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MEASURING THE EFFICIENCY IN SPANISH MUNICIPAL REFUSE COLLECTION SERVICES (*)

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ABSTRACT

The objective of this study is to analyse the technical or productive efficiency of the refuse collection services in 75 municipalities located in the Spanish region of Catalonia. The analysis has been carried out using various techniques. Firstly we have calculated a deterministic parametric frontier, then a stochastic parametric frontier, and finally, various non-parametric approaches (DEA and FDH). Concerning the results, these naturally differ according to the technique used to approach the frontier. Nevertheless, they have an appearance of solidity, at least with regard to the ordinal concordance among the indices of efficiency obtained by the different approaches, as is demonstrated by the statistical tests used. Finally, we have attempted to search for any relation existing between efficiency and the method (public or private) of managing the services. No significant relation was found between the type of management and efficiency indices.

RESUM

L'objectiu d'aquest estudi és analitzar l'eficiència tècnica o productiva dels serveis de recollida d'escombraries a 75 municipis de Catalunya. L'anàlisi s'ha portat a terme utilitzant varies tècniques. En primer lloc, hem calculat una frontera paramètrica determinística, després una frontera paramètrica estocàstica, i finalment, varies aproximacions no-paramètriques (DEA i FDH). Pel que fa als resultats, aquests naturalment difereixen en funció de la tècnica utilitzada per aproximar la frontera. No obstant això, guarden una aparença de solidesa, al menys pel que fa referència a la concordança ordinal entre els índexs d'eficiència obtinguts per les diferents aproximacions, com mostren els tests estadístics utilitzats. Finalment, hem intentat buscar si existeix alguna relació entre l'eficiència i el mètode (públic o privat) de gestionar els serveis, no trobant-se cap relació significativa entre el tipus de gestió i els índexs d'eficiència.

KEY WORDS: local public services, efficiency, management

JEL CLASSIFICATION: D24, H49, H72

I. INTRODUCTION

The objective of this study is to analyse the efficiency of the refuse collection services in 75 municipalities located in the region of Catalonia (Spain).

Regarding the concept of efficiency, in no case do we attempt to measure anything other than productive efficiency as this concept allows the evaluation of the efficiency obtained by a greater productivity of the factors. We do not enter into considerations of higher costs due to higher wages or greater employment. We think that, although they are as important as greater productivity, this would obscure the framework of the comparison[1]. Consequently, in every case the variables used in the analysis are *physical*, and not monetary, and therefore the study concentrates initially on the *quantity* side, and not on the *price* side. The fact that in competition a greater marginal productivity of the factors of production goes together with their greater remuneration will obviously be important when explaining differences in the cost of providing services between different units, given that the total cost is a product of quantities and prices. However, we believe that at this first stage of analysis it is of greater interest to limit ourselves exclusively to the area of quantities both from the input and from the output side. This concept of efficiency is equally appropriate in deciding whether the type of production (public or private) explains differential efficiency in the provision of a service, as it does not conflict with other objectives that may be latent, and also has evident informational advantages.

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[1] See Cubin et al. (1986) Ganley and Grahl (1988).

With regard to the characteristics of production in the sector analysed, there is a broad consensus about which factors of production are the most relevant[2]. Accordingly, the number of containers and their geographical distribution, the vehicles used (in terms of collection capacity or, rather, the number of kilometres covered by them, with the purpose of internalising the effect caused by the distance between the centres of collection and those of disposal) and, of course, the number of workers (or rather the number of hours contracted, in order to homogenise the use of the labour factor, given the presumed simultaneous presence of full-time and part-time workers) are indispensable inputs. A further degree of refinement would be obtained if a distinction could be made between sub-categories of the three mentioned factors. For example types or material of the containers, special characteristics (crushers, for example) of the vehicles or categories of employee (or at least a distinction between administrative personnel and those directly involved) in the case of the labour factor could be tried.

The principal output as far as we are concerned is the number of tons of refuse collected and subsequently transported to the corresponding dump. However, a distinction should also be made here between various types of refuse, such as general and organic refuse (the usual type in domestic collection), voluminous refuse (furniture, domestic appliances...), those more irregular in time, specific collection in markets, peripheral areas, abandoned vehicles... or selective collection with ecological objectives or recycling (glass, paper-cardboard, batteries, pharmaceutics). In this sense it is necessary to underline that refuse collection is a quasi-exception to the problem of output measurement, given that

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[2] See for example Kemper and Quigley (1976) or the recent study concerned with the analysis of costs in the sector made in CEA (1994) on the same territorial basis of our study..

(as opposed to what occurs with other public services such as education, health, the administration of justice, etc.) it is well-defined and can reasonably be measured.

In our study, we have selected the following variables to be included: Number of containers, total number of vehicles and total number of direct workers (non-administrative employees) expressed in terms of full working days, as inputs and tons of refuse of organic material collected as output.

The lack of data has impeded the use of more closely adjusted inputs, among which we especially regret the number of kilometres covered by the refuse collection vehicles. These figures, we believe, would have allowed the production frontier to be adjusted more precisely.

As far as the outputs are concerned we finally decided to only use tons of organic refuse. This choice was done for two basic reasons: firstly because we understand that nowadays they still represent the essential nucleus of the service[3]. Moreover, and due to the informational restrictions of our study (referring only to one year) the use of a single output facilitates the parametric estimation of the production frontier and allows more homogenous comparisons of the results obtained from the employment of different techniques.
The analysis was carried out on a base composed of 75 Catalan municipalities that satisfactorily responded to a questionnaire that was sent to them[4]

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[3] In fact, according to a study made by the CEA (1994) in 31 municipalities in the metropolitan area of Barcelona, such refuse grouped into domestic collection represented 85.8% of the total costs of the service.

[4] In fact the questionnaire was sent to all Catalan municipalities with more than 5,000 inhabitants (in total 144), but only the data from 75 provided the minimum of information,

concerning a large number of variables related to the provision of the refuse collection service during the year 1994. Of them, 7 have more than 100,000 inhabitants, another 7 between 50,000 and 100,000, 14 between 20,000 and 50,000, 23 between 10,000 and 20,000 and 24 less than 10,000 inhabitants, but in any case more than 5,000. Table 1 offers some descriptive statistics concerning the sample mentioned.

II. ALTERNATIVE APPROACHES MEASURING EFFICIENCY

We used different techniques, so parametric as well as non-parametric, to approach productive efficiency. As is well known, more restrictive assumptions are required by the first (parametric ones), the non-parametric techniques being more flexible. Both approaches are used in a complementary way, with the aim of identifying the best practices in the provision of refuse collection services.

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in terms of quantity and quality, necessary in order to be taken into account. The survey process and the data offered by the municipalities were audited by the *Court of Auditors of Catalonia*.

II. 1. THE PARAMETRIC APPROACH[5]

As is known, parametric methods impose *a priori* a determined functional form on the production frontier. This frontier is estimated from the consumption of inputs and the production of outputs of the services analysed. Therefore it is assumed that the frontier has the following form:

$$Y = f(X_i) \qquad [1]$$

Where Y represents the output, X_i the vector of the inputs and $f(.)$ is the functional form of the frontier.

As we have indicated, in our case, the consideration of a single output, tons of refuse, as well as expressing the production of the service with extreme precision in relation to other services, is also perfectly adapted to the need to define a single dimension of output in these models.

The following step is the specification of the functional form of the frontier, an extremely important decision as the final results (indices of efficiency) will vary according to the functional forms used. We used a functional form from Cobb-Douglas that is a relatively rigid homogenous function, but its results were to be compared to those obtained from the much more flexible non-parametric viewpoints. Moreover, the functional forms used in previous parametric studies of the service are equally rigid[6].

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[5] A detailed treatment of parametric methods can be seen in Lovell and Schmidt (1988).
[6] See Hirsch (1965), Kemper and Quigley (1976), or Domberger et al. (1986).

