"Introducing and enhancing competition to improve solid waste management in Barcelona"

Germà Bel and Marianna Sebő

UBIREA | Institut de Recerca en Economia Aplicada Regional i Pública

UBIREA | Institut de Recerca en Economia Aplicada Regional i Pública
UNIVERSITAT DE BARCELONA

WEBSITE: www.ub.edu/irea/ • CONTACT: irea@ub.edu

The Research Institute of Applied Economics (IREA) in Barcelona was founded in 2005, as a research institute in applied economics. Three consolidated research groups make up the institute: AQR, RISK and GiM, and a large number of members are involved in the Institute. IREA focuses on four priority lines of investigation: (i) the quantitative study of regional and urban economic activity and analysis of regional and local economic policies, (ii) study of public economic activity in markets, particularly in the fields of empirical evaluation of privatization, the regulation and competition in the markets of public services using state of industrial economy, (iii) risk analysis in finance and insurance, and (iv) the development of micro and macro econometrics applied for the analysis of economic activity, particularly for quantitative evaluation of public policies.

Abstract

Over the last two decades, Barcelona has implemented a far-reaching reform of the city's solid waste management. In 2000, the city was divided in four zones, with four separate solid waste collection contracts being awarded to private firms, with none being allowed to obtain more than two zones, a rule that was revised in 2009 to just one contract per firm. This division of the market via exclusive territories sought to enhance competition in the expectation of the convergence of relative costs, efficiency and service quality throughout the city. Based on monthly observations of costs and outputs between 2015 and 2018, this paper analyzes and evaluates the creation of lots as a tool of competition. We find that firms producing in larger zones report higher costs, that increased competition was not sufficient to lead to converging costs, and that none of the firms operate under increasing returns to scale. As such, we recommend creating an additional zone. We further suggest that if one of the zones were to be subject to public production, and adopted a mixed delivery provision strategy, the ability of the regulator to deal with asymmetric information would improve and a more reliable system could be created.

JEL classification: L32, L33, L38, Q53

Keywords: Waste collection, Management, Privatization, Re-municipalization, Competition

Germà Bel: Department of Econometrics, Statistics and Applied Economics. John Keynes 1-11. 08034 Barcelona, Spain. Email: gbel@ub.edu

Marianna Sebő: Department of Econometrics, Statistics and Applied Economics. John Keynes 1-11. 08034 Barcelona, Spain. Email: marianna.sebo@ub.edu

1. Introduction

The growing predisposition in many countries to turn to privatization and private companies to build and operate infrastructure and deliver public services has seen a corresponding increase in interest in the regulation of private actors. Discussions as to whether public or private ownership is more beneficial for social welfare have been central to debates in both economics and public policy and arguments for the superiority of both have been offered. However, most recent meta-analyses of the production choice and its associated costs show no significant cost differences between the two forms of production (Bel and Warner 2008; Bel, Fageda, and Warner 2010). Beyond the public versus private production dilemma, competition has been theoretically argued and empirically shown to be crucial for a cost-advantageous production (Boyne 1996; Hefetz and Warner 2004; Bel 2006), and, as a result, local governments have made increasing efforts to enhance competition in the market place (Bel and Fageda 2011; Gradus, Schoute and Dijkgraaf 2018; Hefetz and Warner 2012).

The objective of this study, therefore, is to analyze waste management reforms that can successfully contribute to enhancing competition in the waste market. To do so, we study the waste collection service in the city of Barcelona, where regulation by competition has been in operation for several decades. In the city of Barcelona, four exclusive waste collection zones have been awarded by means of a 'split auction' (Laffont and Tirole 1993), for which the duplication of fixed costs is justified by the yardstick competition effect (Auriol and Laffont 1992).

Besides promoting competition, innovations in management styles and in the use of information and communication technology are key to improving the quality and efficiency of public service delivery (Lundsgaard 2003). Similarly, and more specifically in local service delivery, a number of strategies other than managing competition have gained traction in recent decades, such as inter-municipal cooperation, re-municipalization, and mixed public/private delivery (Bel, Hebdon, and Warner 2018). For this reason, we devote the next section to undertaking a brief

review of the most relevant literature on privatization and the alternatives to it. Then, we describe the main historical and institutional characteristics of solid waste management in Barcelona.

In reporting our empirical analysis, we, first, analyze the cost determinants of solid waste services in Barcelona, and investigate whether there are any differences in the cost and scale economies of the four existing waste collection zones. Based on these results, we then propose a design for a potential reform aimed at improving the efficiency of solid waste management, the specific objective being to enhance competition and improve the city authorities' regulatory capabilities vis-à-vis private contracts for solid waste collection. In this way, we contribute to the existing literature by developing a technically based design for the reform of a waste management system which, given that it serves a large urban area (specifically, the city of Barcelona), can be applied to similar contexts where large scales of operation allow the service management to be split without being detrimental to the economies of scale.

2. Privatization and its alternatives

2.1 Regulation by competition

Since the cost-saving effects of privatization appear to be neither systematic nor sustainable, cost-saving competition has emerged as a key concern in management reform for delivering positive economic effects. One of the most frequently used methods for promoting such competition has traditionally been public procurement through auctions. Yet, when bidders only compete *for* the market in a static fashion, as opposed to competing *in* the market in a more dynamic fashion, the positive cost-saving effects of competition are decreasing over time and may even disappear (Bel and Costas 2006; Gradus, Schoute, and Dijkgraaf 2018; Hefetz and Warner 2012). Even if at the time of bidding *rivalry* exists, a more dynamic form of competition – which we can be defined as *extended rivalry* (Porter 1998) – is missing.

Dynamic competition among several producers in the same market can be induced by delimiting exclusive territories, that is, dividing the market up into different areas, each served by a different service provider. This division can be seen both spatially, but also in terms of market

segmentation (Tirole 1988), and can be said to lie somewhere between the two polar models of perfect competition and pure monopoly (Rey and Stiglitz 1995). The entry of new players may be socially desirable if players can be compared and even when they cannot be, if we allow for differentiated output. However, the strategy can induce inefficiency as a result of the duplication of fixed costs and by being detrimental to the exploitation of economies of scale. As for the monitoring of private actors, group incentive mechanisms are likely to arise in which the actions of one agent provide information about the actions of other agents, and the principal is able to monitor 'agents with other agents' (Varian 1990).

2.2 Inter-municipal Cooperation

Unlike privatization, inter-municipal cooperation (IMC) is based on strategic collaboration rather than on competition, the aim being to achieve economies of scale (and, hence, improve the cost conditions of the service) and to enhance coordination so as to better tackle externalities (Bel and Warner 2015 and 2016; Plata-Díaz et al. 2014; Pérez-López et al. 2016). The advantages of IMC include the possibility of retaining greater control over production and, hence, of incurring lower transaction costs than those incurred under privatization (Levin and Tadelis 2010; Hefetz and Warner 2012; Bel, Fageda, and Mur 2014). Such a situation is particularly desirable when enhanced service quality and cross-jurisdictional coordination are also sought (Aldag and Warner, 2018). Indeed, IMC affords policy-makers with the possibility of 'finding equilibrium' and avoiding extreme ideological positions in relation to public or private provisions (Voorn, Van Genugten, and Van Thiel 2020). It should, however, be noted that service provision by means of IMC is compatible with both private production (i.e. as illustrated by cases in Spain and France) and limited public production (i.e. as illustrated by cases in the Netherlands and Norway).

