^0$, thus obtaining an efficiency coefficient $\left(\tilde{\theta}^m\right)$.

For the above-described process, we must resolve the following algorithm, based on a non-convex technology[1]. For a given average level of inputs ($\tilde{x}^0$) and outputs ($\tilde{y}^0$), we derive a coefficient of Free Disposal Hull (FDH) efficiency with panel data[2]:

$$Min_{\lambda^{k,t}\theta}\ \tilde{\theta}$$

[1] Based on the data observed on the production set of units under analysis, non-parametric techniques use mathematical programming to build a frontier that represents the best practices, and compares the position of each unit with respect to the frontier in terms of a behavior index (Charnes et al., 1978). According to the properties assumed that the technology production set accomplishes, the index can be interpreted as the percentage of input/ouput that can be reduced/increased.

[2] In studies of municipal efficiency, it is more appropriate to estimate values by reference to inputs, since outputs are mainly determined by external factors, and the prices of local administration inputs and outputs are difficult to establish (Cherchye et al., 2014).

$$s.a. \sum_{k=1}^{K} \lambda^{k,t}\, x_n^{k,t} \leq \theta\, \tilde{x}_n^0 \quad \text{n} = 1, \dots, \text{N}$$

$$\sum_{k=1}^{K} \lambda^{k,t}\, y_m^{k,t} \geq \tilde{y}_m^0 \quad \text{m} = 1, \dots, \text{M}$$

$$\sum_{k=1}^{K} \lambda^{k,t} = 1$$

$$\lambda^{k,t}\{0,1\} \quad k = 1, \dots, K \qquad [1]$$

This procedure is repeated *B* times, to obtain *B* efficiency coefficients $\tilde{\theta}^{m,b}$ (b = 1; 2; ...; B). By calculating the average of these efficiency coefficients, we obtain the order-m panel data cost efficiency:

$$\theta^m = \frac{1}{B} \sum_{b=1}^{B} \tilde{\theta}^{m,b}$$

In the use of order-m frontiers, several considerations must be taken into account. First, it is important to note that efficiency coefficients beyond the estimated frontier can be obtained, due to random replacement; these are termed ‘super-efficient’ units[3]. However, order-m frontiers based on panel data obtain fewer super-efficient values than those which are not so based, and therefore present less volatility than contemporary partial frontiers.

Second, with order-m estimation we must determine the value of *m.* The larger this value, the more observations are taken into account and therefore the more units will meet the

[3] In this case, taking an input orientation, a municipality becomes super-efficient when $\theta^m > 1$.

condition $y_{sm} \geq \tilde{y}^{0}$[4]. In this respect, Daraio and Simar (2007) observed that m is the value by which the percentage of super-efficient units decreases with each additional m[5].

In the second stage of the analysis, we apply the procedure described by Simar and Wilson (2007). Thus, the order-m panel data cost efficiency values are estimated by bootstrapped truncated regression, which is specified as follows:

$$\alpha_{Si}^{m} = a + z_i\beta + \varepsilon_i, \qquad i = 1, 2, \ldots n$$

where:

α_{Si}^{m}: Order-m panel data cost efficiency (dependent variable)

a: Constant term

z_i: Independent variables, specific variables for DMU i

ε_i: Statistical noise

Bootstrapped truncated regression provides a valid inference within models and increases the robustness of the efficiency estimation, versus possible alternatives such as Tobit regression (Simar and Wilson, 2007; Prior et al., 2019), as the efficiency scores are not observed directly and the efficiency frontier is estimated according to the sample considered (Barros and Dieke, 2008). In this context, we apply this methodology to four different models: the first one contains all the municipalities of the sample, and the other three will be structured by municipal size in order to deepen in the differences between larger and smaller municipalities. The specific ranges of population will be explained in the next section.

4. Data and variables

[4] We are applying a non-convex technology. This means that when m → ∞, the efficiency coefficients obtained by the order-m panel data frontiers converge with the FDH panel data coefficients.

[5] In the present case, having made a detailed study and obtained estimates for different values of *m*, we find that this condition is met with m = 2500.

Study data were obtained from multiple databases and subjected to comprehensive filtering and treatment to facilitate the estimation of long-term efficiency (the first stage of the analysis) and to identify its determinant factors (the second stage). Input and outputs variables are based on data supplied by the Virtual Office of Local Government Financial Coordination[6] and on the Survey of Local Infrastructure and Equipment. This survey does not provide information for municipalities with more than 50,000 inhabitants and does not include municipalities in the Spanish regions of the Basque Country, Navarre and Madrid, thus limiting our sample size.

Moreover, second stage variables comes from diverse databases: management forms are based on the Survey of Local Infrastructure and Equipment, the inventory of local public sector bodies maintained by the Ministry of Finance and Public Administration and from a private database maintained by a company specializing in the analysis of economic and financial information to determine which local municipalities have contracted out one or more public services[7]; political variables are obtained from the database of city mayors and councils maintained by the Ministry of Territorial Policy and Civil Service and data from the Ministry of the Interior; and finally, socioeconomic variables comes from the Spanish Economic and Social Yearbook published by La Caixa[8], from the National Institute of Statistics, and the Virtual Office of Local Government Financial Coordination.

Thus, having sourced the necessary databases and applied the filtering processes described above, the final study sample consisted of 283 Spanish municipalities. Of these, 57

[6] Despite the municipalities' obligation to provide budgetary information to the Virtual *Office of Local Government Financial Coordination* (Ministry of Finance and Public Administration), a number of municipalities do not comply with this requirement, thus further limiting our sample size. For example, in 2005, 18.25% failed to comply, or in 2015 (last year studied), 9.89%.

[7] As concerns the selective collection of waste, in Spain each municipality can decide the management form it sees fit, for every type of waste. Our analysis focuses on the municipalities that maintained the same management form throughout the study period, and for all types of waste (whether collected selectively or otherwise), in order to exclude changes that might distort the study findings (Pérez-López et al., 2021).

