Introducing and enhancing competition to improve delivery of local services of solid waste collection

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Abstract:

Over the last two decades, Barcelona has implemented a far-reaching reform of the city's solid waste collection. 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. This study analyzes and evaluates the creation of lots as a tool of competition with monthly observations of costs and outputs between 2015 and 2019. Main findings are 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. Based on our results, we recommend creating an additional zone. We further suggest that if a public firm managed one of the zones, the regulator would obtain more reliable information on the service costs and technical characteristics, thus increasing her capabilities as supervisor of the private firms delivering the service in other zones.

Keywords: Waste collection, management, privatization, re-municipalization, competition

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1. Introduction

This study aims to evaluate waste collection reforms that can successfully contribute to enhance competition. The waste service in the city of Barcelona is evaluated, where regulation by competition has been in operation for several decades, as four exclusive waste collection zones have been awarded by means of a 'split auction'. The empirical analysis studies the cost determinants of solid waste services in Barcelona and investigates whether there are any differences in the cost and scale economies of the four existing waste collection zones.

The first research question is: Did waste collection costs converge between the different service-zones (as competition would make to expect)? To the best of our knowledge, this is the first analysis comparing waste collection costs for different concessions in different zones within the same political jurisdiction, which means all studied management units are under exactly the same regulation [see Bel and Rosell (2016) for such type of analysis for bus transportation].

Based on these results, a reform aimed at improving the efficiency of solid waste collection is proposed. To do so, the results on returns to scale must be analyzed, because it is a prerequisite to understand whether increasing the number of collection zones, while potentially good for competition, could negatively affect costs because of scale reasons. Hence, the second research question is: Is it possible to increase the number of service-zones to increase competition without damaging returns to scale? We are not aware of any technical analysis of this type previously conducted in order to inform a proposal of policy reform to improve waste collection in a city. In this way, the study further contributes to the literature by developing a design for the reform of a waste collection system. Given that it serves a large urban area (Barcelona), it could eventually be applied to similar urban contexts. According to the existing knowledge on economies of scale in waste collection, returns to scale tend to be fully exhausted at volumes corresponding to between 25,000 and 50,000 inhabitants, and even smaller (Stevens, 1978; Dubin and Navarro, 1988:

Dijkgraaf and Gradus, 2003; Bel and Costas, 2006; Simões, Carvalho, and Marques, 2012, 2013; Abrate et al., 2014; Greco et al., 2015; Chifari et al., 2017; Di Foggia and Beccarello, 2020). Therefore, many cities operate at scales that are large enough to consider splitting waste collection without damaging 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 (Bel, Fageda and Warner, 2010), 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 can be defined as *extended rivalry* (Porter 1998) – is missing. Indeed, specifically in waste management as local service delivery the appropriateness of competitive tendering has been questioned (Massarutto 2007). Given that the European market of municipal waste management is concentrated (the top 15 companies achieving 1/3 of the total industries turnover) and country-wise the market is usually divided between the top-5 operators (Antonioli and Massarutto 2012), local governments have been incentivized to come up with new delivery strategies.

If the (local) government chooses to divide production among several bidders through a 'split auction' or 'dual sourcing', it also motivates competition in later auctions (Laffont and Tirole 1993). The duplication of fixed costs is justified by the yardstick competition effect (Auriol and Laffont 1992) Early research had already predicted the cost-reducing effects of yardstick competition due to the presence of comparable firms (Shleifer 1985). Since then the efficiency gains from yardstick competition have been widely reported as regulatory tool. Examples include port reforms in Mexico (Estache, González, and Trujillo 2002), efficiency patterns of local governments in Norway (Revelli and Tovmo 2007), welfare spending of 93 departments in France (Paul Elhorst and Fréret 2009), public education (Terra and Mattos 2017) or electricity distribution (Kumbhakar and Lien 2017).

The approach of exclusive territories as a tool to achieve yardstick competition lies 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 allowing 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 (Pérez-López et al. 2016; Bel and Sebő, 2019). 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). 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.

