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Cost Efficiency in Municipal Solid Waste (MSW): Different Alternatives in Service Delivery for Small and Medium Sized Spanish Local Governments

Jose-Luis Zafra-Gómez *, Germán López-Pérez, Marta Garrido-Montañés and Elisabeth Zafra-Gómez

Department of Accounting and Finance, University of Granada, 18071 Granada, Spain
* Correspondence: jlzafra@ugr.es

Abstract: The provision of local public services has become one of the main concerns of local governments. Therefore, the selection of the most appropriate form of management to maximize efficiency levels in the provision of local public services has been widely analyzed throughout the academic literature. In this context, the aim of this paper is to add new knowledge to the literature on efficiency in the provision of local public services. To this end, we propose the study of four forms of management (interested indirect management; indirect management by concession; intermunicipal co-operation; public service provision) through a free disposal hull data panel (FDHDP) methodology for the 2014–2016 period. We find that public-private partnership contracting is less efficient on waste removal services when accounting for quality. However, the promised benefits of contracting out are realized when contractors are made responsive to service quality through concessions.

Keywords: efficiency; MSW; municipalities; public management; privatization

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1. Introduction

The increasing difficulties that local public administrations have had to face in the last decade have led to an incipient interest in measuring the efficiency achieved in the provision of different public services [1]; thus, the monitoring of these services has become especially relevant within local public agendas [2,3].

In this context, numerous studies have analyzed the relationship between efficiency and the choice of management methods that generate higher levels of efficiency and cost savings in the provision of these services [4–10]. In this sense, the academic literature contains several studies that analyze the efficiency of local public agents in the provision of services, such as urban public transport [11,12], street cleaning [13] or solid urban waste collection [14–16].

Among the different forms of management, three main categories can be distinguished: privatization of public services (either through concessions or public–private participatory management), direct public management and intermunicipal co-operation. In this sense, the municipal solid waste service (MSW) has become one of the most studied services due to the difficulty of its provision and the costs involved [7,17,18].

Consequently, analyzing which forms of management generate higher levels of efficiency in MSW has become an issue of great relevance; empirical evidence can be obtained to demonstrate which of the different methods of public service management is more appropriate for the provision of public services.

In this sense, the aim of this paper is to analyze how the different forms of management affect the cost efficiency of Spanish municipalities to determine which of them is the most efficient in terms of MSW service provision.

For this purpose, a total of 1563 Spanish municipalities were analyzed using the meta–frontier methodology developed by Battese and Rao [19] and Battese et al. [20]. To obtain the cost efficiency of the MSW service, non-parametric partial frontiers have been used by

applying order–m frontiers [21,22]. Due to the robustness of the models and as a replacement for the use of data envelopment analysis (DEA), non-parametric partial frontiers are proposed in the presence of extreme outliers and units [23]. The results obtained in this study show that outsourcing achieves higher levels of cost savings in MSW. These results show the differences between the different forms of management in terms of cost efficiency depending on the size of the municipalities. In this sense, it is observed that smaller municipalities have higher levels of efficiency when they combine joint management with outsourcing of the service, the latter being more efficient in municipalities with a larger population.

This paper is structured as follows. In the second section, a theoretical analysis of the MSW efficiency is carried out. The third section presents the methodology applied to meet the objectives set out in this study. The fourth section presents the data used for the analysis and a study of the results obtained. Finally, the last section shows the conclusions and limitations of the study.

2. Theoretical Approach

2.1. A Review of Forms of Management and Efficiency

The debate on the cost of the service and the most appropriate form of management to maximize efficiency levels has been the subject of numerous studies [7,10,13,16,24–26], making it an extremely important issue. The need to find the most appropriate way of managing public services has led to the analysis of a wide variety of ways of providing local public services [27]. In this context, a wide range of theories can be found that explain the use of these forms of management, such as the theory of property rights, the exploitation of economies of scale and transaction costs or public choice theory, among others [3,11,24,28]. In this sense, the most analyzed forms of management in the academic literature are mainly the privatization of public services, direct public management or intermunicipal co-operation [1,14,16].

