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Germà Bel

Georgia State University | ANDREW YOUNG SCHOOL OF POLICY STUDIES

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Local Government Size and Efficiency in Capital Intensive Services: What Evidence is There of Economies of Scale, Density and Scope?

Germà Bel [1]
Universitat de Barcelona & GiM-IREA
gbel@ub.edu

Abstract: This paper aims to contribute to an understanding of the cost conditions that influence the patterns of production and governance of local public services. The central issue is that some of these services are characterized by economies of scale, density and scope, which means that the jurisdictions of local governments are, in some cases, smaller than the optimal scale of production. This study focuses on capital intensive local services, and reviews available empirical evidence for metropolitan transit services, airports, water supply and solid waste collection.

1   Introduction

The analysis of the optimal size of the municipality as an appropriate unit for the provision of services has formed an essential part of the economic literature since the appearance of seminal studies by Oates (1972), Mirrlees (1972) and Dixit (1973). Key studies have subsequently shown that phenomena such as the size and spatial dispersion of the population determine the formation of economies of scale and those of density at the local level (e.g. Deller, 1992; Ladd, 1992; Carruthers and Ulfarsson, 2003; Hortas-Rico and Solé-Ollé, 2010).

The existence of economies of scale characterizes many publicly provided goods. However, when these goods are provided by the local government, the problem of the sub-optimal size of this jurisdiction for their provision might arise. Thus, the first question to address, and one of an eminently functional nature, is the optimal geographic scale for this service: does the municipality coincide with what might be determined as the optimal scale of production. In answering this, certain elements acquire particular importance, most significantly the size of the population. However, the question as to the optimal size of the jurisdiction might also arise in the absence of economies of scale, but where the service is characterized by economies of density. This frequently occurs in services typified by their essential network features. In this case, the crucial elements are related to the distribution of the population throughout the territory and the geographic contiguity of urban areas, which determine the connectivity of networks and the formation of economies of density.

Problems of the optimal jurisdiction size arising from the existence of economies of scale and density constitute major challenges for economic analysis and public policy. On the one hand, the examination of formulas which allow economies of scale and/or economies of density to take advantage of the network externalities are required so that services can be performed more efficiently and effectively. On the other hand, the use of aggregation or coordination formulas in the production of the services can introduce problems of governance derived from transaction costs and the dissociation between representation and control that occurs in the government organs at the derived level.

This paper focuses its attention, therefore, on the relationship between economies of scale (Baumol, Panzar and Willig, 1988), economies of density (Baldwin and Caves, 1999; Shy, 2001), economies of scope (Caves, Christensen and Tretheway, 1980, 1984) and organizational forms of service provision and production. And in the section that follows

certain theoretical and conceptual aspects are discussed concerning economies of scale, density and scope.

After establishing our theoretical framework, we review existing empirical evidence on such core issues as the existence of economies of scale, density and scope. This review confines itself to an examination of capital intensive local services. Thus, within the realm of passenger services we focus on urban and metropolitan transport, as well as airports, as they are the main local facilities used to provide long distance transportation services. We also examine other local services with significant network features, including water supply, and those with a transport dimension, as is the case of solid waste management services. This focus has two main advantages: (a) they represent the local services with the greatest economic impact and (b) empirical data on solid waste and water services are the most widely available at the local level (Bel 2006a; Bel and Warner 2008; Bel, Fageda and Warner, 2010). Finally, we present our main conclusions drawn from the preceding analysis.

2 Returns to scale: theoretical and conceptual framework

The existence of significant fixed costs is a characteristic of the delivery of certain services at the local scale. As these fixed costs are incurred independent of the scale of production, having been committed to the service (albeit for a variable period of time) they cannot be recovered. In a number of specific sectors, characterized above all for their exploitation of physical networks, very high sunk costs exist given that the investment requirements for creating such networks can be enormous. As these sunk costs are independent of the subsequent level of use afforded the infrastructure, they become fixed costs,[2] and as a result the networks have significant economies of scale. The key idea here is that most of these initial fixed costs are sunk: they are irrecoverable once the investment has been made, and these facilities have no economic value for alternative uses, or no more than a residual value.

When fixed costs are sufficiently high they generate a structure of natural monopoly. In an industry with such a cost structure, a single firm can produce all its units of service at a lower cost than those that would be incurred by two or more companies.

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[2] A clear distinction should be drawn between fixed and sunk costs. While the former are independent of the scale of production for a short period of time, the latter are investments that have a useful life, generating a stream of revenue to a distant and indefinite horizon, but which cannot be recovered in the event of the termination of activity. Thus, the difference between the two is one of degree rather than of their intrinsic characteristics. Tirole (1990) provides an in-depth analysis of the differences between fixed and sunk costs.