Since service delivery by IMC means the participants use 'functional consolidation' (as opposed to the full amalgamation of municipalities), a potential efficiency gain can be made. However, cost-advantage studies of IMC have produced diverging results. In a recent meta-regression, Bel and Sebő (2019) found that studies conducted in municipalities with small

populations, in which the governance of cooperation is delegated to supra-municipal governments, especially as regards solid waste collection, tend to show cost-savings from cooperation.

2.3 Re-municipalization

Reforms in the form of contract reversal have shown the existence of a 'two-way street', that is, from the privatization of management toward contracting back in (or reverse privatization) (Warner and Hefetz 2012). Indeed, processes of re-municipalization have become the subject of considerable political debate in recent decades, although they are by no means a new phenomenon (Bel 2020). However, these has been a resurgence in these contract reversals for reasons of managerial pragmatism, disappointment with the outcomes achieved with service delivery privatization and the failure of governments to monitor and manage the contract; hence, re-municipalization may be grounded in market failure, government failure or in both (Hefetz and Warner 2004). To a lesser extent, political context and ideological motivation have also been identified as factors in some cases (Gradus and Budding 2020).

Service characteristics are an important factor determining the likelihood (or otherwise) of contracting back in. Overall, if monitoring is costly and there are measurement difficulties, and competition is absent, a government is more likely to consider contracting back in (Nelson 1997). According to Hefetz and Warner (2004) examples of such services include utility billing, building maintenance, heavy equipment and emergency vehicles, street repair, traffic signs, recreation facilities, tree trimming, legal services, street cleaning and sanitary inspection. Moreover, re-municipalization can be a useful tool for local governments seeking to correct dynamic inefficiencies and so satisfy a broader range of public values (Lindholst 2019).

2.4 Mixed Delivery

Between the extremes of fully contracting out and re-municipalization, an intermediate solution is offered by mixed delivery. This involves the fragmentation of a jurisdiction into several territories, of which at least one is subject to public production and another to private production (Savas 1981; Miranda and Lerner 1995; Warner and Hebdon 2001; Warner and Bel 2008; Bel and Rosell 2016).

In theory, the primary argument in support of a mixed system of production is derived from the reliability engineering rule, which requires that the units of the system – in our case public and private companies – be independent (Bendor 1985). The desirability for some duplication can only be analyzed in the context of the consequences of system vulnerability and the probability of failure. If bankruptcy is expensive and its probability of occurrence is high, redundancy can be a convenient instrument. From an innovation perspective, doubling organizational units increases the likelihood of improving the quality of production of public services and, in the long run, greater efficiency can be achieved (Bendor 1985). Therefore, while noting that redundancy is not always convenient in public policy, it can be an important asset in a large, metropolitan city facing pressures emanating from a variety of sources.

Moreover, a mixed system ensures that the government gains knowledge and expertise about the delivery of the service. This has two important implications: First, it improves the government's ability to monitor and supervise private providers; and, second, it reduces the vulnerability of the whole system, since it is easier for the government to take over a private district in case of service failure. Hence, mixed delivery ensures a failsafe service, as emphasized by Miranda and Lerner (1995). Indeed, this works in the other direction too: For example, in a city vulnerable to public sector strikes, the presence of a private firm and its ability to take over the delivery of the public unit create a more reliable system. Evidence also suggests that the participating units can learn from each other in terms of process innovation (Ammons and Hill 1995). This property of 'equipotentiality' allows the system to offer creative responses to adjustments in the environment (Landau 1969). Indeed, an adaptable and reliable mixed system can contribute to meeting the challenges of a growing city and its increasing demand for waste collection. Finally, a mixed system can imply a behavioral effect, given that the public unit can provide an audit function, in the sense that the private units may change their behavior if being audited is probable (Aharoni 1982).

3. Institutional context: Waste management in the city of Barcelona

Solid waste collection has historically been delivered by private firms in the city of Barcelona. By the end of the Franco Dictatorship and following the first democratic municipal election in 1979, a shift in focus saw greater importance being given to citizen participation and greater relevance to the city districts and local democracy (Ajuntament de Barcelona 1999). With the Municipal Action Plan 1992–1995 (*Programa D'Actuació Municipal*), the city government launched its plan to extend selective waste collection throughout the city, promoting the market of recycled products and attempting to provide an urgent solution to uncontrolled dumping (Ajuntament de Barcelona 1992, 65). The two private concessions managing solid waste collection at that time, held by Fomento de Construcciones y Contratas (FCC) and Concesionaria y Contratas de Usuarios de Servicios de Limpieza Pública (CLD), were due to expire in 2000 (Bel and Warner 2009).[1]

In 2000 the city was divided into four zones, with four separate solid waste collection contracts being awarded to private firms, with none being allowed to obtain more than two zones.[2] Barcelona's solid waste management model was the outcome of systematic planning, with importance being attached to the role in this of both the private and public sectors (Bel and Warner 2009). The municipality of Barcelona believed that its policy would create redundancy in public service delivery and lead to improvements in efficiency, innovation and quality and to a more reliable system to react to the city's unexpected or novel needs. The city argued that fragmentation would allow private firms to address the specific characteristics of each territory, which it was known could differ markedly with the season of the year.

---

[1] The first direct contract between CLD and the Barcelona city council for waste collection provision dates back to 1964, whereas FCC, established initially in 1900 as Fomento de Obras y Construcciones (FOCSA), had a long history of cooperation with Barcelona in local service delivery, starting with a contract in 1911 for street cleaning and conservation.

[2] The service reform involved the joint awarding of solid waste collection and street cleaning in each zone to the same private firm. This characteristic has been maintained in all subsequent contracting processes. It should be stressed, however, that all contracts, supervision and payments clearly distinguish between the two services in each zone and, consequently, all the data used in our empirical strategy refer solely to the solid waste collection service.

The contracts awarded in 2000 had an initial duration of seven years; yet, before termination, they were extended for an additional two years. In 2009, after a new bidding process, the city kept the number of zones the same, but modified their structure by making some changes in the districts included within each. In this bidding process, firms were obliged to bid for all four zones, even though it was now dictated that only one contract would be awarded per firm. As a result of the bidding process, the award of contracts in each zone (comprising city districts) was as follows: North (Horta-Guinardó and Nou Barris) was awarded to CLD Urbaser; Center (Ciutat Vella, Eixample and Gràcia) was awarded to FCC; East (Sant Andreu and Sant Martí) was awarded to Urbaser; and West (Sants-Montjuic, Les Corts and Sarrià-Sant Gervasi) was awarded to CEPSA. The Center zone also included pneumatics and the East zone included the city's beaches.

In the upcoming concession for the period 2019-2027,[3] the fragmentation into four zones has been maintained, and each bidder has to make a bid for at least two zones, although – as in the previous process – only one contract can be awarded per firm. The new contracts have an eight-year duration with the possibility of a two-year extension (Ajuntament de Barcelona 2018a). In the latest call for waste management contracts, the city has stressed the importance of environmental quality and sustainability, information, transparency and social policies (Ajuntament de Barcelona 2018b). These changes have been introduced to create a more innovative system, deemed particularly important in a Mediterranean city like Barcelona, where tourism is high and, the potential impact of climate change is great.