Following this approach we analysed efficiency firstly considering a *deterministic* model of frontier. Afterwards, we applied a stochastic model in a way that made deviations from the frontier possible due to random perturbations that are added to the existence of behaviour that is more or less efficient.

1. The deterministic frontier

Aigner and Chu (1968), taking the work of Farrell (1957) as a base, proposed a homogenous Cobb-Douglas production function on which they imposed the condition that all the observations were located *on* or *below* the production frontier:

$$Y_i = A\prod_{k=1}^{n} X_{ki}^{b_k} e_i = Y_i^* e_i \qquad [2]$$

In which ε_i is a random perturbation between zero and one. Y^*_i constitutes the production frontier, that is the maximum quantity of output that can be reached with the consumption of inputs made. ε_i is also the *index of productive efficiency* that reaches the value of 1 when the organisation is totally efficient (that is to say when the organisation is situated on the production frontier ($Y_i=Y^*_i$) and a value nearer to zero the more inefficient the organisation is.

To calculate the efficiency of each of the units analysed, the production function can become linear taking logarithms:

$$\ln Y_i = b_0 + \sum_{k=1}^{n} b_k \ln X_{ki} + u_i$$

[3]

Where n is the number of inputs included in the analysis, $\beta_0 = \ln A$ y $u_i = \ln \varepsilon_i$ ($u_i < 0$).

When measuring deviations from the frontier from ε_i, a term that exclusively reflects productive inefficiency, the procedure is called a deterministic approach to the frontier. Farrell's measurement of productive efficiency is consequently given by:

$$e_i = e^{u_i} = \frac{Y_i}{Y_i^*}$$

[4]

The term for error mentioned could be estimated through a wide variety of methods. The simplest is Corrected Ordinary Least Squares (COLS)[7]. This method supposes the upward displacement of the ordinary least square estimator of the constant until one residual is zero and all the others are negative[8]. This is achieved adding to the independent term obtained through OLS the value of the residual that is highest among the positive ones. Using this procedure the

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[7] Aigner and Chu (1968) proposed two alternative methods of estimation that guarantee the negativity of the residuals u_i. The first consists of the application of linear programming techniques, minimising the sum of the absolute values of the residuals, subject to the restriction that every residual is not positive. The second method proposed was quadratic programming, minimising the sum of the squares of the residuals, subject to the same restriction.

parameters of the production frontier can be estimated and, departing from them, the productive efficiency of the services analysed. The results of the estimation are shown in Table 2.

The coefficients estimated for each of the inputs considered reflect the elasticity of output for variations of every input. It can be seen that the signs of the coefficients estimated for the three variables are, as can be expected, positive and highly significant in the case of the 'container' and 'personnel' variables. The fact that the coefficient estimated for the variable 'trucks' was not significant could be due to the high correlation (0.907) that there is between this variable and the variable 'personnel'. Nevertheless, we thought it was better to maintain the variable 'trucks' from the analysis of efficiency because including it does not significantly distort the results given by the parametric approaches[9] and it enriches those given by the non-parametric approaches that are shown in the following section.

An aspect of great interest for the posterior comparative analysis that we carried out among the distinct approaches refers to the rate of returns to scale of the production frontier. In our case, the sum of the coefficients estimated, $\beta_1+\beta_2+\beta_3$, is 1.09929, which seems to contradict the existence of constant returns to scale, a supposition upheld by the greater part of empirical studies of the sector[10]. Even so, to test whether the hypothesis of constant returns was acceptable, we

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[8] See Førsund et al. (1980) and Schmidt (1986).

[9] Using only the variables 'containers' and 'personnel' the results are practically identical to those given in the study.

[10] See Hirsch (1965), Kemper and Quigley (1976), Collins and Downes (1977) and Cubbin et al. (1986).

carried out the Wald test on the null hypothesis $\beta_1+\beta_2+\beta_3=1$, that was 97% rejected (Table 3).

Once the coefficients of each parameter of the production frontier are estimated, the index of efficiency of each unit can be calculated immediately:

$$e_i = e^{u_i} = \frac{Y_i}{Y_i^*} = \frac{Y_i}{e^{b_0} X_{1i}^{b_1} X_{2i}^{b_2} X_{3i}^{b_3}}$$

[5]

Where the parameters β_0, β_1,β_2 and β_3 take the values that appear in Table 2. In Table 4 the individual indices of efficiency are given for the different units. The average efficiency of the 75 units, estimated through the deterministic model of frontier is 51.31%. This indicates that, on average, significant savings could be achieved in inputs (approximately 45% of those existing) to obtain the same objective in terms of output. Two-thirds of the units have indices of efficiency below 60% and a third of the units are below 50%.

2. The stochastic frontier

The stochastic production frontier[11] is built on the possible double origin of deviations from the production frontier: inefficiency and factors that are outside the control of the organisations. In the case of the Cobb-Douglas function the formulation of the model will be:

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[11] See Aigner, Lovell and Schmidt (1977), Battese and Corra (1977) and Meeusen and Van Den Broeck (1977).

$$\ln Y_i = b_0 + \sum_{k=1}^{n} b_k \ln X_{ki} + v_i + u_i$$

[6]

Where $u_i \leq 0$ y v_i has no restrictions of sign.

The term for error v_i+u_i is made up of two parts. The first, v_i, gathers together the stochastic perturbations and random shocks, that is to say it represents factors outside the control of the organisation. The second part (u_i) is equivalent to the residual of the deterministic frontier. It reflects productive inefficiency and it must have a non-positive value.

In stochastic frontier models, the frontier has, as such, two components. The first, $\beta_0+\Sigma\beta_k \ln X_{ki}$, is the non-stochastic part of the frontier, common to all organisations[12]. The second, v_i, is a random component that as such varies from one organisation to another.

In the application of these models it is supposed that the statistical perturbation follows a normal distribution, while various distributions are supposed for the term inefficiency, such as a half-normal distribution, a truncated normal distribution or an exponential distribution[13]. In our application we have supposed a half-normal distribution around u_i[14]. The results obtained are those offered in Table 5.

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[12] See Aigner, Lovell and Schmidt (1977) p.25.
[13] See Meeusen and Van Den Broeck (1977).
[14] We have used the program TSP version 4.3 for the estimation.

As can be appreciated, all the parameters are significant at the usual levels of reliability and the value of χ^2 allows the rejection of the null hypothesis in which the group of parameters given would jointly be zero.

Table 6 shows the individual indices of efficiency for the different units. The average efficiency of the 75 units, calculated with the stochastic model of frontier, is 76.95% and none of the units appears as efficient. Nevertheless, four units (Canet, Canovelles, Mataró and Premià) present indices of efficiency above 90% and another 15 (in total a quarter) indices above 85%. In contrast, only one unit (Navas) has an index of efficiency below 50% and only eight were found to be below 60%.

II.2. THE NON-PARAMETRIC APPROACH

These approaches do not specify a functional form a priori, but some formal properties that satisfy points on the production set.

Farrell (1957) followed this approach and established the hypothesis of free disposal of inputs and outputs, convexity and proportionality. In general the term Data Envelopment Analysis (DEA) is reserved for those methods that assume convexity and calculate efficiency through linear programming techniques.

Below we will carry out a measurement of efficiency using the technique mentioned. We will make also some reference to another approach that is also non-parametric, the FDH, more 'kind-hearted' than the DEA in the evaluation of efficiency as it does not include the assumption of convexity in determining the frontier.

1. Data envelopment analysis (DEA)

Data envelopment analysis was developed by Charnes, Cooper and Rhodes (1978a and 1978b) and was based upon the seminal work of Farrell (1957). The model uses linear programming techniques to compare the efficiency of a group of units that produce similar outputs from a common group of inputs.

