Intermunicipal cooperation and privatization of solid waste services among small municipalities in Spain

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Abstract: The aim of this paper is to analyze the effects of intermunicipal cooperation and privatization on the delivery costs of urban solid waste services. The results of our empirical analysis, which we conducted among a sample of very small municipalities, indicate that small towns that cooperate incur lower costs for their waste collection service. Cooperation also raises collection frequency and improves the quality of the service in small towns. By contrast, the form of production, whether it is public or private, does not result in systematic differences in costs. Interestingly, the degree of population dispersion has a significant positive relation with service costs. No evidence of scale economies is found because, it would seem, small municipalities exploit them by means of intermunicipal cooperation.

Key words: local government, intermunicipal cooperation, privatization, contracting-out, solid waste collection.

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INTERMUNICIPAL COOPERATION AND PRIVATIZATION OF SOLID WASTE SERVICES AMONG SMALL MUNICIPALITIES IN SPAIN

1. Introduction

In recent years, the organization of the solid waste service in Europe has grown in complexity. A set of European Union directives now obliges member states to reduce their waste production and to adopt measures to recover waste by means of recycling (Article 3 of Directive 2006/12/EC), while at the same time, the management of solid waste services has undergone major changes with a growth in the contracting-out of this service.

Today, private production in urban solid waste services is extremely widespread in Europe (Warner and Bel, 2008; Dijkgraaf and Gradus, 2008). In over half of Spain's municipalities (Bel 2006a), this service is handled privately; and, in the region of Aragon, where we focus our study, private production is the majority practice, being present in more than 60% of the municipalities, and serving more than 80% of the population.

One reason commonly forwarded for contracting-out solid waste services is to lower service production costs; however, the empirical evidence regarding such savings are somewhat ambiguous (Bel and Warner, 2008). Recently, Warner and Hefetz (2003) and Bel and Costas (2006) have suggested that intermunicipal cooperation might be a viable alternative to local privatization, especially in smaller municipalities with a lower number of potential outside contractors. Interestingly, intermunicipal cooperation has been shown to be incompatible with private production in the US (Warner and Hefetz, 2002a, 2002b), Norway (Sørensen, 2007) and the Netherlands (Dijkgraaf and Gradus 2007), but this is not the case in Spain (Warner and Bel, 2008). Building on the findings of these earlier studies, this study considers the intermunicipal cooperation provided by *comarcas* (counties) and *mancomunidades* (associations of municipalities) in order to test the hypothesis that such cooperation plays a key role in enabling scale economies to be exploited, both in private and public production.

The aim of this study, therefore, is to examine the effects of cooperation and a pattern of highly dispersed municipalities on the costs of solid waste service under private and public production. To this end, this paper analyses the urban solid waste service in the Autonomous Region of Aragon, chosen because it comprises a large number of very small municipalities, a level of organization that has typically been ignored, or is at least very poorly represented, in previous analyses. In this sense, our work contributes to the specific analysis of this issue as it relates to sparsely populated municipalities, which would appear to provide suitable conditions for achieving scale economies either through intermunicipal cooperation or privatization.

The rest of this study is organized into four sections. In the section that follows, we review the empirical research analyzing the costs paid for solid waste services, with special emphasis on organizational issues and, particularly, on the relationship between the form of service production and costs. In the third section, we specify and estimate an econometric model adapted to the unique characteristics of our geographical area of reference. In the fourth section, we present the main results obtained from the above estimation. Finally, we summarize our conclusions.

2. Solid waste organization, form of production, and costs: empirical evidence

In this paper we undertake a review of previous empirical studies of the factors that have a bearing on municipal costs for solid waste services in large samples of municipalities, and which have analyzed the relationship between public production, private production and costs. More specifically we are concerned here with econometric studies that have used multivariate analysis and which employ control variables to ensure the robustness of their results, since this is the aim of our own study.

The relation between the costs of solid waste services and their public or private production has been carefully examined in many articles, the first of which can be traced back to Hirsch (1965). From Hirsch to the mid-70s, several econometric studies attempted to explain the costs of urban solid waste services (Kitchen, 1976; Kemper & Quigley, 1976; Collins & Downes, 1977), but any conclusions were largely preliminary in nature and they failed to find any common effects in their various models, due primarily to limitations in data availability and the exploratory nature of the specified models. Thus, for example, the form of service production, when included, gave rise to contradictory results in the models. The estimations of Kemper and Quigley (1976, 64) and Collins and Downes (1977, 344) indicated that private (market) provision was more expensive than municipal (public) provision. Within municipal provision, but Hirsch (1965, 91) and Collins and Downes (1977, 344) failed to find any significant differences in costs between public and private delivery; however, in Kitchen (1976, 70) and Kemper and Quigley (1976, 64) contracting-out was associated with lower costs than public delivery.