4. Empirical strategy

4.1 Empirical background

Empirical analyses of the factors impacting solid waste management – starting with Hirsch (1965) – have sought to model refuse collection costs taking into account factors related primarily to scale

[3] The bidding process is still undergoing. The firms will take over the service nine months after the award. The current contract has been prolonged till 31 August 2021 or until the new contracts come into force.

economies, break-even points and price determination. Following Hirsch's pioneering study, Stevens (1978) introduced significant improvements by considering the market structure, differentiating between (1) market provision under a competitive system, and (2) public provision with either (2a) a public monopoly or (2b) private monopoly. Stevens reported the existence of economies of scale up to 50,000 inhabitants, while beyond this population size, he found constant returns to scale. In his comparative study, he showed market provision to be between 26 and 48% more costly than monopolies under public provision, indicating that the gains from competition were lower than the transaction costs incurred, since there was no sign of additional inefficiency due to competition. In the case of public provision, he reported no significant cost difference between public and private production below a population of 50,000, while private production was less costly above that population threshold.

Another major advance was made in empirical studies by Dubin and Navarro (1988). Here, the authors also analyzed solid waste collection costs under market and public provisions (with either a public or private monopoly), but prior to this they controlled for the form of production, so that any potential endogeneity of the latter and costs was dealt with. As in Stevens (1978), market provision was found to be the least efficient system; while, within public provision, private production was less costly than public.

Following on from these empirical analyses of solid waste management, an increasing number of studies have appeared, especially after 2000 (see Bel and Warner, 2008, and Bel, Fageda, and Warner, 2010, for a review). Most papers failed to find a significant difference in the outcomes of public and private production (Allesch and Brunner 2014). Indeed, similar conclusions have been obtained in more recent studies (e.g. Jacobsen, Buysse, and Gellynck 2013; Abrate et al. 2014).

When modelling the costs of waste management parametrically, the relationship between outputs and inputs has usually been represented by a cost or production function. Both can include a variety of variables and may be either linear or non-linear. Similarly, many previous studies, in line with Stevens (1978), base their empirical analysis on the Cobb-Douglas production function.

In this paper, we also adopt this type of modelling; however, our study is unique as it analyzes the costliness of the waste management lots following the divisions made in the city of Barcelona, which provides us with a jurisdictionally but also politically (in the sense of the governing party, see Benito-López, Moreno-Enguix, and Solana-Ibañez, 2011) homogeneous context. As in Bel (2006), and omitting the variables that this author found not to cause additional variability in our framework – namely, salaries and frequency of collection, which are equivalent in all four of the city's concessions – our cost function can be expressed as:

$$TC = F\left(Quantity_{rest},\ Quantity_{select,}\ Firm,\ \ Density,\ Prod, Tourism\right) \quad (1)$$

The variables are described in

Table *1*. Data for the variables used in our estimations refer to the period 2015–2018 and were provided by the city agency that supervises the solid waste service. We have available monthly observations for the costs and solid waste quantities of each type. Data regarding inhabitants in each district are annual. Descriptive statistics for the main variables are displayed in table A-1, in the appendix. We computed the variance inflation factor (VIF) to check the potential relevance of multicollinearity and found an average value equivalent to 598.74. For this reason, we excluded the variables with the highest individual VIF values (that is, density, surface, and population). Moreover, given that the various categories of waste are correlated, we opted to use the variable *Rest waste* expressed in absolute terms, while for the other categories we used the relative weight of the waste as a percentage of total waste. After this we ran the VIF check again and found that individual value for tourism was 27.91, and so we eliminated this variable. As a result, the remaining equation presented an average VIF = 5.39, with all variables presenting low individual VIF values.

Table 1: Description of the variables used in the estimations.

Dependent Var	Description
Total Cost	Total costs incurred by the municipality for the service of waste management by zones by month from 2015 to 2018
Independent Var	Description
Rest waste	Monthly volume of rest waste collected by zone from 2015-2018 in tones
Organic waste	Monthly volume of organic waste collected by zone from 2015-2018 in tones
Paper waste	Monthly volume of paper waste collected by zone from 2015-2018 in tones
Packaging waste	Monthly volume of packaging & plastic waste collected by zone 2015-2018 in tones
Voluminous waste	Monthly volume of voluminous waste collected by zone 2015-2018 in tones
Glass waste	Monthly volume of glass waste collected by zone 2015 to 2018 in tones
Surface	Area of the zones in km^2
Population	Number of inhabitants in the zone
Density	Inhabitants per km^2
Tourism	Number of touristic establishments in the zone
August	Dummy variable taking the value of 1 in the month of August
FCC	Dummy variable taking the value of 1 for the zone of FCC
CESPA	Dummy variable taking the value of 1 for the zone of CESPA
URBASER	Dummy variable taking the value of 1 for the zone of Urbaser
CLD	Dummy variable taking the value of 1 for the zone of CLD

5. Estimations and results of the empirical analysis

Our basic estimations are shown in Table 2. The first model using OLS gives the expected results in terms of *Rest waste*, which is not selective, paper, packaging, glass and voluminous residues. All of them have a positive impact on costs, except packaging, which is probably due to the more specialized and more costly service for handling selected waste. Due to heteroskedasticity, we applied robust standard errors; however, our results did not change substantially. Exploiting the panel structure of our data, we tested both the fixed and random effects models. Since we could not reject the null hypothesis of no systematic difference in coefficients, the random effects model is our preferred choice.

Table 2: Empirical Results of the Estimation of the Determinants of the Cost of Waste Management.

Ind. Variables	OLS (Pooled)	Robust OLS (Pooled)	Fixed effects	Random effects
Rest waste	198.86***	198.86***	283.45***	198.86***
	(26.58)	(33.05)	(49.18)	(26.58)
Organic	3,468,132	3,468,132	3,873,489	3,468,132
	(3,210,734)	(4,368,260)	(6,633,206)	(3,210,734)
Paper	17,592,453***	17,592,453***	16,073,670**	17,592,453***
	(5,048,028)	(4,103,530)	(5,201,442)	(5,048,028)
Packaging	-4,386,370	-4,386,370	-1.22e+07	-4,386,370
	(12,555,090)	(10,780,383)	(14,878,618)	(12,555,090)
Glass	3,304,917	3,304,917	13,508,703	3,304,917
	(7,827,504)	(11,553,536)	(10,051,124)	(7,827,504)
Voluminous	-4,271,215	-4,271,215	-865,984	-4,271,215
	(4,401,988)	(4,204,447)	(5,738,558)	(4,401,988)
August	252,954**	252,954***	375,594**	252,954**
	(93,040)	(62,915)	(118,491)	(93,040)
Constant	-1,325,916**	-1,325,916*	-2,569,745	-1,325,916**
	(474,914)	(583,269)	(1,433,090)	(474,914)
R-sq	0.8205	0.8205	within=0.2604 between=0.9963 total=0.8159	within= 0.2466 between = 0.9996 total= 0.8205
#Observations	192	192	192	192
# groups			4	4
F	120.12***	238.39***	9.10***	
Prob>F	0 .0000	0 .0000	0 .0000	
Wald chi2				840.84***
prob>chi2				0.0000

Note: *** indicates significance at 1% level; indicates significance at 5% level; * indicates significance at 10%. In parenthesis standard errors.

Next, we analyzed differences between zones/firms. We should stress that we cannot disentangle differences in a given area's productivity from that of the specific conditions of a zone. Our results are shown in

Table . CESPA has higher costs than the average firm, whereas CLD has lower costs than average. Additionally, we compared the costs of each firm with the costs incurred by the other three (see Table A-2 in the Appendix). FCC's costs are not statistically different from those of any other firm; CESPA is more expensive than Urbaser, which is also cheaper than CLD, although the statistical significance of this last relationship is weaker. Overall, CESPA appears to be the most expensive firm, whereas Urbaser seems to be the most cost advantageous.

Table 3: Empirical Results of the Estimation of the Determinants with a random effects model of the Cost of Waste Management.