The cost savings achieved by the monopoly may have different origins. There are *economies of scale* when the average cost decreases as production increases. When the average cost reduction is due to the fixed cost being spread across a larger number of consumers or users there exist *economies of density*. On the other hand, when the average cost decreases as the number of services produced by the same infrastructure increases, or as a result of the integration of several successive phases in the production process, *economies of scope* exist.

2.1. Economies of scale

Economies of scale are present when, in seeking to increase the production of a given service, production costs do not have to be increased in the same proportion. Thus, average production costs fall as the scale of output increases; in other words, we have a situation of increasing returns to scale (in which factor prices are independent of scale). In the presence of economies of scale, the number of companies operating in a market should be reduced. In the extreme case where economies of scale are so great that a natural monopoly exists, what is needed is a single company to provide the entire service to ensure efficiency.[3] Following the formula of Baumol, Panzar and Willig (1988: 50), economies of scale can be expressed as follows:

$$S = \frac{C(q)}{q \, \frac{\partial C}{\partial q}}$$

where *C* is cost, *q* is output, and *S* is returns to scale. Thus, economies of scale exist as long as S>1. Our interest in demonstrating their existence is to determine whether or not an activity constitutes a natural monopoly. If this is the case, the presence of multiple producers might damage productive efficiency: Thus, it may be appropriate to prohibit the entry of new operators or encourage the merger of two or more production units, as the existence of decreasing average costs would justify the existence of a regulated monopoly.

Economies of scale can originate from either within or outside the firm. Internal economies of scale reflect an increase in organizational efficiency; external economies of scale occur in an expanding sector when all companies in the sector benefit from cost improvements. For example, discounts can be obtained on the purchase of inputs when

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[3] In most cases, economies of scale are not inexhaustible. As production increases, a company might incur costs that grow proportionally more than the product itself. In this case, the firm has exceeded its efficient level of production and its average costs increase. In this scenario, the average cost curve is U-shaped.

suppliers of intermediate goods know they can sell large volumes of production. Efficiency can also be improved when the increase in production allows more specialized inputs, be they labor or physical capital, to be used. Increases in the scale of production mean the company gains access to better organizational techniques. Finally, there is scope for reducing costs by taking advantage of the experience acquired in the expansion process.

2.2 Economies of density

A critical feature in industries characterized by a strong physical network is that the cost per user decreases with increasing population density. By analogy with the formula used above, economies of density can be expressed as follows:

$$S = \frac{C(n)}{n \dfrac{\partial C}{\partial n}}$$

Where C is cost, n the number of users (expressed in terms of spatial concentration), and S is returns to scale. Hence, economies of density exist when $S>1$.

Economies of density have been used to justify the existence of monopolies in network services as a form of public intervention to achieve production efficiency and to protect universal access to services. In line with this argument, when a monopoly derives its income in the most densely populated areas (usually urban zones or those within a metropolitan area) cross-subsidies can be used to fund the service in less populated areas (usually rural areas or the peripheral zones of metropolitan districts). This reasoning is very much alive in sectors such as electricity, transportation and water supply in many countries, which has meant that, even in the context of liberalization of these sectors, operators exploit the monopoly service in specific areas

2.3 Economies of scope

Economies of scope are present when cost savings are made by producing two or more goods or services simultaneously. This situation arises when joint production allows the use of production factors to be optimized. Consequently, the production costs of a single service are greater than when it is produced in conjunction with other services. The multi-vendor nature of governments is a clear example of this concept. Grosskopf and Yaisawarng (1990) analyze municipalities as multi-product companies, and find that they are characterized by the existence of economies of scope.

The existence of economies of scope can be analyzed as follows. Suppose that a production unit delivers the solid waste collection service comprising disposal - *d* - as well as selective - *s* - (for recycling). The costs for each of these services are C_d and C_s, and their respective output is q_d and q_s. These services require fixed costs F_d and F_s, and involve variable costs that depend on production volume and αq_d and βq_s. The services can be produced separately or jointly. If they are produced separately, the respective cost is:

Cost of disposal collection: $C_d(q_d) = F_d + \alpha_d q_d$

Cost of selective collection: $C_s(q_s) = F_s + \beta_s q_s$

In the case of joint production, the variable cost is determined by γ, and is expressed as follows:

Cost of joint production: $C_{ds}(q_d, q_s) = F_{ds} + \gamma_d q_d + \gamma_s q_s + \gamma_{ds} q_d q_s$

The cost savings (or increases) achieved by means of joint production can be expressed as follows:

Scope economies: $C_d(q_d) + C_s(q_s) - C_{ds}(q_{ds}) = (F_d + F_s - F_{ds}) + (\gamma_d - \alpha_d) q_d + (\gamma_s - \beta_s) q_s - \gamma_{ds} q_d q_s$

If there exist positive scope economies – i.e., if $C_d(q_d) + C_s(q_s) > C_{ds}(q_{ds})$, then the production unit (or level of government) must jointly produce the services.