In seeking to identify the existence of scale economies in output, Hirsch (1965) and Kemper and Quigley (1976) reported their absence for this service provision. Elsewhere, Collins and Downes (1977) reported scale diseconomies for very small collection systems. And finally, Kitchen (1976) obtained an inverse U-shape in his analysis of scale economies with diseconomies of density in the cost (where economies of density referred to variations in average costs when faced with changes in the concentration of the population served).

From the late seventies onwards, more robust empirical studies were published, including those of Pommerehne and Frey (1977), Stevens (1978), Tickner & McDavid (1986), Domberger, Meadowcroft & Thompson (1986), Dubin & Navarro (1988,) Szymanski & Wilkins (1993), Szymanski (1996) and Reeves and Barrow (2000). The main innovation in each of these studies was that, thanks to the wider availability of information and the improvement in technical statistics, their results were more robust. In strict comparisons of public and private forms of production, some studies reported the cost of the service to be higher in municipalities employing public production, independently of the existence of competition [Pommerehne & Frey (1977, 233), Tickner & McDavid (1986, 358), Reeves & Barrow (2000, 141)]. In others, such as Domberger, Meadowcroft and Thompson (1986, 79) and Szymanski and Wilkins (1993, 124), private and public costs seemed not to differ with competitive bidding; however, in Szymanski (1996, 11), private costs were lower than public costs with competitive bidding as well, since the advantages of competitive contracting were gradually eroded over time. This phenomenon was reported as developing less quickly in the case of contracts won by private companies, but more rapidly in those secured by public units.

Most studies have identified the existence of scale economies, albeit that they tend to disappear as population (output) grows [e.g., Stevens (1978), Bel and Costas (2006)]. Other factors that have come under analysis, however, have presented less ambiguous results, and thus, larger amounts of waste, increased collection frequency, or higher salary costs increase costs. Finally, the statistical results for other explanatory factors do not show statistical significance or offer mixed results.

In addition to the studies published at the end of the 20th century, more recent analyses have tended to adopt more sophisticated and robust statistical techniques in comparing municipal costs for the public and private management of waste services. While the majority estimate total costs for the service, they have tended to analyze very different contexts. Dijkgraaf and Gradus (2003, 2007) in Holland, Bel and Costas (2006) in Spain, and Ohlsson (2003) in Sweden employ a double logarithmic form. Callan and Thomas (2001), meanwhile, used a linear functional form of the cost equation in their study for the US.

These studies indicate that the costs of public and private production do not differ significantly. Interestingly, Ohlsson (2003) finds private production to be more costly than public production. All in all, these models tend to reiterate earlier findings that the competition for service production is more important than ownership. Based on their review of empirical studies of solid waste, Bel and Warner (2008) suggest that the lack of competition might explain why in many cases no evidence is found of a positive effect being derived from contracting out.

More ambiguous results are obtained in response to such questions as the existence of scale economies or economies of density. Meanwhile, a greater volume of waste generated, the amount of selective waste, the number of collection points, wage level, frequency of service, and a longer distance to the landfill site tend to have a positive and significant effect on costs.

Finally, two recent papers have explicitly addressed the influence of intermunicipal cooperation on costs. Bel and Costas (2006) studied the effects of cooperation and of old versus new experiences of privatization. On the one hand, intermunicipal cooperation was found to reduce costs. On the other, they found that the cost savings derived from contracting out tended to disappear over time and, hence, the more recent the experience of contracting out, the greater the competition and, therefore, the greater the negative effect recorded on service costs. The detrimental impact of business concentration and lack of competition are also noted by Dijkgraaf and Gradus (2007).

Sørensen (2007) explicitly considers the existence of inter-municipal cooperation in solid waste services as well. Unlike the studies previously reviewed, he does not adopt the Hirsch-Stevens model, nor does he examine the relationship between public or private ownership and costs. Using a sample of Norwegian municipalities, Sørensen takes the cost per inhabitant of the service as the explained variable, and considers as explanatory variables different measures of ownership concentration (including the use of inter-municipal companies or cooperation), municipal revenues, population density, and the population of the municipality. Sørensen's empirical results suggest that municipalities that cooperate bear a cost for the service that is around 10% higher than those municipalities that do not cooperate. In many cases, the loss of efficiency attributable to the presence of various owners is greater than the cost reduction obtained through scale economies.