Ind. Variables	FCC	CESPA	Urbaser	CLD
Rest waste	68.17*** (22.98)	59.53*** (21.73)	61.68*** (22.71)	60.56*** (21.66)
Organic	-4,732,590 (4,434,889)	8,290,278 (5,714,873)	458,038 (3,631,409)	1,182,653 (3,181,605)
Paper	2.45e+07** (1.16e+07)	2.02e+07* (1.13e+07)	2.09e+07* (1.15e+07)	2.74e+07** (1.13e+07)
Packaging	-9,917,620 (8,721,079)	-2,576,929 (9,249,483)	-7,374,006 (8,928,627)	-3,114,223 (9,198,119)
Glass	3.96e+07*** (8,681,643)	4.04e+07*** (6,925,529)	3.36e+07*** (9,585,093)	4.85e+07*** (7,468,806)
Voluminous	-1.03e+07** (4,130,832)	-1.36e+07*** (3,721,202)	-1.69e+07*** (5,624,739)	1,999.32 (6,391,193)
August	597,823*** (182,194)	538,636*** (181,297)	475,097** (206,199)	746,786*** (190,962)
FCC	138,706 (274,157)			
CESPA		300,168** (137,349)		
Urbaser			-222,359 (170,217)	
CLD				-454,267** (213,611)
Time effects	YES	YES	YES	YES
Constant	-1,006,890 (869,166)	-2,648,266*** (911,428)	-809,380 (763,373)	-2,956,505*** (1,029,724)
R-sq	within: 0.7977 between: 0.9999 total: 0. 9522	within: 0.8037 between: 1.0000 total: 0. 9537	within: 0.7995 between: 0.9999 total: 0. 9527	within: 0.8035 between:0.9999 total: 0.9536
#Observations	192	192	192	192
# groups	4	4	4	4
Wald chi2	2,726.19***	2,820.48***	2,756.45***	2,815.19***
Prob > chi2	0.0000	0.0000	0.0000	0.0000

Note: *** indicates significance at 1% level; indicates significance at 5% level; * indicates significance at 10%. In parenthesis standard errors.

5.1 Economies of Scale

Following the theoretical outcome regarding the importance of enhancing competition via split auctions, the next step in our research involved analyzing the convenience of increasing the number of solid waste collection zones in Barcelona, so as to increase competition. Thus, in this section we determine whether the creation of more zones and, hence, a reduction in the size of the current zones, leads to a loss of economies to scale. Preserving the current cost functions, if the firms already produce with constant returns to scale, a loss in size would not result in an increase in average costs. Note, however, that an increase in the level of fragmentation would be more

advisable in the case of diseconomies of scale, since reducing the size of the zones would lead to lower average costs.

Some of the earlier studies of waste management costs undertook analyses of scale economies. The first to incorporate a systematic and robust analysis was Stevens (1978), who reported the presence of economies of scale for US municipalities with between 20,000 and 50,000 inhabitants and constant returns to scale above that threshold. Likewise, Dubin and Navarro (1988) found increasing returns to scale for US municipalities with up to 20,000 inhabitants; Dijkgraaf and Gradus (2003) reported scale economies in Dutch municipalities with a population of fewer than 40,000 inhabitants; and Bel and Costas (2006) found increasing economies of scale in the smaller municipalities of Catalonia, and full exploitation of economies of scale in municipalities with between 20,000 and 50,000 inhabitants. A notable exception is Bohm et al. (2010), who observed increasing returns to scale across all quantities of disposal waste in their sample of US municipalities. However, increasing returns to scale were soon exhausted in recycling waste, and diseconomies of scale appeared thereafter. Most of the evidence reported up to 2010 was analyzed by Gomez-Reino (2010) by means of meta-regression. The author concluded that there were only slight economies of scale in waste management, and that they were less relevant than those in the other public services considered in his study (e.g. education).

More recent studies typically provide additional information. For example, Simões, Carvalho, and Marques (2012) show that the optimal scale in Portuguese municipalities depends on the producer and mode of production, but that, generally, the service delivery fully exploits scale economies with a population of between 25,000 and 50,000 inhabitants. Increasing returns to scale limited to smaller Portuguese municipalities are also found in a study by Simões, Cavalho, and Marques (2013). In a study of Japanese municipalities, Chifari et al. (2017) report economies of scale, but find that they are much less relevant in the case of waste collection than they are for waste processing and waste disposal. In a study of Italian municipalities, Abrate et al. (2014) report

constant returns to scale for the average municipality in their sample of 42,500 inhabitants. In the case of larger municipalities, the authors find diseconomies of scale in waste collection; however, these are counterbalanced by economies of scope up to a population size of 300,000 inhabitants. Finally, Greco et al. (2015) disentangled undifferentiated versus separate waste collection, finding the former to be cheaper and capable of achieving higher rates of economies of scale than the more expensive and specialized separate waste collection.

In the case of the city of Barcelona, all the zones have populations above 300,000, which, based on previous studies, would seem to imply that their volumes of waste are well above the threshold at which of economies of scale can be fully exploited. As such, we expect to find either constant returns to scale or diseconomies of scale. In neither case, however, would the policy recommendation of creating an additional zone to enhance competition eliminate gains of increasing returns to scale, given that all existing zones are already well above that size.

Many of the empirical studies that analyze solid waste use Hirsch's (1965) definition, which states that the optimal scale is the level of operation at which average costs are lowest. This coincides with a scale elasticity of a unit value, and many empirical papers use the inverse of scale elasticity to define economies of scale (Baumol, Panzar, and Willig 1988), reflecting the proportional increase in total costs due to a proportional increase in output, *ceteris paribus* (Farsi, Filippini, and Lunati 2008). Hence, if this relation is lower than 1, it means that average costs increase (decrease) as output increases (decreases) and that we are in a situation of diseconomies (economies) of scale. In this paper, however, we are concerned with describing the current situation and of determining the effect of a one-unit increase in output on average costs, rather than on finding the optimal size. Broadly speaking, similar empirical studies either make use of the relationship identified by Baumol, Panzar, and Willig (1988) using a logarithmic function or explain average costs with a linear (e.g. Dubin and Navarro 1988) or quadratic function (e.g. Hirsch 1965).

Here, we adhere to the average cost explanation and estimate both the linear and quadratic structures, as specified in Table 4: Random effects models with average costs as dependent variable.Table . These estimations do not include the quadratic component since it was found not to be statistically significant in any of the estimations. This implies that the relationship between the unit cost and output is similar to that reported in Stigler (1958), in the sense that scale economies are exhausted at relatively small sizes. After that, average costs are found until increasing marginal costs are achieved following a highly significant growth in population. Hence, our preferred specification is the linear model shown in the first column in Table 4 According to our estimation, 10,000 additional tons of waste would lead, on average, to an increase in costs of 1.13 euros per ton. This specification, however, is unable to capture any possible differences between zones; hence, we can only conclude that the average zone in Barcelona is already in a state of diseconomies of scale at 10%.

To see zone-specific effects, we use interaction models as described in Brambor, Clark, and Golder (2006). Multiplicative models of this type are common in quantitative analyses in political science because they can capture the relationship between (political) inputs and (political) outputs depending on the institutional context (Brambor, Clark, and Golder 2006).[4]

[4] For example, Frère, Hammadou, and Paty (2011) interact a dummy variable representing urban areas with population size to see the effect on the range of public services provided; Andrews and Boyne (2014) use an interaction term between task complexity and size to determine a change in administrative intensity in UK universities; Sundell and Lapuente (2012) examine political incentives to contract out when both political competition and government ideology interact; Bos, Lamoen and Economidou (2010) seek to determine whether big banks under competition adopt different innovative behavior to that adopted by smaller banks; Trebesch and Zabel (2017) measure costs of sovereign debt by interacting default with a coerciveness index; Al-Jarrah, Al-Abdulqader and Hammoudeh (2019) interact characteristics of banks to see their joint effects; and Baccini (2014) interacts country traits to estimate transaction costs in negotiating.

