Long-term cost efficiency of alternative management forms for urban public transport from the public sector perspective

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Abstract: The aim of this paper is to analyse the long-term efficiency of different management forms for urban public transport, using a sample of 193 Spanish municipalities for the period 2014-2016. The analysis is performed using the order-m data panel method proposed by Garrido et al. (2018) and the concept of the meta-frontier (Battese et al., 2004). This approach is based on an analysis of panel data cost efficiency as described by Surroca et al. (2016) and provides a stable, homogeneous and comparable estimate of the efficiency obtained by different management forms in the delivery of urban public transport. The study results indicate that inter-municipal cooperation is the most efficient form of long-term management.

Key words: Efficiency, Transport, Municipalities, Panel data, Meta-frontier

1. Introduction

Public transport is of fundamental importance to urban development and mobility. In many cases, the service is strictly regulated (Von Hirschhausen and Cullmann, 2010) because mobility planners must address diverse concerns, including environmental issues (Kerstens, 1996) and the implications for economic and social agents in different sectors (Albalate and Bel, 2010). Therefore, a major question for public managers is that of identifying the most suitable form of service provision. In view of these considerations, many researchers have focused on the problems of urban public transport, and cost efficiency is a fundamental component in their analyses (Odeck, 2008; Avenali et al., 2016).

The question of efficiency, and perceived deficiencies in this respect, has motivated the search for alternative forms of service delivery, often with the participation of private sector operators, which are traditionally associated with higher levels of

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efficiency than their public sector counterparts (Andrews and Entwistle, 2013). Such alternatives may take the form of privatisation or public-private collaboration.

In view of the various formulas that have been proposed for the provision of urban public transport, we believe it necessary to study which management forms would be most appropriate, especially as regards maximising cost efficiency.

To do so, however, a different research focus is needed, as most previous studies in this context have analysed the situation of private service providers (Pestana Barros and Peypoch, 2010), with particular emphasis on the characteristics of the service and the costs incurred by the company awarded the contract for its provision. Accordingly, several recently-published papers have sought to broaden this research scope, focusing not only on efficiency but also taking into account whether the service provider is publicly or privately owned (Karlaftis and Tsamboulas, 2012). Nevertheless, to our knowledge no studies have yet been undertaken to analyse these questions in terms of public sector interest (in the understanding that the public manager/agency is ultimately responsible for ensuring satisfactory provision of the service), to determine whether the service should be delegated to other operators, public or private, or continue to be centrally administered. In this context, it is essential to calculate the costs that a municipality would incur in assigning service delivery to another public or private entity. In this sense, el studio de este fenómeno en un país como España, con una cultura administrative fuertemente burocratizada y en el que existe una gran predominancia hacia la prestación de servicios de forma directa, al igual que el resto de países europeos con tradición weberiana (Lee Rhodes et al., 2012), como Alemania, Francia o Italia, va a ayudar a profundizar en la importancia que radica en la forma de gestionar el servicio de transporte público urbano, y a mejorar las bases sobre las que los gestores públicos toman las decisions relativas en esta materia.A further consideration motivating the present study is that very little empirical evidence has been reported concerning the cost efficiency of urban public transport services. Most previous studies in this respect have only used cross-sectional data, but in our opinion a long-term analysis is also needed.

In the present study, therefore, we examine the impact on costs to the local public administration of delegating the delivery of public urban transport to another operator. To do so, we analyse the cost efficiency of various forms of service management and delivery (direct, private, inter-municipal cooperation and joint management). For the first time in this sector, frontier analysis evaluation techniques are used to estimate the long-term efficiency of service management forms, highlighting those which are most efficient and thus enabling public managers to make an informed decision. This approach differs from that of most previous studies in this field, which have considered efficiency exclusively from the standpoint of the (private) company awarded the contract for service delivery. Our analysis is based on a sample of 193 Spanish municipalities, with respect to the period 2014-2016. An adaptation of the order-m data panel method is applied, together with the meta-frontier analysis proposed by Garrido-Rodríguez et al. (2018), which in turn is based on work by Battese et al. (2004), Cazals et al. (2002) and Surroca et al. (2016). This approach provides a stable, homogeneous and comparable estimate of the long-term efficiency achieved by different management forms for urban public transport.

The results obtained from this analysis show that for medium-sized municipalities (between 5,000 and 50,000 inhabitants), inter-municipal cooperation was the most efficient form of service management during the study period, while direct municipal

management was more appropriate for larger municipalities. In both cases, formulas involving a private-sector operator were associated with lower levels of cost efficiency. These findings represent an important contribution to the literature on the efficiency of urban public transport, highlighting the increased costs incurred when private or public-private companies participate in the management and delivery of this service.

The rest of this paper is structured as follows. In Section 2, we review certain issues related to the efficiency of public urban transport and the management forms that may be adopted. The following section describes the study method applied, after which the study data and variables are presented. In Section 5, we discuss the results obtained and, finally, the main conclusions drawn are summarised in Section 6.

2. Cost efficiency and alternative delivery forms for urban public transport: literature review

Planning urban public transport is no easy task, requiring managers to establish prices, routes and frequencies for the service, among other aspects, in order to foster mobility and also to overcome the difficulties inherent to the geographic characteristics of the area in question (Daraio et al., 2016). Moreover, planners must take into account other policy priorities, such as promoting tourism in the municipality (Albalate and Bel, 2010). When social welfare goals are foregrounded, the costs of providing effective public transport often exceed the revenues obtained. This financial inefficiency (Piacenza, 2006) can spur public managers to seek a more cost-efficient means of providing the service.