To sum up, based on our review of the literature that analyses the municipal cost structure of solid waste services, it can be seen that in the most robust studies, no significant differences are systematically observed between public and private delivery. As far as the other variables are concerned, the amount of waste generated and, alternatively, the population served as an approximation of output, increased collection frequency, the distance to the disposal site and greater salary costs significantly increase the municipal costs of this service. However, the existence in the municipality of waste disposal facilities reduces costs. Ambiguous results are obtained regarding intermunicipal cooperation: cost reduction in Bel and Costas (2006), and cost increase in Sørensen (2007). Meanwhile, questions such as the existence of scale economies offer ambiguous evidence as well

3. Empirical study

In this section we conduct an empirical analysis of the relation between intermunicipal cooperation and the costs of the solid waste service in a region of small municipalities. As is customary in comparable studies, our model incorporates other variables which we expect to have some incidence on the dependent variable.

3.1. The model and the data

In order that we might compare our results with those contained in econometric studies published elsewhere, the techniques applied here are the same as those used in the studies reviewed above. Thus, the basic function of the municipal cost of solid waste services takes the following form:

$$TC = f(Pop, Freq, Land, Dens, Disp, Prod, Coop, Wage) \quad (1)$$

The dependent variable, which we shall call *TC*, is the total municipal cost paid for solid waste services in the municipalities of Aragon. This includes collection, transportation, and disposal and elimination. The total costs incurred by the municipality are determined by the population of the municipality *(Pop)* [a proxy for the amount of waste generated], a variable that reflects the quality of the service - collection frequency (*Freq*), a number of service conditions that affect the requirements of input *(Land, Dens, Disp, Prod, Coop),* and the price of the labor factor *(Wage)*.

The data relating to municipal costs were obtained through the preparation and subsequent implementation of the *1st Survey on the Production of Urban Solid Waste Services and Water Supply in Aragon* (referred to below as the Survey), which enabled us to obtain complete information for 56 municipalities with more than 1,000 inhabitants [Mur (2008) provides detailed information on the sample]. Table 1 shows the general characteristics of the sample obtained. The sample includes 50% of the Aragonese municipalities with more than 1,000 inhabitants. Additionally, the sample includes 44.60% of the municipalities with a population below 5,000 inhabitants, a very high percentage for municipalities of this size. It should be noted that few econometric studies include significant information for municipalities with fewer than 5,000 inhabitants. In the case of mid-sized (from 5,000 to 10,000 inhabitants) and large (over 10,000 inhabitants) municipalities, the sample contains 75% of the municipalities.

[Insert Table 1 about here]

If we consider the number of inhabitants served, the level of coverage is actually higher than the number of municipalities. This is because the frequency of responses grows with the size of the population, resulting in some ranges being over-represented. The population analyzed represents 87.4% of the total population of municipalities with more than 1,000 inhabitants, but if the comparison is made with the entire population of Aragon, then the sample includes 75.25% of the total population.

Below we define the explanatory variables used in our model. We also provide information on the data sources, and describe the expected effects of each variable. All the data used in the empirical analysis refer to 2003.

1) Population of the municipality, *Pop*. Information on waste generated at the local level could not be obtained, as most municipalities did not have records on the amounts generated. As an approximation of output, we use the population of the municipality according to the 2003 census of inhabitants. We call this first explanatory variable *Pop,* and we expect to find a

significant and positive relation between population and total costs. Population data were obtained from the Spanish National Statistic Institute.

2) Collection frequency, *Freq*. We include the variable of weekly frequency (*Freq*) to show the number of days waste is collected each week. This variable was obtained from the *1st Survey on the Production of Urban Solid Waste Services and Water Supply in Aragon*. In line with the literature we expect to find a positive relation between the variable *Freq* and costs, i.e., as collection frequency increases, so do service costs.

3) Municipal landfill, *Land*. We adopt a dummy variable to reflect the existence of a landfill in the municipal area. This variable takes the value 1 if the municipality has a landfill, and the value 0 if not. This suggests that transport costs are higher when there is no landfill in the municipality. Consequently, we expect this variable to have a negative effect on costs. The information for 2003 was obtained from the Survey.

4) Municipal density, *Dens*. We take 'population density', defined as the number of inhabitants per square kilometer, as an indicator. The data on population and municipal sizes were obtained from the website of the Spanish National Statistics Institute (http://www.ine.es). As population density increases, the amount of waste collected at each stop grows, in principle reducing the costs of collection. However, greater population concentration leads to greater problems of traffic congestion, so that over time, transport time can be greater and so, therefore, can costs . Thus, the final effect of the variable *Dens* is *a priori* undetermined.