3   Economies of scale, density and scope: empirical evidence for capital intensive local services.

The existence of economies of scale seems almost to be taken for granted in many studies (Byrnes and Dollery, 2002), and the assumption is often implicit in major reforms proposed for the reorganization of local services (Boyne 1995). Do economies of scale in local services matter? Based on a review of available evidence for a variety of local services, Martín-Vazquez and Gómez Reino (2009) conclude that, in reality, economies of scale in the production of local services may not be relevant in many cases, a fact that contrasts with the almost universal acceptance of the existence of significant economies of scale at the local level.

Certainly, the heterogeneity of the cost structures of local services makes it more convenient to adopt the perspective of the service rather than that of the country in

reviewing the existence of increasing returns. Here, we review recent empirical evidence for three types of local service,[4] characterized by the weight of the transport activity involved, which is usually associated with the existence of substantial fixed costs, sometimes sunk, and major network characteristics. These services are (a) urban/ metropolitan transport services, (b) airports, (c) urban water supply, and (d) solid waste management. Finally, we present our conclusions drawn from the available empirical evidence.

3.1 Urban/metropolitan transportation services

There is a strong tradition of empirical studies examining the existence of economies of scale, as well as those of density, in the field of urban bus transport.[5] Studies conducted since the early 1980s have raised questions about this issue; among these the seminal work of Viton (1981) introduced the translog cost function, which has become usual in this field of study. Results from this preliminary literature suggest the existence of economies of density, but are more ambiguous about scale economies.[6] Since the late 1990s, a number of studies have appeared using more robust techniques and more complex databases, and it is these that we focus on below.

Matas and Raymond (1998) study the technical characteristics and efficiency of Spain's city bus companies. Nine companies operating between 1983 and 1995 in the country's main cities make up their sample. Their results suggest the existence of significant increasing returns to density, in line with the previous literature on economies of density. Matas and Raymond (1998) find constant economies of scale on average, but with decreasing returns to scale for the largest companies in the sample. When dividing the sample according to company size, they find a U-shaped curve for average costs, which fall as the size of the smallest companies increase, but which rise for the largest companies. They conclude that in the long term the results do not differ from constant returns to scale.

In their study conducted in Switzerland, Filippini and Prioni (2003) work with a sample of 34 companies for the period 1991-1995. Their empirical analysis shows the existence of significant positive economies of density, while their results indicate a situation

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[4] The aim of this review is not to provide an exhaustive description of available empirical evidence, but rather to highlight its basic features and to report the results of the most robust and recent studies in each field.

[5] Although not as extensive, there is also empirical evidence for regional bus services, contained mainly in Cambini and Filippini (2003).

[6] Shaw-Er, Chiang and Chen (2005) briefly review this preliminary literature. This paper studies a case of the second metropolitan area of Taiwan, Kaohsiung. Their results show significant positive economies of density.

close to constant returns to scale. Farsi, Fetz and Filippini (2007) analyze the existence of economies of scale and scope for a sample of 16 companies of multimodal transportation (trams, trolley- and motor-buses) also in Switzerland between 1985 and 1997. Their results indicate the existence of increasing returns to scale for most of the companies, which are of small size. Moreover, they find evidence of significant economies of scope. In general, their results show the existence of characteristics of a natural monopoly, which would recommend avoiding the fragmentation of supply, especially in the case of multiproduct firms. Table 1 displays the main characteristics of these works.

Table 1. Characteristics and results of empirical works for urban transportation services

Work	Country	Functional form	Results on returns
Viton (1981)	United Kingdom	Translog	Increasing returns to density
Matas & Raymond (1998)	Spain	Translog	Increasing returns to density. Constant returns to scales, with decreasing returns for larger companies.
Filippini & Prioni (2003)	Switzerland	Translog	Increasing returns to density. Constant returns to scales
Farsi, Fetz & Filippini (2007)	Switzerland	Quadratic	Increasing returns to scale. Important scope economies.
Work of reference			
Matas & Raymond (1998)	Translog	**Explained variable**: Operational costs.	
		Explanatory variables: Price of labor, output km., network km.	