In view of these considerations, various studies have been undertaken to analyse the efficiency of urban public transport (Jørgensen et al., 1995; Iseki, 2008; de Grange et al., 2018), with technical efficiency coming under particular scrutiny. This term is used to describe the situation obtained when an optimal level of input is used to generate a certain level of output in the production of goods (Karlaftis and Tsamboulas, 2012) or in delivering a service, as in the present case.

Privatisation, i.e. the provision of public services by a private company that expects to gain economic profits thereby (López-Hernández et al., 2017), is traditionally expected to achieve higher levels of efficiency than under public forms of service delivery. Thus, various studies of urban transport have reported that privatisation tends to raise the cost efficiency of the service thus affected (Savage, 1993; White, 1997; Lee and Rivasplata, 2001). This conclusion is in line with the postulates of New Public Management (NPM), according to which privatisation is an effective means of achieving cost savings (Da Cruz and Marques, 2012).

The above conclusion is also supported by other theoretical approaches, such as public choice theory, property rights theory and agency theory (Pérez-López et al., 2015; Máñez et al., 2016). In the case of urban public transport, private providers commonly receive economic compensation from the public sector when the service costs exceed the revenues produced. However, this situation does not encourage the operating company to seek greater efficiency (or even to maintain current levels) (Piacenza, 2006).

In recent years, new forms of public service provision, other than direct management or privatisation have emerged, arousing great interest with respect to

efficiency. As Perez-López et al. (2015) pointed out, it is often the management form adopted that determines the efficiency obtained. Although many urban transport services have been privatised (Daraio et al., 2016), others are now being provided via mixed management contracts or through inter-municipal cooperation.

Mixed management, involving both the public and the private sectors, confers certain advantages, by combining the advantages of each. For example, the control exercised by public managers helps reduce the transaction costs that normally arise from the opportunistic behaviour of private providers (Da Cruz and Marques, 2012) and promotes a relationship of trust between the parties (Goldsmith and Eggers, 2005). On the other hand, private sector involvement normally spurs innovation and improvement within the activity (Warner and Hefetz, 2008). Therefore, this form of management offers the possibility of obtaining significant cost savings (Garrone et al., 2013).

Another approach, that of inter-municipal cooperation, has also attracted considerable interest in the academic literature on the efficiency of public services. This form of service delivery is usually adopted in the expectation that the union of two or more municipalities will increase the volume of service provided (Bel and Warner, 2015), producing economies of scale and hence improved service efficiency (Dijkgraaf and Gradus, 2013). Studies have highlighted the particular advantages of this form of management for small municipalities (Pérez-López et al., 2015), whose limited dimensions mean that, individually, they cannot privatise services such as urban public transport (Pérez-López et al., 2016).

Data and variables

For the purposes of this study, a database was constructed for the period 2014-2016, composed of 193 municipalities, of which 29.02% have fewer than 20,000 inhabitants, 26.94% have between 20,000 and 50,000 inhabitants, and 44.04% have more than 50,000 inhabitants. This sample represents 40.38% of the total Spanish population.

To analyse cost efficiency, service inputs and outputs must be identified (Cowie and Asenova, 1999). In view of the lack of consensus in the literature as to what information from the public sector and from private operators should be considered (Roy and Yvrande-Billon, 2007), in the present study we take the service input to be the effective cost, in the view that this parameter best measures the use made of resources to provide the service. To our knowledge, this is the first time, in this type of study, that the concept of effective cost has been used to represent the input to the service. The effective cost was calculated from information published by the Spanish Ministry of Finance, detailing the direct and indirect costs of municipal services, according to official criteria in this respect (approved by Ministerial Order HAP/2075/2014 of 6 November 2014 of the Ministry of Finance and Public Administration), to determine the cost of service provision through direct or shared management, allocating this cost in proportion to the level of service provided in each municipality. When the service is provided via indirect management, the effective cost assumed includes the economic considerations paid by the municipality to the contractor, or if these considerations are received directly from the consumer, the revenue derived is calculated at the rate established for the service plus any subsidy provided by the municipal authorities.

In relation to the outputs, various specifications have been proposed. In the present study, we focus on cost efficiency in service provision in order to select the most appropriate study variables, representing not only the provision of the service, but also the demand, in accordance with the recommendations of Cowie and Asenova (1999) and Bhattacharyya et al. (1995). In this respect, Daraio et al. (2016) [5] examined two main types of output: service supply and service consumption. According to these authors, when efficiency is analysed from the perspective of the service provider, if the latter does not have decision-making powers in planning the service, then the service consumption variables should not be taken into account. However, if the operator has some flexibility in this respect, then the outputs of both service supply and of demand-oriented measures should be included in the analysis. According to this reasoning, in analysing the cost efficiency achieved by the municipal authority, which has total control over the service planning, both types of service output should be considered. In this context, based on the contents of the effective cost database, and taking into account the findings obtained by a specific search of each municipal website, and in some cases by directly contacting the municipal official responsible for the service, we obtained information on the output variables 'number of passengers' and 'number of vehicles' per kilometre offered.

The descriptive statistics for these input and output variables for each year considered are included in Annex 1, while Table 1 classifies the different forms of transport service management proposed in this study.

Table 1. Management forms for the provision of urban public transport (n=193)

Management form		**Frequency**
Direct	Direct management by municipality, public commercial agency or local commercial company.	74
Indirect	Indirect management by concession. Awardees manage the service at their own risk, or according to contract.	78
Mixed	Indirect profits-oriented management, coordinated between the municipality and the private operator. Operating results are shared in the proportion contractually stipulated or through a mixed economy company.	22
Inter-municipal cooperation	Joint management – at regional, provincial or other geographic level, by inter-administrative accord or through a consortium.	19
Total		193

Source: Devised by the authors, from information provided by the Ministry of Finance and Public Administration.