It is not the purpose of this study to describe DEA[15] in detail. We will only indicate that this technique can be understood as an extension of traditional analysis of input/output ratios. The efficiency of the unit to be evaluated is defined as the ratio of a weighted quantity of outputs to a weighted quantity of inputs. The weightings used are generated by the technique itself. Therefore, if we consider a group of n units consuming m inputs and producing s outputs, the efficiency of a unit can be measured in the following form:

$$\text{Max}\, h_0 = \frac{\sum_{r=1}^{s} U_r Y_{r0}}{\sum_{i=1}^{m} V_i X_{i0}}$$

[7]

Subject to

$$\frac{\sum_{r=1}^{s} U_r Y_{rj}}{\sum_{i=1}^{m} V_i X_{ij}} \leq 1 \qquad j = 1\ldots.n$$

[8]

$U_r, V_i \geq 0 \qquad r = 1\ldots.s \qquad i = 1\ldots.m$

Where:

h_0: is the index of efficiency of the unit being evaluated.

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15 For a meticulous analysis of this, see Banker et al. (1989) and Seiford (1996).

Y_{r0}: is the quantity of output r produced by the unit being evaluated.

X_{i0}: is the quantity of input i consumed by the unit being evaluated.

Y_{rj}: is the quantity of output r produced by the unit j.

X_{ij}: is the quantity of input i consumed by the unit j.

U_r: is the weighting assigned to output r.

V_i: is the weighting assigned to input i.

By solving the linear programming problem it is possible to calculate, for each of the units analysed, the group of weightings of inputs and outputs that permits a greater index of efficiency to be reached, with the single condition that using the same group of weightings none of the other units examined obtains a ratio of efficiency greater than one. If in this way a group of weightings can be found with which the index of efficiency of the unit being evaluated is equal to one, that unit will be considered efficient [16]. If this is not the case, the unit will be considered relatively inefficient.

The previous formulation is fractional. However, the model can be easily presented as a linear programming problem. In its input-oriented version, and assuming variable returns to scale, the model can be written:

Min θ_0

Subject to

16 Always whenever the additional requisite is fulfilled that the slack variables corresponding to the various outputs and inputs are equal to zero.

$$q_0 X_{io} \leq \sum_{j=1}^{n} X_{ij} \, l_j \qquad i = 1 \ldots m$$

[9]

$$Y_{ro} \leq \sum_{j=1}^{n} Y_{rj} \, l_j \qquad r = 1 \ldots s$$

[10]

$$\sum_{j=1}^{n} l_j = 1 \qquad \lambda_j \geq 0 \qquad [11]$$

The data envelopment technique provides particularised information on the units analysed, supplying individual indices of efficiency for each one of them, and reference groups and objectives for consumption and production for the units evaluated to be inefficient.

In our case, to calculate efficiency we have assumed, taking into account previous studies of the sector and the results obtained with the parametric approach, that the points on the production set and their corresponding frontier do not satisfy the hypothesis of constant returns to scale.

As for the results, of the 75 units, 28 are relatively efficient, that is approximately 37% of the units examined. The average efficiency of the whole group of municipalities reached 81%, there being, to judge by these results, a considerable margin for improvement in the refuse collection services. Table 7 shows the indices of efficiency in decreasing order.

Even so, there are some exogenous factors that could affect the conditions in which the service is carried out, and the consideration of which could substantially affect the indices of efficiency. More precisely, it would be useful to use two exogenous factors with the purpose of incorporating into the analysis the possible presence of economies of density and the influence of seasonal factors. In the first case it is necessary to calculate the advantages derived from the agglomeration of the population into urban nuclei, as opposed to their geographical dispersion at the moment the refuse collection is undertaken. The second confronts the problems raised in certain municipalities that because of their attraction for tourists have to maintain a refuse collection service for a population well above their normal resident population. These factors would respectively be the density of the urban population and the seasonal population.

Taking these factors into account, the results vary in the following way. In addition to the units previously declared to be efficient, a group of five more are added (Castellar, Lleida, Montblanc, Olesa and Terrassa), to complete a total of 33 relatively efficient units, some 45% of the units examined, and an average of nearly 85% efficiency is reached. The case of Olesa has special relevance, as it was on the borderline of being declared efficient when we did not take exogenous factors into account (efficiency index of 0.9843) and now passes over to be declared efficient and also forms part of the reference group for another 23 units. Table 8 shows the new indices of efficiency.

In order to grade the efficient units, we have used a method that has frequently been applied in the DEA literature. We refer to the number of times that an efficient unit appears in the reference group of the inefficient units. So, when the number is higher the unit being evaluated is genuinely efficient in respect to a good number of units. On the other hand, if a unit appears exclusively in its own reference group, or in the reference groups of a very small number of units, its efficiency is dubious[17].

Lloret and Canovelles (26 times) come in first place followed by Mataró (25) and Olesa (23). The rest of the units that serve as a reference for others are Cassà (20 times), Premià (18), Santa Perpetua (16), Sallent and Rubí (10), Llinars (6), Montblanc (5), Sabadell, and Badalona (3) and Canet, Cervelló and Terrassa (2). The remainders form a group of 17 units that are efficient by default and only appear in their own reference groups.

2. The Free Disposal Hull (FDH)[18]

As we pointed out before, FDH makes a less restrictive evaluation of the behaviour of the units being examined within the non-parametric approaches. FDH does not impose the requirement of convexity (as DEA does), in such a way that, logically, the units considered inefficient with this method will also be so with DEA (although the reverse is not certain), for which reason FDH is often considered a special case of DEA. Specifically, adding to the linear programme formulated previously, the following n+1 restrictions:

$$\sum_{j=1}^{n} l_j = 1 \qquad [12]$$

And

$$l_j \in \{0,1\} \qquad j = 1,\ldots,n \qquad [13]$$

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17 See Smith and Mayston (1987).

18 The seminal work can be seen on FDH by Deprins, Simar and Tulkens (1984). More recent applications can be found in Tulkens (1990) or De Borger et al. (1994a and 1994b).

We assume that the production set is the *Free Disposal Hull* (FDH) of the data.

The great virtue of FDH in relation to other methods is that the reference units for the inefficient services are real units, which gives full meaning to the comparison between production units. On the other hand, and apart from the suitability of the assumptions, on which the construction of the frontier is based, such generous treatment of the sector being analysed could lack any practical meaning apart from a certain percentage of efficient units.

The results of FDH applied to our sector (without taking the exogenous factors considered previously into account) appear in Table 9. In tune with that said previously, 85% of the units are considered efficient (64 out of 75), reaching an average efficiency of 95.87%, the highest value in all the approaches used.

III. COMPARISON OF RESULTS

In the previous sections we have examined various parametric and non-parametric approaches to calculate the level of efficiency with which the refuse collection services acted in the sample of 75 Catalan municipalities in 1994. Under this heading we compare the results given by the different approaches.

Beforehand, we should insist upon the essential difference that can give rise to discrepancies in the results. This derives from the different assumptions on which they are based, much more restrictive in the case of the parametric frontiers in which the analyst must specify the functional form of the production frontier. The different hypotheses from which they depart could, reasonably, be the origin of divergences in the results, without, to this time, the unquestionable superiority of any one of them having been demonstrated.

Having made these observations, we compare the results obtained, examining the average efficiency, the coefficient of correlation and the order of the units when applying each of the methods considered.

Table 10 presents the complete data on efficiency and Table 11 summarises the average efficiencies according to various methods. The fact that the average efficiency is considerably less when applying the parametric models of frontier is as expected, due to the lesser flexibility of these approaches, resulting as a consequence in a great number of efficient units and high indices of efficiency when applying the DEA models and even more so with the FDH.

Tables 12 and 13 respectively show the Pearson correlation coefficients and the Spearman correlation coefficients of ranking between the indices of efficiency calculated by the various procedures. In both cases, the highest values are to be found in the relations between the two parametric models (0.9288 and 0.9950 respectively) and between the two DEA models (0.9003 and 0.9115), those corresponding to cross relations between parametric and non-parametric models being substantially lower. In any case, the presence of statistically significant values almost always above 0.5 reflects the existence of a certain similarity between the rankings offered by the various types of model.