Table 4: Random effects models with average costs as dependent variable.

Ind. variables	Baseline Model	FCC	CESPA	CLD	URBASER
Volume of Waste	0.000113**	0.000140**	0.000067	0.000131*	0.000098*
	(0.000051)	(0.000058)	(0.000057)	(0.000070)	(0.000052)
FCC		0.930151			
		(1.289607)			
VolxFCC		-0.000063			
		(0.000058)			
CESPA			0.199694		
			(1.142799)		
VolxCESPA			0.000023		
			(0.000067)		
CLD				0.150256	
				(1.150852)	
VolxCLD				0.000004	
				(0.000115)	
URBASER					-1.953874
					(1.378008)
VolxURBASER					0.000060
					(0.000096)
Organic	-9.454073*	-3.114316	9.615739	-11.776011	2.295074
	(5.733382)	(10.248733)	(13.375124)	(8.285627)	(7.244014)
Glass	39.088399	39.320678	49.695070**	40.407800	52.780849**
	(24.583959)	(25.575476)	(25.222633)	(24.990285)	(25.222346)
Paper	45.905687*	42.150427*	39.344686	48.169020*	55.779296**
	(24.604821)	(25.196411)	(24.801222)	(26.111249)	(24.603053)
Packaging	-2.963021	-2.440052	6.265167	-3.948508	18.562198
	(19.290849)	(19.412636)	(21.447781)	(19.585031)	(20.702795)
Voluminous	-29.671139***	-32.623877***	-33.685388***	-24.838187*	0.782834
	(7.876873)	(8.985234)	(8.647200)	(14.704238)	(14.015941)
August	1.248604***	1.385631***	1.480314***	1.173003***	0.809371**
	(0.332547)	(0.395306)	(0.355297)	(0.386955)	(0.367689)
Constant	0.346667	-0.583818	-2.205452	0.031213	-3.843442
	(1.355573)	(1.855066)	(2.176383)	(1.620774)	(2.087978)
R-squared					
within	0.8259	0.8276	0.8298	0.8261	0.8340
between	0.9998	0.9998	0.9999	0.9998	0.9999
total	0.9242	0.9250	0.9260	0.9243	0.9278
Time effects	YES	YES	YES	YES	YES
Nr of observations	192	192	192	192	192
Nr of groups	4	4	4	4	4
Wald chi2	1682.84***	1677.28***	1701.12***	1660.46***	1748.33***
Prob > chi2	0.0000	0.0000	0.0000	0.0000	0.0000

Note: *** indicates significance at 1% level; indicates significance at 5% level; * indicates significance at 10%. In parenthesis standard error.

This "context conditionality" suggests that the relationship between two variables depends on the values of other variable(s). In our case, we are concerned with whether the relationship

between output and average costs is modified (increases or decreases) when the dummy variables of the firms are equal to 1. When we include the interaction term between the firm and the volume of production (e.g. FCCxVolume), all the constitutive terms must be included in the estimation (both the dummy of FCC and Volume). Our results in Table show that the average effect of one additional ton of waste has a positive and significant effect on the average costs, hence the zones, on average, produce diseconomies of scale. Nevertheless, when including firm dummies and firm interactions, the statistical significance of volume disappears. Still, we obtain evidence that none of the firms is producing under increasing returns to scale. Similarly, the fact that none of the dummies for zones (nor the interactions) has a significant coefficient implies that they do not have any additional effect, whether decreasing or increasing, with respect to the average level of costs.

6. Discussion and Policy Implications

Our empirical analysis confirms the results of earlier empirical studies as regards the usual variables identified as affecting total costs in waste management. However, it should be borne in mind when interpreting our findings herein that it has often proved difficult to determine whether the service differences are attributable to the local conditions of each zone or to the firms' production and cost function. Having said that, we proceeded to analyze any firm/zone-related differences between the lots and were able to determine that the four zones are indeed different from each other. Subsequently, we estimated which is the most costly and which the least. Thus, it is apparent that the current level of competition created by the local government through market fragmentation is insufficient to achieve the outcome of perfect competition (i.e., no differences in the firms' relative costs).

One way to enhance competition would be to increase fragmentation by introducing more lots, a solution that means bidders would have to compete both statically and dynamically: First, because now, in the auction phase, the zones are not so big, firms with lower capacities would also be able to participate and bid for the market(s) (Pavel and Slavík 2018); and, second, in the phase

of regulation by competition with one more participant, the local regulator would have more information and the incentives of the participants would change. In addition, potential collusion would be less likely with more participants.

One of the potential disadvantages of a higher level of fragmentation, however, is the possible elimination of economies of scale. To address this risk, we examined whether the firms are producing with increasing returns to scale. Since we have found evidence – on average – of the absence of economies of scale in every zone, one of our policy recommendations is for the creation of one additional zone. An example resulting from the creation of a new zone comprising the city districts of Sarrià-Sant Gervasi and Gràcia is shown in

Table .[5] Figure compares the map of the existing division of zones with the one that would correspond to the proposal formulated.

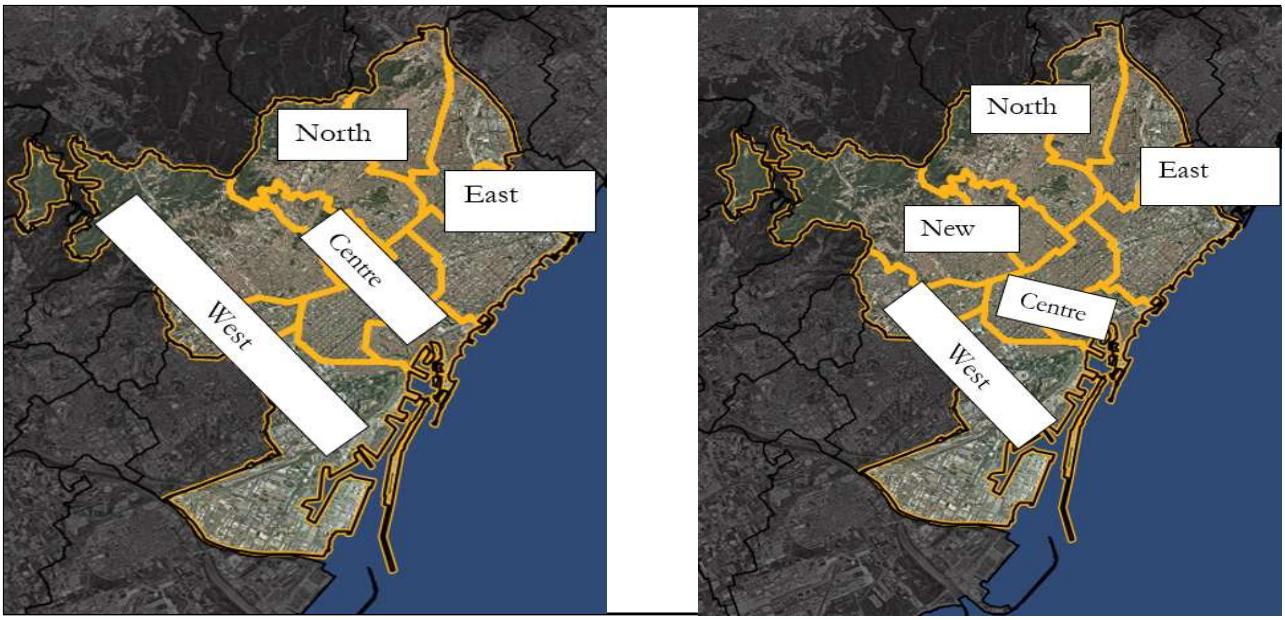
Table 5: Possible fragmentation considering economies of scale and mixed delivery.