Note: - For the technical characteristics of the Translogarithmic function, see the seminal work by Christensen, Jorgenson y Lau (1973).
- For the technical characteristics of the Translogarithmic function, see the seminal works by Caves, Christensen y Tretheway (1980, 1984).
Source: Author

3.2 Airports[7]

The existing body of literature on the econometric estimation of airports' cost functions is not very large, probably as a consequence of difficulties in collecting comparable data across different-sized airports.

The pioneering paper by Keeler (1970) applied Ordinary Least Squares to estimate two Cobb-Douglas partial cost functions over pooled data from 13 US airports between 1965 and 1966, with air transport movements (ATMs) as the output variable. The study found constant returns to scale (CRS) in airport operations. Using a similar Cobb-Douglas specification, yet over a cross-section of 18 UK airports for 1968, Doganis and Thompson (1974) found increasing returns to scale (IRS) up to 3 million work-load units (WLU; a work-load unit represents a passenger or 100 kg of cargo). More recently, Main et al. (2003)

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[7] This subsection is heavily based on the review in Martín and Voles-Dortas (2011a).

constructed four Cobb-Douglas models, shifting between WLUs or passengers as the output measure. They found economies of scale up to 5 million WLUs or 4 million passengers, using a data set of 27 UK airports for 1988 and a pool of 44 airports worldwide between 1998-2000. All these studies, however, suffer from the severe technological constraints imposed by the Cobb-Douglas specification.

Tolofari et al. (1990) was the first to specify a translog cost function. They used pooled data for seven UK Airports between 1979-87 to construct a short-run total cost model, featuring WLUs as the only output, capital stock, plus the input prices of labor, equipment, and residual factors (among other variables). They found IRS up to 20.3 million WLUs. A significant jump from Doganis' minimum efficient scale, yet hardly a robust result because only one airport in their sample (London Heathrow) operated more than 20 million WLUs. Similar translog studies, such as Jeong (2005), provide results more in line with the previous literature, finding IRS up to 2.5 million passengers or 3 million WLUs, the latter backed by a relatively large database of 94 US airports for the year 2003.

Up to this point, all studies had been based in single-output characterizations of airport technology. Only recently, Martín et al. (2011) provides a first approximation to a multiproduct airport cost function (including ATMs, WLUs, and non-aviation revenues) and explicitly showing that single-output specifications lead to biased cost elasticities and underestimated returns to scale. In a large departure from previous studies, they found unexhausted multi-output IRS in a pool of 37 Spanish airports between 1991 and 1997. Note that the largest sample airport was Madrid-Barajas serving slightly over 23 million passengers. Even though this result can be criticized for the same reason as Tolofari's, the introduction of commercial revenues in the output vector was shown to expand the range within airports enjoy IRS.

Taking into account that returns to scale are derived from a formal representation of technology that characterizes optimal firm behavior, there is also need to consider the possibility of sample airports not behaving optimally. Airports can be inefficient for a number of reasons, including their position as natural monopolies, and this inefficiency is bound to bias the estimation results if not modeled appropriately. In that regard, the next methodological improvement was the introduction of Stochastic Frontier Analysis (Aigner et al., 1977) in the study of airport technology. The first SFA airport study was Pels et al. (2003). They used data from 34 European airports between 1995 and 1997 to estimate two

stochastic production frontiers for ATMs and passengers, using the first model's predictions as an intermediate input for the second. They found that most airports displayed CRS in ATMs but exhibited IRS in passenger processing that become exhausted at the largest airports.

It was not until the recent contribution of Martín and Voltes-Dorta (2011a) that the SFA method was mixed with a multi-output long-run cost function specification and a large airport database (partially to mitigate the impact of multicollinearity in the output vector). This cost frontier features five outputs; ATMs, domestic and international passengers, cargo, and commercial revenues. The model was estimated over an unbalanced sample of 161 airports worldwide between 1991 and 2008. As in the case above, unexhausted IRS were found at all production levels, up to 88 million annual passengers at Atlanta. Using the same cost frontier parameters, Martín and Voltes-Dorta (2011b) explores returns to scale beyond observed traffic levels and concludes that the industry's minimum efficient scale should be located beyond the 120 million passenger benchmark that many airports around the world are using as capacity targets in their expansion programs (Dubai, Atlanta, Chicago, etc…). In addition, the presence of non-neutral scale-biased technical change in the specification suggests that the location of the industry's minimum efficient scale, yet still unknown, can be expected to increase further in the near future.