[8] This database provides information only for municipalities with over 1,000 inhabitants.

had a population of 1,000-5,000 inhabitants (representing 20.14% of the sample and 3.12% of all municipalities in this population class); 171 had a population of 5,001-20,000 inhabitants (representing 60.42% of the sample and 18.92% of the municipalities in this population class); and 55 had a population of 20,001-50,000 inhabitants (representing 19.43% of the sample and 20.75% of the municipalities in this population class).

The input values are the municipal budget expenditure, obtained from the functional budget classification[9], for each municipality, following previous studies in this field (Benito-López et al., 2011; Zafra-Gómez et al., 2013; Plata-Díaz et al., 2014; Pérez-López et al., 2016, among others). The outputs are the tonnes of waste collected, the annual production of waste corrected by the index of technical quality of the service, and the number of containers available on public roads, for each municipality. In contrast to previous studies (see the review included in Pérez-López et al., 2021), we also broke down these outputs according to the type of waste (non-selective, paper, glass, plastic, organic matter and batteries), thus enhancing the consistency of the efficiency coefficients obtained. Table 1 presents their descriptive statistics and Figure 1 disaggregates the mean tonnes of waste collected for each type by municipal size.

Table 1. Input and output variables (first stage of analysis)

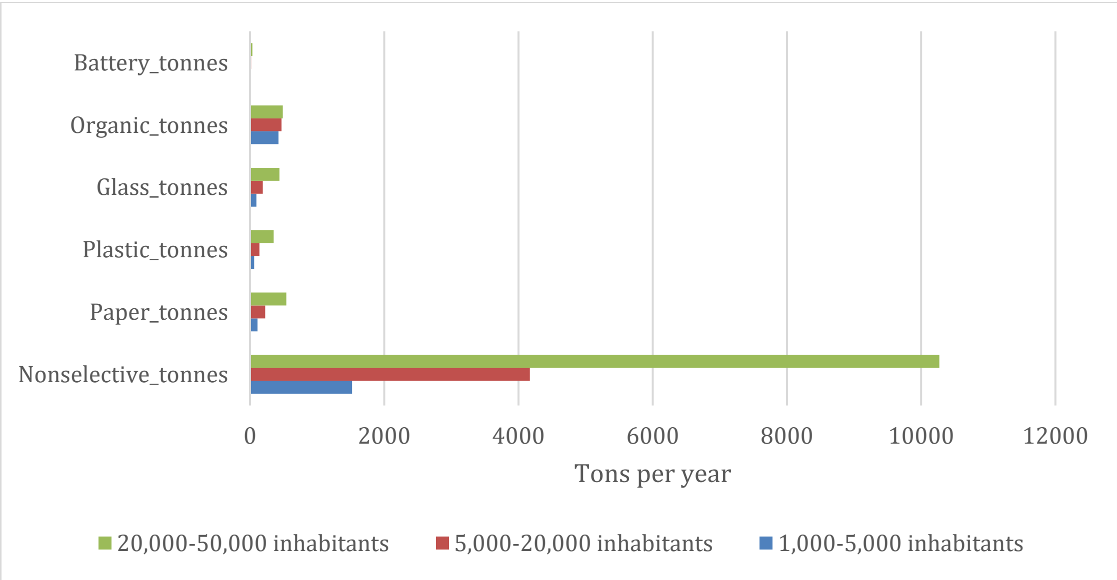
Variable	N	Mean	p50	Min	Max	Std. Dev.
Total Cost	283	850892.41	552805.00	901.20	4236929.39	793884.42
Nonselective_tonnes	283	4770.95	3544.10	9.20	28250.40	4015.84
Nonselective_containers	283	336	257	0	1973	285
Nonselective_quality	283	9398.37	6769.00	0.00	56500.80	8065.43
Paper_tonnes	283	262.87	156.00	8.20	3987.10	304.86
Paper_containers	283	46	32	0	410	50
Paper_quality	283	508.13	285.52	16.40	7974.20	601.87
Plastic	283	166.32	98.34	1.00	1910.00	194.96
Plastic_containers	283	60	35	0	831	80
Plastic_quality	283	320.25	186.14	0.00	3820.00	380.73

[9] Municipal budgets in the Spanish context include the expenditures -considered from the perspective of the financial accounting- for different categories of public services. Concretely, the functional classification applied is *Category 442 – MSW removal and street cleaning* and the equivalent *Category 162 – Waste collection, disposal and treatment,* for the years 2010 onwards - as a new classification system was implemented in Spain.

Glass	283	219.12	126.30	1.60	4727.80	268.72
Glass_containers	283	45	34	0	323	42
Glass_quality	283	426.30	239.58	3.00	9455.60	539.07
Organic_tonnes	283	463.71	75.00	0.30	6506.32	1007.00
Organic_containers	283	32	3	0	651	94
Organic_quality	283	915.50	149.60	0.30	13012.64	2016.78
Battery_tonnes	283	17.87	0.80	0.01	2936.78	125.76
Battery_containers	283	13	5	0	294	22
Battery_quality	283	35.61	1.52	0.01	5873.56	251.53

Source: The authors.

Figure 1. Waste collected by municipal size



As can be observed, the proportion of waste collected is maintained by municipal size, being non-selective waste, the highest -among the three categories-. Organic waste is similar between municipal categories and the mean value of batteries is residual. It is important, however, that largest municipalities (which is the smallest group into the sample) accumulate a greater amount of collected waste.

The variables included in the second stage of the analysis are presented in Table 2.