Zone	District	Population	%	**Firm**	%	Population	District	Zone
North	Horta-Guinardó Nou Barris	337,388	20.8%	**A**	20.8%	337,388	Horta-Guinardó Nou Barris	North
Centre	Ciutat Vella Eixample Gràcia	486,593	30.0%	**B**	22.6%	365,588	Ciuta Vella Eixample	Centre
East	Sant Andreu Sant Martí	384,192	23.7%	**C**	23.7%	384,192	Sant Andreu Sant Martí	East
West	Sants-Montjuic Les Corts Sarrià–S .Gervasi	412,170	25.4%	**D**	16.2%	263,058	Sants-Montjuic Les Corts	West
				New	16.7%	270,117	Gràcia Sarrià – S Gervasi	New Zone
Total		1,620,343	100%		100%	1,620,343		Total

Note: The service of pneumatics belongs to the zone of Center and beaches belong to the zone of East. The number of inhabitants refers to the year of 2018.

[5] In making this suggestion we consider the existing constraint that solid waste collection zones must include entire city districts and that they cannot be split between different waste management zones. Ideally, the analysis should be conducted at the neighborhood (73 neighborhoods in the city) or even at the street level rather than at the district level (10 districts). However, the information available only permits a district level analysis.

Map 1: Division of Barcelona into four zones (1.a) and Proposed division into five zones (1.b).



Apart from fulfilling the goal of avoiding decreasing returns to scale, this reform could facilitate entry for smaller firms. Recall that the private contractors that initiated the service provision in the early stages (2000–2009) held onto the service and successfully won subsequent contracts. Hence, even though the market was divided into lots, competition was still quite weak.

As outlined earlier, other than privatization and the management of competition, present-day local delivery options include IMC, contract reversal or re-municipalization and mixed delivery. However, IMC is not recommendable for big markets like the city zones of Barcelona, being better suited to small municipalities where scale economies have yet to be fully exploited (Bel and Sebő, 2019), The other two reforms can, though, be considered similar in the sense that they would involve the partial or full re-municipalization of waste management services in Barcelona. Moreover, if the newly created zone were to be public (or failing that if one of the original four zones were to be re-municipalized), information asymmetry could be improved, insofar as the possibilities for benchmarking by local government would be enhanced (Mols 2010a; 2010b) and a form of yardstick competition could be created (Girth et al. 2012; Hefetz and Warner 2012).

Furthermore, creating a mixed system ensures that the public unit gains more knowledge about the service and is in a better position to assess the performance of the private agents. It also ensures that creative responses are given to specific problems and that knowledge is shared (Parmigiani 2007). Additionally, the emergence of new technological opportunities calls for a flexible organization to ensure their full exploitation, something that is particularly relevant in waste management, because this is one of the main public services in terms of budget consumption and because the links between the environment and waste generation are a pressing concern in these times of climate change.

7. Conclusion

In this paper we have analyzed the current situation and performance of the solid waste management service in the city of Barcelona. Based on our empirical findings, we have recommended a series of reforms that should help to improve the service by lowering costs and by improving system reliability. Consistent with our finding of the absence of increasing returns to scale in the city service with the current configuration of zones, our first policy recommendation is for the city to create – at least – one additional zone. Second, it is our belief that further improvements can be achieved in terms of system reliability, public values and symmetric information if one of the zones (either the newly created one or one of the original four zones) were to be subject to public production.

One of the limitations of our paper is that we are largely unable to distinguish the characteristics of a given firm from those of the zone it is managing. Furthermore, the information available on costs and output is measured at the zone level (including full city-districts). Hence, we have been unable to examine other market design possibilities at a more micro-level. This is due lack of data below the zone level, which hinders effective monitoring by the local government. Future research would benefit from the additional availability of observations at district or neighborhood levels, since this would allow a more refined analysis and service reform design.

Acknowledgements

This research was funded by the Chair of Local Economic Policy at University Pompeu Fabra (Barcelona). We are thankful to information, data and support provided by the city unit responsible for supervision of the waste management service. David Tomàs provided useful research assistance.

References

Abrate, G., Erbetta, F., Fraquelli, G., Vannoni, D., 2014. The Costs of Disposal and Recycling: An Application to Italian Municipal Solid Waste Services. Reg. Stud. 48, 896–909. https://doi.org/10.1080/00343404.2012.689425

Aharoni, Y., 1982. State-owned enterprise: an agent without a principal, in: Jones, L.P. (Eds.), Public Enterprise in Less-Developed Countries. Cambridge University Press, Cambridge, pp. 67–76. https://doi.org/10.1017/CBO9780511752988.005

Ajuntament de Barcelona, 2018a. Nova contracta de neteja i recollida de residus a Barcelona. https://ajuntament.barcelona.cat/premsa/2018/04/16/barcelona-prepara-la-nova-contracta-de-neteja-i-recollida-de-residus-2019-2027/ (accessed 13 November 2019)

Ajuntament de Barcelona, 2018b. Plec de clàusules administratives particulars per a la contractació dels serveis de recollida de residus municipals i la neteja de l'espai públic de la ciutat de Barcelona (2019-2027), amb mesures de contractació pública sostenible. Barcelona. https://contractaciopublica.gencat.cat/ecofin_pscp/AppJava/notice.pscp?reqCode=viewCn&idDoc=43192689&version=31128100&lawType=3 (accessed 13 November 2019)

Ajuntament de Barcelona, 1992. Programa d'Actuació Municipal 1992-1995. https://bcnroc.ajuntament.barcelona.cat/jspui/browse?type=materia&value=Programa+d%27Actuaci%C3%B3+Municipal+%28PAM%29+1992-1995+%28Barcelona%29 (accessed 13 November 2019

Ajuntament de Barcelona, 1999. Gobierno y gestión de la ciudad : una experiencia de modernización municipal. Ediciones Díaz de Santos, Madrid.

Al-Jarrah, I.M.W., Al-Abdulqader, K., Hammoudeh, S., 2019. How Do Bank Features and Global Crises Affect Scale Economies? Evidence from the Banking Sectors of Oil-Rich GCC Emerging Markets. Emerg. Mark. Financ. Trade 1–23. https://doi.org/10.1080/1540496x.2019.1602765

Aldag, A.M., Warner, M., Aldag, A.M., Warner, M., 2018. Cooperation , not cost savings : explaining duration of shared service agreements of shared service agreements. Local Gov. Stud. 44, 350–370. https://doi.org/10.1080/03003930.2017.1411810

Allesch, A., Brunner, P.H., 2014. Assessment methods for solid waste management: A literature review. Waste Manag. Res. 32, 461-473. https://doi.org/10.1177/0734242X14535653

Ammons, D.N., Hill, D.J., 1995. The Viability of Public-Private Competition as a Long-Term Service Delivery Strategy. Public Product. Manag. Rev. 19, 12–24. https://doi.org/10.2307/3380817

Andrews, R., Boyne, G.A., 2014. Task Complexity, Organization Size, and Administrative Intensity: The Case Of UK Universities. Public Adm. 92, 656-672. https://doi.org/10.1111/padm.12078

Auriol, E., Laffont, J. -J, 1992. Regulation by Duopoly. J. Econ. Manag. Strateg. 1, 507–533. https://doi.org/10.1111/j.1430-9134.1992.00507.x

Baccini, L., 2014. Cheap talk: Transaction costs, quality of institutions, and trade agreements. Eur. J. Int. Relations 20, 80–117. https://doi.org/10.1177/1354066112443272

Baumol, W.J., Panzar, J.C., Willig, R.D., 1988. Contestable Markets and the Theory of Industry Structure. Harcourt Brace Jovanovich, Orlando (Florida).