In relation to the above, some authors argue that direct public provision is the best option, as this will avoid the creation of monopolies by private companies and may even be cheaper than private sector provision [8,10,29–31]. In this regard, authors such as Zafra-Gómez et al. [24] and Ohlsson [32] argue that private management of the service does not necessarily have to be cheaper than public management.

On the other hand, privatization can be defined as the outsourcing of a public service to a private company [33,34]. The advantages of using this type of management include cost savings, as services can be provided at a lower cost and in a more efficient way [30,35–37]. Within this category can be found the contracting out form, which can be defined as a form of privatization in which a private company makes residual profits from the provision of the service [34,38], and the public-private partnership (PPP), where the local authority and the entrepreneur share the operating results on the basis of what is fixed in the contract. In this way, the equity is held by both the public partner, who ensures that the public objectives of the service are met, and the private partner with industry experience, who is usually responsible for the day-to-day operation of the service [38,39]. However, several authors have criticized this form of management as, in certain cases, it is not cost effective.

In this respect, the choice of the most appropriate form of management may depend on a number of external factors, including the size of the municipality. In the case of small municipalities, many cannot afford to privatize public services since such municipalities are not attractive to potential providers [7,14]. This, together with the fact that smaller municipalities need to share resources and increase the volume of service provision to save costs and achieve optimal production [14,31], has made it necessary to analyze an alternative to the management models already defined: intermunicipal co-operation.

According to Bel and Warner [40], intermunicipal co-operation is a reform of public service delivery that is not only concerned with costs or economic efficiency, but addresses aspects such as spatial context and governance structure. A more comprehensive and current definition can be found in the study by Luca and Modrego [41], who define

intermunicipal co-operation as a governance structure where two or more municipalities cooperate, either directly or indirectly, to provide goods and/or services. Applying this form of managing public services has numerous advantages, especially the cost savings that can be obtained through economies of scale, which is one of the key motivations for opting for this model of joint action [42]. Co-operation allows two or more organizations to participate jointly in the provision of public services [42], which is why governments around the world have promoted joint action between municipalities with the aim of improving the management of these services [43].

2.2. Forms of Management and Municipal Solid Waste Service (MSW)

Public waste collection and its treatment is a highly complex service. This, together with its high costs, makes it a very important service for local governments [44]. For this reason, the relationship between different forms of management and the efficiency of the MSW service has been widely analyzed in the academic literature [7,45,46]. However, there is no global consensus on the best alternative for the provision of this service [3,38].

On the one hand, there are a group of authors [10,35] who argue that contracting out can have certain advantages when providing the MSW service, including cost reductions, since the private sector usually has lower production costs than the public sector [47], presenting itself as an alternative that achieves high levels of efficiency [3,28]. However, some authors argue that the efficiency gains from private contracting for the provision of MSW may be offset by the high transaction costs of contracting [48].

However, when analyzing which forms of management have higher levels of efficiency, a number of external factors need to be taken into account. In this regard, Casado-Aranda et al. [49] argue that there are a number of exogenous factors (political, financial and socio-demographic) that can influence the cost efficiency of MSW service provision. Related to this, numerous studies show that contracting out does not necessarily lead to economies of scale, especially in smaller municipalities [7,14,24]. This is because the size of the municipality is related to the costs of providing this public service [15,24,28].

As can be seen, there is some controversy in the academic literature as to what is the best form of management to obtain higher levels of efficiency in the provision of different public services and, more specifically, the MSW service. In this context, the present paper has two main objectives: firstly, finding out which form of management is more efficient for the public waste service; and, secondly, to analyze how the different forms of service management affect the size of the municipalities.