We would like to give special mention to the units that are clearly more efficient, by way of a common outcome for all the methods used. So, the index of efficiency of which four units (Canet, Canovelles, Premià and Sallent) is equivalent to one (they are completely efficient) with all the non-parametric approaches also rises above the value of 0.85 in all cases in the more demanding parametric estimations. Two more units (Lloret and Mataró) are also completely efficient according to the non-parametric techniques and reach a level above 0.80 with the parametric techniques. Finally, the case of Olesa should be underlined. The indices of efficiency, calculated with the parametric approaches, are 0.8273 and 0.8979 respectively for the deterministic and stochastic methods, even through its index calculated with DEA without considering exogenous variables does not reach a value equivalent to one (it remains at 0.9843). However it does achieve this value when exogenous variables are included in DEA (it also being the third case of those units that appear most times in the reference group with this technique) and when we calculated the frontier using FDH. Given that these seven units were also found in all cases among the reference groups of other units apart from themselves (that are not efficient by default in the DEA models). For that reason it would not be taking a very great risk to consider them the most genuinely efficient and it would seem to us to be very interesting to know the real organisation of these units as precisely as possible.

IV. EFFICIENCY AND MANAGEMENT

From the results obtained and including additional information about the different types of administration of the refuse collection services, we can compare to see whether these differentiated administrations affect or not the degree of efficiency with which these services are performed.

The spatial separation between the various municipalities and, in consequence, between the services analysed, contributes to an appropriate framework for comparison, as this impedes the uniformity in incentive schemes that would occur if public and private units acted in the same space.

For the purpose of deciding whether the type of administration affects the efficiency with which the service is provided, we carried out, in the first place, a simple regression between the indices of efficiency obtained and the type of administration[19]. Due to truncated character of the indices (with a top of 1 and a bottom of 0) the regression made was one double censured Tobit type. The results, gathered together in Table 14, were not significant either using the individual efficiencies obtained with a parametric approach or with those provided by the data envelopment technique.

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[19] Using a dual variable taking the value of 1 if the service is provided by the municipality directly and 0 if it is carried out through a concession.

For the same purpose we also used the Mann-Whitney test, a non-parametric contrast based on the ranks of the individual samples, and because of this resistant to outliers. The results appear in Table 15. The Mann-Whitney statistics show that efficiency does not significantly differ between one type of administration and another and this occurs, as before, whichever approach is used in the calculation of efficiency.

All in all, we consider that the results of this last analysis could be enriched if additional information on the forms of administration of the service were available. We have only managed to distinguish between municipalities which themselves, or their own entities, provide this service, and those that have 'privatised', in the sense of having made an administrative concession of this to a private company. The lack of relevance, in terms of efficiency, of the type of administration that emerges from our results, could be biased perhaps, on the one hand, by the absence of complementary information about the effective form of administration performed by the municipalities that administer directly, as in fact there are multiple organisational forms that represent various degrees of flexibility in administration and, on the other, by the conditions on which administrative concessions are made. The use of autonomous administrative bodies, or even municipal companies with a company legal structure could in practice be bringing both types of administration closer. Alternatively, it could be that the conditions established in the tenders for the concession of the service to private companies or the excessive duration of the concession period of the service to private companies in practice leads to the substitution of the public monopoly for a private monopoly, which would also lead to results open to discussion. Since in the greater part of previous research it has been demonstrated that the most relevant aspect is not so much the public-private dichotomy, but rather the degree of competition in which the sector operates, the analysis of these conditions is an outstanding and unavoidable task.

VI. CONCLUSIONS

This study contains the results of an analysis made about the efficiency of the refuse collection services in 75 municipalities located in the region of Catalonia in Spain.

We have attempted to carry out a defined analysis of efficiency for these Catalan municipalities, accepting as a basic premise that this analysis refers only to the technical and production areas, for which reason any reference whatsoever to the relative price of the variables used was consciously excluded. In addition to this, it was still necessary to take a series of important previous decisions before beginning the approach or estimation of the frontiers that would allow us to evaluate the efficiency of each productive unit. In particular, three decisions to be taken were what variables (inputs and outputs) and what techniques (parametric o non-parametric) should be used and what type of returns to scale should be considered.

Concerning the first choice, we decided to use, as a starting point, only four variables (a single output, Tons of Organic Refuse Collected, and three inputs, the Number of Containers, the Number of Trucks and the Number of Direct Employees -non-administrative employees-, reduced to full working days, involved in providing the service). The lack of data prevented us from using more finely adjusted inputs that could have gathered more information, such as the number of kilometres covered by the vehicles, their capacity and their technical characteristics or categories of employee. With regard to the outputs, we chose only one because of its quantitative significance (see footnote 2) and to facilitate the parametric estimation of the frontier and, in consequence, the comparison of the results with other methods, given the restrictions in information we were faced with (a single period).

In this sense, and with reference now to the second choice, and seeing that a broad range of options can be derived from an analysis of previous theoretical and empirical writing, we decided to try various alternatives going from the more rigid towards the more flexible and using, when applicable, the information we were obtaining to take more fundamental decisions at the later stages. Therefore the sequence followed was, in the first place, to estimate a deterministic parametric frontier departing from the specification of a Cobb-Douglas production function (relatively rigid), and then a stochastic parametric frontier (with a half-normal functional form), and finally to use various non-parametric approaches. The latter were respectively, (always from lesser to greater flexibility), a DEA exclusively on the basis of the variables used in the parametric calculations, a DEA that included, in addition, the presence of exogenous factors or factors out of the control of the productive unit such as the population density and its seasonal nature, and an FDH.

Finally, and with regard to the third of the mentioned choices (types of returns to scale), we have used the results of the deterministic parametric estimation to maintain the hypothesis of variable returns in the non-parametric approaches.

With regard to the results obtained, these naturally differ according to the technique used to approach the frontier, given the different implicit assumptions in the various techniques. Nevertheless, they have an appearance of solidity, at least with regard to the ordinal concordance of the indices of efficiency obtained by the various approaches used, as the statistical tests used show.

All in all, choosing one of the techniques used, we would choose those results that emanate from the fourth technique used (DEA with exogenous variables) for two fundamental reasons. On the one hand, in our opinion, the technique is sufficiently flexible, above all once variable returns to scale are assumed, to compute certain specific characteristics of the productive process that a more rigid formulation would not take into account, and it does this without being as kind in the extreme as the FDH. In addition, the inclusion of exogenous factors (outside the control of the managers of the service) introduces into the analysis a greater framework of flexibility that is in our judgement in no way unappreciable.

Finally, we have attempted to confirm the presumed relation between the type of management of the service (public or private) and the indices of efficiency reached, for which purpose we used a simple regression analysis and a non-parametric Mann-Whitney contrast. In both cases the results obtained show that no significant relation exists between either variables (type of management and efficiency). Nevertheless the shortcomings of the data base used, in which we neither had information available on the type of public administration (direct, through autonomous bodies, public companies...), nor on the conditions on which administrative concessions were given, made it insufficient in describing the framework of competence in which the service is carried out. For that reason the explanatory power of these results could be notably depleted.

References

AIGNER, D.J. and S.F. CHU (1968). - "On Estimating the Industry Production Function", *American Economic Review*, vol.58, pp. 226-239.

AIGNER, D.J., C.A.K. LOVELL, and P. SCHMIDT (1977). - "Formulation and Estimation of Stochastic Production Function Models", *Journal of Econometrics*, vol. 6, pp.21-37.

ALI, A.I and L.M. SEIFORD (1993). - "The mathematical programming approach to efficiency analysis", in FRIED, LOVELL and SCHMIDT (1993).

BANKER, R.D, A. CHARNES, W.W. COOPER, J. SWARTS and D.A. THOMAS (1989). - " An Introduction to Data Envelopment Analysis with Some of Their Models and its Uses", *Research in Governmental and Non-profit Accounting*, vol. 5, pp. 125-163.