3. Method

In this paper we extend the long-term efficiency estimate procedure developed by Surroca et al. (2016) to the concept of meta-frontier (Battese et al., 2004), using order-m partial frontiers (Cazals et al., 2002) to do so, as proposed by Garrido-Rodríguez et al. (2018). Así, mientras que los modelos de evaluación frontera no paramétricos tradicionales, como puede ser el DEA, presentan un comportamiento determinista, otorgando un comportamiento ineficiente a aquellas unidades que se alejen de la frontera (De Witte and Marques, 2010), this method allows us to take into account observations beyond the estimated efficiency frontier, gracias al uso de fronteras parciales no

[5] In fact, these authors classified outputs into three groups, with the addition of financial service revenue. However, given the nature of our analysis, it is not necessary to implement this type of measure.

paramétricas (Simar and Wilson, 2008). Moreover, la gran sensibilidad a la presencia de outliers que tienen estos modelos no paramétricos tradicionales (Daouia and Simar, 2007), han derivado en la búsqueda de nuevas técnicas que permitan superar dicha limitación, lográndose con la aplicación de datos de panel para la estimación de la eficiencia en el largo plazo to obtain more robust results, ya que los mismos son menos dependientes de los valores específicos de un año concreto siendo possible el calculo de time-variant efficiency coefficients, frente a los time-specific efficiency coefficients que se estiman con los modelos anteriores. Igualmente, con ello también se va a controlar la presencia de outliers and random perturbations that may appear at certain moments. From the combined effect of these three methodological developments, we obtain a stable and homogeneous estimate of efficiency with which to compare different delivery forms for urban public transport (Garrido-Rodríguez et al., 2018).

The method takes the following form. First, a frontier is estimated for each set of municipalities grouped by management form (local frontiers, $CE^{f,t}$). A global frontier is then obtained for all municipalities, irrespective of management form. This is termed the meta-frontier (CE^{t}) and incorporates all the local frontiers (Rao et al., 2003). Finally, the local frontiers and the meta-frontier are compared to determine the technology gap ratio ($TGR^{f,t}$) (Battese et al., 2004), which is defined, for a given level of output, as the lowest possible cost at the meta-frontier divided by the lowest total cost at the local frontier[6]:

$$TGR^{f,t} = \frac{CE^{t}}{CE^{f,t}}$$

The most appropriate management form for the provision of urban public transport can then be determined by a long-term analysis of $TGR^{f,t}$, in which for each case we calculate the distance from the local frontier to the meta-frontier.

The necessary analysis is then performed taking into account both the order-m frontiers of the panel data and the concept of the meta-frontier. Hence, five frontiers are determined: the order-m panel data meta-frontier (for all municipalities) and a local panel data frontier for each management form considered (S_1, S_2, S_3, S_4), thus producing a single coefficient of efficiency that reflects the long-term evolution of the performance achieved by each municipality, both for the meta-frontier (θ_S^m) and for each of the management forms considered in the study (θ_S^{m,S_1}, θ_S^{m,S_2}, θ_S^{m,S_3}, θ_S^{m,S_4}). In addition, a $TGR^{f,t}$ is obtained for each management form, from the following quotients: $\frac{\theta_S^m}{\theta_S^{m,S_1}}$, $\frac{\theta_S^m}{\theta_S^{m,S_2}}$, $\frac{\theta_S^m}{\theta_S^{m,S_3}}$, $\frac{\theta_S^m}{\theta_S^{m,S_4}}$. To do so, the frontiers are estimated in order-m panel data, as described below.

In contrast to traditional nonparametric techniques that compare each unit with the whole sample, order-m frontiers calculate the efficiency values of each unit by comparison with a sub-sample of *m* units, after resolving integer programming algorithms in which a non-convex technology is assumed. Therefore, taking into account the panel data structure proposed in this paper, the algorithm used to estimate the efficiency coefficients considers a fixed positive integer *m* such that, for a given average cost ($\tilde{c}^0$) and average output ($\tilde{y}^0$), the estimate considers *m* random production units with output variables ($Y_1, \dots, Ys, \dots, Y_m$), derived from the distribution of the output matrix *Y* that

[6] As our study aim is to analyse long-term efficiency, the technology gap ratio is defined taking the time dimension into account.

meets the condition $Y_s \geq \tilde{y}^0$. Therefore, the following steps must be taken to obtain the efficiency estimate by order-m frontiers using panel data[7]:

1. For a given level of $\tilde{y}^0$, a random sub-sample of size *m* with replacement is created with all the y_{sm} that satisfy the condition $y_{sm} \geq \tilde{y}^0$.

2. The coefficient of efficiency $\tilde{\theta}^m$ is estimated from this random sub-sample and from the resolution of non-convex algorithms of FDH programming with panel data[8].

3. The first two steps are then repeated *B* times, estimating a FDH coefficient of efficiency with panel data in each round, so that by the end of the process *B* efficiency coefficients $\tilde{\theta}^{m,b}$ (b = 1; 2; ...; B) have been obtained.

4. Finally, a central value (the arithmetic mean) of the *B* efficiency coefficients is calculated, as:

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

Due to the random replacement procedure applied, the order-m frontiers can produce efficiency coefficients that lie beyond the estimated frontier, and so as well as providing an indication of the cost, a mean value will be super-efficient when $\theta^m > 1$[9]. Moreover, $\tilde{\theta}^{m,b}$ depends on the value of *m*; therefore, the greater this value, the more observations are taken into account in the estimate provided, and the more units will meet the condition $y_{sm} \geq \tilde{y}^0$[10].