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. 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 reliability considerations (Bendor 1985), which requires the units of the system – in our case public and private companies – to be independent. Combining governance modes in case of private sector (which is often referred as concurrent sourcing) is seen as a way to manage technological volatility (Krzeminska, Hoetker, and Mellewigt 2013). Institutions that provide reliability are adaptive, flexible and can handle better unanticipated conflicts (Bendor and Moe 1985). Indeed, it has been found that concurrent sourcing decreases the negative effects of both technological and performance uncertainty (Mols et al. 2012). In addition, it increases the internal agent's monitoring power and reduces the opportunism of the external supplier (Mols 2017). It mitigates agency costs, signals quality and gives bargaining power the internal agent or franchisor (Hefetz, Warner, and Vigoda-Gadot 2014).

Apart from the alleviation of uncertainty, the efficiency and knowledge effect are also important, it is a flexible delivery mode which gives opportunities to experiment and test shifts in the delivery (Hefetz 2016). Besides its role to improve competition, mixed systems are associated with higher tendency of exploration of new contracts (Warner and Hefetz 2020). Usually, local governments use this type of delivery when they have prior contracting experience but they capabilities are low (Porcher 2016). The role of the local government in this setting can be diverse. Apart from sharing the production, it acts as organizing hub, oversees the whole production and regulates it (Brown, Potoski, and Van Slyke 2015). Mixed delivery arrangements can bring together the benefits of both contracting-out and in-house production. In the US municipalities, one-fifth of all services are delivered this way, either through bilateral or multilateral arrangements based on the number of partners splitting the delivery (Brown, Potoski, and Van Slyke 2015).

3. Institutional context: Waste collection 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 past century, two private concessions were managing solid waste collection, held by

Fomento de Construcciones y Contratas (FCC) and *Concesionaria y Contratas de Usuarios de Servicios de Limpieza Pública* (CLD), both 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] The city 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 (Bel and Warner, 2009) . Fragmentation would allow private firms to address the specific characteristics of each territory, which could differ markedly with the season of the year.

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

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1 English names for these organizations are: (FCC): Promotion of Construction and Contracts; (CLD): Concessionaire and Contracts of Users of Public Cleaning Services. The first direct contract between CLD and the city for waste collection dates to 1964. FCC, established initially in 1900 as *Fomento de Obras y Construcciones* (FOCSA: Promotion of Works and Concessions), had a long history of cooperation with Barcelona, 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 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. Thus, all data used in our empirical strategy refer solely to the solid waste collection service.

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.[3]

4. Empirical strategy

4.1 Methodology

Empirical analyses of the factors impacting solid waste collection – starting with Hirsch (1965) – have sought to model refuse collection costs taking into account factors related primarily to scale 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 of economies of scale up to 50,000 inhabitants, while beyond this population size he found constant returns to scale. She 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

[3] In the upcoming concession for the period 2019-2027, 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 (Ajuntament de Barcelona, 2018). The bidding process is still undergoing, and the current contract has been prolonged till 31 August 2021, or until the new contracts come into force.

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 collection, an increasing number of studies have appeared, especially after 2000 (see 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; Romano et al, 2020).

When modelling the costs of waste collection parametrically, the relationship between outputs and inputs has usually been represented by a cost or production function. Both can include several variables and may be either linear or non-linear. Similarly, and in line with Stevens (1978) and Dubin and Navarro (1988), many previous studies base their empirical analysis on a cost function. In this paper this type of modelling is followed, as usual in studies of costs of waste collection (see Bel, Fageda and Warner, 2010). However, our study is unique as it analyzes the cost of the waste collection 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 and Costas (2006), and omitting the variables that these authors 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:

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

We initially estimated the following model for the delivery zones for the period of five years:

$$\begin{aligned} TotalCosts_{it} = \beta_0 &+ \beta_1 DisposalWaste_{it} \\ &+ \beta_2 OrganicWaste_{it} + \beta_3 PaperWaste_{it} + \beta_4 PackagingWaste_{it} \\ &+ \beta_5 VoluminousWaste_{it} + \beta_6 GlassWaste_{it} + \beta_7 Surface_{it} \\ &+ \beta_8 Population_{it}\ + \beta_9 Density_{it}\ + \beta_{10} Tourism_{it} + \varepsilon_{it} \end{aligned}$$