Bel, G., 2020. Public versus private water delivery, remunicipalization and water tariffs. Util. Policy 62, 100982. https://doi.org/10.1016/J.JUP.2019.100982

Bel, G., 2006. Gasto municipal por el servicio de residuos sólidos urbanos. Rev. Econ. Apl. 14, 5–32. https://dialnet.unirioja.es/servlet/articulo?codigo=2187485

Bel, G., Costas, A., 2006. Do Public Sector Reforms Get Rusty? Local Privatization in Spain. J. Policy Reform 9, 1–24. https://doi.org/10.1080/13841280500513084

Bel, G., Fageda, X., 2011. Big Guys Eat Big Cakes: Firm Size and Contracting in Urban and Rural Areas. Int. Public Manag. J. 14, 4–26. https://doi.org/10.1080/10967494.2011.547746

Bel, G., Fageda, X., Mur, M., 2014. Does Cooperation Reduce Service Delivery Costs? Evidence from Residential Solid Waste Services. J. Public Adm. Res. Theory 24, 85–107. https://doi.org/10.1093/jopart/mus059

Bel, G., Fageda, X., Warner, M., 2010. Is private production of public services cheaper than public production? A meta-regression analysis of solid waste and water services. J. Policy Anal. Manag. 29, 553–577. https://doi.org/10.1002/pam.20509

Bel, G., Hebdon, R., Warner, M., 2018. Beyond privatisation and cost savings: alternatives for local government reform. Local Gov. Stud. 44, 173–182. https://doi.org/10.1080/03003930.2018.1428190

Bel, G., Rosell, J., 2016. Public and Private Production in a Mixed Delivery System: Regulation, Competition and Costs. J. Policy Anal. Manag. 35, 533–558. https://doi.org/10.1002/pam.21906

Bel, G., Sebő, M., 2019. Does Inter-Municipal Cooperation Really Reduce Delivery Costs? An Empirical Evaluation of the Role of Scale Economies, Transaction Costs, and Governance Arrangements. Urban Aff. Rev. https://doi.org/10.1177/1078087419839492

Bel, G., Warner, M., 2008. Does privatization of solid waste and water services reduce costs? A review of empirical studies. Resour. Conserv. Recycl. 52, 1337–1348. https://doi.org/10.1016/j.resconrec.2008.07.014

Bel, G., Warner, M.E., 2016. Factors explaining inter-municipal cooperation in service delivery: a meta-regression analysis. J. Econ. Policy Reform 19, 91–115. https://doi.org/10.1080/17487870.2015.1100084

Bel, G., Warner, M.E., 2015. Inter-municipal Cooperation and Costs: Expectations and Evidence. Public Adm. 93, 52–67. https://doi.org/10.1111/padm.12104

Bel, G., Warner, M.E., 2009. Managing Competition in City Services: The Case of Barcelona. J. Urban Aff. 31, 521–535. https://doi.org/10.1111/j.1467-9906.2009.00456.x

Bendor, J.B., 1985. Parallel Systems: Redundancy in Government. University of California Press, Berkeley.

Benito-López, B., Moreno-Enguix, M. del R., Solana-Ibañez, J., 2011. Determinants of efficiency in the provision of municipal street-cleaning and refuse collection services. Waste Manag. 31, 1099–1108. https://doi.org/10.1016/j.wasman.2011.01.019

Bohm, R.A., Folz, D.H., Kinnaman, T.C., Podolsky, M.J., 2010. The costs of municipal waste and recycling programs. Resour. Conserv. Recycl. 54, 864–871. https://doi.org/10.1016/j.resconrec.2010.01.005

Bos, J., Lamoen Van, R., Economidou, C., 2010. Too Big to Innovate? Scale (dis)economies and the Competition-Innovation Relationship in U.S. Banking. Res. Memo. 054. https://ideas.repec.org/p/unm/umamet/2010054.html

Boyne, G.A., 1996. Scale, Performance and the New Public Management: An Empirical Analysis of Local Authority Services. J. Manag. Stud. 33, 809–826.

Brambor, T., Clark, W.R., Golder, M., 2006. Understanding interaction models: Improving empirical analyses. Polit. Anal. 14, 63–82. https://doi.org/10.1093/pan/mpi014

Chifari, R., Piano, S. Lo, Matsumoto, S., Tasaki, T., 2017. Does recyclable separation reduce the cost of municipal waste management in Japan? Waste Manag. 60, 32–41. https://doi.org/https://doi.org/10.1016/j.wasman.2017.01.015

Dijkgraaf, E., Gradus, R.H.J.M., 2003. Cost Savings of Contracting Out Refuse Collection. Empirica 30, 149–161. https://doi.org/10.1023/A:1024175730230

Dubin, Jeffrey A., Navarro, P., 1988. How Markets for Impure Public Goods Organize: The Case of Household Refuse Collection. J. Law, Econ. Organ. https://doi.org/10.2307/764922

Farsi, M., Filippini, M., Lunati, D., 2008. Economies of Scale and Efficiency Measurement in Switzerland's Nursing Homes. Swiss J. Econ. Stat. 144, 359–378. https://doi.org/10.1007/bf03399259

Frère, Q., Hammadou, H., Paty, S., 2011. The range of local public services and population size: Is there a "zoo effect? in French jurisdictions? Rech. économiques Louvain 77, 87-104. https://doi.org/10.3917/rel.772.0087

Frisch, R., 1965. Theory of Production, Theory of Production. Springer Netherlands, Dordrecht. https://doi.org/10.1007/978-94-017-6161-1

Girth, A.M., Hefetz, A., Johnston, J.M., Warner, M.E., 2012. Outsourcing Public Service Delivery: Management Responses in Noncompetitive Markets. Public Adm. Rev. 72, 887–900. https://doi.org/10.1111/j.1540-6210.2012.02596.x

Gomez, J.L., 2010. Essays on Optimal Jurisdictional Size for Local Service Delivery. Georgia State University. https://scholarworks.gsu.edu/pmap_diss/43

Gradus, R., Budding, T., 2020. Political and Institutional Explanations for Increasing Re-municipalization. Urban Aff. Rev. 56, 538-564. https://doi.org/10.1177/1078087418787907

Gradus, R., Schoute, M., Dijkgraaf, E., 2018. The effects of market concentration on costs of local public services: empirical evidence from Dutch waste collection. Local Gov. Stud. 44, 86–104. https://doi.org/10.1080/03003930.2017.1380629

Greco, G., Allegrini, M., Del Lungo, C., Gori Savellini, P., Gabellini, L., 2015. Drivers of solid waste collection costs. Empirical evidence from Italy. J. Clean. Prod. 106, 364–371. https://doi.org/10.1016/j.jclepro.2014.07.011

Hefetz, A., Warner, M., 2004. Privatization and its reverse: Explaining the dynamics of the government contracting process. J. Public Adm. Res. 14, 171-190. Theory. https://doi.org/10.1093/jopart/muh012

Hefetz, A., Warner, M.E., 2012. Contracting or Public Delivery? The Importance of Service, Market, and Management Characteristics. J. Public Adm. Res. Theory 22, 289–317. https://doi.org/10.1093/jopart/mur006

Hirsch, W.Z., 1965. Cost Functions of an Urban Government Service: Refuse Collection. Rev. Econ. Stat. 47, 87-92. https://doi.org/10.2307/1924127

Jacobsen, R., Buysse, J., Gellynck, X., 2013. Cost comparison between private and public collection of residual household waste: Multiple case studies in the Flemish region of Belgium. Waste Manag. 33, 3–11. https://doi.org/10.1016/j.wasman.2012.08.015

Laffont, J.-J., Tirole, J., 1993. A Theory of Incentives in Procurement and Regulation, MIT Press. Cambridge.