3. Data and Methodology

3.1. Data

The data used to test these situations came from the waste removal service in Spanish municipalities. In Spain, the removal of waste is one the public services that local municipalities are required to provide under Article 26 of the Spanish Law 7/1985 (Bases de Regimen Local). This service tended to represent a large share of the budget of each municipality. This study focused on the 2014–2016 period and analyzes data from 1583 municipalities for waste removal services. Due to data limitations, this work focused on the municipalities with between 1000 and 50,000 inhabitants (this restriction with respect to the population size of the municipality arose from the non-availability of data for municipalities with fewer than 1000 inhabitants, and from a parallel absence of data on the MSW service (outputs) for municipalities with over 50,000 inhabitants [3]); the sample group represented 50% of all municipalities of this population bracket that had a public waste service.

Spanish municipalities were a helpful case for the analyses, as they (a) were large enough in number for panel data analyses, (b) offered objective data on service quality (see below), and (c) offered variation in organizational forms (public, intermunicipal, contracting-out, public-private partnership) for the same services across municipalities of similar size.

3.1.1. Dependent Variable

To measure the efficiency of the waste municipal service, this study was based, firstly, on the effective cost of local services (CESEL) (the effective cost of these public services has been defined in the Rationalization and Sustainability Law of the Local Administrations (Law 27/2013, 27 December 2013)), which considers the real costs, direct and indirect, for public services (this estimation was conducted in accordance with the criteria specified by the Spanish Ministry of Taxes (Orden HAP/2075/2014, 6 November 2014)); and, secondly, on a service quality-adjusted performance measure. Service quality was measured through the Survey of Equipment and Local Infrastructures, an official survey run by the Spanish Ministry for Political, Territorial and Public Function. As described in Table 1, this survey measures objective characteristics of service [50]. The waste collection quality was measured by the availability and cleaning of containers, together with the collection periodicity [50]. Indicators such as collection periodicity were plausibly observable to users, and thus considered aspects of service quality on which users could hold service providers accountable.

Table 1. Quality values of waste service.

Characteristics of Service	Quality
1 (Availability and cleaning of containers)	Inadequate
2 (Collection periodicity)	Adequate

Source: EIEL.

3.1.2. Explanatory Variables

The main explanatory variables were the organizational forms used to provide public services. As Table 2 shows, four different organizational forms could be distinguished: (1) public service provision (services provided directly by the municipality); (2) public-private partnership (PPP); (3) contracting out (GIC) (services provided directly by private company); and (4) intermunicipal co-operation (IC) (public-to-public alliances in which several municipalities create a new public entity to deliver the service).

Table 2. Effective cost of public services by organizational form.

Organizational Form	Description
Public service provision	Direct expenditure was calculated for each service by aggregating the amounts directly attributable to them corresponding to personnel expenses, current expenses in goods and services, amortization of investments, net interest payments for financial leasing operations, expenses in current and capital transfers, and other non-financial expenses related to the provision of the service. Indirect costs: these were expenses related to the general administration.
Indirect management, with the local authority and the entrepreneur sharing the operating results in the proportion established in the contract (PPP)	The effective cost was determined by the totality of spending by the municipality to the contractor, including the contract price, as well as, where appropriate, operating subsidies or coverage of the price of the service.
Indirect management by concession, with the concessionaire managing the service at its own risk (GIC)	Where the contractor's remuneration was received directly by the user (through fees), the effective cost was determined by the income derived from the fees paid by them, and any service price subsidies from the municipality.
Intermunicipal co-operation (IC)	The same as public provision, but with the distribution of expenses that corresponds to each of the municipalities.

Source: Own elaboration from Order HAP/2075/2014.

3.2. Methodology

To assess the objective, the meta–frontier developed by Battese and Rao [19] and Battese et al. [20] was applied using the RStudio R 4.2.1. software. This allowed us to compare the efficiency of municipalities providing public services under different organizational forms. When the meta–frontier was applied, different frontiers were obtained for each organizational form considered; in other words, local frontiers were obtained. In this way, the efficiency of each municipality was estimated, and all the municipalities that have the same organizational form—that is, that were under the same local frontier—were compared. In addition, a homogeneous frontier was obtained that encompassed all municipalities (meta–frontier) without considering the organizational forms and incorporated all local frontiers [51]. Once the meta–frontier was computed, it became possible to obtain the technology gap ratio (TGR), which was the lowest possible cost per municipality [19,20,52]. This was measured by the distance between the efficiency of the municipality and the local frontier, and the latter with the meta–frontier.