(2)

When evaluating the relevance of collinearity between the regressors (see Table SP1 and Table SP2 in Supplementary materials), the model had to be modified accordingly, and to control for seasonality a dummy variable of *August* was introduced to the estimations.

$$\begin{aligned} TotalCosts_{it} = \beta_0 + \beta_1 DisposalWaste_{it} \\ + \beta_2 OrganicWaste\%_{it} + \beta_3 PaperWaste\%_{it} + \beta_4 PackagingWaste\%_{it} \\ + \beta_5 VoluminousWaste\%_{it} + \beta_6 GlassWaste\%_{it} + \beta_7 August_t + \varepsilon_{it} \end{aligned}$$

(3)

4.2 Data

The variables are described in Table 1. Data for the variables used in our estimations refer to the period 2015–2019 and were provided by the city agency that supervises the solid waste service. Monthly observations for the costs incurred by the municipality and solid waste quantities of each type are available. Data regarding inhabitants in each district are annual.

(Insert table 1 here)

The variance inflation factor (VIF) was computed to check the potential relevance of multicollinearity and found an average value equivalent to 559.84. For this reason, the variables with the highest individual VIF values (that is, density, surface, and population) were excluded. Moreover, given that the various categories of waste are correlated, the variable *Disposal waste* was expressed in absolute terms, while for the other categories the relative weight of the waste as a percentage of total waste was used. After doing this, a new VIF check was conducted and individual value for tourism was 23.56; hence this variable was excluded from the analysis. As a result, the remaining equation presented an average VIF = 6.41, with all variables presenting low individual VIF values, with the relative exception of Disposal waste, which value of 10.33 was slightly above the comfort threshold of 10. Therefore, while we keep in mind this result for Disposal waste, we believe that no relevant multicollinearity problems subsist in our final specification.

5. Estimations and results of the empirical analysis

Our basic estimations are shown in Table 2. Exploiting the panel structure of our data, both the fixed and random effects models were tested. Since it was not possible to reject the null hypothesis of no systematic difference in coefficients (the Hausman test resulted in p=0.3759), the random effects model is the preferred choice. All estimations were conducted using Stata v. 14.2 software.

(Insert table 2 here)

Next, differences between zones/firms were analyzed. Recall that differences in a given area's productivity from that of the specific conditions of a zone cannot be disentangled. Results are shown in Table 3. In every regression the association between one chosen firm and outcome variable – total costs of waste collection – was estimated. In the first column FCC was introduced but the variable is not statistically significant meaning that FCC is not different from the average firm of waste collection. The same applies to CLD. In the case of CESPA the coefficient is positive, and the statistically significant result suggests that in CESPA's zone the total costs of waste collection are significantly higher than in the average zone in Barcelona. In Urbaser, in contrast, the negative coefficient and statistical significance imply that the total costs of the zone are significantly lower than average.

(Insert table 3 here)

Additionally, the costs of each firm with the costs incurred by the other three firms were compared (see Table 4). FCC's costs are not statistically different from those of any other firm except Urbaser, which with lower statistical significance appears to have lower costs; CESPA is more expensive than Urbaser, which is also cheaper than CLD, although the statistical significance of this last relationship is also weaker. Overall, CESPA appears as the most expensive firm, whereas Urbaser seems to be the most cost advantageous. The following random effects model was estimated including a_i and u_{it} for the unobserved disturbances for firm *i* at time *t*.

$$TotalCosts_{it} = \beta_0 + \beta_1 DisposalWaste_{it} + \beta_2 OrganicWaste\%_{it} + \beta_3 PaperWaste\%_{it} + \beta_4 PackagingWaste\%_{it} + \beta_5 Voluminous\%_{it} + \beta_6 GlassWaste\%_{it} + \beta_7 Firm_i + \beta_8 August_t + a_i + u_{it}$$

(4)

(Insert table 4 here)

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, this section studies 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. Notice, 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 collection 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 collection.