5) Dispersion of municipalities, *Disp*. One variable that can affect costs is the number of population units within a municipal jurisdiction. This variable has not previously been considered in the economic literature on waste services, and as such constitutes a significant innovation in our analysis. Data describing the dispersion of municipalities were gathered from the information published on the website of the *Instituto Aragonés de Estadística* (http://www.portal.aragob.es). In Aragon, the population is very unevenly distributed throughout the territory. In fact, half the population is concentrated in the city of Zaragoza, and

the rest is distributed over more than 700 municipalities. Consequently, the population of these municipalities tends to be very small and the jurisdictions are typically made up of scattered, small population centers. For this reason, waste collection can be more expensive as the distances separating the different population centers within a municipal area need to be covered. Therefore, we expect the variable *Disp* to have a positive effect on costs.

6) Private production, *Prod*. To capture the influence of either the private or public production of the service on costs, we include a dummy variable that takes the value 1 if the service is delivered by a private firm, and the value 0 in the case of public production (direct management or public firm). Data describing the form of production were obtained from the Survey. In Aragon, private production of the service is particularly widespread (see Table 2) with 62.90% of the municipalities being served by private firms. This form of production is the majority in all population ranges, with the exception of the largest. However, in line with the recent literature, the expected effect of this variable is undetermined.

[Insert Table 2 about here]

7) Municipal cooperation, *Coop*. This variable is represented by a dummy variable which takes the value 1 if the municipality is significantly involved in intermunicipal cooperation, through a *comarca* or *mancomunidad*, and 0 if not. As discussed above, the empirical literature considers intermunicipal cooperation as an alternative to privatization for smaller municipalities with fewer available external contractors (Warner and Hefetz, 20003). In this way, smaller municipalities are able to exploit scale economies.

Table 3 shows the extent of municipal cooperation in waste services in relation to the size of the municipality. In Aragon, characterized by a preponderance of small municipalities and very few large cities, cooperation in solid waste services is particularly widespread, which means the "municipal cooperation" variable is of great relevance to this study.

[Insert Table 3 about here]

To determine whether municipal cooperation is a formula that can be used to exploit scale economies, we include the variable *Coop*. We assume that municipalities co-operate so as to reduce costs, therefore, *a priori*, the expected effect of this variable on costs is negative. However, in line with previous studies (Bel and Costas, 2006), we do not expect the effect of this variable to be significant for municipalities with larger populations. Such a finding would be consistent with results in Sørensen (2007).

8) Wage level, *Wage*. This variable is measured as a salary cost (in euros) per employee in the private services sector for each province of Aragon, in 2003. Price differences in productive factors, in particular the variability in wages between municipalities, can influence the total municipal costs of the service. However, as there is no information available on local wage levels, we have opted to calculate the wage level for each province of Aragon, based on the average provincial value for each municipality. This approach, however, is consistent with the widespread practice of collective bargaining at the provincial level in Spain. Alcaide and Alcaide (2003) provide estimations of labor costs at the province level, differentiating between public and private service sectors. Since 62.90% of the municipalities in the sample have privatized waste services, we have preferred to use the labor costs for the private sector. The expected effect of provincial salary cost in the private services sector is, in line with the empirical literature, positive and significant.

Table 4 describes the variables that we use in our applied study, and their expected sign. Table 5 shows descriptive statistics for the model's variables.

[Insert Table 4 about here]

[Insert Table 5 about here]

3.2. The estimated equation

A more precise description of the general model with which we are working, based on the costs function (1) given above, is:

$$TC_i = \beta_0 Pop_i^{\beta 1}\, Disp_i^{\beta 2}\, Dens_i^{\beta 3}\, Freq_i^{\beta 4}\, Wage_i^{\beta 5}\, e^{(\beta 6 Prod_i + \beta 7 Land_i + \beta 8 Coop_i + u_i)}$$

Following the empirical literature, the double logarithmic form was estimated including the logarithms of the dependent and independent variables within the equation. This section presents the results obtained, therefore, with the estimation of the equation:

$$\text{Log}\, TC_i = \beta_0 + \beta_1 \log Pop_i + \beta_2 \log Disp_i + \beta_3 \log Dens_i + \beta_4 \log Freq_i + \beta_5 \log Wage_i + \beta_6\, Prod_i + \beta_7 Land_i + \beta_8\, Coop_i + u_i$$

Stevens (1978) questioned the structural stability of the cost equation based on municipality size and reported evidence of a different structure in large and small municipalities. Subsequently, Dubin and Navarro (1988) and Bel and Costas (2006) similarly divided the sample according to population size. These empirical studies have identified scale economies among municipalities with smaller populations, but that these gradually disappear beyond a certain population size. Therefore, we have considered it appropriate to divide the sample into different subgroups by population (municipalities up to 5,000 inhabitants, up to 10,000, and up to 20,000) and to estimate the equations for each of these subgroups. In this study we have opted for this criterion of segmentation as a further breakdown would have resulted in estimations with very few observations.