There are different techniques to calculate non-parametric frontiers. This study was based on the application of the free disposal hull data panel (FDHDP). This methodology allowed us to estimate the partial frontiers by bootstrapping the values of the sample. Thereafter, as suggested by Cazals et al. [53], an average value of all the estimations was calculated. This methodological approach was chosen following recent studies analyzing public service delivery [3,46]. One of the strengths of this methodological approach was that it produced more robust frontiers than estimates based on data envelopment analysis (DEA) [54] and allows the obtaining of long-term robust estimations. Thus, this approach overcame certain limitations of the intertemporal models that did not allow comparison of the same unit over a period of time [3,46]); it also allowed us to calculate the efficiency values of a municipality by comparing it with real productive units and avoiding the convexity condition of DEA, as well as envelope the data much more closely than DEA, taking into account the panel nature of the data.

When introducing the concept of meta–frontier, local partial frontiers were made with panel data ($CE^{f,t}$) for each of the organizational forms analyzed. Subsequently, a joint estimate for all units was derived through an estimation called meta–frontier panel data ($CE^{f,t}$). Thus, both frontiers were estimated by an analysis of the FDH data panel. This output-oriented methodology was used as the study sought to understand which management form was more efficient when the same input was given, and the outputs changed by introducing quality measures. Thus, following the approach of Cordero et al. [55], the efficiency coefficient will be obtained through the following equation:

$$\hat{\theta}_{FDH} = max\left\{\lambda y \leq \sum_{i=1}^{N} \gamma_i y_i; x \geq \sum_{i=1}^{N} \gamma_i = 1; \gamma_i \in \{0,1\}; i = 1, \ldots, n\right\} \quad (1)$$

where $\hat{\theta}_{FDH} = 1$ means that the municipality is efficient and, if the value is smaller than 1, the municipality is inefficient.

With the estimation of the local frontiers and the meta–frontier (see Appendix B) conducted to estimate which organizational form was more efficient over time, the technology gap ratio in the Long Term was applied ($TGR^{f,t}$); this ratio showed the distance of the local frontier with respect to the meta–frontier [3,46,55]. This ratio was calculated as follows:

$$TGR^{f,t} = \frac{CE^{t}}{CE^{f,t}} \quad (2)$$

Finally, to study the different levels of efficiency by organizational form, the Kruskal–Wallis test, the Mann–Whitney U test and the Li test were applied. The Kruskal–Wallis test determined whether there were differences in the efficiency values calculated for each organizational form analyzed. This non-parametric test assumed the normality of the analyzed variables and determined if two or more samples were independent; however, it did not establish what differences exist between the samples. Therefore, the Mann–Whitney

U test was applied, which tested the independence of two samples with the null hypothesis that there are no differences. The Li test [56] was used to compare the distributions of the different groups analyzed and measure the distance between two density functions through their integrated mean square error [57].

Table 3 explains the variables used as inputs and outputs for waste service, while Appendix A shows descriptive statistics for service. The main input at the service was the effective cost of the local service, which was explained above. As outputs at the service were, the tons of waste, the tons of waste adjusted for quality (based on quality, production and the quality index published by the Survey of Local Infrastructure and Equipment (EIEL)), the number of containers and the network size were used.

Table 3. Inputs and outputs.

Service	Type	Variable	Definition	Source
Waste management	Input	Effective cost	Effective cost of the local service (ECLS)	Virtual Office of Local Government Financial Coordination of the Ministry of Public Administration and Treasury
	Output	Tons of waste	Annual production of waste, in tons/year	Survey of Local Infrastructure and Equipment (EIEL), from the Ministry of Public Administration's website
		Tons quality	Annual production of waste, in tons/year, adjusted by the index of service quality	
		Containers	Number of containers recorded as installed on public roads in the municipalities, for each type of MSW collection	
		Network size	Kilometers of distance by municipality	

Virtual Office of Local Government Financial Coordination and the Survey of Local Infrastructure and Equipment.