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. 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 Barcelona, all the zones have populations above 300,000; based on previous studies (Stevens, 1978; Dubin and Navarro, 1988: Dijkgraaf and Gradus, 2003; Bel and Costas, 2006; Simões, Carvalho, and Marques, 2012, 2013; Abrate et al., 2014; Greco et al., 2015; Chifari et al., 2017), that would imply that their volumes of waste are well above the threshold at which of economies of scale can be fully exploited. As such, the expectation is 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 a situation of diseconomies (economies) of scale exists. This paper, however, is 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, the average cost explanation is followed and both the linear and quadratic structures are estimated, as specified in **Error! Reference source not found.** These estimations do not include the quadratic component since it was found not to be statistically significant in any of the estimations except one with low statistical significance and the coefficient close to zero (see Table SP3 in Supplementary materials). 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 **Error! Reference source not found.**5. According to our estimation, 10,000 additional tons of waste would lead, on average, to an increase in average costs of 1.15 euros. This specification, however, is unable to capture any possible differences between zones; hence, it can only be concluded that the average zone in Barcelona is already in a state of diseconomies of scale at 1%.

To see zone-specific effects, interaction models as described in Brambor, Clark, and Golder (2006) are used. 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] The following equation was estimated:

$$\begin{aligned} AverageCosts_{it} \\ &= \beta_0 + \beta_1 VolumeOfWaste_{it} + \beta_2 Firm_i + \beta_3 VolxFirm_{it} \\ &+ \beta_4 OrganicWaste\%_{it} + \beta_5 PaperWaste\%_{it} + \beta_6 PackagingWaste\%_{it} \\ &+ \beta_7 VoluminousWaste\%_{it} + \beta_8 GlassWaste\%_{it} + \beta_9 August_t + a_i + u_{it} \end{aligned}$$

(5)

(Insert table 5 here)

This "context conditionality" suggests that the relationship between two variables depends on the values of other variable(s). This study is 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 including 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 **Error! Reference source not found.** 5 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. Also, evidence that none of the

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[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; and Baccini (2014) interacts country traits to estimate transaction costs in negotiating.

firms is producing under increasing returns to scale is obtained. 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

This research has empirically addressed two main research questions. The first one is whether awarding different contracts after splitting in four zones the waste collection service in the city of Barcelona had caused a convergence in costs, as competition for contacts would make to expect. Our results show that costs have not converged between concessions. Therefore, introducing more competition for the contracts could be advisable.

Our second main research question is whether current conditions of returns to scale in the four existing service zones pose any potential problem to increase the number of zones, hence increasing potential competition. Our results show that none of the four existing zones is operating under increasing returns to scales. Therefore, increasing the number of zones would not imply scale-related damages.

When interpreting our results, it should be borne in mind 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, the analysis of whether any firm/zone-related differences between the lots was undertaken, which allowed determining that the four zones are indeed different from each other. Subsequently, the study determined which is the most expensive 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, as mentioned, whether the firms are producing with increasing returns to scale was examined. Since evidence – on average – of the absence of economies of scale in every zone was obtained, one of the policy recommendations is 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 6.[5]

(Insert table 6 here)

Figure 1 compares the map of the existing division of zones with the one that would correspond to the proposal formulated.

(Insert Figure 1 here)

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. Increasing the number of zones and maintaining the one-concession-per-firm criteria would surely increase the possibilities for smaller firms, because the solid waste market in Catalonia -relevant

[5] In making this suggestion it is considered 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.

market- has only three big players (Bel and Fageda 2011). Hence, smaller firms would have more chances of having one zone awarded.

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 collection 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). Regarding comparative performance of public and private delivery in the region of Catalonia, available evidence (Bel and Costas, 2006) indicates that no systematic difference exists in costs paid for municipalities.

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 collection, 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

This study has analyzed the current situation and performance of the solid waste collection service in the city of Barcelona. Based on the empirical findings, a series of reforms that should help to improve the service by lowering costs and by improving system reliability have been recommended. Consistent with findings 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. Whereas in this paper the possibilities of designing new reforms have focused on economies of scale, other management scenario analyses in the literature have examined improving the combinations of energy and materials recovery (Massarutto, De Carli, and Graffi 2010) or distinct recycling programs (Lavee and Khatib 2010, Lavee and Nardiya 2013).