4. Results

Table 6 presents the results obtained from the estimation of the equation for the aggregate sample. In general, neither the perturbation nor the systematic part of the model presents serious problems, suggesting that this would be a valid model for explaining annual costs for solid waste services. The value of R^2 is over 90%, indicating a very high explanatory capacity for the variability of the total costs paid by municipalities, as is common in studies of this type. The F-test indicates that the fit of the equation is very significant at the 1% level. The Ramsey-RESET test shows that there are no problems regarding the absence of significant variables in the model at a confidence level of 99%.

[Insert Table 6 about here]

Below, we focus on the variables contained in the model and examine their influence on total costs. In general, the signs of these variables (listed in Table 6) were as expected in theoretical terms. The population of the municipality variable has a positive and very significant relation to costs, with a confidence level higher than 99%, indicating that this variable - an approximation of the amount of waste generated - is a major determinant of total costs. Higher salary costs also affect service costs positively, confirming the hypothesis that higher provincial salary costs in the private services sector have a positive relation with the costs of solid waste services.

The variable measuring "the dispersion of population centers" within a municipality, *Disp*, has a positive effect on costs and is also significant, with a confidence level higher than 95%. This indicates that the higher the number of population centers within a single municipality, the higher the costs of solid waste services will be, which is simply a reflection of the greater complexity of the organization of the service.

By contrast, the sign obtained for the frequency variable, *Freq*, is negative, unlike the empirical studies reviewed above, where the significant sign is positive. However, the very low degree of variability in the data for the frequency of collection means that this result should be treated with caution. Indeed, one of the characteristics of intermunicipal cooperation – a particularly common practice in Aragon - is that it leads to greater collection frequency, especially in the smaller municipalities. Thus, it might be the case that frequency is negatively associated with costs because of the fact that the high number of municipalities working in *comarcas* and *mancomunidades* means that collection frequency becomes disconnected from municipality size, without representing an increase in costs. This might also explain why the smaller Aragonese municipalities have a higher collection frequency than that reported in other institutional settings. Indeed, in Aragon collection frequency is highly independent of municipality size. In 84% of the municipalities in the sample the frequency is six times per week. However, it is among the municipalities with the lowest levels of population that the greatest differences are observed in comparison to other institutional settings.

The rest of the variables included in the model have the expected sign, but show no significant relation to costs. Thus, our analysis indicates that in Aragon the intermunicipal cooperation variable lacks statistical significance when considering the aggregate sample and municipalities with larger populations are included.

Table 7 presents the results obtained from the estimation of the equation for different population segments. The F-test indicates that the equation is very significant at the 1% level. The Ramsey-RESET test does not allow us to reject the hypothesis of the non-absence of significant variables with a confidence level of 99%. The value of R^2 ranges from 74% (municipalities with fewer than 5,000 inhabitants) and 85% (municipalities with fewer than 20,000 inhabitants), suggesting that the estimations fit the data reasonably well. These models are also valid for explaining the service costs of waste, based on the study of perturbation and the systematic part of the model.

[Insert Table 7 about here]

Our results are largely similar in the three estimations that aggregate municipalities of up to 5,000, 10,000 and 20,000 inhabitants and essentially coincide with those obtained in the estimation for the aggregate sample. Further, most of our results are consistent with expectations, and are supported by findings in the literature. The variable population *(Pop)* increases the cost of the service, presenting a confidence level higher than 99%. The dispersion of municipalities (*Disp*) and salary costs per employee *(Wage)* also increase service costs and are both significant determinants. Municipal cooperation (*Coop*) reduces costs in those municipalities with lower populations, i.e., municipalities providing the service as part of an association obtain a reduction in costs at a confidence level higher than 95%. However, cooperation (*Coop*) loses its significance in the estimation for municipalities of fewer than 20,000 inhabitants, when including municipalities of 10,001 to 20,000 inhabitants in the sample.