Table 2. Second-stage variables

Variable	Definition	N	Mean	p50	Min	Max	Std. Dev.
Efficiency	Order-m panel data cost efficiency.	283	0.5675	0.5672	0.0015	1.1599	0.3423
Selective	Dummy variable that takes the value 1 if the municipal waste management service differentiates between types of refuse (at least, the complete cycle of paper, glass and plastic) and 0 otherwise.	283	0.9287	1	0	1	0.2574
MUD	Dummy variable that takes the value 1 if the service is managed directly by the municipality and 0 otherwise.	283	0.0395	0	0	1	0.1948
MUC	Dummy variable that takes the value 1 if the service is provided by municipal under contract and 0 otherwise.	283	0.4828	0	0	1	0.4998
IC	Dummy variable that takes the value 1 if the service is provided by intermunicipal cooperation and 0 otherwise.	283	0.2756	0	0	1	0.4469
PPC	Dummy variable that takes the value 1 if the service is provided via public-private cooperation and 0 otherwise.	283	0.2021	0	0	1	0.4016
Gender	Dummy variable that takes the value 1 if the mayor is female and 0 otherwise.	283	0.1648	0	0	1	0.3711
Ideology	Dummy variable that takes the value 1 if the governing party has a progressive ideology, and 0 otherwise.	283	0.5622	1	0	1	0.4962
Strength	Dummy variable that takes the value 1 if the governing party has an absolute majority, and 0 if not.	283	0.6033	1	0	1	0.4893
Tourism	Index of tourism. Highlights the importance to the municipality of tourist-oriented activities. Obtained from the tax imposed on tourism activities.	283	2.0507	0.2574	0	98.5596	8.1082
Industrial	Index of industrial activity. Highlights the importance to the municipality of industrial activity. Obtained from the tax imposed on industrial activities.	283	2.7995	1.3610	0	216.9880	11.0173
Unemp_rate	Rate of local unemployment.	283	7.1343	6.7790	1.2463	19.3723	3.2547
Foreign	Percentage of foreign-origin population resident in the municipality	283	11.7621	7.5228	0.4318	87.7174	11.5493
Finindep	Financial Independence Index. Budgetary receivables except grants divided by budgetary payables. Winsorised[10].	283	0.6081	0.5963	0.0815	1.8717	0.1973
Lnwomen	Natural logarithm of the number of women in the municipality	283	8.4629	8.4672	6.3474	10.0892	0.7991

Source: The authors.

[10] The winsorization of the variable was made taking into account only the 1% of both tail values, in order to correct the outliers.

5. Results and discussion

In the following, we first present the results obtained in the initial stage of analysis, quantifying the panel data cost efficiency of the municipal waste management service considered, and then those obtained in the second stage, in which the determining factors of efficiency were identified and analysed.

Table 3 presents the main descriptive statistics obtained for panel data cost efficiency during the period 2005-2015. The order-m frontier panel data approach reveals the annual efficiency of each decision-making unit (municipality) and also provides a measure of overall panel data efficiency during the study period. Thus, we can compare the estimated efficiency for each year, which is not the case with contemporary frontiers (Surroca et al., 2016; Pérez-López et al., 2018).

Table 3. Panel data cost efficiency, interannual and overall (2005-2015)

Year	N	Mean	p50	Min	Max	Std. Dev.
2005	283	0.607428	0.5986099	0.0149622	1.001077	0.3460057
2006	283	0.5574479	0.5652174	0.010606	1.000001	0.3231662
2007	283	0.6100415	0.6735961	0.011707	1	0.3344076
2008	283	0.5499958	0.5598283	0.0111445	1	0.3157246
2009	283	0.5647393	0.5673965	0.0106542	1	0.3398865
2010	283	0.5814151	0.5843983	0.0089827	1	0.3458813
2011	283	0.582744	0.6025327	0.0014771	1.000004	0.3461842
2012	283	0.5739922	0.6	0.0014747	1.000011	0.3517677
2013	283	0.5715604	0.5518976	0.0014747	1.000185	0.354201
2014	283	0.4913272	0.4628092	0.0016347	1.058057	0.3401027
2015	283	0.5522658	0.5483871	0.0041541	1.159942	0.3562507
Overall panel data	283	0.6311026	0.6540723	0.0125476	1	0.3525543

cost efficiency

Source: The authors.

As can be seen, the average annual efficiency is 50-61% and the the average overall efficiency for the period is slightly higher (63%). Accordingly, these Spanish municipalities have the potential to reduce the cost of their waste management service by around 50%.

As explained above, the waste management service can be provided using different formulas, and our calculation of overall panel data cost efficiency helps determine whether the panel data cost efficiency of the waste management service varies according to the management form adopted. Accordingly, Table 4 presents the descriptive statistics for panel data overall efficiency according to the management forms considered[11]. As we can observe, on the one hand, that on average the direct management form (MUD) is the least cost efficient, while inter-municipal cooperation (IC) obtains the best results in this respect. Moreover, there are significant differences in panel data cost efficiency among the different forms of management, which justifies our analysis of this question in the second stage of the study.

Table 4. Overall panel data efficiency, by management form (2005-2015)

Variable	N	Mean	p50	Min	Max	Std. Dev.
MUD	11	0.3439647	0.1439236	0.0185118	1	0.347809
IC	84	0.6929888	0.8233635	0.0144293	1	0.3417719
PPC	38	0.5830781	0.5528663	0.072999	1	0.3450813
MUC	150	0.6296693	0.6297823	0.0125476	1	0.3516376

MUD: Municipal direct; IC: Intermunicipal cooperation; PPC: Private production with cooperation; MUC: Municipal under contract.
Source: The authors.

[11] Appendix I shows the results obtained by the Kruskal-Wallis test, which determines whether two or more samples are independent.

The first stage of our analysis obtained the cost efficiency coefficients for the municipalities considered. In the second stage (see Table 5), these results are used to analyse the determinants of efficiency in waste management service, using bootstrapped truncated regression to do so (Simar and Wilson, 2007). The characteristic feature of this analysis is that the dependent variable only reflects part of the values, while those above or below a specific value cannot be observed. In the present case, only efficiency values above 0 can be observed (Tobin, 1958; Goldberger, 1981).