The type of analysis and design for a reform proposal of waste collection services could be conducted for similar urban contexts. Existing empirical evidence is consensual in the conclusion that returns to scale in waste collection tend to be fully exhausted in all large cities and most medium cities (above 50,0000 inhabitants) Therefore, many cities operate at scales that are large enough to consider zoning waste collection services, without damaging returns to scale. In that regard, the potential relevance of our study goes well beyond the specific case of the city of Barcelona, here empirically analyzed.

One of the limitations of this paper is the impossibility 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, it was not possible to examine other market design possibilities at a more micro-level. This is due to 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.

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

Dependent Var	Description	Periodicity	Source
Total Cost	Total costs incurred by the municipality for the service of waste collection by zones	Monthly data 2015-2019	city agency supervising waste collection service
Independent Var	Description		
Disposal waste	volume of disposal waste collected by zone	Monthly data 2015-2019	city agency supervising waste collection service
Organic waste	volume of organic waste collected by zone	Monthly data 2015-2019	city agency supervising waste collection service
Paper waste	volume of paper waste collected by zone	Monthly data 2015-2019	city agency supervising waste collection service
Packaging waste	volume of packaging & plastic waste collected by zone	Monthly data 2015-2019	city agency supervising waste collection service
Voluminous waste	volume of voluminous waste collected by zone	Monthly data 2015-2019	city agency supervising waste collection service
Glass waste	volume of glass waste collected by zone	Monthly data 2015-2019	city agency supervising waste collection service
Surface	Area of the zones in km^2	Yearly data 2015-2019	bcn.cat
Population	Number of inhabitants in the zone	Yearly data 2015-2019	ides.cat
Density	Inhabitants per km^2	Yearly data 2015-2019	bcn.cat

Tourism	Number of touristic establishments in the zone	Yearly data 2015-2019	bcn.cat
August	Dummy variable taking the value of 1 in the month of August		Own elaboration
FCC	Dummy variable taking the value of 1 for the zone of FCC		Own elaboration
CESPA	Dummy variable taking the value of 1 for the zone of CESPA		Own elaboration
URBASER	Dummy variable taking the value of 1 for the zone of Urbaser		Own elaboration
CLD	Dummy variable taking the value of 1 for the zone of CLD		Own elaboration

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

Ind. Variables	Fixed effects	Random effects
Disposal waste	261.08***	196.30***
	(40.63)	(21.98)
Organic%	4,795,423	3,888,061
	(4,763,969)	(2,602,580)
Paper%	1.09e+07***	1.23e+07***
	(3,725,651)	(3,318,121)
Packaging%	-1.49e+07	-1.01e+07
	(1.19e+07)	(1.00e+07)
Glass%	1.21e+07	2,343,534
	(7,792,125)	(6,333,890)
Voluminous%	3,243,387	-1,857,780
	(4,528,310)	(3,438,226)
August	308,742***	215,702***
	(96,501)	(75,911)
Constant	-2,280,851**	-1,000,587***
	(1,007,228)	(354,150)
R-sq	within=0.2458	within= 0.2332
	between= 0.9914	between = 0.9995
	total=0.8337	total= 0.8402
#Observations	240	240
# groups	4	4
F	10.66***	
Prob>F	0 .0000	
Wald chi2		1219.93***
prob>chi2		0.0000

Note: *** indicates significance at 1% level; indicates significance at 5% level; * indicates significance at 10%.

In parenthesis standard errors.