Our findings regarding intermunicipal cooperation and costs are similar to those reported in Bel and Costas (2006) but differ from those obtained by Sørensen (2007). We believe that a variety of factors might explain why our results differ from the latter author's. First, we use different empirical models; in our case we adopt the Hirsch-Stevens model and so control for key factors such as municipality dispersion, frequency, output and form of production (public or private). Second, we estimate separate subsamples according to municipality size, and so can focus our attention on the smallest towns. Furthermore, the average population of the municipalities in Aragon (at around 1,700 inhabitants) is much smaller than that of the Norwegian municipalities (over 10,300 inhabitants); therefore, the potential for exploiting scale economies through cooperation is much greater in Spain, and particularly in Aragon. Finally, intermunicipal cooperation is compatible with private production in Spain, whereas it is not in Norway.

Interestingly, and contrary to what is typically reported in the empirical literature, collection frequency is associated with lower municipal costs, at a confidence level higher than 95%. We are able to confirm that in the region of Aragon, the high rate of collection frequency seen in most municipalities, especially the smaller ones, does not increase the municipal costs of the service, given that in most cases the municipalities have formed associations with their counterparts through "*comarcas*" or "*mancomunidades*" to produce the service. Thus, intermunicipal cooperation can help the smallest municipalities provide a better quality service without raising individual costs.

Finally, the variables "population density" (*Dens*), "private production of the service" (*Prod*) and "existence of landfill in the municipality" (*Land*) do not present a significant relation with municipal costs.

4.1. Analysis of the existence of scale economies

The double logarithmic model enables scale economies to be simply measured on a global level. Based on the formula of Baumol, Panzar and Willig (1988), scale economies can be expressed as follows:

$$S = \frac{TC(Pop)}{Pobl\,\frac{\partial TC}{\partial Pop}}$$

Scale economies exist when S>1. In the presence of a double logarithmic function, this formula has a simple application (2).

$$S = \frac{1}{\beta_1} \qquad (2)$$

Consequently, scale economies exist when $\beta_1<1$. Table 8 shows the results obtained in the different tests carried out under the hypothesis of the absence of scale economies (H_0: $\beta_1 \geq 1$), contrasted against the alternative hypothesis that scale economies do exist (H_1: $\beta_1<1$), indicating that the hypothesis of the absence of scale economies cannot be rejected for either the aggregated estimation or for the estimations of segments of municipalities by population. However, it is of little surprise that scale economies are not found in our geographical context of reference. The instruments of management reform used by the municipalities, i.e., increased outsourcing and/or the numerous examples of supramunicipal aggregation of the service (particularly among smaller municipalities), have had the effect of exploiting scale economies in the relevant segment of municipalities. Hence, not many scale economies remain to be exploited.

[Insert Table 8 about here]

4.2. Stability of the model, the test of structural change

When cost functions are available, it is always interesting to contrast the null hypothesis that the cost equation is stable to the form of production of the service (no structural change exists) against the alternative that there is structural instability between public and private production, i.e., to test whether a dummy variable of the form of production is a correct specification for the cost comparison. If structural instability between public production and private production is obtained, a dummy variable would be an incorrect specification.

The most typically used contrast for this type of analysis is the Chow test. As can be seen in Table 9, when we conducted this test for our model, we were unable to reject the null hypothesis that the cost equation is stable to the form of production of the service, at a confidence level of 99%. To sum up, the dummy variable "form of production of the service" is a correct specification for comparing municipal costs between private production and public production.

[Insert Table 9]

$$F = \frac{\left(S_0 - \sum S_{1,j}\right) / \left[(n-k) - (n-2k)\right]}{\sum S_{1,j} / (n-2k)} = 1{,}1105 < 2{,}99 = F_{0{,}99(8,40)}$$

5. Conclusions

In this empirical study we have conducted a multivariate analysis of the factors that influence the municipal costs paid for solid waste services. In addition to the factors typically included in the literature, we have incorporated intermunicipal cooperation and an analysis of the degree of dispersion of municipalities, given the particular characteristics of our area of study, a sample of municipalities in the region of Aragon, Spain.

The empirical results have a high explanatory power and, in general, are consistent with the hypotheses established in the empirical evidence. In our model, however, one variable not previously considered in the literature, the "dispersion of municipalities" (number of population units within a municipal jurisdiction), was found to be significant. Thus, a greater degree of dispersion (*Disp*) within a municipal area affects total costs positively, as the complexity of the service is necessarily increased.

At the same time, the "intermunicipal cooperation" variable (*Coop*) leads to a reduction in costs in municipalities with smaller populations, i.e., small municipalities providing the service as an association incur lower service costs. In short, the high level of municipal cooperation in operation in Aragon has two main effects: on the one hand, cooperation reduces service costs, while, on the other, it raises collection frequency in the smallest municipalities, thereby improving the quality of the service.