Table 5. Results of the bootstrapped truncated regression by municipal size (2005-2015)[12]

Variable	Global Model	1000-5000 inhab	5000-20000 inhab	20000-50000 inhab
Selective	0.223***	0.216	0.156**	0.254**
MUC	0.281***	0.488	0.177**	0.319***
IC	0.475***	0.672*	0.369***	0.426***
PPC	0.435***	0.655*	0.326***	0.483***
Gender	0.02	0.054	0.054*	-0.068
Ideology	0.062***	0.297***	0.039**	0.030**
Strength	-0.034*	-0.019	0.013	-0.145***
Tourism	0.002*	0.041*	0.003**	-0.003**
Industrial	0.002***	0.001**	0.018***	-0.033***
Unemp_rate	-0.025***	-0.011	-0.036***	-0.020**
Foreign	-0.003**	-0.009***	-0.006***	0.003**
Finindep	1.4E-08***	0.179*	0.064	0.046
Lnwomen	0.093**	0.084	0.228***	0.139**
_Cons	-0.771***	-1.137*	-1.022***	-0.924
/Sigma	0.372	0.395***	0.396***	0.260***
N	283	57	171	55
Prob >chi^2	**0.000**	**0.000**	**0.000**	**0.000**
R^2	**0.1569**	**0.1759**	**0.1514**	**0.2914**

Source: The authors.

Level of significance: *p<0.1 **p<0.05 ***p<0.01

[12] Correlation matrix is presented in Appendix II.

Analysing the first column in Table 5, the proposed model (Global model) is statistically significant (Prob >chi^2 = 0.000). The goodness of fit value (R^2) of 15.69% reflects the degree of association. It is obtained by correlating the dependent variable with the predicted value and squaring the result (Pérez-López et al., 2015).

Our analysis of the determinants of panel data cost efficiency, according to the global model, confirms that the waste management service is more efficient when carried out selectively (i.e. when at least paper/cardboard, containers and glass are separated). Therefore, although selective collection increases costs, as observed by Greco et al. (2015) and Fernández-Aracil et al. (2018), the cost efficiency is improved, which corroborates Lavee (2007) and Carvalho and Marques (2014) with respect to solid waste collection. These findings highlight the importance of including this variable as a determinant of cost efficiency, especially in view of the fact (as reported by Expósito and Velasco, 2018) that the selective collection of waste is still not being implemented consistently by different municipalities, despite the major development of public policies in this area and the intensifying government focus on the selective collection of municipal solid waste and on the importance of recycling (Guerrini et al., 2017).

Regarding management forms, we find that direct management (MUD)[13] is the least efficient in the context considered. This finding confirms Pérez-López et al. (2016, 2018), who analysed the same four management forms, according to the size of the municipality. Similarly, Carvalho and Marques (2014) and Simões et al. (2012) concluded that participation by the private sector in the provision of public services improves their efficiency.

[13] This dummy variable is used as a reference in the proposed model, which includes the dummy variables MUC, IC and PPC.

With respect to the political factors analysed, we find that municipalities in which the governing party has a progressive orientation tend to be more cost efficient than those with conservative governments. These results are in line with those obtained by Benito-López et al. (2011) and Benito et al. (2014). Furthermore, municipalities governed by a coalition of two or more parties are more cost efficient than those with single-party governments, which corroborates the results obtained by De Borger and Kerstens (1996) and Benito et al. (2014). This finding highlights the value of governing parties being in agreement on service provision, which usually enhances efficiency. However, in contrast to the results obtained in previous studies of the relationship between the gender of the municipal leader and the efficiency of service provision (Fox and Schuhmann, 1999; Hamidullah et al., 2015; De la Higuera-Molina et al., 2020), there is no evidence that this variable significantly influences the cost efficiency of the waste management service.

Among the municipalities in our study sample, greater financial independence was positively associated with cost efficiency, which is important in terms of their capacity to take decisions without depending on other organisations. These results are in line with Silkman and Young (1982), who suggested that the provision of grants to local authorities could encourage local service provision, but at the same time would tend to reduce efficiency.

Our findings also show that municipalities with greater industrial and tourist activity are more cost efficient in their provision of the waste management service, which corroborates Benito-López et al. (2011), who observed the same association.

Finally, our analysis of the demographic variables highlights two interesting associations. Firstly, we find that the higher the proportion of immigrant resident in the municipality, the lower the cost efficiency, which is in line with Narbón-Perpiñá and De Witte (2018b). Secondly, the larger the female population of the municipality, the more cost efficient its provision of this public service. This finding confirms our study hypothesis, and the prior conclusions of Brough et al. (2016), that women are more likely than men to be motivated by environmental concerns and to favour recycling.

We then analyse the results obtained by municipal size. Table 5 includes the results of the regressions performed for the following municipal sizes: 1000-5000 inhabitants, 5000-20000 inhabitants and 20000-50000 inhabitants. In this sense, it is important to highlight that results are similar for different sizes of municipalities, and more specifically, the influence of choosing Intermunicipal Cooperation (IC) and Private production with cooperation (PPC) to provide the service and having a progressive party in the government is the same in all models, so we can consider the previous comments of these variables for all the models.

However, there are some differences considering the smaller municipalities (1000-5000 inhabitants). So, the influence of using a selective waste collection in smaller municipalities is not significant, which can be explained by the size of the municipalities and also, as we mentioned before, because this measure has not being implemented completely in many municipalities (Expósito and Velasco, 2018). It is also remarkable that the provision of the service by a private opertator (MUC) do not have a significant effect in municipalities of 1000-5000 inhabitants, which is in line with the results of Pérez-López et al (2016, 2018) and Garrido-Rodríguez et al (2018), becausethere are no economies of scale and private operators cannot take other advantages as on larger municipalities. The unemployment ratio and the proportion of women in the smallest municipalities are not significant neither, which can be a proper effect of the municipal size. By contrast, the financial independence ratio is significant only at this range, which explains the low coefficient on the global model.

Also, taking into account the range of 5000-20000 inhabitants, although most of the variables have the same effect as in the global model, it is necessary to notice that gender variable only have a significant effect for this municipal size. So, when there is a woman as municipal leader, the efficiency of the service increases, which is in line with other studies (Fox and Schuhmann, 1999; Hamidullah et al., 2015; De la Higuera-Molina et al., 2020).