4. Implementation and Results

After applying the proposed FDH-DP methodology, we assessed whether there were significant differences in average efficiency levels between different organizational forms using the Kruskal-Wallis test. The null hypothesis was that the k samples or groups had equal means. This test was applied to the TGR of the municipalities included in each organizational form for the analyzed period (Table 4). Results displayed in Table 4 allow us to reject the null hypothesis with a significance level of 99; thus, the cost-efficiency of each of the organizational forms studied was significantly different from each other for waste service.

Table 4. Kruskal–Wallis Test.

Service	Waste Management	
Quality	No	Yes
Chi-squared	925.12	1079.96
Freedom degrees	3	3
p-value	0.000	0.000

Secondly, the Mann–Whitney test and the Li test [56,58,59] were performed to assess differences in efficiency levels between each organizational form and service of waste management. The findings again show significant differences (Table 5).

Table 5. Assessing differences in efficiency between different organizational forms (Mann–Whitney test and Li test).

Null Hypothesis (H0)	Waste No Quality	Waste Quality	Waste No Quality	Waste Quality
CE_t^k (PPP) = CE_t^k (GIC)	H0 rejected ***	H0 rejected ***	H0 rejected ***	H0 rejected ***
CE_t^k (PPP) = CE_t^k (IC)	H0 rejected *	H0 not rejected	H0 rejected ***	H0 rejected ***
CE_t^k (PPP) = CE_t^k (PSP)	H0 rejected ***	H0 rejected ***	H0 rejected ***	H0 rejected ***
CE_t^k (GIC) = CE_t^k (IC)	H0 rejected ***	H0 rejected ***	H0 rejected ***	H0 rejected ***
CE_t^k (GIC) = CE_t^k (PSP)	H0 rejected ***	H0 rejected ***	H0 rejected ***	H0 rejected ***
CE_t^k (IC) = CE_t^k (PSP)	H0 rejected ***	H0 rejected ***	H0 v rejected ***	H0 rejected ***

Level of significance: * 0.05, *** 0.001; CE_t^k: local frontier; PSP: public service provision; IC: intermunicipal co-operation; PPP: public-private partnership; GIC: contracting out; Mann-Whitney test estimated in SPSS 21; Li Test estimated in R. (See Appendix C).

Thirdly, this study assessed which organizational forms deliver services most efficiently, with and without accounting for service quality (see Table 6 and Figure A1, Appendix D). As shown in Table 6, higher values in the TGR indicate that the organizational form was closer to the meta–frontier—and thus more efficient.

Table 6. $TGR^{f,t}$ for waste management (all differences between efficiency and quality-adjusted efficiency are statistically significant across organizational forms (Appendix D)).

Organizational Form	Without Quality *	With Quality *	Rate of Change
Public-private partnership	0.459	0.516	12.49%
Contracting out	0.662	0.763	15.30%
Intermunicipal co-operation	0.487	0.539	10.54%
Public service provision	0.644	0.675	4.90%

* Significance levels in Table 5.

The results show that contracting out form is most efficient for waste service without adjusting for quality (Average $TGR^{Waste\,f,t}$ of 0.662), while public-private partnership is least efficient (Average $TGR^{Waste\,f,t}$ of 0.459). When accounting for service quality, contracting out form remains the most efficient organizational form (Average $TGR^{Waste\,f,t}$ of 0.763), ahead of other organizational forms such as public-private partnership (Average $TGR^{Waste\,f,t}$ of 0.516), intermunicipal co-operation (Average $TGR^{Waste\,f,t}$ of 0.539) and public service provision (Average $TGR^{Waste\,f,t}$ of 0.675). These results support the first objective of this study, showing that contracting out form is more efficient than public-private partnership, when adjusting for service quality. This is consistent with previous studies showing greater quality shading in private provision—and thus a greater effect on quality-adjusted efficiency in private provision [60–62]. Furthermore, the results show that contracting out is more efficient than direct public provision. In Table 6, the results show that contracting out has a TGR of 0.763 in waste services, while direct provision has a value of 0.675; the differences are also applicable to the rates of change. Finally, the results show that direct provision is more efficient than public-private partnership; thus, it might be concluded that contracting out is the best form of management in this public service.