Our empirical analysis, however, failed to find any evidence of scale economies in the service. This, however, is not surprising given a geographical context in which the instruments of management reform adopted by the municipalities (contracting-out and/or supramunicipal aggregation of the service) have had the effect of creating scale economies in the sector in practically all the region's municipalities.

Other variables, including a larger municipal population (*Pop*) and salaries (*Wage)*, have been found to be significant in explaining the endogenous variable, its sign - positive in both instances - in line with the expected results. However, no significant relation was found between population density (*Dens)* and the municipal costs of the service.

Finally, a comparison of public and private forms of production (*Prod*) failed to reveal any significant differences in costs. This result confirms previous recent analyses, which in the main report that competition is a more relevant factor than ownership in solid waste services provision. Thus, managing competition and reforming the scale at which the service is delivered by means of intermunicipal cooperation can be effective tools for enhancing solid waste delivery, particularly in areas in which small municipalities predominate.

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Tables

Table 1. Representativeness of the information

Municipalities with more than 1,000 habitants					
Number of inhabitants	1,001-2,000	2,001-5,000	5,001-10,000	> 10,000	Total > 1,000
Number of municipalities	14	27	6	9	56
Percentage	24.56%	77.14%	75%	75%	50%
Population	19,012	80,797	44,634	791,190	935,633
Percentage	25%	79.82%	76.65%	94.75%	87.40%
All municipalities in Aragon (> 1,000 inhabitants) and population (2003)					
Number of inhabitants	1,001-2,000	2,001-5,000	5,001 a 10,000	> 10,000	Total > 1,000
Number municipalities	57	35	8	12	112
Population	76,035	101,219	58,234	834,992	1,070,480

Source: Authors' own drawn from the *1st Survey on the Production of Urban Solid Waste Services and Water Supply in Aragon*. Data on population obtained from the *Spanish National Statistic Institute*.

Table 2. Production forms for solid waste collection in Aragon (2003)

Municipality size (population)	Aragon (2003)						
	Direct public management		Public firm		Private firm		Total
	N	%	N	%	N	%	N
1,001-2,000	5	35.7	1	7.1	8	57.1	14
2,001-5,000	5	18.5	2	7.4	20	74.1	27
5,001-10,000	1	16.7	0	0.0	5	83.3	6
>10,000	4	44.4	1	11.2	4	44.4	9
Total (adjusted)*	15	29.9	4	7.2	37	62.9	56

* Aggregated results have been adjusted to correct the bias resulting from differences in coverage of the sample.
Source: Authors' own drawn from the *1st Survey*.

Table 3. Intermunicipal cooperation in Aragon (2003). Municipalities with more than 1,000 habitants (in %)

Municipality size (population)	Municipality		Intermunicipal cooperation		Total
	Number	Percentage	Number	Percentage	
Municipalities between 1,001 and 2,000	3	14.29	18	85.71	21
Municipalities between 2,001 and 5,000	4	11.43	31	88.57	35
Municipalities between 5,001-10,000	1	12.50	7	87.50	8
Municipalities over 10,000 inhabitants	7	58.33	5	41.66	12
Total	15	18.00*	61	82.00*	76

Note: * The total results have been adjusted to correct bias by differences in the representation of municipalities in the sample.
Source: Estimated based on data from the *1st Survey*.

Table 4. Summary of variables

Dependent Variable	**Description**	
TC	Total costs incurred by the municipality for the service of municipal solid wastes, including expenditures for the collection, transport and disposal of the centre's own disposal or treatment.	
Independent Variable	**Description**	**Hypothesis**
POP	Number of inhabitants in the municipality in 2003.	+
FREQ	Frequency: Number of days per week refuse is collected from each location.	+
LAND	Landfill in the municipality. Dummy variable that takes value 1 if the landfill is in the municipality and 0 otherwise.	-
DENS	Population density: Inhabitants per square kilometer (2003).	Ambiguous
DISP	Municipality dispersion: Number of populations units within the municipal area (2003).	+
PROD	Mode of production: Dummy variable that takes value 1 if a private firm produces the service and 0 if a public unit or firm does so.	Ambiguous
COOP	Intermunicipal cooperation: Dummy variable that takes value 1 if the municipality is significantly involved in intermunicipal cooperation and 0 otherwise.	-
WAGE	Wage level: this variable takes the average provincial value for each municipality within a province.	+