In addition, some variables change their effect over waste management efficiency for larger municipalities (20000-50000 inhabitants), such as the tourism or industrial index or the presence of foreign residents. In the case of the tourism and the industrial index, the negative effect of these variables on efficiency could be a consequence of the remarkable increasing of waste generation, as Bernardino-Benito et al. (2011) pointed out, the increase of waste makes waste management more difficult, and in consequence less efficient. In the case of the foreign variable, it has a positive effect on waste management efficiency in larger municipalities, unlike what happens with smaller ones. This changing behaviour could be motivated by a notable increase in waste generated in larger municipalities as consequence of higher migrant rates (Lampe et al., 2015; Hage and Söderholm, 2008), what could leads to economies of scale that improve the efficiency of the service (Bel and Costas, 2006).

6. Conclusions

In recent years, many studies have focused on the provision of public services, reflecting the impact of major legislative, economic and social changes on public administrations (Bel and Fageda, 2010; Zafra-Gómez et al., 2013; Pérez-López et al., 2018). In this respect, a fundamental area of research is that of the cost efficiency achieved in the provision of public services, according to the different forms of service management that may be adopted (Jacobsen et al., 2013; Pérez-López et al., 2016; Campos-Alba et al., 2020). In this area, many studies have analysed the situation of waste management services, which are of mandatory provision, represent a significant element in the municipal budget and are characterised by the need for specific, costly assets (Bel and Mur, 2009; Benito-López et al., 2011). Moreover, the implementation of EU environmental regulations may affect service costs and efficiency (Ferreira et al., 2017; Callan and Thomas, 2001; D'Onza et al., 2016).

The fundamental aim of our study is to consider whether waste management services might be provided more efficiently by undertaking selective collection, i.e. distinguishing between different types of waste (paper/cardboard, glass, plastic, organic matter and batteries), rather than the traditional non-selective approach. As part of this analysis, we examine how external factors (political, financial and sociodemographic) may influence efficiency, as this knowledge is considered essential to the design of efficient service management (Guerrini et al., 2017).

The study goals were addressed by means of a two-stage analysis: in the first, order-m frontiers with panel data were used to estimate the cost efficiency (Garrido-Rodríguez et al, 2018). From the coefficients thus obtained, we then applied bootstrapped truncated regression, following Simar and Wilson (2007), to identify the factors that most influence cost efficiency. We estimated four models following this procedure: a global model considering all municipalities includes in the sample and three models considering specific groups of municiaplities by population size.

The results obtained show that factors which influence efficiency depend on the municipal size. In essence, municipalities which perform selective waste collection are more cost efficient, despite the greater costs incurred, except for smallest municipalites. We also show that direct service provision by the municipality is the least cost-efficient management form, which corroborates previous research findings (Pérez-López et al., 2016; Carvalho and Marques, 2014; Simões et al., 2012). Our analysis of related factors shows that cost efficiency is greater when the municipality is governed by a progressive party, when the government is composed of a coalition (mainly in largest ones), when it enjoys greater financial independence from other organisations (mainly in smallest ones), and when there is greater tourist and industrial activity (except in the largest one, which is the opposite). Contrary to our expectations, no significant association was observed between the mayor's gender and cost efficiency, except for municipalities with 5000-20000 inhabitants. However, the proportions of women and of foreign-born residents in the municipality were both associated with higher levels of efficiency.

The main contribution of the present study is to show that the efficiency of the waste management service is enhanced by selective collection (when this selection involves at least the complete cycle of paper, glass and plastic) and varies according to the management form adopted and the municipal size. Several implications lie behind these results: medium and larger municipalities that continue taking the waste generated to landfills should revise their policies. On the other hand, although cost efficiency of smallest municipalities seems not be affected by selective collection, central government should assist them to implement selective collection, in accordance with the Directive (EU) 2018/851 that encourages to the Member States to develop the necessary management infrastructure.

Moreover, the European regulation allows different waste management systems according to the allocation of responsibilities between public and private actors. In this sense, our results support the provision of waste management service by cooperating formulas, both through intermunicipal cooperation and private production with cooperation, as well as, the participation of private operators in the provision of the service in medium and larger municipalities.

Besides, the normative background in Europe recognizes the complexity of the municipal wate management but, also the importance of enhance the waste management in the Union in order to improve the efficiency of resource use, so public policies should be oriented towards greater awareness and education of citizens in recycling efforts in order to improve the waste management service cost efficiency.

However, several limitations arise from the study as municipalities obtains different output mix into the waste management service and each type of waste can be managed through a different management form. So, further research into these questions is still needed, and a more exhaustive analysis of the differences into the cost efficiency between municipalites with different outuput mix is needed. Moreover, the determination of which management form into the municipal solid waste is more appropriate must be addressed, taking into account the type of waste collected, rather than employing a single management form to the collection of all types of waste. Finally, it would be useful to determine the relation between the collection of non-recyclable waste and cost efficiency.

1. References

Abarca-Guerrero, L., Maas, G. & Hogland, W. (2013). Solid waste management challenges for cities in developing countries, Waste Management, 33 (1): 220-232, https://doi.org/10.1016/j.wasman.2012.09.008.

Abrate, G., Erbetta, F., Fraquelli, G., & Vannoni, D. (2014). The costs of disposal and recycling: an application to Italian municipal solid waste services. *Regional Studies*, *48*(5), 896-909.

Agovino, M., Garofalo, A., & Mariani, A. (2016). Effects of environmental regulation on separate waste collection dynamics: empirical evidence from Italy. Journal of Cleaner Production, 124, 30-40.

Andrews, R., & Entwistle, T. (2013). Four faces of public service efficiency: What, how, when and for whom to produce. *Public Management Review*, *15*(2), 246-264.

--------(2015). Public–private partnerships, management capacity and public service efficiency. *Policy & Politics*, *43*(2), 273-290.

Barros, C., & Dieke, P. (2008). Measuring the economic efficiency of airports: A Simar–Wilson methodology analysis. *Transportation Research Part E: Logistics and Transportation Review* 44(6):1039-1051.

Balaguer-Coll, M. T., & Prior, D. (2009). Short-and long-term evaluation of efficiency and quality. An application to Spanish municipalities. *Applied Economics*, 41(23), 2991-3002.

Bel, G., & Costas, A. (2006). Do public sector reforms get rusty? Local privatization in Spain. *The Journal of Policy Reform*, *9*(1), 1-24.