Robustness Checks

To ensure that the results are not driven by municipalities of different sizes selecting different organizational forms for service delivery, TGRs were estimated by population size (small, medium and large), following the ranges of the Spanish Public Administration regulation. Based on governed of Law 7/1985, Regulating the Bases of Local Regime (incorporated by Law 53/2003, on measures for the modernization of local government), there are municipalities classified as "large population", which are those with between 20,000

and 50,000 inhabitants; "medium population", with between 5000 and 20,000 inhabitants; and "small population", with between 1000 and 5000 inhabitants.

As illustrated in Tables 7 and 8, a similar pattern is observed across population sizes, suggesting that the results do not simply mask differences in population across municipalities.

Table 7. Results of TGRs by population size.

	No Quality			**Quality**		
Population size	1000–5000	5000–20,000	20,000–50,000	1000–5000	5000–20,000	20,000–50,000
Public-private partnership	0.407	0.448	0.704	0.420	0.473	0.803
Contracting out	0.661	0.701	0.743	0.749	0.748	0.856
Intermunicipal co-operation	0.478	0.517	0.482	0.558	0.539	0.533
Public service provision	0.606	0.633	0.709	0.609	0.670	0.802

Table 8. Rates of change by population size.

Population Size	**1000–5000**	**5000–20,000**	**20,000–50,000**
Public-private partnership	3.06%	5.65%	14.10%
Indirect management by concession	13.35%	6.78%	15.22%
Intermunicipal co-operation	16.72%	4.24%	10.61%
Public service provision	0.47%	5.94%	13.09%

With the results obtained in Tables 7 and 8, it is possible to analyze the second objective of this study. On one hand, contracting out is the best form of management in all municipalities regardless of their size. This result contrasts with the findings of authors such as Bel et al. [28], who highlighted the influence of the size of the municipalities. However, intermunicipal co-operation is more efficient for small municipalities but not for the rest of the population size. On the other hand, in the larger and smaller municipalities, public-private partnership is slightly more efficient than direct provision; these results contrast with the findings suggested by authors such as Petkovšek et al. [10] and González-Gómet et al. [30]. One possible explanation for this result is that, in large municipalities, the private contractor that offers the service can generate economies of scale in their provision (See Appendix E).

5. Conclusions

Our findings suggest that the accountability problems that have so far plagued governments in their attempts to involve private contractors in the provision of public services may be remedied when the contracting out form is introduced. First of all, our results confirm previous findings that the market and managerial accountability mechanisms present under the traditional form of contracting out, where the service is funded through taxation, are not sufficient to ensure superior performance. The findings show that public-private partnership contracting is less efficient on waste removal services when accounting for quality. However, the promised benefits of contracting out are realized when contractors are made responsive to service quality through concessions. The use of long-term efficiency evaluation methodologies thereby "allows us to contrast which forms of management are more efficient in a long period, which provides a more robust evaluation than analyzed through cross-section" [46].

By comparing efficiency in different organizational forms, our study contributes to the literature by addressing important questions related to the best managed local public services and, more specifically, the MSW service. Our study moves beyond the public-private dichotomy as, by introducing a quality-adjusted measure of efficiency, it is possible to assess an overview of the evaluation of the efficiency of services and actively contribute to recent debates on the relationship between quality and outsourcing [60,63–69]; we concluded that outsourcing can remedy some of the quality failures.