In order to derive the order-m estimate with panel data from the meta-frontier and local frontiers, the most appropriate *m*-value must be determined. According to Daraio and Simar (2007), *m* is the value by which the percentage of super-efficient units decreases marginally with an increase of *m*. At this point, the value of *m*, in estimating the local frontiers and the meta-frontier, is determined according to whether this *m* value is used for all the frontiers. If the same value is used whatever the size of the groups, then the more numerous groups will have a higher proportion of super-efficient units. Although the use of a variable value for *m* could overcome this problem, the estimations obtained would still not comparable because there would be no single baseline value with which to compare the different groups. Therefore, and following the recommendation of Pérez-López et al. (2016), we used the same value of *m* in estimating the frontiers, both

[7] The stages are defined according to the steps proposed by Daraio and Simar (2007).
[8] The extension of the development proposed by Surroca et al. (2016) to non-convex FDH frontiers is discussed by Garrido-Rodríguez et al. (2018).
[9] In contrast to order-m frontiers, the use of panel data order-m frontiers obtains fewer super-efficient values. Therefore, estimates obtained from panel data will be less volatile than contemporary partial frontiers.
[10] In consequence, when m → ∞ the efficiency coefficients obtained by panel data order-m frontiers will converge with the panel data FDH coefficients.

the local ones and the global frontier. This approach facilitates comparison of the results obtained, avoids problems of dimensionality and neutralises the influence of outliers[11].

4. Results

Table 2 shows the values obtained for global and local efficiency and the long-term technology gap ratio (TGR), for each management form[12]. These results are complemented with Table 3 and Annex 2, which present the corresponding density graphs.

Before analysing the efficiency of the management forms, the nonparametric Kruskal-Wallis test is performed to determine whether the data examined were derived from the same population. Intuitively, this test is identical to the ANOVA, but with the data replaced by categories. In another words, it is an extension of the Mann-Whitney U test for three or more groups, applied to the local frontiers of each management form. The test results highlight the existence of significant differences among the TGR values obtained (Table 2), which justifies performing separate analyses according to management form.

Table 2. Descriptive statistics: order-m data panel results for meta-frontier, local frontier and TGR, by management form

Management form	Mean	Median	Minimum	Maximum	Standard deviation
Direct (n =74) ***					
Meta-frontier	0.1663	0.0968	0.0009	1.1203	0.2140
Local frontier	0.1462	0.0892	0.0009	1	0.1813
TGR	1.1725	1.2321	0.4722	1.7418	0.2856
Indirect (n= 78) ***					
Meta-frontier	0.1003	0.0556	0.0008	0.6576	0.1289
Local frontier	0.5984	0.5334	0.0877	1.4237	0.3484
TGR	0.1788	0.1330	0.0008	0.5872	0.1463
Mixed (n= 22) ***					
Meta-frontier	0.0545	0.0373	0.0092	0.1802	0.0498
Local frontier	0.5859	0.5424	0.0609	1.0225	0.3628
TGR	0.1651	0.1621	0.0094	0.5982	0.1783
Cooperation (n= 19) ***					
Meta-frontier	0.1987	0.0757	0.0062	0.7217	0.2518
Local frontier	0.4218	0.1409	0.0115	1.0015	0.4385

[11] For this reason, and taking into account the structure of the panel data, a sensitivity analysis was carried out with values of *m* ranging from 50 to 75. Convergence in the results was observed for *m* = 70, and therefore all the estimates were obtained with this parameter.

[12] The calculation was performed using R software (R Development Core Team, 2011), with the FEAR package (Wilson, 2006).

TGR	1.3446	1.7759	0.0062	2.6096	0.9857

*** Differences were assumed to be significant at 1% according to the Kruskal-Wallis test for the TGR.

Li's test (Li, 1996) together with the subsequent development by Simar and Zelenyuk (2006), was used to determine whether there were significant differences between each pair of management forms, in order to identify the most appropriate one for the urban transport service. Traditionally, in order to test whether two distributions are significantly different or not, the value used is the t-value for related parametric samples, the Wilcoxon value for nonrelated nonparametric samples or the Mann-Whitney U value for related nonparametric samples. However, an interesting alternative to these tests (based on mean values) focuses, instead, on the notion of global distance, or closeness, between two densities f(x) and g(x), via their integrated square error (Pagan and Ullah, 1999). Under this approach, and following Balaguer-Coll et al. (2012), the existence or otherwise of significant differences is established by Li's test (1996), which measures the distance between two density functions according to the integrated square error of each one (Zafra-Gómez and Muñiz, 2010:621).

Table 3. Analysis of significant differences between the technology gap ratios of different management forms for the urban public transport service, 2014-2016

	Li's test		
Null hypothesis (H_0)	**10% signif.**	**5% signif.**	**1% signif.**
TGR (Direct) = TGR (Indirect)	H_0 rejected	H_0 rejected	H_0 rejected
TGR (Direct) = TGR (Mixed)	H_0 rejected	H_0 rejected	H_0 rejected
TGR (Direct) = TGR (Cooperation)	H_0 rejected	H_0 rejected	H_0 rejected
TGR (Indirect) = TGR (Mixed)	H_0 rejected	H_0 rejected	H_0 rejected
TGR (Indirect) = TGR (Cooperation)	H_0 rejected	H_0 rejected	H_0 rejected
TGR (Mixed) = TGR (Cooperation)	H_0 rejected	H_0 rejected	H_0 rejected