Bel, G., & Fageda, X. (2008). Reforming the local public sector: Economics and politics in privatization of water and solid waste. *Journal of Economic Policy Reform*, *11*(1), 45-65.

-------- (2010). Empirical analysis of solid management waste costs: Some evidence from Galicia, Spain. *Resources, conservation and recycling*, *54*(3), 187-193.

Bel, G., & Mur, M. (2009). Intermunicipal cooperation, privatization and waste management costs: Evidence from rural municipalities. *Waste management*, *29*(10), 2772-2778.

Bello, H., & Szymanski, S. (1996). Compulsory competitive tendering for public services in the UK: the case of refuse collection. *Journal of Business Finance & Accounting*, *23*(5-6), 881-903.

Benito-López, B., Moreno-Enguix, M. R. & Solana-Ibañez, J. (2011). Determinants of efficiency in the provision of municipal street-cleaning and refuse collection services, *Waste Management*, Volume 31, Issue 6,1099-1108, doi: 10.1016/j.wasman.2011.01.019.

Benito, B., Solana, J., & Moreno, M. R. (2014). Explaining efficiency in municipal services providers. *Journal of Productivity Analysis*, *42*(3), 225-239. https://doi.org/10.1007/s11123-013-0358-7

Blaeschke, F., & Haug, P. (2018). Does intermunicipal cooperation increase efficiency? A conditional metafrontier approach for the Hessian wastewater sector. *Local Government Studies*, *44*(1), 151-171.

Bosch-Roca, N., Mora-Corral, A. J. & Espasa-Queralt, M. (2012). Citizen control and the efficiency of local public services. *Environment and Planning C: Government and Policy* 30, 2, 248.

Brough, A. R. Wilkie, J.E.B., Ma, J., Isaac, M.I. & Gal, D. (2016). Is Eco-Friendly Unmanly? The Green-Feminine Stereotype and Its Effect on Sustainable Consumption, *Journal of Consumer Research*, Volume 43, Issue 4, 567–582, https://doi.org/10.1093/jcr/ucw044

Bruns, C., & Himmler, O. (2011). Newspaper circulation and local government efficiency. *Scandinavian Journal of Economics*, *113*(2), 470-492

Caldas, P., Ferreira, D., Dollery, B., & Marques, R. (2019). Are there scale economies in urban waste and wastewater municipal services? A non-radial input-oriented model applied to the Portuguese local government. *Journal of Cleaner Production*, *219*, 531-539.

Callan, S. J., & Thomas, J. M. (2001). Economies of scale and scope: A cost analysis of municipal solid waste services. *Land economics*, *77*(4), 548-560.

Campos-Alba, C. M., de la Higuera-Molina, E. J., Pérez-López, G., & Zafra-Gómez, J. L. (2019). Measuring the efficiency of public and private delivery forms: An Application to the waste collection service using order-M data panel frontier analysis. *Sustainability*, *11*(7), 2056.

Campos-Alba, C. M., Prior, D.; Pérez-López, G. & Zafra-Gómez, J.L. (2020). Long-term cost efficiency of alternative management forms for urban public transport from the public sector perspective, *Transport Policy*, 88: 16-23. https://doi.org/10.1016/j.tranpol.2020.01.014.

Carrozza, C. (2010). Privatising local public services: between industrial legacy and political ambition. *Local Government Studies, 36*(5), 599-616.

Carvalho, P., & Marques, R. C. (2014). Economies of size and density in municipal solid waste recycling in Portugal. *Waste management*, *34*(1), 12-20.

Carvalho, P., Marques, R. C., & Dollery, B. (2015). Is bigger better? An empirical analysis of waste management in New South Wales. *Waste Management*, *39*, 277-286.

Cazals, C., J. P. Florens & Simar, L. (2002). Nonparametric frontier estimation: a robust approach, *Jounal of Econometrics*, 106, 1–25.

Chifari, R., Piano, S. L., Matsumoto, S., & Tasaki, T. (2017). Does recyclable separation reduce the cost of municipal waste management in Japan? *Waste management*, *60*, 32-41.

Daouia, A., & Simar, L. (2007). Nonparametric efficiency analysis: a multivariate conditional quantile approach. *Journal of Econometrics*, *140*(2), 375-400.

Daraio, C. & L. Simar (2007). *Advanced Robust and Nonparametric Methods in Efficiency Analysis: Methodology and Applications*, New York, Springer.

Das, S., Lee, S. H., Kumar, P., Kim, K. H., Lee, S. S., & Bhattacharya, S. S. (2019). Solid waste management: Scope and the challenge of sustainability. *Journal of cleaner production*, *228*, 658-678.

De Borger, B., & Kerstens, K. (1996). Cost efficiency of Belgian local governments: A comparative analysis of FDH, DEA, and econometric approaches. *Regional science and urban economics*, *26*(2), 145-170.

De Groot, H. & Van der Siuis, J. (1987). *Bureaucracy response to a budget cut: An economic model*, Kyklos 40, 103-109.

De La Higuera-Molina, E. J., Plata-Díaz, A.M., Zafra-Gómez, J.L., & Campos-Alba, C. M. (2020). A Dynamic Model for Analysing Partisan Political Corruption in Local Government: the Spanish Experience. *Lex Localis-Journal of Local Self-Government*, *18*(1).

Demirbas, A. (2011). Waste management, waste resource facilities and waste conversion processes. *Energy Conversion and Management*, *52*(2), 1280-1287.

De Witte, K. & R. C. Marques (2010). Influential observations in frontier models, a robust non-oriented approach to the water sector, *Annals of Operations Research*, 181(1), 377-392.

Dijkgraaf, E., & Gradus, R. H. (2003). Cost savings of contracting out refuse collection. *Empirica*, *30*(2), 149-161.

-------- (2013). Cost advantage cooperations larger than private waste collectors. *Applied Economics Letters*, *20*(7), 702-705.

D'Onza, G., Greco, G., & Allegrini, M. (2016). Full cost accounting in the analysis of separated waste collection efficiency: A methodological proposal. *Journal of environmental management*, *167*, 59-65.