This paper adds new insights to the previous literature; however, there are certain issues that have not yet been addressed and which are of great interest. In this sense, although there is a vast literature about the relationship between forms of management and efficiency, these studies tend to focus on the analysis of a specific service. Therefore, as a future line of research, it would be interesting to compare more than one service under the same criteria to see the effects that a specific form of management have on several services. Another potential line of research would be to examine the effect of forms of management on the efficiency of local public services using other methods than those used so far, such as spatial econometric models. In addition, extending the sample to municipalities with a larger number of inhabitants can provide relevant insights to contribute to the previous literature within this field of knowledge.

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Appendix A

Descriptive statistics.

Table A1. Average descriptive statistics of the cost and outputs of the management forms of the waste services for the period 2014–2016.

	N	Obs	Cost/Outputs	Average	Median	Min	Max	Std. Desv.
Public-private partnership (PPP)	60	180	Effective cost	305,893.30	117,646.80	25,000	1,396,138.5	408,436.4
			Tons of waste	3201.15	1282	220	14,047	4200.45
			Tons quality	6270.70	2404.38	315	28,094	8463.96
			Containers	240.83	192	30	916.22	209.27
			Red size	1242.30	493.56	20	9722.48	2196.61
Contracting out	584	1752	Effective cost	324,270.04	116,456.90	11,054.1	1,474,650.8	418,379.3
			Tons of waste	3534.19	1584.29	202.48	18,476	4350.69
			Tons quality	6643.28	2956.02	298	36,952	8406.16
			Containers	260.96	208.17	24	957	227.86
			Red size	1805.48	493.56	15	19,725.05	3561.86
Intermunicipal co-operation	226	678	Effective cost	132,882.16	100,618.55	11,900.1	1,330,018	197,668.8
			Tons of waste	1755.17	1100	160	15,998	2611.57
			Tons quality	3376.74	2027.80	202.48	31,996	5199.67
			Containers	176.81	168	21	962	146.83
			Red size	2192.18	2058.55	15	19,725.05	2848.89

Table A1. *Cont.*

	N	Obs	Cost/Outputs	Average	Median	Min	Max	Std. Desv.
Public service provision	693	2079	Effective cost	207,950.94	117,116.90	11,210.1	1,414,097.7	283,107.7
			Tons of waste	2330.36	1298.10	220	18,887.50	2833.80
			Tons quality	4331.89	2338.25	231	37,775	5424.74
			Containers	225.46	208.17	26	952	174.92
			Red size	160.47	141.23	14.70	8500	418.98

Source: The authors; N: Number of municipalities. Obs: Number of observations in the period 2014–2016.

Appendix B

Proposed methodology.

Following the proposal of Daraio y Simar [70] to obtain the estimation of the frontiers, these steps was followed:

1. For a determined level of $\tilde{y}^{o}$, a random sub-sample with size m is created, with replacements among the y_{km} that meet the condition $y_{km} \geq \tilde{y}^{o}$.
2. The efficiency coefficient $\tilde{\theta}^{m}$ was estimated from a random sub-sample and the resolution of non-convexe algorithms of FDHDP programming.
3. Thirdly, we repeated the first two steps a total of B times, so that an efficiency coefficient FDHDP could be estimated on each round; end of the process, a total of B efficiency coefficients $\tilde{\theta}^{m,b}$ (b = 1; 2; . . . ; B) were obtained.
4. Finally, the average of the B estimated efficiency coefficients was calculated:

$$\theta^{m} = \frac{1}{B} \sum_{b=1}^{B} \tilde{\theta}^{m,b} \quad \text{(A1)}$$

In addition, $\tilde{\theta}^{m,b}$ depends on the value of m; thus more m observations were considered in the estimation and more units fulfilled the condition $y_{km} \geq \tilde{y}^{o}$. To obtain the different local frontiers and the meta–frontier, it was necessary to calculate an adequate m, which represented the number of units to which each efficiency value was to be compared.