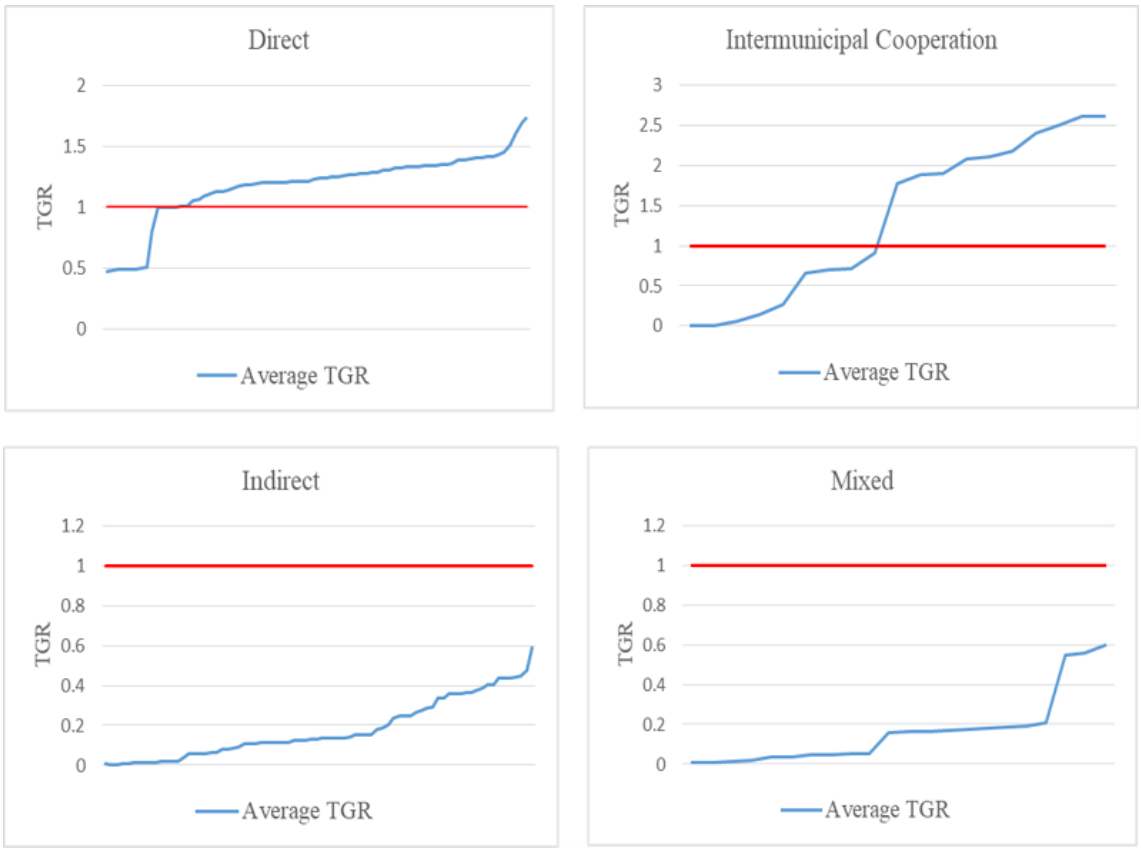
These results lead us to reject the null hypothesis of equality between each of the management form pairs considered. In other words, there are significant differences between the efficiencies of the different management forms and therefore robust conclusions can be drawn about how each form contributes to the level of efficiency in the provision of urban public transport.

The next step in our analysis is to consider the technology gap ratio (TGR), which measures the distance between long-term local cost efficiency ($CE^{f,t}$) and long-term global or meta-frontier cost efficiency (CE^{t}) for each municipality. The first of these parameters determines the position held by each municipality within a homogeneous group of service providers, while the global frontier represents the position held with respect to all municipalities. Hence, the TGR can be interpreted as the (in)efficiency derived from the form of management that is applied (Pérez-López et al., 2016). The greater the distance between the TGR and the value 1, the further apart the local and global frontiers, and hence the lower the level of efficiency obtained by this management form. Therefore, the most appropriate management form produces the highest TGR. It is important to note that the application of order-m frontiers may give rise to super-efficient

units (with an efficiency greater than one, as shown in Table 2), a consideration that also affects the calculation of the TGR (Pérez-López et al., 2016).

Figure 1 shows the TGR values obtained during the period, according to the management form adopted, highlighting the value at which the meta-frontier coincides with the local efficiency. It can be observed that, although direct and indirect management forms are the most commonly employed by these municipalities in providing urban public transport services, the pattern reflected in the local and global long-term frontiers is quite different; when the service is managed directly by the municipality, in most cases the long-term TGR is equal to or greater than one; however, with indirect management, for all municipalities there is a greater distance between the frontiers. A similar outcome is apparent with the management forms that are less commonly adopted, i.e. mixed management and inter-municipal cooperation. In these cases, the figures show that when the private sector participates in the provision of urban public transport, the long-term TGR is reduced.

Figure 1. Mean TGR during the study period, by management form



In relation to the average long-term local cost efficiency values ($CE^{f,t}$) obtained by each management form, the differences within each of the groups analysed are not very significant, except in the case of direct management (Table 2). Thus, the municipalities using indirect management (59.84%) or mixed management (58.59%) present a somewhat greater level of homogeneity than those which have adopted inter-municipal cooperation (42.18%). However, direct management has a $CE^{f,t}$ index of 14.2%, which indicates considerable inefficiency within this group. On the other hand, when the four management forms are compared at the meta-frontier, the average long-

term cost efficiency with direct management (CE^t) is greater than that obtained at the local frontier ($CE^{f,t}$), which suggests that although the average values achieved are the lowest within this group, direct management outperforms both indirect management and mixed management.

In order to establish which management form is technologically more efficient in the long term, we must examine the TGR obtained in each case (see Table 2). The lowest average TGR values are obtained with mixed management (0.165) and by indirect management (0.178), which suggests that management forms in which the private sector is involved are technologically less efficient.