It is worth noting that this result finally seems to agree with airport expansion trends observed during the last decades, as airports have grown far beyond the scales predicted by earlier studies. On the other hand, also note that most estimates provided in this chapter refer only to common operating costs (i.e. capital, materials, and labor) and do not take into account the costs of airport externalities (e.g. noise, pollution, congestion, etc…). The impact of these undesirable outputs on scale economies in the airport industry can be expected to be negative.

Table 2 summarizes all relevant studies on this particular subject during the last four decades and their conclusions regarding returns to scale in the airport industry. Note the progressive shift in the location of the industry`s minimum efficient scale. This can be linked to technological development, but also to the use of larger and broader airport databases, and the improved estimation methodologies.

Table 2 Characteristics and results of empirical works for airports

Work	Country	Functional form	Results on returns
Keeler (1970)	United States	Cobb-Douglas	No increasing returns to scale exist in ATMs
Doganis & Thompson (1974)	United Kingdom	Cobb-Douglas	Increasing returns to scale between 1-3 million WLUs
Tolofari et al. (1990)	United Kingdom	Translog	Increasing returns to scale up to 20.3 million WLUs
Main et al. (2003)	United Kingdom World	Cobb-Douglas	Increasing returns to scale up to 4 million passengers or 3 million WLUs
Pels et al. (2003)	European Union	Translog SFA (Production frontier)	Constant returns to scale in ATM, Increasing returns to scale in passenger processing
Jeong (2005)	United States	Translog	Increasing returns to scale up to 2.5 million passengers or 3 million WLUs
Martín et al. (2011)	Spain	Translog SFA	Unexhausted Increasing returns to scale (23 million passengers)
Martín & Voltes-Dorta (2011a)	World	Translog SFA (Cost frontier)	Unexhausted Increasing returns to scale (88 million passengers)
Martín & Voltes-Dorta (2011b)	World	Translog SFA (Cost frontier)	Unexhausted Increasing returns to scale (120 million passengers)
Work of reference			
Martín & Voltes-Dorta (2011b)	Translog SFA (Cost frontier)		**Explained variable**s: Domestic and International passengers, ATMs, cargo and commercial revenues **Explanatory variables:** Input prices (capital, materials, personnel).

Source: Based on Martín and Voltes-Dorta (2011a,b)

3.3 Urban water distribution services

Research examining the presence of economies of density and of scope in urban water supply services has a long tradition and has been extensive.[8] As such, studies are available for many countries, among which particular note should be made of those conducted in the U.S. by Bhattacharyya, Harris, Narayanan, and Raffiee (1995), which reports returns to scale solely for privately owned utilities; in Korea by Kim and Lee (1998), which overall describes increasing returns to scale, but which notes diseconomies of scale in major cities and economies of scale in smaller locations when taking population size into consideration; in the United Kingdom by Saal and Parker (2000), which finds large diseconomies of scale for large privatized utilities; in Italy by Fabbri and Fraquelli (2000), which reports positive economies of scale at small output levels and diseconomies of scale at large output levels;

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[8] See Bel (2006a) for a review of this literature.

in France by Garcia and Thomas (2001) which finds increasing returns in the short term, but constant returns to scale in the long term.

Among recent studies that explicitly examine the characteristics of returns to scale, Sauer (2005), in an analysis of a sample of 47 water suppliers in rural areas of Germany in 2000-2001, reports that most suppliers (30) operate under a regime of increasing returns to scale, while 15 do so with decreasing returns of scale, and just two operate with constant returns. In the long term, he finds a reduction in returns to scale for all measures, probably as a result of over-capitalization. Thus, an increase in the size of operations would allow many suppliers to exploit economies of scale.

Aubert and Reynaud (2005), in a study of 211 water utilities in the state of Wisconsin (USA), employ translog functions to analyze returns to scale. By clearly distinguishing between economies of scale and economies of density, this methodology represents a marked improvement on previous studies. Their analysis identifies significant economies of scale in the short term, for both water production and distribution, which decrease both with the volume served and with the number of service users. However, these short-term economies of scale are much smaller than those of density. In the long term, average returns to scale for the panel are constant. Yet, the smaller companies (in terms of volume served and users) also present increasing returns to scale in the long term.