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

Ind. Variables	FCC	CESPA	Urbaser	CLD
Disposal waste	152.32***	128.76***	138.55***	159.63***
	(28.95)	(28.17)	(25.84)	(36.35)
Organic%	1,892,309	6,517,393	4,937,039*	-200,534
	(3,759,927)	(3,988,697)	(2,591,423)	(2,830,707)
Paper%	9,302,254	7,456,300	1.33e+07**	1.11e+07*
	(6,310,569)	(6,249,613)	(6,091,118)	(6,595,291)
Packaging%	-6,385,313	-1,442,768	5,259,720	-6,783,580
	(7,557,839)	(8,002,792)	(8,267,561)	(7,587,547)
Glass%	1.92e+07**	2.09e+07**	2.42e+07***	1.90e+07**
	(8,605,673)	(8,375,855)	(8,321,548)	(8,437,642)
Voluminous%	-7,627,461**	-9,129,601***	3,980,872	-4,754,840
	(3,385,846)	(3,280,312)	(4,658,556)	(5,618,711)
August	597,901***	610,077***	314,224**	534,585***
	(163,047)	(147,956)	(165,325)	(163,195)
FCC	-84,799			
	(204,227)			
CESPA		175,034*		
		(98,495)		
Urbaser			-491,742***	
			(158,419)	
CLD				83,500
				(170,379)
Time effects	YES	YES	YES	YES
Constant	-1,214,511	-1,790,527***	-2,668,209	-1,204,636**
	(610,540)	(911,428)	(641,827)	(537,661)

R-sq	within: 0.7977	within: 0.8009	within: 0.8078	within: 0.7978
	between: 0.9999	between: 1.0000	between: 1.0000	between:0.9999
	total: 0.9582	total: 0.9589	total: 0.9604	total: 0.9582
#Observations	240	240	240	240
# groups	4	4	4	4
Wald chi2	3,965.64***	4,036.99***	4,191.79***	3,967.26***
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.

Table 4: Direct comparison of the firm dummies with the chosen reference group

	FCC	CESPA	Urbaser
CESPA	37,644		
	(243,135)		
Urbaser	-483,778+	-521,422***	
	(328,086)	(173,771)	
CLD	-50,830	-88,474	432,947**
	(407,126)	(216,201)	(216,336)

Note: Firms in the first row indicate the reference category in each estimation. *** indicates significance at 1% level; ** indicates significance at 5% level; * indicates significance at 10%, +indicates significance at 15%. In parenthesis standard errors.

Table 5: Random effects models with average costs as dependent variable.

Ind. variables	Baseline Model	FCC	CESPA	CLD	URBASER
Volume of Waste	0.0001146***	0.0001578***	0.0000764*	0.0001271**	0.0000998**
	(0.00004)	(0.0000462)	(.0000421)	(0.0000549)	(0.0000396)
FCC		0.6751835			
		(1.083312)			
VolxFCC		-0.0000632			
		(0.0000482)			
CESPA			-0.0440294		
			(0.9160006)		
VolxCESPA			0.0000368		
			(0.0000542)		
CLD				-0.0636076	
				(0.9686429)	
VolxCLD				0.0000189	
				(0.0000974)	
URBASER					-1.590688
					(1.121753)
VolxURBASER					0.0000244
					(0.0000779)
Organic%	-10.72443**	-0.3742947	7.49011	-12.23164*	1.125449
	(4.604285)	(7.947679)	(9.399558)	(6.732878)	(5.70768)
Glass%	37.117000*	37.07115*	45.3512**	37.74618*	52.04941***
	(18.99537)	(19.90401)	(18.98156)	(19.43697)	(19.11558)
Paper%	12.05251	6.85513	5.533799	14.05125	21.11603
	(13.97826)	(14.48616)	(13.99599)	(15.25925)	(13.92194)
Packaging%	-11.07958	-8.869408	2.007219	-11.76851	19.50666
	(16.67308)	(16.6694)	(18.61685)	(16.91852)	(18.38975)

Voluminous%	-24.59843***	-29.57171***	-29.23682***	-21.45513*	4.770295
	(6.881505)	(7.65964)	(7.439307)	(12.01539)	(10.83903)
August	1.174488 ***	1.388899***	1.328958***	1.11969***	0.5165666
	(0.3302451)	(0.3650669)	(0.331738)	(0.3685213)	(0.3700132)
Constant	2.281632	0.7220327	-0.2151134	2.055045**	-2.158094
	(0.7770934)	(1.251622)	(1.410389)	(1.014099)	(1.465268)
R-squared					
within	0.8140	0.8174	0.8209	0.8142	0.8263
between	0.9996	0.9998	0.9999	0.9995	0.9999
total	0.9266	0.9281	0. 9295	0.9267	0.9316
Time effects	YES	YES	YES	YES	YES
Nr of observations	240	240	240	240	240
Nr of groups	4	4	4	4	4
Wald chi2	2196.88***	2218.87***	2268.11***	2268.11***	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.