Ekere, W., Mugisha, J., & Drake, L. (2009). Factors influencing waste separation and utilization among households in the Lake Victoria crescent, Uganda. *Waste management*, *29*(12), 3047-3051.

European Union (2008). Directive 200898EC of The European Parliament And of The Council on Waste and Repealing Certain Directives. *Official Journal of the European Union*, 312, 330.

--------- (2018). Directive (UE) 2018/851 of The European Parliament And of The Council of May 30th of 2018, which modifies the Directive 2008/98/CE on Waste. *Official Journal of the European Union*, *150*, 109-140.

Expósito, A., & Velasco, F. (2018). Municipal solid-waste recycling market and the European 2020 Horizon Strategy: A regional efficiency analysis in Spain. *Journal of Cleaner Production*, *172*, 938-948.

Fernández-Aracil, P., Ortuño-Padilla, A., & Melgarejo-Moreno, J. (2018). Factors related to municipal costs of waste collection service in Spain. *Journal of Cleaner Production*, *175*, 553-560.

Ferreira, M. A., Jabbour, C. J. C., & de Sousa Jabbour, A. B. L. (2017). Maturity levels of material cycles and waste management in a context of green supply chain management: an innovative framework and its application to Brazilian cases. *Journal of Material Cycles and Waste Management*, *19*(1), 516-525.

Fox, R. L., & Schuhmann, R. A. (1999). Gender and local government: A comparison of women and men city managers. *Public Administration Review*, 231-242.

Funk, K., & Philips, A. (2019). Representative Budgeting: Women Mayors and the Composition of Spending in Local Governments. *Political Research Quarterly, 72*(1), 19-33. doi:10.2307/45276888

García-Sánchez, I. M. (2008). The performance of Spanish solid waste collection. *Waste Management & Research, 26(4), 327–336.* doi:10.1177/0734242x07081486

Garrido-Rodríguez, J. C., Pérez-López, G., Zafra-Gómez, J. L. & Prior, D. (2018). Estimación de la eficiencia a largo plazo en servicios públicos locales mediante fronteras robustas con datos de panel. *Hacienda Pública Española / Review of Public Economics*, *226*(3), 11-36. DOI: 10.7866/HPE-RPE.18.3.1

Goldberger, A. S. (1981). Linear regression after selection. *Journal of Econometrics*, *15*(3), 357-366.

Greco, G., Allegrini, M., Del Lungo, C., Savellini, P. G., & Gabellini, L. (2015). Drivers of solid waste collection costs. Empirical evidence from Italy. *Journal of Cleaner Production*, *106*, 364-371.

Guerrini, A., Carvalho, P., Romano, G. Cunha-Marques, R. & Leardini, C. (2017). Assessing efficiency drivers in municipal solid waste collection services through a non-parametric method, *Journal of Cleaner Production*, *147*, 431-441, https://doi.org/10.1016/j.jclepro.2017.01.079.

Hage, O., & Söderholm, P. (2008). An econometric analysis of regional differences in household waste collection: the case of plastic packaging waste in Sweden. *Waste management*, *28*(10), 1720-1731.

Halkos, G. & Petrou, K. N. (2019). Assessing 28 EU member states' environmental efficiency in national waste generation with DEA. J. Clean. Prod., 208, pp. 509-521

Hamidullah, M. F., Riccucci, N. M., & Pandey, S. K. (2015). Women in city hall: Gender dimensions of managerial values. *The American Review of Public Administration*, *45*(3), 247-262.

Hernández-Nicolás, C.M., Martín-Ugedo, J.F & Mínguez-Vera, A (2018). Women Mayors and Management of Spanish Councils: An Empirical Analysis, Feminist Economics, 24:1, 168-191, DOI: 10.1080/13545701.2017.1347695

Huang, Y. T., Pan, T. C., & Kao, J. J. (2011). Performance assessment for municipal solid waste collection in Taiwan. *Journal of environmental management*, *92*(4), 1277-1283.

Jacobsen, R., Buysse, J., & Gellynck, X. (2013). Cost comparison between private and public collection of residual household waste: multiple case studies in the Flemish region of Belgium. *Waste management*, *33*(1), 3-11.

Kallgren, C.A., Reno, R. R. & Cialdini, R. B. (2000). A Focus Theory of Normative Conduct: When Norms Do and Do Not Affect Behavior, *Personality and Social Psychology Bulletin*, 26 (8), 1002–12.

Karak, T., Bhagat, R. M., & Bhattacharyya, P. (2012). Municipal solid waste generation, composition, and management: the world scenario. *Critical Reviews in Environmental Science and Technology*, *42*(15), 1509-1630.

Karlaftis, M. G., & Tsamboulas, D. (2012). Efficiency measurement in public transport: are findings specification sensitive?. *Transportation Research Part A: Policy and Practice*, 46(2), 392-402.

Kinnaman, T. C. (2006). Policy watch: examining the justification for residential recycling. *Journal of Economic Perspectives*, 20(4), 219-232.

Lampe, H. W., Hilgers, D., & Ihl, C. (2015). Does accrual accounting improve municipalities' efficiency? Evidence from Germany. *Applied Economics*, *47*(41), 4349-4363.

Lavee, D. (2000). Are Economic Tools Preferable to Direct Regulatory Measures in Achieving Environmental Goals?. *Environmental Policy and Law*, (Preprint), 1-11.

Lavee, D. (2007). Is municipal solid waste recycling economically efficient? *Environmental Management*, *40*(6), 926-943.

Lavee, D., & Khatib, M. (2010). Benchmarking in municipal solid waste recycling. *Waste management*, *30*(11), 2204-2208.

Lavee, D., & Nardiya, S. (2013). A cost evaluation method for transferring municipalities to solid waste source-separated system. *Waste management*, 33(5), 1064-1072.

Lavee, D., & Regev, U. (2010). A proposal for alternative government policy to reduce landfill of household waste in Israel. *Israel Economic Review*, 8(1), 91-110.