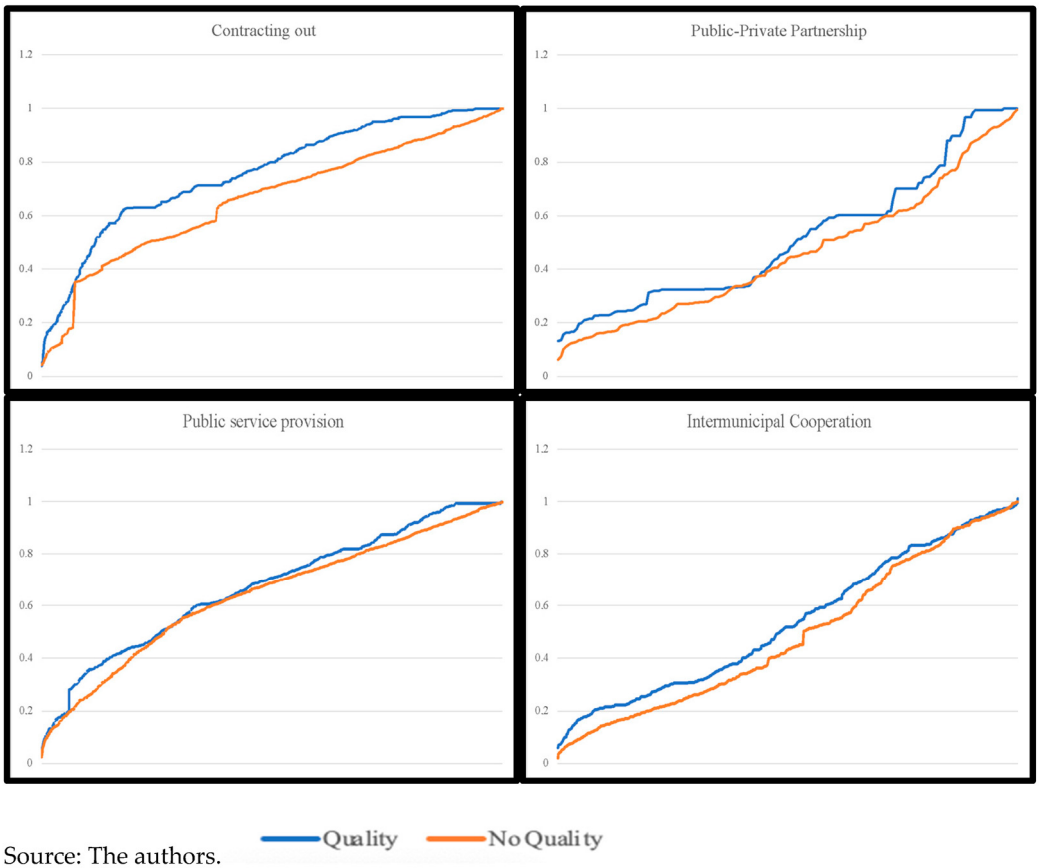
Appendix C

Table A2. Li Test to assess whether quality adjustments lead to statistically significantly different efficiency estimates.

Null Hypothesis (H0)	Li TEST
CE_t^k (PPPwq) = CE_t^k (PPPnq)	H_0 rejected ***
CE_t^k (GICwq) = CE_t^k (GICnq)	H_0 rejected ***
CE_t^k ($ICwq$) = CE_t^k ($ICnq$)	H_0 rejected ***
CE_t^k (PSPwq) = CE_t^k ($PSPnq$)	H_0 rejected ***

Source: The authors; level of significance: *** 0.001; CE_t^k: local frontier; PSPwq: public service provision with quality; PSPnq: public service provision without quality; ICwq: intermunicipal co-operation with quality; ICnq: intermunicipal co-operation without quality; PPPwq: public-private partnership with quality; PPPnq: public-private partnership without quality; GICwq: contracting out with quality; GICnq: contracting out without quality; results of Li Test obtained through R-project.

Appendix D



Source: The authors.

Figure A1. Evolution of TGRs for waste services.

Appendix E

Table A3. Summary with the result of this study and previous studies.

Public Service Provision	Public-Private Partnership	Contracting Out	Intermunicipal Co-operation	No Difference Significative
[29]	[38]	[5]	[24]	[46]
[32]	[28]	[33]	[15]	[4]
[13]	[9]		[25]	
	[68]			

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