BATTESE, G.E. and G.S. CORRA (1977). -"Estimation of a Production Frontier Model: With Application to the Pastoral Zone of Eastern Australia", *Australian Journal of Agricultural Economics*, vol. 21, nº 3, pp.169-179.

CEA (1994). - *Anàlisi dels costos del servei municipal de recollida de residus sòlids urbans. Fase II - Els municipis metropolitans.* Centre d'Estudis Ambientals. Barcelona.

CHARNES, A., W.W. COOPER and E. RHODES (1978a). - "Measuring the Efficiency of Decision Making Units", *European Journal of Operational Research*, vol. 2, pp.429-444.

CHARNES, A., W.W. COOPER and E. RHODES (1978b). - "Short Communication: Measuring the Efficiency of Decision Making Units", *European Journal of Operational Research*, vol. 3, p. 339.

COLLINS, J.N. and B.T. DOWNES (1977). - "The Effects of Size on the Provision of Public Services: The Case of Solid Waste Collection in Smaller Cities". *Urban Affairs Quarterly*. March 1977.

CUBBIN, J., S. DOMBERGER and S. MEADOWCROFT (1986). - "Competitive tendering and refuse collection: identifying the sources of efficiency gains", *Fiscal Studies*, vol. 7, nº 4, pp. 49-58.

DE BORGER, B., K. KERSTENS, W. MOESEN and J. VANNESTE (1994a). - "Explaining differences in productive efficiency: An application to Belgian municipalities", *Public Choice*, vol. 80, nº 2, pp. 339-356.

DE BORGER, B., K. KERSTENS, W. MOESEN and J. VANNESTE (1994b). - "A non-parametric Free Disposal Hull (FDH) approach to technical efficiency: an illustration of radial and graph efficiency measures and some sensitive results", *Swiss Journal of Economics and Statistics*, vol. 130, nº4, pp. 647-667.

DEPRINS, D., L. SIMAR and H. TULKENS (1984). - "Measuring Labour-Efficiency in Post Offices", M. Marchand et alter. (Eds.). - *The Performance of Public Enterprises: Concepts and Measurements*, Elsevier. Amsterdam, pp. 243-267.

DOMBERGER, S., S.A. MEADOWCROFT and D.J. THOMPSON (1986). - "Competitive Tendering and Efficiency: The case of Refuse Collection", *Fiscal Studies*, vol. 7, nº 4, pp. 69-87.

FARRELL, M.J. (1957). - "The Measurement of Productive Efficiency", *Journal of the Royal Statistical Society*, nº 120, pp. 253-281.

FØRSUND, F.F., C. LOVELL and P. SMITH (1980). - " A Survey of Frontier Production Functions and of Their Relationship to Efficiency Measurement", *Journal of Econometrics*, vol. 13, pp. 5-25.

FRIED, H.O; C. LOVELL and P.S. SCHMIDT (eds.) (1993). - *The Measurement of Productive Efficiency*. Oxford University Press. Oxford.

GANLEY, J. and J. GRAHL (1988). - "Competition and Efficiency in Refuse Collection: A Critical Comment", *Fiscal Studies*, vol. 9, nº 1, pp. 80-85.

HIRSCH, W.Z. (1965). - "Cost Functions of an Urban Government Service: Refuse Collection". *Review of Economics and Statistics*. February 1965.

KEMPER, P. and J. QUIGLEY (1976). - *The Economics of Refuse Collection*. Cambridge, Mass: Ballinger.

LOVELL, C. and P. SCHMIDT (1988). - "A comparison of alternative approaches to the measurement of productive efficiency", Dogramaci, A. and R. Färe (Eds.). - *Efficiency and Productivity*. Kluwer Academic Publishers, Boston. MA.

MEEUSEN, W. and J. VAN DEN BROECK (1977). - "Efficiency Estimation from Cobb-Douglas Production Functions with Composed Errors", *International Economic Review*, vol. 2, pp. 435-444.

SEIFORD, L.M (1996). - "Data envelopment analysis: The evolution of the state of the art (1978-1995)", *Journal of Productivity Analysis*, 7 (2-3), 99-137.

SCHMIDT (1986). - "Frontier Production Functions", *Econometrics Review*, vol. 4, nº 2, pp. 289-328.

Table 1

Descriptive statistics

	Tons	Containers	Trucks	Workers
Maximum	**101,100**	**3,912**	**18**	**49**
Minimum	**2,032**	**25**	**1**	**2**
Average	**15,271**	**542**	**3**	**10**
Standard deviation	**18,916**	**666**	**3**	**9**
Coefficient of variation	**1.2387**	**1.2291**	**0.9075**	**0.9704**

Table 2

Estimate of the deterministic frontier

Variable	Parameter	Coefficient	t statistic
Constant	b_0	**4.65476**	**17.753*** **
LContainers	b_1	**0.48839**	**7.434*** **
LTrucks	b_2	**0.16073**	**1.594**
LWorkers	b_3	**0.45017**	**4.568*** **

Adjusted R^2 = 0.90364 **F = 232.325**

(***) Significant to a level of reliability of 99%

(**) Significant to a level of reliability of 95%

(*) Significant to a level of reliability of 90%

Table 3

Wald Test

Null hypothesis: $b_1 + b_2 + b_3$ **= 1**			
F	**4.712140**	**Probability**	**0.033295**
c^2	**4.712140**	**Probability**	**0.029950**

Table 4

Deterministic frontier - Indices of efficiency

MUNICIPALITIES	INDICES	MUNICIPALITIE S	INDICES
PREMIÀ	**1.0000**	**VALLS**	**0.5293**
CANET	**0.8752**	**IGUALADA**	**0.5273**
SALLENT	**0.8563**	**BISBAL**	**0.5131**
CANOVELLES	**0.8544**	**SANT BOI**	**0.5087**
OLESA	**0.8273**	**ABRERA**	**0.5041**
RIPOLLET	**0.8259**	**CASTELLAR**	**0.5021**
MATARÓ	**0.8233**	**GARRIGA**	**0.4979**
LLORET	**0.8162**	**TORELLÓ**	**0.4940**
MOLLERUSSA	**0.7752**	**SITGES**	**0.4883**
FIGUERES	**0.7662**	**CERVELLÓ**	**0.4795**
RUBÍ	**0.7182**	**FRANQUESES**	**0.4792**
SANT JUST	**0.7060**	**MARTORELL**	**0.4737**
PARETS	**0.7048**	**SANT QUIRZE**	**0.4736**
SANT VICENÇ	**0.7036**	**VILASSAR**	**0.4696**
LLINARS	**0.7002**	**LLEIDA**	**0.4693**
BADALONA	**0.6947**	**SANT CELONI**	**0.4650**
ESPLUGUES	**0.6794**	**CERDANYOL A**	**0.4647**
SANTA PERPETUA	**0.6691**	**MONTMELÓ**	**0.4607**
MASNOU	**0.6468**	**PRAT**	**0.4570**

CORNELLÀ	**0.6362**	**SANT ADRIÀ**	**0.4560**
HOSPITALET	**0.6237**	**VILANOVA**	**0.4498**
MOLLET	**0.6184**	**VALLIRANA**	**0.4492**
SANTA COLOMA	**0.6148**	**SANT JOAN**	**0.4328**
LLAGOSTA	**0.6000**	**BERGA**	**0.4239**
GIRONA	**0.5926**	**SURIA**	**0.4185**
SALOU	**0.5896**	**PALLEJÀ**	**0.4060**
BLANES	**0.5774**	**CAMBRILS**	**0.3968**
GAVÀ	**0.5773**	**SOLSONA**	**0.3964**
CASSÀ	**0.5720**	**AMPOSTA**	**0.3937**
VILADECANS	**0.5631**	**MONTBLANC**	**0.3509**
CASTELLDEFELS	**0.5621**	**ROSES**	**0.3325**
SANT ANDREU	**0.5617**	**ALMACELLES**	**0.3213**
GRANOLLERS	**0.5472**	**OLOT**	**0.3105**
ESPARREGUERA	**0.5428**	**BALAGUER**	**0.3016**
TERRASSA	**0.5407**	**PALAFRUGELL**	**0.2961**
PINEDA	**0.5382**	**PIERA**	**0.2770**
SABADELL	**0.5314**	**NAVAS**	**0.2511**
ARGENTONA	**0.5294**		