Leviäkangas, P., Kinnunen, T., & Aapaoja, A. (2016). Infrastructure public–private partnership project ecosystem–financial and economic positioning of stakeholders. *The European Journal of Finance*, *22*(3), 221-236.

Little, T. H., Dunn, D. & Deen, R. E. (2001). A View from the Top: Gender Differences in Legislative. Priorities among State Legislative Leaders. *Women & Politics* 22 (4), 29-50.

López-Hernández, A. M., Zafra-Gómez, J. L., Plata-Díaz, A. M., & de la Higuera-Molina, E. J. (2018). Modeling fiscal stress and contracting out in local government: The influence of time, financial condition, and the great recession. *The American Review of Public Administration*, *48*(6), 565-583.

Máñez, J., Pérez-López, G., Prior, D., & Zafra-Gómez, J. L. (2016). Understanding the dynamic effect of contracting out on the delivery of local public services. *Regional Studies*, 50(12), 2069-2080. DOI: 10.1080/00343404.2015.1090561

Narbón-Perpiñá, I., & De Witte, K. (2018a). Local governments' efficiency: a systematic literature review. Part I. *International Transactions in Operational Research*, *25*(2), 431-468.

Narbón-Perpiñá, I., & De Witte, K. (2018b). Local governments' efficiency: a systematic literature review. Part II. *International Transactions in Operational Research*, *25*(4), 1107-1136.

Narbón-Perpiñá, I., Balaguer-Coll, M. T., Petrović, M., & Tortosa-Ausina, E. (2019). Which estimator to measure local governments' cost efficiency? The case of Spanish municipalities. *SERIEs*, 1-32.

Ohlsson, H. (2003). Ownership and production costs: choosing between public production and contracting-out in the case of Swedish refuse collection. *Fiscal Studies*, *24*(4), 451-476.

Pérez-López, G., Prior, D., & Zafra-Gómez, J. L. (2015). Rethinking new public management delivery forms and efficiency: Long-term effects in Spanish local government. *Journal of public administration research and theory*, *25*(4), 1157-1183.

-------- (2018). Temporal scale efficiency in DEA panel data estimations. An application to the solid waste disposal service in Spain. *Omega*, *76*, 18-27. DOI: https://doi.org/10.1016/j.omega.2017.03.005

Pérez-López, G., D. Prior, J. L. Zafra-Gómez & A. M. Plata-Díaz (2016): Cost efficiency in municipal solid waste service delivery. Alternative management forms in relation to local population size, *European Journal of Operational Research*, nº 255 (2), págs. 583-592, http://dx.doi.org/10.1016/j.ejor.2016.05.034

Perez-Lopez, G., Thanh Dung Tran, C. T., & Dollery, B. (2021). Is council co-operation cost efficient? An empirical analysis of waste collection in Spanish local government. *Public Money & Management*, 1-11.

Plata-Díaz, A. M., Zafra-Gómez, J. L., Pérez-López, G. & López-Hernández, A. M. (2014). Alternative management structures for municipal waste collection services: the influence of economic and political factors, *Waste Management*, 34 (11), 1967-1976.

Prior, D. Martín-Pinillos, I., Pérez-López, G., & Zafra-Gómez, J. L. (2019). Cost efficiency and financial situation of local governments in the Canary Isles during the recession, *Spanish Accounting Review*, 22(2), 129-144.

Prior, D., Verges, J. & Vilardell, I. (1993). La evaluación de la eficiencia en los sectores privado y público. *Instituto de Estudios Fiscales, Madrid*, 231-268.

Rogge, N. & De Jaeger, S. (2013). Measuring and explaining the cost efficiency of municipal solid waste collection and processing services, *Omega*, 41(4): 653-664 https://doi.org/10.1016/j.omega.2012.09.006.

Romano, G. & Molinos-Senante, M. (2020). Factors affecting eco-efficiency of municipal waste services in Tuscan municipalities: An empirical investigation of different management models, *Waste Management*, Volume 105,384-394, https://doi.org/10.1016/j.wasman.2020.02.028.

Sidique, S. F., Lupi, F., & Joshi, S. V. (2010). The effects of behavior and attitudes on drop-off recycling activities. *Resources, conservation and recycling*, *54*(3), 163-170.

Silkman, R. & Young, D.R. (1982), X-Efficiency and state formula grants, *National Tax Journal* 35, 383-397.

Simar, L., & Wilson, P.W. (2007). Estimation and inference in two-stage, semi-parametric models of production processes. *Journal of Econometrics* 136:31-64.

Simões, P., & Marques, R. C. (2012). On the economic performance of the waste sector. A literature review. *Journal of Environmental Management,* 106, 40-47.

Surroca, J., Prior, D. & Tribó Giné, J. A. (2016). Using panel data DEA to measure CEOS' focus of attention: an application to the study of cognitive group membership and performance. *Strategic Management Journal*, 37(2), 70–388. DOI: 10.1002/smj.2350

Teixeira, C. A., Russo, M., Matos, C., & Bentes, I. (2014). Evaluation of operational, economic, and environmental performance of mixed and selective collection of municipal solid waste: Porto case study. *Waste Management & Research, 32(12),* 1210-1218.

Tobin, J. (1958). Estimation of relationships for limited dependent variables. *Econometrica: journal of the Econometric Society*, 24-36.

Wittenberg-Cox, A. (2010). *How women mean business: A step by step guide to profiting from gender balanced business*. John Wiley & Sons.

Zafra-Gómez, J. L., Prior, D., Plata-Díaz, A. M., & López-Hernández, A. M. (2013). Reducing costs in times of crisis: delivery forms in small and medium sized local governments' waste management services. *Public Administration*, *91*(1), 51-68.

Zafra-Gómez, J. L., Plata-Díaz, A. M., Pérez-López, G., & López-Hernández, A. M. (2016). Privatisation of waste collection services in response to fiscal stress in times of crisis. *Urban Studies*, *53*(10), 2134-2153.

Zelezny, L. C., Chua, P. P., & Aldrich, C. (2000). New ways of thinking about environmentalism: Elaborating on gender differences in environmentalism. *Journal of Social issues*, *56*(3), 443-457.