Torres and Morrison Paul (2006) likewise analyze 255 water utilities in the U.S. with data for 1996. The average size of the population served by these companies is greater than 40,000 inhabitants, while in Aubert and Reynaud's (2005) Wisconsin study it is just 5,000. Torres and Morrison Paul find significant economies of scale, especially in the case of smaller companies that tend to have a lower density of output. By contrast, larger utilities that extend their networks in expanding their service generate decreasing returns of scale. Thus, consolidation may only be an appropriate measure for small companies, providing that in doing so a major extension of the network is not required.

Saal, Parker and Weyman-Jones' (2007) UK study provides an update of earlier analyses for this country (e.g. Saal and Parker, 2000). By examining data for a much longer period (1985 to 2000), they are able to examine the post-privatization period more robustly. Their results confirm the previously reported substantial decreasing returns to scale for large privatized companies in England and Wales, suggesting that any eventual mergers or aggregations in this sector would probably not generate efficiencies.

Filippini, Hrovatin and Zoric (2008) study Slovenia's water distribution utilities, using a sample of 52 companies providing the service between 1997 and 2003. They also inspect economies of density and those of scale separately. They find increasing returns to density (i.e., the amount of water distributed and the number of users) for all company sizes and significant increasing returns to scale for small firms and medium-sized companies, although in the latter case the dimension of these returns is extremely limited. By contrast, the largest companies present diminishing returns of scale, having exhausted their ability to achieve economies of scale and operating under increasing average costs.

Finally, mention should be made of Nauges and van den Berg's (2008) study of the evidence for economies of density, scale and scope in four very different countries: Brazil, Moldova, Romania and Vietnam, for which they use samples of 26, 38, 23 and 47 productive units, respectively, for varying periods of time. Their results provide evidence of economies of density for the number of users and the product in Moldova, Romania and Vietnam, while in Brazil they identify economies of density for the product, but constant returns for the number of users. They also report increasing returns to scale in Moldova, Vietnam and Romania (albeit in the latter case of a very small dimension), but constant returns to scale in Brazil. Finally, although their data do not allow such a broad analysis in terms of economies of scope, their results indicate that these are positive, and that it is more economical to integrate water and sanitation services. Table 3 displays the main characteristics of these works.

Table 3. Characteristics and results of empirical works for water service

Work	Country	Functional form	Results on returns
Bhattacharyya, Harris, Narayanan and Raffie (1995)	USA	Translog	Increasing returns to scale only for private firms
Kim and Lee (1998)	Korea	Translog	Increasing returns to scale for smaller cities, negative returns to scale for larger cities
Saal and Parker (2000)	United Kingdom	Translog	Decreasing returns to scale for privatized firms
Fabbri and Fraquelli (2000)	Italy	Translog	Constants returns to scales; positive returns to density
García and Thomas (2001)	France	Translog	Increasing returns to scale in the short run, but constant returns in the long run. Decreasing returns to density in the long run.
Sauer (2005)	Germany	Symmetric Generalized McFadden	Increasing returns to scale in the short run. Returns to scale decrease in the long run.
Aubert and Reynaud (2005)	EEUU	Translog	Important positive results to density; limited economies of scale. On the long run, constant returns to scale, but for the very small firms.
Torres and Morrison Paul (2006)	EEUU	Quadratic	Increasing returns to scale for small firms, and decreasing returns for large firms.
Saal, Parker and Weyman-Jones (2007)	United Kingdom	Translog	Decreasing returns to scale for privatized firms
Filippini, Hrovatin and Zorić (2008)	Slovenia	Translog	Increasing returns to scale for small firms, which disappear when size increases.
Nauges and van de Berg (2008)	Several Brazil, Moldavia, Romania and Vietnam	Translog	In general, increasing returns to scale and increasing returns to density. Might exist scope economies between water delivery and sanitation.
Work of reference			
Nauges and van de Berg (2008)	Translog		**Explained variable**: Operational costs. **Explanatory variables**: Output (water volume); Sanitation (volume); number of connections; length of distribution network; population served; hours per day of operation.

Source: Author.

3.4 Urban solid waste management

Urban solid waste management involves a substantial transportation component. In this service, the analysis of the existence of economies of scale in output has a long tradition, dating back to the seminal work by Hirsch (1965).[9] While this study concludes the absence

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[9] An extensive review of this literature can be found in Bel (2006a). The existence of economies of density associated with population concentration has also been examined, but the literature seems to point to their absence.

of economies of scale, their existence has been a frequent outcome in subsequent studies that employ more robust techniques and more complete data bases, and where scale economies are explicitly examined as part of the analysis.