Our analysis shows that public management obtains better average TGR values. In this respect, inter-municipal cooperation performed best, with a mean TGR of 1.344. Thus, although efficiency in this group was reduced, in comparison with the other management forms considered at the meta-frontier (CE^f), inter-municipal cooperation is technologically more efficient than the alternatives. In fact, in the majority of these municipalities (52.63%) the TGR is greater than one.

Direct management obtained the second best results in terms of average TGR (1.1725). Thus, in 83.78% of the municipalities where the urban transport service is managed directly by the municipality, the TGR is greater than one. However, these values are lower than those obtained where inter-municipal cooperation is employed (average TGR for superefficient units: 1.27 and 2.20 for direct management and inter-municipal cooperation, respectively) (see Figure 1).

According to these results, the municipalities that opt for inter-municipal cooperation in the provision of urban public transport tend to be more efficient than those which adopt other management forms (as reflected in the higher TGR obtained). This finding is in line with the conclusions drawn by Pérez-López et al. (2016) with respect to waste management services, or those obtained by Warner and Hefetz (2002) in their comparison between privatization and cooperation efficiency in the provision of public services. The municipalities that manage the service directly also obtain satisfactory results. On the other hand, when a private operator participates in service provision, the TGR values are usually worse, showing that these management forms are less technologically efficient, in contrast with the affirmations done by Filippini and Prioni (2003) in their study of the public transport service in Switherland, or those done by Karlaftis and Tsamboulas (2012) in their analysis of different european transit systems, confirming both of them the existence of better efficiency levels in privated or contracted transport services than in publicly provided ones.

However, as reported previously in studies of efficiency in the provision of public services (Pérez-López et al., 2016), the size of the municipality is significantly associated with the efficiency obtained by different forms of service management. Table 4 shows the average values obtained for long-term efficiency at the meta-frontier and at the local frontiers, and the TGR values by management form and by the size of the municipality. Table 5 shows the results obtained by Li's test for each pair of management forms according to municipal size. Analysis of these two tables reveals that inter-municipal cooperation obtains a higher TGR in medium-sized municipalities, although significant differences are only apparent for municipalities with between 5,000 and 20,000 inhabitants. In the larger municipalities (over 50,000 inhabitants), direct management is

the most cost-effective form, and the differences obtained in this respect are statistically significant. The latter results are of particular interest because in Spain the provision of urban public transport is mandatory for municipalities of this size (according to Local Government Act No. 7/1985, of 2 April). These findings are in line with those reported by Bel and Russell (2016), who studied interurban transport in Barcelona, using a stochastic cost frontier to analyse the cost savings obtained by four transport companies, distinguishing between those which were private or publicly-owned.

Table 4. Order-m data panel efficiency: mean values by municipal size and management form

Size 1				
Management form	**Direct (n=6)**	**Indirect (n=2)**	**Mix (n=1)**	**Coop (n=0)**
Meta-frontier	0.2385	0.0789	0.0622	--
Local frontier	0.1879	0.2900	0.3765	--
TGR	1.2866	0.2675	0.1651	--
Size 2				
Management form	**Direct (n=25)**	**Indirect (n=14)**	**Mix (n=1)**	**Coop (n=7)**
Meta-frontier	0.1853	0.1726	0.0367	0.1470
Local frontier	0.1646	0.6657	0.2105	0.0777
TGR	1.1515	0.2759	0.1742	2.1961
Size 3				
Management form	**Direct (n=21)**	**Indirect (n=26)**	**Mix (n=3)**	**Coop (n=3)**
Meta-frontier	0.1713	0.1620	0.0416	0.0779
Local frontier	0.1545	0.6983	0.4748	0.2311
TGR	1.1498	0.2233	0.1366	1.6157
Size 4				
Management form	**Direct (n=22)**	**Indirect (n=36)**	**Mix (n=17)**	**Coop (n=9)**
Meta-frontier	0.1206	0.0288	0.0573	0.2792
Local frontier	0.1060	0.5172	0.6400	0.7532
TGR	1.1872	0.1040	0.1696	0.5920

Size 1: <5000 inhabitants; Size 2: 5000 – 20000 inhabitants; Size 3: 20000 – 50000 inhabitants; Size 4: >50000 inhabitants

Table 5. Analysis of significant differences among technology gap ratios for different forms of urban transport management, by municipal size, 2014-2016

Li's test				
Null hypothesis (H_0)	**Size 1**	**Size 2**	**Size 3**	**Size 4**
TGR (Direct) = TGR (Indirect)	H_0 not rejected	H_0 rejected at 1%	H_0 rejected at 1%	H_0 rejected at 1%
TGR (Direct) = TGR (Mixed)	--	--	H_0 rejected at 10%	H_0 rejected at 1%
TGR (Direct) = TGR (Cooperation)	--	H_0 rejected at 1%	H_0 not rejected	H_0 rejected at 1%
TGR (Indirect) = TGR (Mixed)	--	--	H_0 not rejected	H_0 rejected at 1%

TGR (Indirect) = TGR (Cooperation)	--	H_0 rejected at 1%	H_0 not rejected	H_0 rejected at 10%
TGR (Mixed) = TGR (Cooperation)	--	--	H_0 not rejected	H_0 rejected at 10%

Size 1: <5000 inhabitants; Size 2: 5000 – 20000 inhabitants; Size 3: 20000 – 50000 inhabitants; Size 4: >50000 inhabitants

Conclusions and areas for future research

In recent years, various studies have been undertaken to determine which forms of management are most cost efficient in the provision of local public services. With respect to urban public transport, researchers have examined whether the ownership status of the operator (i.e. public or private) affects this efficiency. However, the approach used in most of these previous investigations has been from the perspective of the company awarded the service. Moreover, the empirical evidence reported has been obtained from cross-sectional studies, and a longer-term analysis is lacking. Finally, new forms of management have appeared, and their cost efficiency must also be determined and compared. The present study addresses these three research goals.