Table 6: Possible fragmentation considering economies of scale and mixed delivery.

Zone	District	Population	%	**Firm**	%	Population	District	Zone
North	Horta-Guinardó Nou Barris	342,164	20.9%	**A**	20.9%	342,164	Horta-Guinardó Nou Barris	North
Centre	Ciutat Vella Eixample Gràcia	491,137	30.0%	**B**	22.6%	369,339	Ciuta Vella Eixample	Centre
East	Sant Andreu Sant Martí	388,136	23.7%	**C**	23.7%	388,136	Sant Andreu Sant Martí	East
West	Sants-Montjuic Les Corts Sarrià–Sant Gervasi	415,325	25.4%	**D**	16.3%	266,065	Sants-Montjuic Les Corts	West
				New	16.6%	271,058	Gràcia Sarrià–Sant Gervasi	New Zone
Total		1,636,762	100%		100%	1,636,762		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 2019. Source: idescat.cat

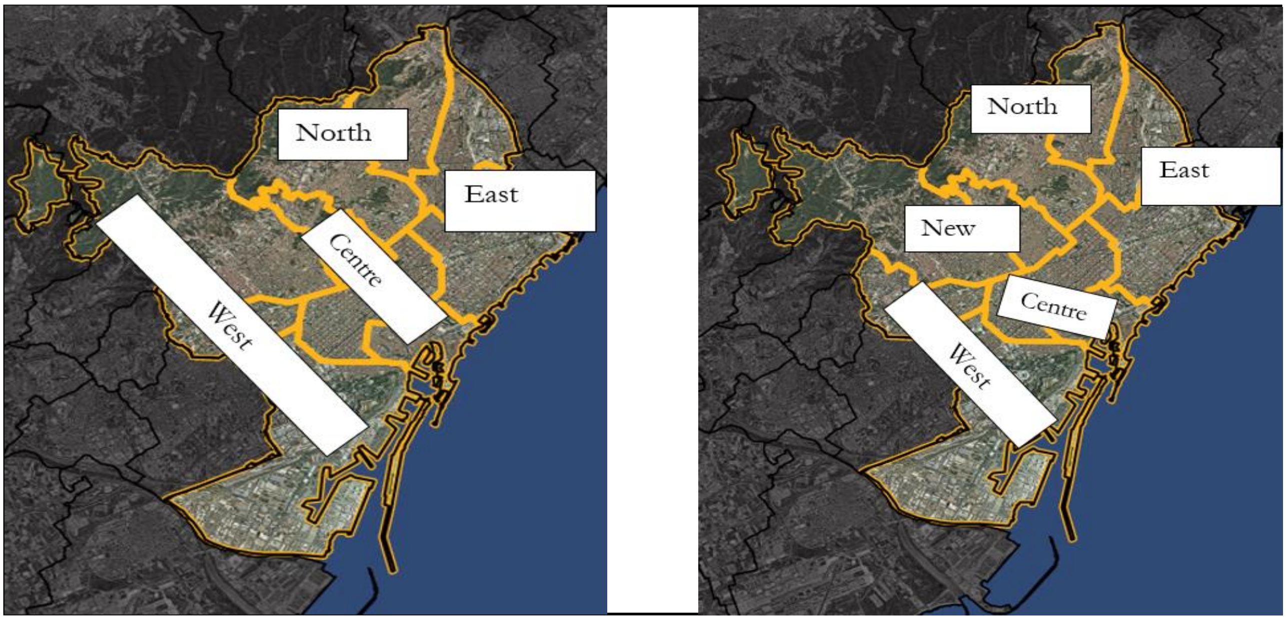

Figure 1: Actual division of Barcelona into four zones (1.a) and Proposed division into five zones (1.b).

Sources: Ajuntament de Barcelona (2018) for 1.a; Table 6, right column, for 1.b