Landau, M., 1969. Redundancy, Rationality, and the Problem of Duplication and Overlap. Public Adm. Rev. 29, 346-358. https://doi.org/10.2307/973247

Levin, J., Tadelis, S., 2010. Contracting For Government Services: Theory and Evidence From U.S. Cities. J. Ind. Econ., Public Management Occasional Papers. 58, 507–541. https://doi.org/10.1787/9789264162174-en

Lindholst, A.C., 2019. Addressing public-value failure: re-municipalization as acts of public entrepreneurship, J. Econ. Policy Reform 1–18. https://doi.org/10.1080/17487870.2019.1671192

Lundsgaard, J., 2003. Competition and Efficiency in Publicly Funded Services. OECD Econ. Stud. 2002, 79–128. https://doi.org/10.1787/eco_studies-v2002-art10-en

Miranda, R., Lerner, A., 1995. Bureaucracy, Organizational Redundancy, and the Privatization of Public Services. Public Adm. Rev. 55, 193. https://doi.org/10.2307/977185

Mols, N.P., 2010a. Economic explanations for concurrent sourcing. J. Purch. Supply Manag. 16, 61–69. https://doi.org/10.1016/j.pursup.2009.09.001

Mols, N.P., 2010b. How does concurrent sourcing affect performance? J. Bus. Ind. Mark. 25, 525–534. https://doi.org/10.1108/08858621011077754

Nelson, M.A., 1997. Municipal government approaches to service delivery: An analysis from a transactions cost perspective. Econ. Inq. 35, 82–96. https://doi.org/10.1111/j.1465-7295.1997.tb01896.x

Parmigiani, A., 2007. Why do firms both make and buy? An investigation of concurrent sourcing. Strateg. Manag. J. 28, 285–311. https://doi.org/10.1002/smj.580

Pavel, J., Slavík, J., 2018. The relationship between competition and efficiency of waste-collection services in the Czech Republic. Local Gov. Stud. 44, 275–296. https://doi.org/10.1080/03003930.2017.1411812

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. Eur. J. Oper. Res. 255, 583–592. https://doi.org/10.1016/j.ejor.2016.05.034

Plata-Díaz, A.M., Zafra-Gómez, J.L., Pérez-López, G., López-Hernández, A.M., 2014. Alternative management structures for municipal waste collection services: The influence of economic and political factors. Waste Manag. 34, 1967–1976. https://doi.org/10.1016/j.wasman.2014.07.003

Porter, M.E., 1998. Competitive strategy techniques for analyzing industries and competitors : with a new introduction. Free Press, New York.

Rey, P., Stiglitz, J., 1995. The Role of Exclusive Territories in Producers' Competition. RAND J. Econ. 26, 431–451. https://www.jstor.org/stable/2555997?seq=1

Savas, E.S., 1981. Intracity Competition between Public and Private Service Delivery. Public Adm. Rev. 41, 46-52. https://doi.org/10.2307/975723

Simões, P., Carvalho, P., Marques, R.C., 2012. Performance assessment of refuse collection services using robust efficiency measures. Resour. Conserv. Recycl. 67, 56–66. https://doi.org/10.1016/j.resconrec.2012.07.006

Simões, P., Cavalho, P., Marques, R.C., 2013. The Market Structure of Urban Solid Waste Services: How Different Models Lead to Different Results. Local Gov. Stud. 39, 396–413. https://doi.org/10.1080/03003930.2013.783477

Stevens, B.J., 1978. Scale, Market Structure, and the Cost of Refuse Collection. Rev. Econ. Stat. 60, 438-448. https://doi.org/10.2307/1924169

Stigler, G.J., 1958. The Economies of Scale. J. Law Econ. 1, 54–71. https://chicagounbound.uchicago.edu/jle/vol1/iss1/4/

Sundell, A., Lapuente, V., 2012. Adam Smith or Machiavelli? Political incentives for contracting out local public services. Public Choice 153, 469–485. https://doi.org/10.1007/s11127-011-9803-1

Tirole, J., 1988. The theory of industrial organization. MIT Press, Cambridge.

Trebesch, C., Zabel, M., 2017. The output costs of hard and soft sovereign default. Eur. Econ. Rev. 92, 416–432. https://doi.org/10.1016/j.euroecorev.2016.10.004

Varian, H.R., 1990. Monitoring Agents with Other Agents. J. Institutional Theor. Econ. 146, 153-174. https://doi.org/10.2307/40751313

Voorn, B., Van Genugten, M.L., Van Thiel, S., 2020. Re-interpreting re-municipalization: finding equilibrium. J. Econ. Policy Reform 3, 1–14. https://doi.org/10.1080/17487870.2019.1701455

Warner, M., Hebdon, R., 2001. Local government restructuring: Privatization and its alternatives. J. Policy Anal. Manag. 20, 315–336. https://doi.org/10.1002/pam.2027

Warner, M., Bel, G., 2008. Competition or Monopoly? Comparing Privatization of Local Public Services in the U.S. and Spain. Public Adm. 86, 723–735. https://doi.org/10.1111/j.1467-9299.2008.00700.x

Warner, M., Hefetz, A., 2012. Insourcing and outsourcing: The dynamics of privatization among U.S. Municipalities 2002-2007. J. Am. Plan. Assoc. 78, 313–327. https://doi.org/10.1080/01944363.2012.715552

Appendix

Table A-1: Descriptive statistics of the main variables.

Main Variables	Mean	Std. Dev.	Min	Max
Cost of waste collection (€)	1,822,884	768,481	580,412	4,319,332
Total Waste (Tons)	14,688	4,553	7,984	23,809
Rest waste (Tons)	10,018	3,053	5,687	16,035
Organic (%)	14.149	1.198	11.655	16.459
Paper (%)	4.761	0.598	3.797	6.696
Packaging (%)	3.138	0.609	2.246	5.023
Glass (%)	4.684	0.939	3.155	6.682
Voluminous (%)	4.917	1.401	2.690	8.138

Table A2: Direct comparison of the firm dummies with the chosen reference group.

Reference / Included	FCC	CESPA	Urbaser
CESPA	100,957 (304,552)		
Urbaser	-460,436 (377,675)	-561,394*** (229,749)	
CLD	-50,820 (487,085)	-151,778 (268,567)	409,616+ (271,673)

Note: *** indicates significance at 1% level; ** indicates significance at 5% level; * indicates significance at 10%, +indicates significance at 15%. In parenthesis standard errors.

UBIREA
Institut de Recerca en Economia Aplicada Regional i Pública
Research Institute of Applied Economics
Universitat de Barcelona
Av. Diagonal, 690 • 08034 Barcelona

WEBSITE: www.ub.edu/irea/ • **CONTACT:** irea@ub.edu