Table 5

Estimate of the stochastic frontier (distribution of u_i: half-normal)

Variable	Parameter	Coefficient	t statistic
Constant	β_0	**5,7276**	**16,327*** **
LContainers	β_1	**0,4594**	**7,155*** **
LTrucks	β_2	**0,2056**	**2,093** **
LWorkers	β_3	**0,4290**	**4,703*** **
	$\lambda = \sigma_u / \sigma_v$	**1,6725**	**1,743* **
	$\sigma = \sqrt{\sigma^2_v + \sigma^2_u}$	**0,3981**	**5,624*** **
	σ_u	**0,3416**	**3,132*** **
	σ_v	**0,2043**	**3,594*** **
	χ^2 = **36,087*** **		

(***) Significant to a level of reliability of 99%

(**) Significant to a level of reliability of 95%

(*) Significant to a level of reliability of 90%

Table 6

Stochastic frontier - Indices of efficiency

MUNICIPALITIES	INDICES	MUNICIPALITIES	INDICES
PREMIÀ	**0.9236**	**SANT BOI**	**0.7777**
CANOVELLES	**0.9066**	**ARGENTONA**	**0.7722**
MATARÓ	**0.9063**	**IGUALADA**	**0.7720**
CANET	**0.9044**	**GARRIGA**	**0.7678**
SALLENT	**0.8998**	**ABRERA**	**0.7629**
LLORET	**0.8980**	**CASTELLAR**	**0.7607**
OLESA	**0.8979**	**TORELLÓ**	**0.7596**
RIPOLLET	**0.8952**	**BISBAL**	**0.7554**
FIGUERES	**0.8933**	**SITGES**	**0.7540**
MOLLERUSSA	**0.8917**	**CERVELLÓ**	**0.7476**
RUBÍ	**0.8856**	**LLEIDA**	**0.7460**
SANT VICENÇ	**0.8745**	**SANT QUIRZE**	**0.7445**
BADALONA	**0.8729**	**MARTORELL**	**0.7397**
SANT JUST	**0.8722**	**SANT ADRIÀ**	**0.7347**
PARETS	**0.8713**	**CERDANYOLA**	**0.7344**
SANTA PERPETUA	**0.8673**	**PRAT**	**0.7317**
ESPLUGUES	**0.8663**	**FRANQUESES**	**0.7311**
LLINARS	**0.8645**	**VILASSAR**	**0.7297**
MASNOU	**0.8512**	**MONTMELÓ**	**0.7237**

CORNELLÀ	0.8507	VALLIRANA	0.7226
HOSPITALET	0.8444	SANT CELONI	0.7207
SANTA COLOMA	0.8387	VILANOVA	0.7195
MOLLET	0.8369	SANT JOAN	0.6989
SALOU	0.8303	BERGA	0.6872
LLAGOSTA	0.8288	SURIA	0.6731
GIRONA	0.8287	PALLEJÀ	0.6724
GAVÀ	0.8182	CAMBRILS	0.6589
CASTELLDEFELS	0.8097	AMPOSTA	0.6545
BLANES	0.8079	SOLSONA	0.6447
CASSÀ	0.8077	MONTBLANC	0.5840
TERRASSA	0.8071	ROSES	0.5824
VILADECANS	0.8027	OLOT	0.5495
GRANOLLERS	0.8023	ALMACELLES	0.5493
SANT ANDREU	0.7984	BALAGUER	0.5360
SABADELL	0.7949	PALAFRUGELL	0.5268
PINEDA	0.7924	PIERA	0.5163
VALLS	0.7875	NAVAS	0.4611
ESPARREGUERA	0.7827		

Table 7

DEA$_1$ frontier- Indices of efficiency

MUNICIPALITIES	INDICES	MUNICIPALITIES	INDICES
ABRERA	**1.0000**	**ARGENTONA**	**0.8076**
BADALONA	**1.0000**	**ALMACELLES**	**0.7877**
CANET	**1.0000**	**CASTELLAR**	**0.7860**
CANOVELLES	**1.0000**	**ESPARREGUERA**	**0.7859**
CASSÀ	**1.0000**	**MASNOU**	**0.7800**
CERVELLÓ	**1.0000**	**GIRONA**	**0.7582**
GARRIGA	**1.0000**	**BLANES**	**0.7574**
HOSPITALET	**1.0000**	**SALOU**	**0.7572**
LLAGOSTA	**1.0000**	**PINEDA**	**0.7396**
LLINARS	**1.0000**	**VILADECANS**	**0.7267**
LLORET	**1.0000**	**BISBAL**	**0.7261**
MATARÓ	**1.0000**	**GAVÀ**	**0.7241**
MOLLERUSSA	**1.0000**	**SOLSONA**	**0.7139**
MONTMELÓ	**1.0000**	**MOLLET**	**0.7116**
PALLEJÀ	**1.0000**	**CASTELLDEFELS**	**0.6907**
PARETS	**1.0000**	**LLEIDA**	**0.6899**
PREMIÀ	**1.0000**	**SANT BOI**	**0.6696**
RUBÍ	**1.0000**	**GRANOLLERS**	**0.6684**
SABADELL	**1.0000**	**SANT ANDREU**	**0.6616**

SALLENT	**1.0000**	**VALLS**	**0.6579**
SANT JOAN	**1.0000**	**IGUALADA**	**0.6477**
SANT JUST	**1.0000**	**PRAT**	**0.6427**
SANT QUIRZE	**1.0000**	**CERDANYOLA**	**0.6246**
SANTA PERPETUA	**1.0000**	**NAVAS**	**0.6218**
SURIA	**1.0000**	**SANT CELONI**	**0.6019**
TORELLÓ	**1.0000**	**SITGES**	**0.5954**
VALLIRANA	**1.0000**	**FRANQUESES**	**0.5941**
VILANOVA	**1.0000**	**VILASSAR**	**0.5888**
OLESA	**0.9843**	**MARTORELL**	**0.5842**
TERRASSA	**0.9747**	**BERGA**	**0.5483**
FIGUERES	**0.9651**	**PIERA**	**0.5104**
RIPOLLET	**0.9583**	**AMPOSTA**	**0.5102**
SANT ADRIÀ	**0.8827**	**BALAGUER**	**0.5000**
SANTA COLOMA	**0.8545**	**CAMBRILS**	**0.4964**
SANT VICENÇ	**0.8423**	**ROSES**	**0.4152**
ESPLUGUES	**0.8350**	**OLOT**	**0.3991**
CORNELLÀ	**0.8341**	**PALAFRUGELL**	**0.3951**
MONTBLANC	**0.8179**		

Table 8

DEA$_2$ frontier- Indices of efficiency

MUNICIPALITIES	INDICES	MUNICIPALITIES	INDICES
ABRERA	**1.0000**	**GIRONA**	**0.8717**
BADALONA	**1.0000**	**SANT VICENÇ**	**0.8598**
CANET	**1.0000**	**SANTA COLOMA**	**0.8545**
CANOVELLES	**1.0000**	**GAVÀ**	**0.8458**
CASSÀ	**1.0000**	**ESPLUGUES**	**0.8350**
CASTELLAR	**1.0000**	**CORNELLÀ**	**0.8341**
CERVELLÓ	**1.0000**	**ARGENTONA**	**0.8106**
GARRIGA	**1.0000**	**SITGES**	**0.7993**
HOSPITALET	**1.0000**	**BLANES**	**0.7964**
LLAGOSTA	**1.0000**	**ALMACELLES**	**0.7935**
LLEIDA	**1.0000**	**MASNOU**	**0.7800**
LLINARS	**1.0000**	**NAVAS**	**0.7790**
LLORET	**1.0000**	**VILADECANS**	**0.7626**
MATARÓ	**1.0000**	**SALOU**	**0.7577**
MOLLERUSSA	**1.0000**	**PIERA**	**0.7461**
MONTBLANC	**1.0000**	**MOLLET**	**0.7455**
MONTMELÓ	**1.0000**	**VALLS**	**0.7451**
OLESA	**1.0000**	**PINEDA**	**0.7396**
PALLEJÀ	**1.0000**	**BISBAL**	**0.7380**