Specifically, we analyse the cost efficiency of urban public transport in 193 Spanish towns and cities, from the perspective of the municipalities involved, analysing the cost data for different forms of management, i.e. the effective cost of public services provided, using a panel data structure for the period 2014-2016. The particular contribution made in this study is its evaluation of four contrasting management forms: direct, indirect, mixed and inter-municipal cooperation. An essential element of our analysis is the use of an order-m approximation with panel data in order to estimate the corresponding meta-frontiers and thus determine which form of management is more efficient. This method provides robust and homogeneous data, facilitating long-term comparisons.

From the results obtained, we conclude that the public management formulas such as inter-municipal cooperation and direct provision obtain greater cost efficiency (TGR) for public urban transport services than those in which private operators are involved. Specifically, the most cost-efficient management form is that of inter-municipal cooperation. The causes of this efficiency are not evaluated in the present study, but the benefits derived from inter-municipal cooperation may be due to the presence of economies of scale. However, on examining the cost efficiency obtained by each management form for different sized municipalities, we find that inter-municipal cooperation is most appropriate for those of intermediate size, while direct management is preferable when the local population exceeds 50,000 inhabitants. When private companies participate in service provision, via formulas such as mixed or indirect management, the cost efficiency is reduced.

These results provide valuable evidence for public managers seeking to identify efficient management formulas for the provision of urban public transport. We show that the change to inter-municipal cooperation provides greatest cost savings for this service. Moreover, this result need not be evaluated in the specific context of the service considered; previous studies have shown that this management form is the most cost-efficient alternative for various public services, such as waste collection, especially when the municipality is relatively small, with fewer than 50,000 inhabitants. Our findings show that direct public management obtains higher levels of cost efficiency for urban

public transport in larger municipalities, thus rebutting the NPM paradigm according to which private forms of service provision are more efficient than public ones.

However, some caveats should be noted. Further study is needed to determine whether factors such as scale efficiency, the characteristics of the socioeconomic environment or inter-government financial transfers might influence the levels of efficiency achieved by each of the management forms considered, and if so, in which direction and to what extent.

Bibliography

Albalate, D. & Bel, G. (2010). What shapes local public transportation in Europe? Economics, mobility, institutions and geography. *Transportation Research Part E: Logistics and Transportation Review*, 46(5), 775-790.

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

Avenali, A., Boitani, A., Catalano, G., D'Alfonso, T. & Matteucci, G. (2016). Assessing standard costs in local public bus transport: Evidence from Italy. *Transport Policy*, 52 (November), 164-174.

Balaguer-Coll, M.T., Prior, D. & Tortosa-Ausina, E. (2012). Output complexity, environmental conditions, and the efficiency of municipalities. *Journal of Productivity Analysis*, 39(3), 303-324.

Battese, G. E., Rao, D. P. & O'Donnell, C. J. (2004). A metafrontier production function for estimation of technical efficiencies and technology gaps for firms operating under different technologies. *Journal of Productivity Analysis*, 21(1), 91-103.

Bel, G. & Rosell, J. (2016). Public and private production in a mixed delivery system: regulation, competition and costs. *Journal of Policy Analysis and Management*, 35(3), 533-558.

Bel, G. & Warner, M. E. (2015). Inter-municipal cooperation and costs: Expectations and evidence. *Public Administration*, 93(1), 52-67.

Bhattacharyya A., Kumbhakar, S. C. & Bhattacharyya, A. (1995). Ownership structure and cost efficiency: A study of publicly owned passenger-bus transportation companies in India. *Journal of Productivity Analysis*, *6*(1), 47-61.

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

Cherchye, L., Demuynck, T., De Rock, B. & De Witte, K. 2014. Nonparametric analysis of multi-output production with joint inputs. *The Economic Journal*, 124(577): 735-775.

Cowie, J. & Asenova, D. (1999). Organisation form, scale effects and efficiency in the British bus industry. *Transportation*, 26(3), 231-248. Doi: 10.1023/A:1005121506841.

Da Cruz, N. F. & Marques, R. C. (2012). Mixed companies and local governance: no man can serve two masters. *Public Administration*, 90(3), 737-758.

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

Daraio, C., Diana, M., Di Costa, F., Leporelli, C., Matteucci, G. & Nastasi, A. (2016). Efficiency and effectiveness in the urban public transport sector: A critical review with directions for future research. *European Journal of Operational Research*, 248(1), 1-20.

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

De Grange, L., Troncoso, R. & Briones, I. (2018). Cost, production and efficiency in local bus industry: An empirical analysis for the bus system of Santiago. *Transportation Research Part A: Policy and Practice*, 108 (February), 1-11.

De Witte, K. & Geys, B. (2013). Citizen coproduction and efficient public good provision: Theory and evidence from local public libraries. *European Journal of Operational Research*, 224(3), 592-602.

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

Dijkgraaf, E. & Gradus, R. H. (2013). Cost advantage cooperations larger than private waste collectors. *Applied Economics Letters*, 20(7), 702-705.

Filippini, M., & Prioni, P. (2003). The influence of ownership on the cost of bus service provision in Switzerland-an empirical illustration. *Applied Economics*, 35(6), 683-690.

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

Garrone, P., Grilli, L. & Rousseau, X. (2013). Management discretion and political interference in municipal enterprises. Evidence from Italian utilities. *Local government studies*, 39(4), 514-540.