Stevens' study (1978) represents a significant improvement in the quality of the model specification and data used. She draws on a sample of 340 private companies and public units that produce solid waste services in 340 U.S. cities across the country. In her study, she deals with issues related to economies of scale and density more formally. The empirical results in Stevens (1978) point to the existence of positive economies of scale in small municipalities, but to the fact that these disappear as the population increases. By contrast, there is no evidence of economies of density.

Dubin and Navarro (1998) study the same issues as those addressed by Stevens (1978).[10] Using the same sample as in Stevens, and with data for 261 municipalities, Dubin and Navarro take the average cost of the service as the explained variable. Their empirical results match those of Stevens regarding the existence of positive economies of scale in municipalities under 20,000 inhabitants, although the importance of these economies of scale is limited. In municipalities with more than 20,000 inhabitants, economies of scale disappear. Finally, they seek to verify Stevens' suggestion (1978) regarding the structural change undergone by the cost equation according to the size of population (which would result from the existence of different scales of costs according to size), but they find no evidence that would allow the hypothesis of structural stability of the cost equation to be rejected.

Various studies conducted for European countries in the early years of the century and which followed Stevens (1978) and Dubin and Navarro's (1988) models report no economies of scale [Reeves and Barrow (2000) for Ireland; Digkgraaf and Gradus (2003) for the Netherlands] or mixed results [Ohlsson (2003) for Sweden]. Reeves and Barrow (2000) and Ohlsson (2003) also report diseconomies of density.

A recent study of the latest generation conducted in the U.S. is that of Callan and Thomas (2001), which considers the possible multi-product nature of solid waste services by distinguishing between its two main components: general-waste for disposal, and selective-waste for recycling. The empirical analysis is conducted with a sample of 110 municipalities in Massachusetts (USA) with data for 1997. Callan and Thomas estimate a

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[10] As well as for Tickner and McDavid (1986) for Canada, who report significant economies of scale, as also shown by McDavid (2001) in his non parametric analysis of the same country.

two-equation model where the dependent variable is the cost of the service (i.e. disposal or recycling). Their empirical analysis highlights the absence of economies of scale and the presence of economies of density for waste disposal, while recycling waste presents economies of scale but not economies of density. On the other hand, economies of scope are reported for both disposal and recycling.

Bel (2006b) contains an analysis of the municipal costs of solid waste services in Spain. This paper has cost data for 186 municipalities in Catalonia for the year 2000. The dependent variable is the total cost for the service of solid waste. In Bel's (2006b) empirical analysis, significant economies of scale are found in small towns, but the intensity of these economies is limited, and both their intensity and significance decrease as the population rises. In fact, the structural change test indicates the need to study the larger and the small-sized municipalities separately. Moreover, there is no evidence of economies of density or of scope. Bel and Costas (2006) extend Bel's (2006b) analysis to include the aggregation of production through inter-municipal cooperation and the age of privatization, and find that small municipalities that cooperate achieve economies of scale with lower costs than those who do not cooperate.

Two further papers for the Spanish case are those by Bel and Fageda (2009) and Bel and Mur (2009). Bel and Fageda study the factors that account for the costs of solid waste services in a sample of 65 municipalities in the region of Galicia. Their estimation results show no significant increasing returns to scale for the sample as a whole. However, for the subsample of municipalities with fewer than 50,000 inhabitants, they find economies of scale that are statistically significant. Bel and Mur's (2009) study is carried out with a sample of 56 municipalities in the region of Aragon, representing in the main municipalities with very sparse populations. The average municipal size in the sample is 16,708 inhabitants, and when the region's capital, Zaragoza, is excluded the average drops to 5,628 people. [11] Paradoxically, the result of the cost function estimation indicates the absence of economies of scale. The authors suggest that the very high degree of inter-municipal cooperation in the region, where over 80% of the municipalities cooperate, may, in practice, have been the cause of almost all the economies of scale being exploited.

Table 4 displays the main characteristics of these works.

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[11] Both figures are much higher than the average size for the region as a whole, given that here are a large number of municipalities with a population under 1000 inhabitants.