Source: Authors' own

Table 5. Descriptive statistics of variables in the model

Continuous variables	Mean	Standard Deviation	Min	Max
TC	438.588,1	2.260.146	11.839	16.950.510
POP	16.707,73	83.288,44	1.035	626.081
DISP	5,09	9,68	1	55
FREQ	5,70	0,85	2	7
WAGE	25.549,13	2.171,93	23.028,98	27.480,22
DENS	69,63	131,41	6	712
Discrete Variables		**Percent 1**	**Percent 0**	**N**
COOP (1=Intermunicipal cooperation; 0= Production municipal level)		80,40	19,60	56
PROD (1= Private; 0= Public)		66,07	33,93	56
LAND (1= Landfill in the municipality; 0=No landfill)		35,71	64,29	56

Source: Authors' own.

Table 6. Empirical results from the estimation of total cost equation

(Whole sample)

Independent Variable	Whole sample
Constant	-5.9880
	(-1.51)
POP (log)	0.9906
	(9.61)**
COOP	-0.0705
	(-1.01)
PROD	-0.0361
	(-0.60)
DISP (log)	0.2039
	(2.61)**
FREQ (log)	-0.3347
	(-1.78)*
WAGE (log)	1.7158
	(1.84)*
DENS (log)	0.0104
	(0.14)
LAND	-0.0281
	(-0.45)
R^2	0.9268
Adjust R^2	0.9144
F-Test	103.11***
Ramsey RESET-test $F(3.44)_{99\%}$= 4.26	F (3.44)= 0.89
Breusch-Pagan/Cook-Weisberg: χ^2 (0.05, 1) $_{95\%}$=3.84	0.50
White Test	ρ=0.3550
Shapiro-Wilk W Test	pr>z= 0.7630
Variance inflation factor (average VIF)	2.27
N	56

Notes: in parentheses, the t-statistic values for the hypothesis that the coefficient is not significantly different from zero.

Significance levels: * 10%, ** 5%; *** 1%.

Source: Authors' own.

Table 7. Empirical results from the estimation of the equation for different population segments

Independent Variable	Municipalities below 5,000 inhabitants	Municipalities below 10,000 inhabitants	Municipalities below 20,000 inhabitants
Constant	-5.5662	-7.2236	-6.9732
	(-1.20)	(-1.60)	(-1.62)
POP (log)	1.0912	0.9798	1.0328
	(8.09)***	(8.26)***	(8.49)***
COOP	-0.1618	-0.1497	-0.0550
	(-1.94)*	(-1.99)**	(-0.77)
PROD	0.0511	-0.0128	-0.0246
	(0.85)	(-0.23)	(-0.39)
DISP (log)	0.2280	0.2190	0.2183
	(2.52)**	(2.57)**	(2.79)***
FREQ (log)	-0.5260	-0.5194	-0.3884
	(-2.17)**	(-2.14)**	(-2.08)**
WAGE (log)	1.6010	2.0300	1.9108
	(1.51)	(1.95)*	(1.91)*
DENS (log)	-0.0712	0.0538	0.0080
	(-0.90)	(0.57)	(0.11)
LAND	0.0125	0.0091	-0.0425
	(0.18)	(0.14)	(-0.66)
R^2	0.7473	0.7875	0.8563
Adjust R^2	0.6841	0.7428	0.8301
F -Test	17.17***	29.73***	65.99***
R. RESET-test (F)	F (3.29)= 0.21	F (3.35)= 0.42	F (3.41)= 0.39
B-P/Cook-W: $\chi^2(0.05,1)_{95\%}=3.84$	1.14	0.84	1.12
White Test	ρ=0.5387	ρ=0.5615	ρ=0.3287
Shapiro-Wilk Test	pr>z= 0.6615	pr>z= 0.6938	pr>z= 0.4421
VIF (average)	1.86	1.85	1.86
N	41	47	53

Notes: in parentheses, the t-statistic values for the hypothesis that the coefficient is not significantly different from zero.
Significance levels: * 10%, ** 5%; *** 1%.
Source: Authors' own.

Table 8. Analysis of the existence of economies of scale with output

Equation	N	*p-value*
Whole sample	56	0.5359
Municipalities below 5,000 inhabitants	41	0.2519
Municipalities below 10,000 inhabitants	47	0.5668
Municipalities below 20,000 inhabitants	53	0.3943

Source: Authors' own.

Table 9. Chow stability test cost function (Adding forms of production)

Equation	N	k	RSS	Degrees of freedom
Whole sample (restricted)	56	8	1.2695	48
Municipalities with private production	37	8	0.8197	29
Municipalities with public production	19	8	0.2190	11

Source: Authors' own.