Goldsmith, S. & Eggers, W. D. (2005). *Governing by network: The new shape of the public sector*. Brookings Institution Press.

Iseki, H. (2008). Economies of scale in bus transit service in the USA: How does cost efficiency vary by agency size and level of contracting? *Transportation Research Part A: Policy and Practice*, 42(8), 1086-1097.

Jørgensen, F., Pedersen, P. A. & Solvoll, G. (1995). The costs of bus operations in Norway. *Journal of Transport Economics and Policy*, 29(3), 253-262.

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

Kerstens, K. (1996). Technical efficiency measurement and explanation of French urban transit companies. *Transportation Research- Part A*, 30(6), 431-452.

Lee, R. W. & Rivasplata, C. R. (2001). Metropolitan transportation planning in the 1990s: comparisons and contrasts in New Zealand, Chile and California. *Transport Policy*, 8(1), 47-61.

Lee Rhodes, M., Biondi, L., Gomes, R., Melo, A. I., Ohemeng, F., Perez-Lopez, G., ... & Sutiyono, W. (2012). Current state of public sector performance management in seven selected countries. *International Journal of Productivity and Performance Management*, 61(3), 235-271.

Li, Q. (1996). Nonparametric testing of closeness between two unknown distribution functions. *Econometric Reviews*, 15(3), 261-274.

López-Hernández, A. M., Zafra-Gómez, J. L., Plata-Díaz, A. M. & de la Higuera-Molina, E. J. (2017). Modelling fiscal stress and contracting out in local government: The influence of time, financial condition, and the great recession. *The American Review of Public Administration*, 48(6), 565-583. Doi: 0275074017699276.

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

Odeck, J. (2008). The effect of mergers on efficiency and productivity of public transport services. *Transportation Research Part A: Policy and Practice*, 42(4), 696-708.

Pagan, A. & Ullah, A. (1999). *Nonparametric econometrics*. Cambridge University Press.

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

Pérez-López, G., Prior, D., Zafra-Gómez, J. L. & Plata-Díaz, A. M. (2016). Cost efficiency in municipal solid waste service delivery. Alternative management forms in relation to local population size. *European Journal of Operational Research*, 255(2), 583-592.

Pestana Barros, C. & Peypoch, N. (2010). Productivity changes in Portuguese bus companies. *Transport Policy*, 17(5), 295–302.

Piacenza, M. (2006). Regulatory contracts and cost efficiency: Stochastic frontier evidence from the Italian local public transport. *Journal of Productivity Analysis*, 25(3), 257-277.

R Development Core Team. (2011). *R:* A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria: School of Economics, University of Queensland, http://www.R-project.org/.

Rao, D. S. P., O'Donell, C. J. & Battese, G. E. 2003. Metafrontier functions for the study of inter-regional productivity differences, CEPA Working Paper No. 01/2003, Australia: School of Economics, University of Queensland.

Roy, W. & Yvrande-Billon, A. (2007). Ownership, contractual practices and technical efficiency: The case of urban public transport in France. *Journal of Transport Economics and Policy*, 41(2), 257-282.

Savage, I. (1993). Deregulation and privatization of Britain's local bus industry. *Journal of Regulatory Economics*, 5(2), 143-158.

Simar, L. & Wilson, P. (2008). Statistical inference in nonparametric frontier models: recent developments and perspectives. In: *The Measurement of Productive Efficiency and Productivity Change* (Fried, H., Lovell, K. & Schmidt, S., eds). Oxford University Press, New York, pp. 421-522.

Simar, L. & Zelenyuk, V. (2006). On testing equality of distributions of technical efficiency scores. *Econometric Reviews*, 25(4), 497-522.

Surroca, J., Prior, D. & Tribo Gine, J. A. (2016). Using panel data dea to measure CEOs' focus of attention: An application to the study of cognitive group membership and performance. *Strategic Management Journal*, 37(2), 370-388.

Von Hirschhausen, C. & Cullmann, A. (2010). A nonparametric efficiency analysis of German public transport companies. *Transportation Research Part E: Logistics and Transportation Review*, 46(3), 436-445.

Warner, M., & Hefetz, A. (2002). Applying market solutions to public services: An assessment of efficiency, equity, and voice. *Urban Affairs Review*, 38(1), 70-89.

Warner, M. E. & Hefetz, A. (2008). Managing markets for public service: the role of mixed public–private delivery of city services. *Public administration review*, 68(1), 155-166.

White, P. R. (1997). What conclusions can be drawn about bus deregulation in Britain? *Transport Reviews*, 17(1), 1-16.

Wilson, P. (2006). *FEAR: Frontier efficiency analysis with R*. US: University of Clemson.

Zafra-Gómez, J. L. & Pérez Muñiz, M. A. (2010). Overcoming cost-inefficiencies within small municipalities: improve financial condition or reduce the quality of public services? *Environment and Planning C: Government and Policy*, 28(4), 609-629.

Annex 1. Descriptive statistics for input and output variables, 2014-2016

Year	Variable	N	Mean	Median	Minimum	Maximum
2014	**Effective cost**	193	7104169	309660.5	1556.55	487000000
	No. of passengers	193	6061266	129186	270	402000000
	Vehicles * kms offered	193	49196.02	188	6.52	6869434
2015	**Effective cost**	193	6888614	299610.7	5688.6	484000000
	No. of passengers	193	6028353	134096	400	406000000
	Vehicles * kms offered	193	49966.44	188	6.52	6893642
2016	**Effective cost**	193	7049347	245436.6	4307.4	494000000
	No. of passengers	193	6355917	148752	380	430000000
	Vehicles * kms offered	193	50003.05	188	6.52	6893642

Annex 2. TGR density, by management form