Table 4. Characteristics and results of empirical works for solid waste collection

Work	Country	Functional form	Results on returns
Hirsch (1965)	USA	Linear	Constant returns to scale
Stevens (1978)	USA	Logarithmic	Increasing returns to scale for small municipalities, which disappear as size increases.
Tickner and McDavis (1986)	Canada	Logarithmic	Increasing returns to scale
Dubin and Navarro (1988)	USA	Linear	Increasing returns to scale (of limited dimension) for small municipalities (below 20,000 inhabitants), which disappear as size increases.
Reeves and Barrow (2000)	Ireland	Logarithmic	Constant returns to scale. Diseconomies of density.
Callan and Thomas (2001)	USA	Linear	Constant returns to scale, and increasing returns to density for disposal; Increasing returns to scale and constant returns to density for recycling. Positive economies of scope for disposal and for recycling.
Ohlsson (2003)	Sweden	Logarithmic	Mixed results for scale economies. Diseconomies of density.
Dijkgraaf and Gradus (2003)	Netherlands	Logarithmic	Constant returns to scale
Bel (2006b)	Spain	Logarithmic and Quadratic	Increasing returns to scale –of limited dimension- for small municipalities. Constant returns to scale for municipalities above 20,000 inhabitants. Constant returns to density, and absence of economies of scope between disposal and recycling.
Bel and Costas (2006)	Spain	Logarithmic	Increasing returns to scale –of limited dimension- for small municipalities. Constant returns to scale for municipalities above 20,000 inhabitants. Constant returns to density.
Bel and Fageda (2009b)	Spain	Logarithmic	Increasing returns to scale of important dimension for municipalities below 50,000 inhabitants.
Bel and Mur (2009)	Spain	Logarithmic	Constant returns to scale. Environment with an extremely high degree of cooperation. . scale economies have been exploited.
Works of reference			
Bel (2006b) and Bel and Costas (2006)	Logarithmic and Quadratic		**Explained variable**: Total costs for municipality. **Explanatory variables**: output (disposal), output (selective), collection frequency, density of population/housing, price of labor, tourism, landfills, intermunicipal cooperation, private production.

Source: Author

4: Conclusions from empirical evidence in capital intensive local services.

Empirical studies of urban/metropolitan bus services coincide in their identification of economies of density in these transport companies, but their findings as regards economies of scale are somewhat more mixed. On the question of company size, Matas and Raymond (1998) report constant returns to scale on average, and a tendency towards diseconomies of scale in large enterprises. This last finding is very similar to that presented by Filippini and Prioni (2003), but differs from that reported by Farsi, Fetz and Filippini (2007), although it should be noted that the more recent study focuses on multiproduct firms, and that the maximum size of urban transport companies in Switzerland is substantially smaller than the largest Spanish companies. All in all, these empirical results have important implications for the management of local bus transportation systems (Albalate, Bel and Calzada, 2012). As returns to scale remain constant on average, and as some large firms even show decreasing returns to scale, no scale benefits would be foregone by creating several concessions in a single large metropolitan area. In this way, large metropolitan areas could benefit for increased competition.

Conventional knowledge on economies of scale in airports suggested increasing returns to scale that were exhausted by three million WLU. However, most recent studies shift upwards the location of the industry`s minimum efficient scale. This can be linked to technological development, but also to the use of larger and broader airport databases, and the improved estimation methodologies. What is clear is that –lacking network characteristics- no economies of density are expected.

Empirical evidence from studies of water services indicates that economies of scale exist and are significant, but that they disappear as the supplier grows in size. The results from studies of very large, privatized firms consistently indicate diminishing returns to scale. Thus, economies of scale tend to be concentrated in small firms, and in those settings in which a small population is being served. It is for this reason that the different institutional features characterizing firms in different countries or regions may produce different cost structures, which is consistent with different policy implications regarding possible mergers or takeovers. Increasing returns to density suggest that the joint delivery of the service may well be advisable in contiguous urban areas. Finally, the evidence regarding economies of scope in the sector is much more limited and ambiguous in terms of its results, preventing the drawing of any general conclusions.

Empirical evidence from studies of economies of scale in solid waste collection points mainly to increasing returns to scale, although these are diluted with increasing output (or population), which typically occurs in regions with between 20,000 and 50,000 inhabitants. Increasing returns to scale are more readily found in environments where the average size of the municipality is small, and in which there are few experiences of inter-municipal cooperation or contracting out. It should be noted that the size of the municipality in a given setting may be of central importance: increasing returns to scale are more frequent in countries where municipalities have a small average size (population), such as the US and Spain. In contrast, in countries where the average size (population) is substantially higher, such as Sweden and the Netherlands, economies of scale are usually absent. This is also the case of economies of density, which are more often than not absent. Finally, evidence on economies of scope is very limited, preventing the drawing of any general conclusions. An important implication of the available empirical evidence is that the use of production forms that allow production to be aggregated, such as cooperation or privatization, could help economies of scale in small municipalities to be exploited effectively. A further implication is that large municipalities can fragment solid waste delivery without the risk of losing returns to scale (Bel and Warner, 2009), thus benefiting from increased competition.

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