PARETS	**1.0000**	**SOLSONA**	**0.7143**
PREMIÀ	**1.0000**	**CASTELLDEF ELS**	**0.7023**
RUBÍ	**1.0000**	**IGUALADA**	**0.6982**
SABADELL	**1.0000**	**SANT ANDREU**	**0.6858**
SALLENT	**1.0000**	**GRANOLLERS**	**0.6725**
SANTA PERPETUA	**1.0000**	**SANT BOI**	**0.6725**
SANT JOAN	**1.0000**	**PRAT**	**0.6558**
SANT JUST	**1.0000**	**MARTORELL**	**0.6294**
SANT QUIRZE	**1.0000**	**CERDANYOLA**	**0.6292**
SURIA	**1.0000**	**FRANQUESES**	**0.6169**
TERRASSA	**1.0000**	**SANT CELONI**	**0.6019**
TORELLÓ	**1.0000**	**VILASSAR**	**0.5888**
VALLIRANA	**1.0000**	**BERGA**	**0.5586**
VILANOVA	**1.0000**	**ROSES**	**0.5094**
RIPOLLET	**0.9950**	**CAMBRILS**	**0.5079**
AMPOSTA	**0.9833**	**BALAGUER**	**0.5029**
FIGUERES	**0.9795**	**OLOT**	**0.4136**
ESPARREGUE RA	**0.9202**	**PALAFRUGEL L**	**0.4115**
SANT ADRIÀ	**0.8827**		

Table 9

FDH frontier - Indices of efficiency

MUNICIPALITIES	INDICES	MUNICIPALITIES	INDICES
ABRERA	**1.0000**	**PARETS**	**1.0000**
ALMACELLES	**1.0000**	**PINEDA**	**1.0000**
AMPOSTA	**1.0000**	**PRAT**	**1.0000**
ARGENTONA	**1.0000**	**PREMIÀ**	**1.0000**
BADALONA	**1.0000**	**RIPOLLET**	**1.0000**
BERGA	**1.0000**	**RUBÍ**	**1.0000**
BISBAL	**1.0000**	**SABADELL**	**1.0000**
BLANES	**1.0000**	**SALOU**	**1.0000**
CANET	**1.0000**	**SALLENT**	**1.0000**
CANOVELLES	**1.0000**	**SANT ADRIÀ**	**1.0000**
CASSÀ	**1.0000**	**SANT ANDREU**	**1.0000**
CASTELLAR	**1.0000**	**SANT BOI**	**1.0000**
CASTELLDEFELS	**1.0000**	**SANT JOAN**	**1.0000**
CERDANYOLA	**1.0000**	**SANT JUST**	**1.0000**
CERVELLÓ	**1.0000**	**SANT QUIRZE**	**1.0000**
CORNELLÀ	**1.0000**	**SANT VICENÇ**	**1.0000**
ESPARREGUERA	**1.0000**	**SANTA COLOMA**	**1.0000**
ESPLUGUES	**1.0000**	**SANTA PERPETUA**	**1.0000**

FIGUERES	**1.0000**	**SOLSONA**	**1.0000**
FRANQUESES	**1.0000**	**SURIA**	**1.0000**
GARRIGA	**1.0000**	**TERRASSA**	**1.0000**
GAVÀ	**1.0000**	**TORELLÓ**	**1,0000**
GIRONA	**1.0000**	**VALLIRANA**	**1.0000**
GRANOLLERS	**1.0000**	**VALLS**	**1.0000**
HOSPITALET	**1.0000**	**VILADECANS**	**1.0000**
IGUALADA	**1.0000**	**VILANOVA**	**1.0000**
LLAGOSTA	**1.0000**	**VILASSAR**	**0.9892**
LLINARS	**1.0000**	**SANT CELONI**	**0.9690**
LLORET	**1.0000**	**SITGES**	**0.8354**
MARTORELL	**1.0000**	**CAMBRILS**	**0.7757**
MASNOU	**1.0000**	**NAVAS**	**0.7500**
MATARÓ	**1.0000**	**PALAFRUGELL**	**0.7496**
MOLLERUSSA	**1.0000**	**BALAGUER**	**0.6250**
MOLLET	**1.0000**	**PIERA**	**0.6143**
MONTBLANC	**1.0000**	**OLOT**	**0.6000**
MONTMELÓ	**1.0000**	**ROSES**	**0.5455**
OLESA	**1.0000**	**LLEIDA**	**0.4513**
PALLEJÀ	**1.0000**		

Table 10

Indices of efficiency by the different approaches

MUNICIPALITIES	Determ. Parametric	Stochastic Parametric	DEA without Exogenous	DEA with Exogenous	FDH
ABRERA	**0.5041**	**0.7629**	**1.0000**	**1.0000**	**1.0000**
ALMACELLES	**0.3213**	**0.5493**	**0.7877**	**0.7935**	**1.0000**
AMPOSTA	**0.3937**	**0.6545**	**0.5102**	**0.9833**	**1.0000**
ARGENTONA	**0.5294**	**0.7722**	**0.8076**	**0.8106**	**1.0000**
BADALONA	**0.6947**	**0.8729**	**1.0000**	**1.0000**	**1.0000**
BALAGUER	**0.3016**	**0.5360**	**0.5000**	**0.5029**	**0.6250**
BERGA	**0.4239**	**0.6872**	**0.5483**	**0.5586**	**1.0000**
BISBAL	**0.5131**	**0.7554**	**0.7261**	**0.7380**	**1.0000**
BLANES	**0.5774**	**0.8079**	**0.7574**	**0.7964**	**1.0000**
CAMBRILS	**0.3968**	**0.6589**	**0.4964**	**0.5079**	**0.7757**
CANET	**0.8752**	**0.9044**	**1.0000**	**1.0000**	**1.0000**
CANOVELLES	**0.8544**	**0.9066**	**1.0000**	**1.0000**	**1.0000**
CASSÀ	**0.5720**	**0.8077**	**1.0000**	**1.0000**	**1.0000**
CASTELLAR	**0.5021**	**0.7607**	**0.7860**	**1.0000**	**1.0000**
CASTELLDEFELS	**0.5621**	**0.8097**	**0.6907**	**0.7023**	**1.0000**
CERDANYOLA	**0.4647**	**0.7344**	**0.6246**	**0.6292**	**1.0000**
CERVELLÓ	**0.4795**	**0.7476**	**1.0000**	**1.0000**	**1.0000**
CORNELLÀ	**0.6362**	**0.8507**	**0.8341**	**0.8341**	**1.0000**

ESPARREGUERA	0.5428	0.7827	0.7859	0.9202	1.0000
ESPLUGUES	0.6794	0.8663	0.8350	0.8350	1.0000
FIGUERES	0.7662	0.8933	0.9651	0.9795	1.0000
FRANQUESES	0.4792	0.7311	0.5941	0.6169	1.0000
GARRIGA	0.4979	0.7678	1.0000	1.0000	1.0000
GAVÀ	0.5773	0.8182	0.7241	0.8458	1.0000
GIRONA	0.5926	0.8287	0.7582	0.8717	1.0000
GRANOLLERS	0.5472	0.8023	0.6684	0.6725	1.0000
HOSPITALET	0.6237	0.8444	1.0000	1.0000	1.0000
IGUALADA	0.5273	0.7720	0.6477	0.6982	1.0000
LLAGOSTA	0.6000	0.8288	1.0000	1.0000	1.0000
LLEIDA	0.4693	0.7460	0.6899	1.0000	0.4513
LLINARS	0.7002	0.8645	1.0000	1.0000	1.0000
LLORET	0.8162	0.8980	1.0000	1.0000	1.0000
MARTORELL	0.4737	0.7397	0.5842	0.6294	1.0000
MASNOU	0.6468	0.8512	0.7800	0.7800	1.0000
MATARÓ	0.8233	0.9063	1.0000	1.0000	1.0000
MOLLERUSSA	0.7752	0.8917	1.0000	1.0000	1.0000
MOLLET	0.6184	0.8369	0.7116	0.7455	1.0000

Table 10 (Cont.)

Indices of efficiency by the different approaches

MUNICIPALITIES	Determ. Parametric	Stochastic Parametric	DEA without Exogenous	DEA with Exogenous	FDH
MONTBLANC	**0.3509**	**0.5840**	**0.8179**	**1.0000**	**1.0000**
MONTMELÓ	**0.4607**	**0.7237**	**1.0000**	**1.0000**	**1.0000**
NAVAS	**0.2511**	**0.4611**	**0.6218**	**0.7790**	**0.7500**
OLESA	**0.8273**	**0.8979**	**0.9843**	**1.0000**	**1.0000**
OLOT	**0.3105**	**0.5495**	**0.3991**	**0.4136**	**0.6000**
PALAFRUGELL	**0.2961**	**0.5268**	**0.3951**	**0.4115**	**0.7496**
PALLEJÀ	**0.4060**	**0.6724**	**1.0000**	**1.0000**	**1.0000**
PARETS	**0.7048**	**0.8713**	**1.0000**	**1.0000**	**1.0000**
PIERA	**0.2770**	**0.5163**	**0.5104**	**0.7461**	**0.6143**
PINEDA	**0.5382**	**0.7924**	**0.7396**	**0.7396**	**1.0000**
PRAT	**0.4570**	**0.7317**	**0.6427**	**0.6558**	**1.0000**
PREMIÀ	**1.0000**	**0.9236**	**1.0000**	**1.0000**	**1.0000**
RIPOLLET	**0.8259**	**0.8952**	**0.9583**	**0.9950**	**1.0000**
ROSES	**0.3325**	**0.5824**	**0.4152**	**0.5094**	**0.5455**
RUBÍ	**0.7182**	**0.8856**	**1,0000**	**1.0000**	**1.0000**
SABADELL	**0.5314**	**0.7949**	**1.0000**	**1.0000**	**1.0000**
SALOU	**0.5896**	**0.8303**	**0.7572**	**0.7577**	**1.0000**
SALLENT	**0.8563**	**0.8998**	**1.0000**	**1.0000**	**1.0000**
SANT ADRIÀ	**0.4560**	**0.7347**	**0.8827**	**0.8827**	**1.0000**

SANT ANDREU	**0.5617**	**0.7984**	**0.6616**	**0.6858**	**1.0000**
SANT BOI	**0.5087**	**0.7777**	**0.6696**	**0.6725**	**1.0000**
SANT CELONI	**0.4650**	**0.7207**	**0.6019**	**0.6019**	**0.9690**
SANT JOAN	**0.4328**	**0.6989**	**1.0000**	**1.0000**	**1.0000**
SANT JUST	**0.7060**	**0.8722**	**1.0000**	**1.0000**	**1.0000**
SANT QUIRZE	**0.4736**	**0.7445**	**1.0000**	**1.0000**	**1.0000**
SANT VICENÇ	**0.7036**	**0.8745**	**0.8423**	**0.8598**	**1.0000**
SANTA COLOMA	**0.6148**	**0.8387**	**0.8545**	**0.8545**	**1.0000**
SANTA PERPETUA	**0.6691**	**0.8673**	**1.0000**	**1.0000**	**1.0000**
SITGES	**0.4883**	**0.7540**	**0.5954**	**0.7993**	**0.8354**
SOLSONA	**0.3964**	**0.6447**	**0.7139**	**0.7143**	**1.0000**
SURIA	**0.4185**	**0.6731**	**1.0000**	**1.0000**	**1.0000**
TERRASSA	**0.5407**	**0.8071**	**0.9747**	**1.0000**	**1.0000**
TORELLÓ	**0.4940**	**0.7596**	**1.0000**	**1.0000**	**1.0000**
VALLIRANA	**0.4492**	**0.7226**	**1.0000**	**1.0000**	**1.0000**
VALLS	**0.5293**	**0.7875**	**0.6579**	**0.7451**	**1.0000**
VILADECANS	**0.5631**	**0.8027**	**0.7267**	**0.7626**	**1.0000**
VILANOVA	**0.4498**	**0.7195**	**1.0000**	**1.0000**	**1.0000**
VILASSAR	**0.4696**	**0.7297**	**0.5888**	**0.5888**	**0.9892**

Table 11

General summary

	Determ. Parametric	Stochastic Parametric	DEA without Exogenous	DEA with Exogenous	FDH
Nº Efficient Units	**1**	**0**	**28**	**33**	**64**
Average Efficiency	**0.5531**	**0.7695**	**0.8110**	**0.8484**	**0.9587**
Standard Deviation	**0.1578**	**0.1066**	**0.1872**	**0.1721**	**0.1182**
Coefficient of Variation	**0.2854**	**0.1386**	**0.2308**	**0.2029**	**0.1232**

Table 12

Pearson's coefficient of correlation

	Determ. Parametric	Stochastic Parametric	DEA without Exogenous	DEA with Exogenous	FDH
Deterministic Parametric	**1.0000**	**0.9288*** **	**0.6002*** **	**0.5084*** **	**0.4589*** **
Stochastic Parametric	**0.9288*** **	**1.0000**	**0.6138*** **	**0.5151*** **	**0.5776*** **
DEA without Exogenous	**0.6002*** **	**0.6138*** **	**1.0000**	**0.9003*** **	**0.5560*** **

DEA with Exogenous	**0.5084*** **	**0.5151*** **	**0.9003*** **	**1.0000**	**0.4222*** **
FDH	**0.4589*** **	**0.5776*** **	**0.5560*** **	**0.4222*** **	**1.0000**

(***) Significant to a level of reliability of 99%

(**) Significant to a level of reliability of 95%

(*) Significant to a level of reliability of 90%

Table 13

Spearman's coefficient of correlation of ranks

	Determ. Parametric	Stochastic Parametric	DEA without Exogenous	DEA with Exogenous
Stochastic Parametric	**0.9950*** **			
DEA without Exogenous	**0.5221*** **	**0.5342*** **		
DEA with Exogenous	**0.4226*** **	**0.4407*** **	**0.9115*** **	
FDH	**0.5046*** **	**0.5086*** **	**0.5793*** **	**0.4445*** **

(***) Significant to a level of reliability of 99%

(**) Significant to a level of reliability of 95%

(*) Significant to a level of reliability of 90%

Table 14

Tobit regression between the indices of efficiency and the type of administration

Approach	Coefficient	Z	$\hat{s}(z_s)$
Deterministic Parametric	**-0.0621**	**-1.163**	**0.157 (12.10)**
Stochastic Parametric	**-0.0399**	**-0.121**	**0.105 (12.24)**
DEA without Exogenous	**-0.0847**	**-0.765**	**0.316 (9.21)**
DEA with Exogenous	**-0.1008**	**-1.036**	**0.272 (8.20)**
FDH	**-0.1230**	**-0.521**	**0.499 (3.80)**

Table 15

Mann-Whitney test

Direct administration versus concession	U	χ^2	Prob.
Deterministic Parametric	**285.0**	**-1.0034**	**0.3157**
Stochastic Parametric	**291.0**	**-0.9135**	**0.3610**
DEA without Exogenous	**251.0**	**-1.5535**	**0.1203**
DEA with Exogenous	**281.5**	**-1.1038**	**0.2697**
FDH	**338.5**	**-0.3286**	**0.7425**